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CANAL NETWORK EFFECTS ON THE WATER BALANCE IN SOUTHEASTERN SREM

Enike Gregorić[1]

Abstract: This paper presents the results of research and analyses of the effects of a drainage canal network on the water balance of southeastern Srem. The paper was derived from a doctoral thesis which contains a detailed study of key components of the water balance of southeastern Srem, including actual amounts of water removed via the drainage canal network. A linear multiple regression model was used to establish an analytical relationship between the amounts of evacuated water (a dependent variable) and four key parameters (total precipitation, total potential evapotranspiration, average stage of the Sava River, and average groundwater level – independent variables). This correlation allows for the forecasting of hydrologic events based on historic measured data and provides answers to some important questions regarding water management and soil conservation practices. The efficiency of the drainage canal network is closely linked with its maintenance. The paper shows that canal maintenance is inadequate, mainly due to financial issues. In some parts of the studied area, drainage canals have become virtual open sewers. For this reason, the future development of the drainage system must be part of comprehensive and integrated water management in southeastern Srem.

Key words: southeastern Srem, water balance, drainage, canal network, GIS.

[1] This is a summary of the author's doctoral thesis presented on June 19, 2008.
Enike Gregorić, Faculty of Agriculture, 11081 Belgrade-Zemun, Nemanjina 6, Serbia.

Introduction

The oldest wetland drainage and flood defense projects in Srem date back to the 3rd century A.D., the time of Roman occupation, when the first canals were dug in this region.

At the beginning of the 20th century, southeastern Srem became the subject of a large number of research projects which addressed a wide spectrum of water management problems, particularly drainage of superfluous water. Professors and associates of the Department of Irrigation, Drainage and Soil Conservation of the Faculty of Agriculture at the University of Belgrade were major participants in these projects. Professors Dr. Nikola L. Cvejić (Cvejić, 1953), Dr. Dragoljub Stojićević (Stojićević, 1965, 1977), and Dr. Dragan Rudić (Rudić, 1979, 2004, 2007) made extensive contributions to the research of highly complex water management issues which exist in southeastern Srem.

The objective of the doctoral thesis was to continue the several decades of scientific research in this area and to enrich such research with new knowledge and methodologies, primarily statistical analyses and the application of digital and visual technologies.

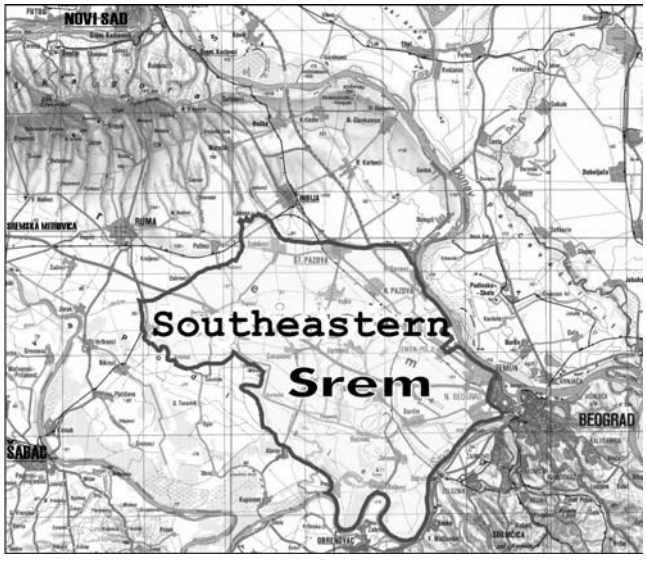

Fig. 1 *Southeastern Srem, researched area*.

The scope of this research is an analysis of the effects of the drainage canal network on the water balance in southeastern Srem (Fig. 1). The

surface area of the studied region is roughly 86,300 ha. It holds a very dense drainage canal network (8.13 – 31.90 m/ha), which is constantly being renewed and extended. From a hydrologic perspective, the canal network services four drainage areas: Galovica, Petrac, Zidine and Progarsko Donje Polje, and evacuates all the water into the Sava River via pumping stations whose total capacity is 37.8m^3/s.

