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APPLICATION OF GEOGRAPHIC INFORMATION SYSTEM (GIS) IN THE SELECTION OF VINEYARD SITES IN CROATIA

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Abstract

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The research determines the methods for site estimation taking into account a number of objective limiting factors that occur in grapevine growing. The relief parameterization was used for calculation of geomorphological parameters. The pedometric mapping was used for calculation of pedological variables. The actual condition of land cover was registered by sketches and plans gathered during on-site investigations. Afterwards the sketches were georeferenced and over-lapped to LANDSAT satellite images in order to verify the actual situation. Logical spatial inquieries were used in the selection of optimal sites for a particular kind of permanent plantations. The optimal vineyard site was defined as an overlapping of locations where, based on the physical plan you can find either valuable or especially valuable land, or other arable land and of southern relief exposition with a total of an annual incoming light level above 1208 KWh/m^2 as well as the relief sloping not above 12% and under 2%.

This implies an altitude not lower than 110 m and the soil acidity up to 5.6 pH. The inquiery produced a simple map showing the areas which are either suitable (1) or not (0) for grapevine growing.

Estimation showed that a total of 17782 ha of the County are suitable for grapevine growing. Compared to the actual situation (1612 ha) it is discernible that about 10% of available resources have been used.

Key words: geoinformation system, site estimation, physical plan, vineyard, utility map

Introduction

According to the statistics and trends in Croatia, the condition of permanent plantations is very disappointing. In the continental part of Croatia there are excellent conditions for vineyard growing. At present there are 58000 ha of vineyards, which means that there are by 60% less vineyards compared to the situation 100 years ago (published in the Glas Slavonije, a newspaper, 2005). The biggest part of today's 58000 ha belongs to non-commercial vineyards, which produce grapes of bad quality.

In order to improve efficiency and competitiveness of agricultural production the Government of Croatia issued in June 2004 an operational financing programme for permanent plantations i.e. vineyards. The aim is to plant about 33500 ha of plantations, out of which 13000 ha of vineyards. It is very important for Croatia to plant as many plantations as possible before joining the EU after which the production lim-

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its will be determined and thus they will limit the production of olives and grapevine. It will not be possible to change those EU production limits easily. This governmental project aims to involve small and big enterpreneurs and farms to enlarge their plantations and to become competitive producers with 20 or 30 and even 50 ha of vineyards or orchards instead of today's average size, which is 2-5 ha per farm.

In order to satisfactorily place the funds from the programme, it is necessary to advise farm owners on the possibilities offered by the programme as well as to carefully choose from the applications. Among others, it is necessary to get to know well the production potentials of a certain site (the land own by the applicant) in order to invest the maximum funds into the areas which have the largest production capacity.

According to Jurisic et al. (1999), Jurisic (2005) and Husnjak et al. (2002) geographic information technology has been developing quickly in Croatia (applied in agriculture) and on account of it large areas can be quickly registered either by satellite images or by GPS positioning or by digital aerophotogrammetry. The Croatian Institute for Viticulture and Enology has already started making a detailed viticulture cadastre, which is a general overview of the statistical data of all viticulture sites in one production area, as well as an overview of potential areas. The question remains which methods to use and what would the demands be considering finances and human resources. These problems have been considered in this paper. The example of Osijek-Baranja County is used in the paper to show how the sites can be estimated taking into account a number of limiting production factors in the production of strategic kinds of permanent plantations.

Materials and Methods

The methods applied in this paper are different on account of the fact that the geomorphologic and pedologic paramaters used for land estimation as well as the ones concerning the actual state of land cover were defined more clearly and into more detail. Relief parametrization was used for calculation of geomorphologic parameters (Hengl et al., 2003), whereas the pedometric mapping methods were used for calculation of pedologic variables (Hengl, 2003). The actual state of land cover was registered by sketches and plans gatherd during field researches. The sketches were lapped over LANDSAT satellite images in order to inspect the actual situation. GIS grid-cell based modelling was applied in the whole research, which means that the basic decision- making unit was a pixel or a grid square (Figure 1).

