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GEOGRAPHIC INFORMATION SYSTEM IN IRRIGATION SYSTEM MANAGEMENT

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ABSTRACT

This paper deals with the significance and potential application of Geographic Information System (GIS) for irrigation system management. In view of their actuality, spatial data contained in the GIS can be divided into two groups: long-term data, which do not change over a longer period of time (like topography) and the data of short-term character, related to rapidly changing parameters, like soil moisture. Possible ways of obtaining spatial data needed to form a GIS are considered. The importance of forming GIS as a step in applying principles of site-specific farming is pointed out.

Key words: *Geographic information system, irrigation, site-specific farming*

1. INTRODUCTION

Modern ways of production and production management require the availability of necessary information at a right time to allow planning and prompt decision making. Agricultural production should not be an exception in this respect. As agricultural production takes place on production plots – parts of land surface, and great deal of information important for production is related to the position of production plots, there appears a need for using Geographic Information System (GIS) for the purpose of manipulating such data.

According to some definitions GIS is described as a sort of digital map or chart of the surface area presented. However, GIS offers much more than can give us a map or topographic plan of a given area. Thanks to this system one can gather at one place more information about the phenomena occurring on the considered territory. The available pieces of information can be combined, updated and/or supplemented with new and actual ones, so that, in contrast to a geographic map, this is a dynamic system

GIS is a system consisting of various pieces of information about land that are spatially organized. The expression ‘spatially organized’ should be understood so that for each piece of data stored in the GIS one can find the place, i.e. the position of the object or phenomenon to which this data is related. This means that, in addition to providing answers to the questions such as *what*?, how?, *how much?,* one can get an answer to the question *where?*

GIS is organized so that it presents spatial units representing spatial objects or phenomena which are related to other pieces of information organized in the databases [1]. The basic spatial units of a GIS are:

- point
- line - polyline
- polygon

These basic units describe the space to which GIS is related.

Point is defined by a pair of coordinates (Y and X or λ and φ). By a point in the GIS we can present objects or phenomena that are of pointwise character, that is those that cover a very small area with respect to the area of the whole region considered.

Line is defined by two points (two pairs of coordinates) representing the beginning and the end of the line. Polyline is a series of continuously connected lines and is represented by an array of points standing for the beginning, breaking points and the end of the polyline. A polyline is not closed, i.e. it does not describe a figure of defined surface area. This spatial unit is related to the objects of linear type, which means of a defined length but negligible width, such as pipelines, canals for irrigation/drainage, etc.

Polygon is a figure described by a closed line. A polygon is represented by a series of points representing breaking points of the boundary line. By polygon we can represent surfaces such as agricultural plots, production sections of a plot, areas with the same type of soil or the same sort of crop, etc.

With the aid of these basic elements all data related to a particular parameter (e.g., amount of fertilizers used to treat the given area represented by a polygon) are spatially collocated. To achieve a better organization of these spatial elements they are organized in layers. In certain situations, particular layers can be excluded, i.e. make invisible, and thus we can combine the current presentation in the GIS.

2. GIS CONTENT FOR THE NEEDS OF AN IRRIGATION SYSTEM

The database contents should be determined in accordance with the functions that the GIS should offer in the irrigation system management.

Generally, the data that may be needed for the purpose of irrigation can be divided into two groups: long-term and short-term data. To the group of long-term data we can include the those data that do not change, at least in a shorter time period, while temporary data are those that are relatively frequently changed in the course of several hours, days, or weeks.

These long-term data make the basis of a GIS. Here we think of the presentation of the terrain on which the irrigation system is situated. This is related to the land surface characteristics, i.e. the terrain inclination as a factor important for irrigation because of the surface water runoff from the higher to the lower terrain. On the basis of the terrain topography it is possible to follow additionally the phenomena such as water erosion, i.e. the transport of surface soil layer from the inclined sections to depressions. Terrain topography in the GIS can be represented through a digital model of the terrain, i.e. by an array of points uniformly distributed over the whole surface area of the irrigation region. The density of particular points should be determined according to the terrain characteristics having in mind that it is necessary to register small inclinations of the terrain and microdepressions. Digital model of the terrain offers the possibility of obtaining isohypses for the cartographic presentation of the terrain on the basis of the necessary equidistances or obtaining a 3D plastic presentation.

The next layer of long-term data may be the cadastre plots presented by a series of polygons. To the polygons in the database should be related all those data that are standard in the soil cadastre, i.e. in the official register of real estates. It may happen that the area found in the GIS differs from the one in the official register because of the different data sources, so that in a separate field of the database we can also register in parallel this area (as the basis for taxation, etc.).