If the drainage systems had not been built, it would not have been possible to sustain agriculture in most of this region, as in the past. However, regardless of the impressive canal network and other water management structures, this region still experiences seasonal water logging at an average level of about 20% (Rudić, 1979). However, it is noteworthy that efficient levees, built within the scope of protection of riparian lands from the Djerdap (Iron Gate) Hydro Power Plant reservoir, have eliminated flooding of this region by the Sava River.

Material and Methods

A large number of natural and anthropogenic factors affect the water balance in southeastern Srem. To determine the effects of the canal network on the water balance of southeastern Srem, it was first necessary to collect data about the topographic, geologic and pedologic characteristics of the terrain, precipitation, river stages, groundwater levels, hydraulic parameters of the canal network, functional condition of the canals, pumping station performance, etc. It was possible to treat some of these parameters as independent parameters and, as such, standard study methods could have been used. However, many of the studied parameters had simultaneous impacts and, as such, correlation and regression analyses had to be applied.

The topography of the region and the characteristics of the canal network were vectorized by colleagues from Geoinfostrategies, based on orthophotographic images of the region (scale 1:2500). 1634 drainage canals are shown (Fig. 2).

The national geological map of the region was digitized based on the National Geological Map (NGM) of the former Yugoslavia, 1:100000, Federal Geological Survey, Belgrade (Šabac section 1974, and Belgrade section 1985), while geomorphological units were digitized based on background documents for the project: Srem Water Supply Master Plan, Hydrogeology, Energoprojekt (1985).

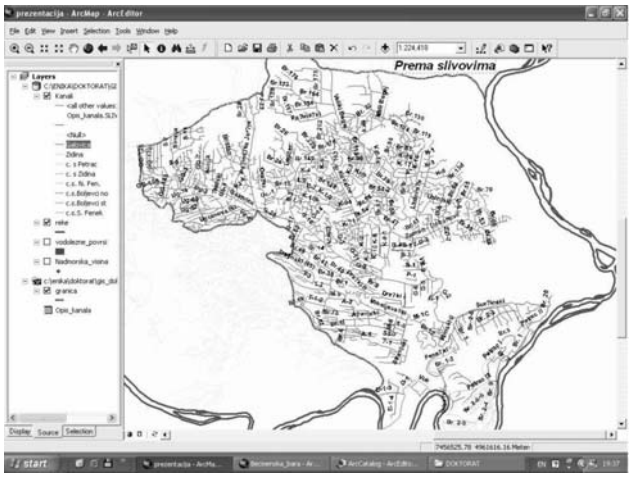

Fig. 2 *Vectorized canal network in the researched area*.

The national pedological map of southeastern Srem was digitized by the Faculty of Agriculture of the University of Novi Sad (B e n k a, 2005), using the Pedological Map of Vojvodina (scale 1:50,000) issued by the Agricultural Research Institute of Novi Sad in 1971. Surfaces on this map are represented by polygons. Attributes were defined for each polygon, such as the soil type and extent, and the group to which the soil type belongs (Živković, 1972).

Precipitation analyses included data obtained from 25 rain-gauge stations located in southeastern Srem during the 1971-2004 period. To analyze the precipitation data on a monthly basis, it was first necessary to supplement the basic data series of precipitation levels measured by the stations where there were long intervals between observations, based on regression analysis results. Basic statistical parameters were identified to obtain a general picture of precipitation characteristics in southeastern Srem. In addition to monthly and annual data, analyses also included data sub-divided into the vegetation period and the non-vegetation period. The spatial distribution of total annual precipitation levels was represented by means of the Thiessen polygon method and the isohyet method, for both the wettest and the driest year. The GIS was used to analyze the spatial distribution of precipitation. Stojšić (Stojšić, 1990) discovered, over the course of his many years of research, that precipitation levels for three consecutive hydrologic years were a sound indicator of flood events in Vojvodina. Therefore, in order to determine the effect of precipitation on groundwater level fluctuations and water logging, total precipitation levels

for three consecutive year periods were also analyzed. Additionally, maximum monthly precipitation levels for one-day, two-day, three-day and five-day periods were analyzed for the two most distant weather stations in the researched area (Belgrade and Sremska Mitrovica). The analyses addressed different return periods for all 12 months. Extreme rainfall events in southeastern Srem were analyzed based on the Log Pearson III and Gumbel functions, using SMADA and Excel software.