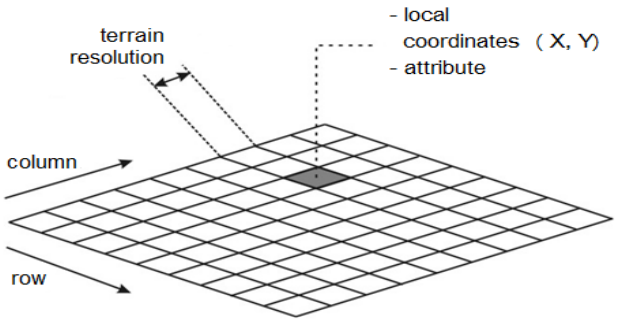

Fig. 1. GIS grid-cell based modelling; each thematic layer consists of at least on pixel unit or one grid-cell which is determined by terrain resolution (Jurisic, M.)

The main producers were paid visit to and the terrain was recorded in order to ensure good estimation and spatial location of the existing plantations. This allowed gathering very important technical data and getting a sufficient insight into the problems bothering grapevine producers. Each producer was asked to hand in maps which show the present plantation condition and its location. The maps were usually in forms of drawings or they were old maps copied by hand or photocopied.

During the preparation of GIS layers the following grid-cell resolutions were used: (a) the basic resolution for calculation of advantages was 100 m; (b) a LANDSAT image was available in the resolution of 30 and 15 m; (c) a detailed topographic map 1: 100 K was made in the resolution of 15 m. The area borders were set as follows: Xmin= 6490027; Ymin= 5005476; Xmax= 6587527; Ymax= 5088076 (Gauss-Krueger System, Zone 6), which means that the size of the whole area was 97x83 km. The resolu-

tion of the panchromatic image was 15 m (5,508×6,501 pixel).

The created thematic layers: a topographic map 1:100K (topo100K) - paper sheets of 1:100K of the topographic map were used as a GIS basis. They were scanned and georeferenced onto a working set of coordinates (zone 6). A total of 19 sheets of the topographic maps of Croatia were georeferenced and pasted together.

The scanned sketches (table) – present the actual state of the permanent plantations (Figure 2). The collected sketches and plans were gathered for four producers. Very often the sketches did not meet the quality demands needed for GIS integration, thus topographic maps 1:25K were used as a control source, because they often show vineyard locations as well. All the scanneded sketches were commuted into the vector format after being georeferenced.

The planned land use (purpose) – the planned use of land was taken over from the physical plan made by the Institute for Space Planning of Osijek - Baranja County, 2002. This is a map with a scale 1:100K, which was scanned, georeferenced in ILWIS, and then digitalized and polygonized. After that the total statistical data for the area were calculated with a special focus on the agricultural areas in the county.

The map showing the planned purposes is important because it limits the selection of optimal fruit and vine growing locations with valuable and especially valuable sorts of soil.

Pedometric parametres (soil type, soil pH, soil carbon) – when choosing the right kind of soil for grapevine planting it is very important to know not only the soil type (deep, fertile, gravel soil, dry) but the lime contents as well for the following soil depths: 0-30 cm and 30-60 cm. The map of soil acidity and the carbonates contents was made by interpolation of a limited number of pedologic profiles. The data collection considering the soils of Croatia was used (Martinovic et al., 1997); a total of 124 profiles from this data collection belong to Osijek-Baranja County. The data were interpolated in the following way: firstly, a map of soil types was created (alluvial soil, chernozem, dystric cambisol, eutric cambisol, colluvial soil,