The objects existing on the territory of the irrigation system can be divided into several layers, depending of the function of particular objects. In dependence of their size they can be represented in the form of a polygon; in the case of covering a small area (fence, wall, etc.) the objects can be represented as a point or a line. The data related to these units would be those that describe the object more closely and some of its characteristics (e.g., pumping station data), and the like.

The most important layers encompassing the irrigation system objects would be those related to canals and water pipelines with all the necessary data about the capacity and other data, underground installations such as power cables and cables to control the irrigation equipment. Also, to this group belong the objects that may represent obstacles in the course of irrigation or land cultivation.

When the organization of agricultural production is concerned it is necessary to have the layer containing production units, which may not coincide with the cadastre plots. This layer can also vary, but in the course of one vegetation season it should be the same. This layer can serve as the base for preparing data that are related to the planning of agricultural production.

In parallel with the production units layer it is necessary to form also the layer containing the communication roads with and without pavement, for the purpose of planning transportation from the production area to the economic yard or storehouse.

The data that we termed as short-term ones are those data that are not of a long-lasting character, that is which are actual several hours, days, weeks. These data are useful while they are actual for decision making about the time of irrigation or amount of water, but can be used later on when analyzing the effects of particular activities or phenomena on the state of plants in the previous periods, for example in the preceding year.

For these data, new layers should be formed. They would contain the data about the current state of soil moisture, content of particular nutritive matter, the growth stage of plants currently grown on the considered section of the irrigation system area. As we deal with data that are periodically changed it is possible to update them through an automatic system, by reading the indication of the sensors placed at the representative points. In the case such system is lacking, especially if we monitor phenomena that change little in the course of several days, it is possible to collect data on the spot and enter them into the database manually. Automatic mode is certainly advantageous, not only because of instantaneous updating, but also because of eliminating possible errors due to human factor.

The values of particular parameters are related to the site on which the given quantity was measured, such as the site of taking soil sample for the purpose of determining its moisture content, nitrogen level, etc. Such site can be represented by a point. However, for the purpose of planning agricultural production on the basis of particular sites we often need the values that are related to the production sections, that is production plots. These values can be obtained by standard tools contained in the GIS software packages that provide the values between the measuring points by interpolation method, similar to drawing isohypses [3]. By further intersecting of the layer containing isolines with production areas appropriate data are obtained for each production unit.

One group of data that are not of lasting character, but which are very important are those concerning the production plot yields. These data allow the analysis of the effect of the measures applied on particular areas on crop yields and getting an insight into the future measures to be undertaken on these production units under particular crops. Contemporary combines have already the facilities for registering current yields that can be used for these purposes.

3. DATA SOURCES

As can be concluded from the above consideration, all pertinent data are defined in space via point coordinates, either of individual points or groups of points connected in a line, polyline or polygon. There are several ways to obtaining these coordinates.

Before beginning the positioning of the interesting points it is necessary to exactly establish the accuracy of positioning we need for data entering into the GIS database. It is necessary to start from the purpose and character of data. In some cases, when we deal with navigation of the agricultural machines in the course of operation on the plot, it is possible to tolerate a positioning error of only a few centimeters (e.g. inter-row cultivation). On the other hand, for pedological profile the accuracy of even several meters would be quite satisfactory as variations of soil properties have no strictly defined boundaries.

If the interesting points are determined with the accuracy at a level of a centimeter the coordinates of previous geodetic surveys (using adequate equipment), field survey using modern geodetic instruments or point recording with the aid of DGPS technology, can serve as source of data.

When the latter group of data is concerned the position of interesting points can be obtained by digitizing the existing plans and maps by manual GPS receivers, by treatment of aerophotogrammetric or satellite images at the appropriate scale or by classical geodetic survey on the terrain. When using the existing plans and maps and airplane or satellite survey it is necessary to bear in mind the correspondence of their contents to the current state on the terrain.

For the needs of establishing land cadastre, i.e. the official real estate register, the area of the Vojvodina province has been surveyed and cadastre plans were made. However, the survey has been carried out in different times and in different ways, so that the collected data are of different quality (accuracy, update, etc.). It is necessary to bear in mind the fact that in 1994 the state was such that on 528,385 ha, or 24.6% of Vojvodina area [2], the survey had been carried out 40 and more years ago, using the fathom system of measures. To the year 2002 there has been almost no attempts to update survey so that these data are still valid. The use of these data for the basis of making GIS may be quite problematic. Namely, there is only a graphic presentation of the terrain, that is the charts and not coordinates of particular points, so that the coordinates had to be obtained by digitizing such plans. As these plans are old, a question arises as to their updating, that is the degree to which they reflect the factual state on the terrain. However, even if we would accept these plans as updated, there would be still a problem of using them. Namely in the current state coordinate system use is made of the Gauss-Krieger projection whereas for the plans made in the fathom system use was made of stereographic projection, as well as the old way of surveying, so that the quality of these data is not high. On the other hand, in the Vojvodina regions for which there is a more recent survey in the metric system it is possible to obtain coordinates of all the points shown in the cadastre plans and thus form the basis for a GIS. Of course, a question has to be posed as to the update of the cadastre plans and their agreement with the factual state on the terrain.