Reference evapotranspiration is another parameter which plays a dominant role in water balance assessments for a given region. The Penmann-Montheit method was applied to estimate evapotranspiration levels since, based on literature data, it yields the most accurate results in our region (Stričević et al., 2001), for stations where multi-annual records of the parameters exist (Surčin and Sremska Mitrovica). The study covered the period from 1971 to 2004. Total annual, seasonal and monthly reference evapotranspiration levels were statistically analyzed. For the two most distant weather stations (Surčin and Sremska Mitrovica), SMADA and Excel software were used to test the adjustability of the obtained total monthly evapotranspiration data to available theoretical functions: Normal, Gumbel and Log Pearson III.

Hydrologic and hydraulic characteristics of the region are generally used to describe the status of groundwater and surface water in southeastern Srem. However, these characteristics are extremely complex to analyze since groundwater and surface water regimes are influenced by both natural and anthropogenic factors.

Data from some 140 piezometers in southeastern Srem were collected for the thesis. Some of these facilities are managed by the Hydro-Meteorological Service of Serbia (HMS Serbia), while others are managed by the Galovica Water Management Company. Based on the criteria that the researched area should be as evenly covered with data as possible, that the measurements should be as reliable as possible, and that the largest number of measured data should be available, 32 piezometers and 3 batteries of piezometers were selected for detailed analyses. A basic statistical analysis was performed for each of the selected piezometers. A 20-year (1985-2005) monitoring period was used. Water level diagrams and water level duration curves were constructed for each observation well. Groundwater isoline maps were prepared for all characteristic groundwater levels relevant to water management issues pertaining to agricultural land. Based on average monthly groundwater levels, the analysis identified the areas which were most threatened by high groundwater levels. Using

monthly average groundwater levels, correlation coefficients were obtained for piezometer readouts and water levels at the nearest monitoring site on the river. These results were helpful in the classification of the groundwater regime. The importance of the role of precipitation in the formation of the groundwater regime was determined by a statistical correlation method used in groundwater studies (Vuković, 1967). In addition to natural factors, two very important anthropogenic factors affect the groundwater regime in southeastern Srem: the impoundment of the Danube following the erection of the Iron Gate 1 dam and the operation of radial wells of the Belgrade water supply system. The Donje Polje area, where the effects of both the Iron Gate 1/2 HPP's and the radial wells are felt, was selected to gain additional insight into the influence of anthropogenic factors on the groundwater regime. Furthermore, 7 piezometers typical of the natural groundwater regime during the 1966-1968 period and 12 piezometers for which there are reliable groundwater level monitoring data as of 2003, for altered hydrologic conditions, were selected and included in the study. The results of basic statistical analyses and a comparison of the data regarding the natural and altered regimes are presented. Water level diagrams and water level duration curves were used to demonstrate the effect of the Iron Gate Hydro Power and Navigation System (the Iron Gate HPNS) on hydrologic conditions and on the groundwater regime in the region. Additionally, the effects of the Sava River and of the radial wells on the groundwater regime are shown by means of cross-sections of the riverside areas, including groundwater level lines. To note the effect of precipitation and evapotranspiration on the groundwater regime, an attempt was made to correlate groundwater level variation to precipitation and evapotranspiration in the researched area. The area was zoned based on the results of statistical analyses of hydrologic indicators. Groundwater levels at different depths were analyzed for batteries of piezometers.

The eastern and southern boundaries of the researched area are natural, defined by the Danube and the Sava, respectively. Reference hydrologic stations for southeastern Srem are at Zemun on the Danube and at Šabac and Belgrade on the Sava. From a hydrologic perspective, the typical stages of these rivers are of interest because of their effect on groundwater levels and aquifer recharge/discharge conditions, and because a significant portion of the riparian lands are exposed to flooding. A basic statistical analysis was performed of river stage data obtained from Hydrologic Yearbooks issued by HMS Serbia.

Multi-variation analysis (regression analysis and correlation analysis) methods are used in statistics to study stochastic processes. They are based on a parallel study of quantitative variation links between two or more processes. In this specific case, there are five factors: precipitation, evapotranspiration, groundwater levels, stages of the Sava River, and performance of pumping stations. Since pumping station performance data are representative of canal network performance, these data were compared to measured precipitation levels, evapotranspiration levels, groundwater levels and stages of the Sava in southeastern Srem by month, year, hydrologic year, and season. Data recorded by the Galovica and Petrac pumping stations were available for the period from 1970 to 2006, and those recorded by other pumping stations for the period from 1988 to 2006. Tests were conducted by including one, two, three or all four independent variables. Analyses were performed for the following drainage areas: Galovica, Petrac, Galovica and Petrac combined, Zidine, Progorsko Donje Polje, and Fenečka Bara.