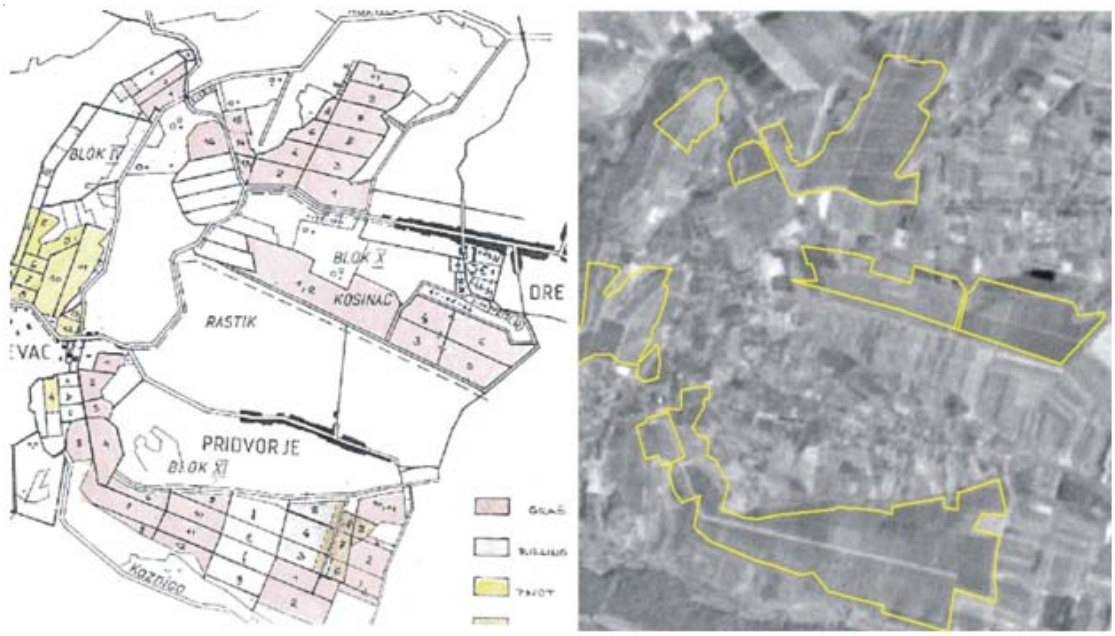

Fig. 2. Inputting and checking old sketches and plans using GIS. Left: an example of an old plan; Right: after georeferencing it is possible to present a plot map by means of a satellite image (Jurisic, M.)

luvisol, meadow soil, gley soil, pseudogley soil, rendzina soil, hydrosol, semigley) by the means of classification of geomorphologic parametres, and then the mean pedologic parametre value was calculated for every soil type (pH, carbonates).

Satellite image (panchromatic) – a LANDSAT panchromatic satellite image with a resolution of 15 m was used (Figure 3). You can either order it or download it from the Internet by a NASA server (http://edcimswww.cr.usgs.gov/pub/imswelcome/). The image is especially useful for projects like this, because it can be compared to a photo mosaic, which is considerably more expensive. In the picture you can clearly distinguish the borders of agricultural plots, and often you can even discern larger aisles inside vineyards themselves. In the future aero or Ikonos images should be used to recognize orchards and vineyards more easily.