4. GIS APPLICATION FOR IRRIGATION SYSTEMS

A geographic information system that contains specific data needed for organizing agricultural production involving an irrigation system allows a legible presentation of these data in the form of thematic maps. On the basis of them we can easier and in a more reliable way make decisions in the process of agricultural production and irrigation system management. By introducing the data on achieved yields on particular plots and intersecting these data with the conditions characterizing these plots (soil type, amounts of fertilizers, protective agents, moisture, water consumption for irrigation) it is possible to get a better insight into the effects of the applied measures.

If one wants to practice site-specific farming on production plots, formation of a GIS for these plots is an indispensable measure. Namely, the idea of site-specific farming is based on the fact that the conditions for agricultural production are not same over the whole production area. Because of that a large production area (several tens or hundreds of hectares) is to be divided into sections (e.g. 10*10 m) on which conditions for plant growing are uniform. For each of these sections of the large plot is separately determined the amounts of fertilizers, protective agents, water for irrigation, all in accordance with the conditions characteristic of that part of the area. To obtain these information it is necessary to store a large amount of data spatially distributed over the region considered. Manipulation of these data is carried out with the aid of some of GIS softwares. Through the appropriate queries the data needed are obtained from the database, which are then forwarded to the computers installed in the agricultural machines. With the aid of a GPS receiver it is possible to determine the instantaneous position of the sprinkler, fertilizer distributor or of the irrigation device, and on the basis of these data the necessary dose is read. In the opposite case, during the harvest, the GPS receivers read the combine position and an automatic device on the combine registers the current yield, which is later introduced into the database, providing thus a feedback, i.e. the information on the effect of the applied measures for each part of the plot.

If we want to navigate the agricultural machines on the plot in certain operation (sowing, inter-row cultivation, plant protection, harvest, etc.) it is necessary to determine the route according to the plot shape and plant rows. These data can be obtained with the aid of GIS software.

5. CONCLUSION

The application of GIS in irrigation of agricultural crops is a truly new approach to the planning of agricultural production involving an irrigation system. Using GIS, on the basis of data stored we can carry out the analysis of the situation and make decisions, first of all thanks to the possibility of different spatial presentation of data.

Recently, with the aim of more rational application and maximal effects of water, fertilizers, protective agents, etc., site-specific farming has been promoted. Since in this mode of farming larger areas are considered as a set of small areas with uniform conditions for agricultural production GIS is needed for storing and manipulating large amount of data about these areas, on the basis of which are determined optimal amounts of water for irrigation, i.e. fertilizers and protective agents for each individual area.

The database content should be determined in accordance with the functions to be fulfilled by GIS. Generally, the database content can be divided into long-term and short-term data. Short-term data are actual in a short period of time (hours, days) and can be activated later on for the purpose of analyzing plant development and effects of the measures applied.

Spatially defined data can be obtained in different ways, subject to their importance and required accuracy. They can be obtained directly in the field (GPS and geodetic survey), which is more accurate but more expensive, and use can be made of the existing charts and maps, photogrametric recording, satellite imaging, when the required precision of measurement is lower. It is necessary to have in mind the updating of data, i.e. how well they agree with the factual state on the terrain.

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6. REFERENCES / BIBLIOGRAPHY

[1.] BENKA P., TABAKOV J., GOSTOVIC M.: Upravljanje zalivnim sistemom prema principima precizne poljoprivrede, Melioracija i poljoprivreda, pp. 156-160, Poljoprivredni fakultet, NOVI SAD, 2002.
[2.] DAMJANOVIC T., BENKA P.: Prilog analizi stanja premera i uredjenja zemljista na teritoriji Vojvodine, Uredjenje, koriscenje i zastita voda Vojvodine, pp. 113-134, Poljoprivredni fakultet, NOVI SAD, 1994.
[3.] PAUL A. LONLGEY, MICHAEL F. GOODCHILD, DAVID J. MAGUIRE, DAVID W. RHIND: Geographic Information System and Science, John Wiley & Sons LTD, pp. 454, 2002.