The GIS was used for chapters which address geology and pedology, in connection with the generation of thematic maps. ESRI GIS tools were applied for spatial analyses of precipitation, evapotranspiration and groundwater regime data (isolines, Thiessen polygons). They were particularly valuable in the analysis of the canal network itself (e.g., its development, year of construction, reconstruction assessments, etc.).

Results and Discussion

The researched area can be divided into three geomorphological units:

The Zemun Loess Plateau along the Danube, which extends all the way to the Belgrade suburb of Zemun and features the highest altitudes (between 80 to 114 m above sea level). It is made up of loess and sandy loess, with a high vertical porosity and good infiltration of atmospheric precipitation. The depth-to-groundwater is relatively large.

The Loess Terrace, made up of loessoid clay and swampy loess, central to the researched area, with altitudes generally between 76 and 90 m. The terrain dips slightly in a northeasterly direction and features a marked depression in the middle of the area. Its origins are redeposited and swampy loess, where, from a pedologic perspective, the soils are of rather poor quality and subject to seasonal water logging.

The spacious Alluvial Plain of the Sava River (left bank), which constitutes the lowest unit, between 71 and 76 m. The thickness of the

surface layer varies between 5 and 20 m; it is semi-pervious and made up of clayey sediments. Beneath this layer, there is a 20 m-thick water-bearing medium comprised of gravel and sand. The aquifers created in this alluvion are generally subartesian in nature and are hydraulically linked with the Sava River. All unconfined groundwaters from the other geomorphological units gravitate to the alluvial aquifers.

From a water logging perspective, the soils in the researched area consist of three types: automorphic soils cover 49,035.59 ha, or 56.82% of the total land surface; hydromorphic soils extend over an area of 35,170.07 ha, or 40.75%; while halomorphic soil coverage is very small, only 2097.34 ha (or 2.43%).

High altitudes of the researched area feature high-quality soils of the black earth (chernozem) type. There are also brown earth varieties, but to a slightly lesser extent. Meadow-type black earth, marshy black soil, solod and solonetz are found in the central, lowest portions of the researched area. The zone along the Sava features alluvial soils.

The researched area encompasses the municipalities of Pećinci, Stara Pazova, Zemun and New Belgrade, and a portion of the municipality of Ruma. Most of the area, about 75%, is agricultural land.

This land is used for plowing fields and gardens (between 86.1 and 97.5%). About two-thirds of the fields are cereal fields, and the remaining 15% are used to grow industrial plants. The average yield is 4395 kg/ha of wheat, 5334 kg/ha of corn, 40514 kg/ha of sugar beets, and 2060 kg/ha of sunflowers.

Surface areas threatened by superfluous water vary by municipality depending on the hydrologic characteristics of the year, but have generally been shrinking during the past twenty years.

Consistent with its geographic location, southeastern Srem belongs to the moderate continental climate belt. The average annual air temperature is 11.0^{o}C, and the average annual temperature fluctuation range is quite wide (20.8^{o}C). Large amplitudes, of 69.5^{o}C, between absolute extreme temperatures are also typical. The spring (11.4^{o}C) is slightly warmer than the fall (11.0^{o}C). The average air temperature during the vegetation period (April through September) is 17.6^{o}C. Frost appears in the October to April period. Total annual insolation is 2022 hours. The average duration of sunshine per day is 5.7 hours. The average annual air humidity is 76%. The maximum average wind speeds of 2.9 m/s (measured at a height of 2 m) occur in March, and the minimum wind speeds occur in July and August (1.9 m/s). The pluviometric regime of southeastern Srem is of the Danubian

type, with maximum levels occurring in June (84.3 mm), abundant levels recorded in October, and minimum levels recorded during the winter period. The lowest average monthly precipitation levels occur in February (33.3 mm). The total multi-annual average monthly precipitation level is 52.8 mm. The total average annual precipitation level is 633.3 mm. There are large variations between total annual precipitation levels by year. A relative spatial uniformity of characteristic total precipitation levels has been noted.