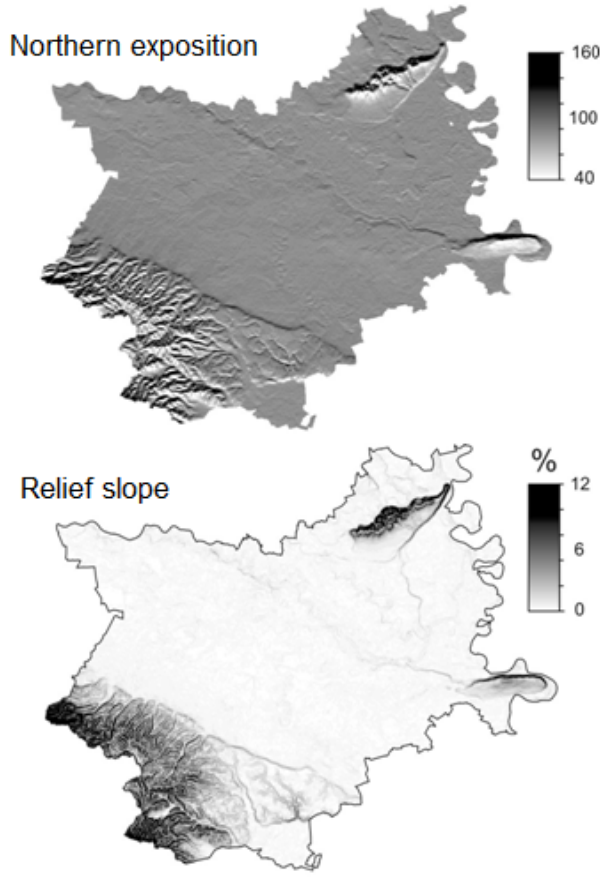

Fig. 3. Geomorphologic parameters calculated by a digital relief model of the county (Jurisic, M.)

Map inputting, georeferencing and integration was done by the use of the following unique method: the maps were scanned in the resolution of 150 DPI; then they were input into the GIS programme package ILWIS and georeferenced onto the local coordinate system with the scale 1:100K. After that the map parts were joined together and converted into the desirable basic resolution and detail scale. Different thematic layers were used for simpler calculations (eg. the map of slope) and more complex calculations (eg. annual amount of direct sun radiation). Finally, the thematic maps were used in decision making when so called spatial inquieries were used. When using ILWIS this is done directly by means of a command line.

Digital relief model and relief parameters (DMR, slope, light) – the digital relief model (DMR) was produced by means of the combination of SRTM DMR-a (NASA, 2005a), and DMR made on the basis of digitalized contour lines acquired from topographic maps with scale 1:100 K. In this case the DMR has a bigger absolute accurateness thanks to digitalized contour lines. On the other hand, a SRTM DMR shows more precise local details (changes in meso- relief). In the areas with thick vegetation, the SRTM DMR was not used, because SRTM DMR usually displays their surface area, but not the actual terrain height. The DMR was used for the calculation of two geomorphologic parameters: the terrain slope (%) and the annual amount of incoming light. The terrain slope was calculated using the ILWIS GIS package, whereas the SaGa GIS package was used to calculate incoming light (KWh/m^2) (http://geosun1.uni-geog.gwdg.de/saga/). These two parameters are of considarable importance in the selection of the most favourable vineyard sites.

Firstly, all the GIS layers have to be taken into and matched to the same grid and after that the selection of the most favourable sites for a particular kind of plant can be performed by logical spatial inquieries. For example, the most favourable vineyard sites are defined as overlapping of the following sites: sites,

where according to the physical plan you can find valuable, especially valuable or other arable sites; southern relief exposition with a total of annual incoming light >1208 KWh/m^2; sites, where the relief slope is not above 12% and under 2% and the altitude is not under 110 m; the soil with acidity up to 5.6 pH. This means that it would be possible to find spots which would meet some of the most important criteria on the same spot (a favourable exposition as well a favourable slope and a favourable altitude, etc.). Such a spatial inquiery can be expressed on the basis of the following ILWIS commands: (the 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).

This is a so called „Boolean operation"and it will result in a simple map which showing the areas either favourable (1) or not favourable (0) for vine growing. If the user wants to tighten the criteria for selection, he can simply change on of the criteria directly in the ILWIS command (eg. slope <10% instead of <12%). Of course, the tighter the criteria, the lesser fewer favourable locations.

An alternative to the Boolean approach would be the application of limitation scores. In that case, each parameter, a limiting agroecological factor, would be converted into a kind of a limiting poin based on a mathematical or empirical formula. In this case the application of limiting (negative) points would be considerably more complex, because the relation between negative points and limiting parameters is unkonown. Besides, the number of agroecological factors can be quite big which would expand GIS calculations.

Results and Discussion

A map of optimal vineyard sites was created using the formula. The map is the final result of the research (Figure 4), and you can find it in a larger size at the end of the study. The estimation shows that a total of 17782 ha of the county are favourable for vineyard growing. Compared to the actual situation, which is 1612 ha, you can see that the present use of vine growing resources is about 10%. The highest potential for planting new vineyards is mainly in the area between the towns of Djakovo and Nasice, besides the existing and acknowledged sites in Baranjska planina and Erdutsko brdo.

The unfavourable sites show a diverse nature when taking into consideration different parts of the county. In the Baranja region it concerns all the sites with an altitide under 120 m as well as the north, north-east and east laid sites, which are under strong influence of cold air fronts.

Furthermore, as far as Erdutsko brdo all the sites affected by water retention and frost (depressions, aisles, micro depressions). Lastly, unfavourable vineyard areas can be found in Djakovo and Nasice region – it concerns all the sites with a relief slope above 12% and with acid or very acid soils (pH<5.0).

Generally we can say that it is necessary to take care of the height, which should be about 120 m. Shortage in precipitation can be substantial during the summer months in the regions of Baranjska planina and Erdutsko brdo. Drought can influence the yield, and to a lesser extent the quality. Due to erosion

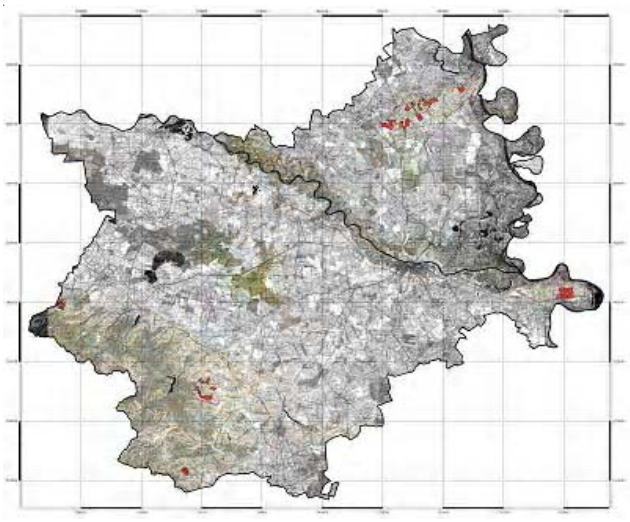

Fig. 4. Map showing optimal conditions for vineyard growing (the present state – red colour; the possibilities – green color) in Osijek-Baranja County (Jurisic, M.)

present on all heavily sloped areas it is necessary to plant grass in the lanes and to avoid heavy machinery. Underground water stagnation in spring is substantial mostly on micro-sites in depressions and on sites where, due to misuse of machinery the upper water-tight soil level has not been treated properly. This problem occurs more often in Fericanci due to a specific micro-relief. The Djakovo area and especially the area of Fericanci have to deal with soil acidity (pH<5.0). Generally speaking only the area of Fericanci has problems while using machinery. It would be advisable to successively terrace the existing plantations (to change the old ones and plant the new ones). Prior to that, the cost and depreciation of the investment should be calculated bearing in mind the size of the sites. If you take good care of proper altitude and the related frost, then the exposition impact should be considered as it influences the product quality through the amount of sun hours. Besides the favourable ones the other expositions which are not favourable by the definition (lower altitude, east or north-west sides) can also be favourable if there is a natural barrier behind them to protect them from cold north or east air fronts. On the other side they have to be sufficiently drained and aired in order not to cause water, fog, cold air and frost stagnation.

You can use these steps to find optimal locations in local areas for vineyard growing. Nevertheless, we cannot suggest vineyard growing in the areas which have not been marked green, i. e. they should in no cases be funded by the county or Croatian Government.

The analysis and processing of the climatic and edaphic parameters shows the presence of very favourable climatic and pedologic conditions for vine growing, as well as the presence of large resources, which can be used for the future production intensification and improvement. As the final conclusion we can point out that the use of natural vineyard resources is about 10% with the most favourable new areas found around Erdutsko brdo as well as on many sites between Djakovo and Nasice.

The average vine yield is between 9-12 t/ha. The yields under 8 t/ha are considered a bad year. The main grapevine sorts which cover over 80% of the vineyard area in the county are: Grasevina Blanc (Italian Riesling), Pinot Blanc and Frankovka Noir (Frankonia). The estimated cost for new „ready to go“vineyards would reach between 12000 and 15000 euros.

Conclusion

The main microclimatic factors which limit the production yield in the whole county are as follows: (a) local frost points; (b) relief sloping over 15% (in the Fericanci region it causes rinsing away the nutrients due to soil erosion, high levels of underground water, and the necessity for terracing, which considerably increases the planting cost and further causes losses in profit because it is very difficult to use machinery); (c) shortage of carbonates in the soil, i. e. too high acidity. In spite that soil acidity can be noticed through sympotoms of growing disturbance, as a matter of fact it is not a simple parameter, because it decreases vine vegetation vigour and yield.

The ideal vine growing terrain is lightly sloped (2-12%) exposed either towards south, south-west or west, with a carbonated or slightly carbonated soil and a humus content of about 3% and a light soil texture (sandy loam/fine sandy loam).

Privately owned vineyards are very small in size, and besides that they are east-west oriented, because their size, form and orientation affected the way of production, which is the most favourable when the orientation is east to west. From the technical point of view as well as when taking into account the terrain configuration, the size and number of plots owned by the The Vinarija – a County owned wine-cellar (large, flat or slight slope which follows the natural orientation of the terrain) we can see that today's form and size of plots, which is the most profitable, was affected by the above mentioned factors. In this case it is the north-south orientation. Private producers should join their plots so that their form and size would match this had by Vinarija and in that way the private plots should share the same production cycle (the most profitable and favourable solution).

Factors which hinder the final definition of the present conditions and future purpose of these areas are as follows: cadastre problems, land recovery, distribution of land ownership and a not defined status of landownership structure. It is necessary to set firm demands for nurseries demanding strict standards and high quality (out-of-date technology). It is necessary to involve both the county and Government to motivate producers and plant new vineyards bearing in mind the short time of a few years available prior to Croatia's joining the EU. It is also important to include both the viticultural business and scientific institutions to put the anticipated strategy into effect.

These scientific researches have mostly a methodological character. Their aim is to instruct the staff working in the agricultural and forestry sector and other interested people.

In contrast with the methods used by the Croatian Institute for Viticulture and Enology, these researches used the GIS system as well as relief and satellite images to determine the present situation. Even better and more detailed results would be achieved in case when an integration of ortophoto images and viticulture cadastre with the relief and satellite images could be made compared to the results presented in this work. If the cost of aerial images used for county GIS plans turns out to be too expensive, IKONOS images should be taken itno consideration.

There are many potential users in Osijek-Baranja County as well as applications based on accurate geoinformation, i. e. digital maps. A decision on a particular use of land and the change in use is still not made based on objective criteria. There are no accurate and detailed regional maps of natural resources (soil, water, relief). The same is with the cadastre base, aerial images and topographic maps, which have not been converted into the digital form to be at disposal of the above mentioned staff. There are no devices which should urgently and objectively record changes in land usage and changes of agricultural plot's borders, positioning (GPS) as well as the general state of human and natural resources.

A further step would be to develop a complete multidisciplinary GIZIS (Geographic and Cadastre Information System) for Osijek-Baranja County and to instruct all the important users, primarily the county staff in charge of the development of the devices. This means that the aim is not only to equip them with necessary tools and data basis, but also to instruct them how to use them on their own. Thematic GIS layers can be then used as a funding base, for giving advice about the right plant choice, for deciding how to change the purpose of land use, to perform mine clearance and reconstruction, to perform land privatization and ensure development of family farms, and to secure physical planning.

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