The average evapotranspiration level during the vegetation period is 661.8 mm; monthly maximum levels occur in July (occasionally in June or August), and minimum levels occur in January (rarely in December or February)

Groundwater flow in southeastern Srem is generally in the southeasterly direction, toward the largest recipients in this region: the Sava and the Danube. At the northern boundary of the region the hydraulic gradient is in the order of 0.25%, while in the central and southern portions it is much lower – about 0.05%.

Aquifer recharge in the researched area exhibits a considerable spatial variation. Recharges from precipitation, direct infiltration and infiltration from deeper reaches are dominant. At the northern edge, there is a significant inflow from upland areas, along the boundary of a lens where the thickness of loessoid roof materials is small. In the south, there is direct contact between the river and the water-bearing medium, where the direction of the flow is determined by the water level of the river.

Groundwaters in the study area can be divided into three zones:

- Zone 1 contains groundwater which is climate-dependent. This zone lies to the north and east of the Putinci > Golubinci > Stara Pazova > Batajnica > Dobanovci line, generally in the loess plateau area. Groundwater in this zone is generally found at a relatively large depth; there are only a few exceptions in valleys, where the groundwater level is very close to the ground surface. The groundwater regime is governed solely by vertical water balance parameters: precipitation and evaporation.

– Zone 2 contains groundwater which is dependent on both climate and hydrology. It includes the central and lowest portions of the researched area and the southern portion of the middle terrace. This zone is mostly under the influence of high groundwater levels which hinder normal agricultural production. The groundwater regime is governed by a combination of vertical water balance parameters and stages of the Sava and the Danube.

– Zone 3 is comprised of the floodplains of the Sava and the Danube. The groundwater is governed by hydrological parameters – stages of the Sava and the Danube.

With regard to the Sava, water level data analyses have shown that flood waves generally occur in the spring (March/April) and fall (October/November). Along the stretch of the Sava which is affected by the impoundment of the Danube, and similar to those observed for the Danube, high stages also occur in July. The water level fluctuation range is about 8 m. A comparison of water level duration curves under different conditions has shown that the duration of stages of 70 m above sea level or higher, at which inflow from the direction of the river occurs, was 55.34% per year on average, under natural conditions. However, after 1972, when construction of the Iron Gate HPNS began, the average annual duration of water levels higher than or equal to 70 m increased to 86.45%. The Iron Gate HPNS reservoir has resulted in a longer duration of water levels of the Sava greater than or equal to 70 m – by 113 days per year on average.

Of the entire canal network, 30% of the canals were built during the past 25 years, applying the criteria required by modern agricultural practices. The remainder of the canal network was built earlier, based on obsolete criteria, where the primary objective was surface water drainage.

The consequences of the poor condition of the existing drainage system included considerable flooding in the region and threats from high groundwater levels. During years with extensive rainfall, groundwater levels often rose to the surface and groundwater came in direct contact with surface water.

These shortfalls of the drainage system constituted a major impediment to any intensification of agricultural production and development. Namely, the climate of the researched area provides all the necessary pre-conditions for a highly developed level of agriculture, but improvement in water and air regimes in the catchment area are still needed to bring this potential to fruition.

The efficiency of the drainage canal network is closely tied to its maintenance. The condition of the secondary canal network is poor, both because it was built based on obsolete criteria and because it is not adequately maintained. Minor maintenance undertakings were unable to significantly improve the effectiveness of such a large system. The coverage of the new secondary canal network is relatively small. The condition of the primary canal network is slightly better but it, too, exhibits signs of inadequate maintenance.

A lack of funding for canal network maintenance has led to a dramatic deterioration in its efficiency. There has been a large disproportion between the required and the actual scope of dredging and general maintenance of the canals during the past 15 years. Estimates suggest that some seven years of intensive supplemental activities, along with ordinary maintenance, would be required to achieve the required performance level of the canal network.

The middle terrace catchment area has a more intricate canal network than the remainder of the researched area, but its performance is unsatisfactory. Considerable surfaces are endangered by superfluous water (groundwater and rainfall). This has led to soil degradation due to salination in some parts of the researched area. The resumption of the project which calls for highly complex development of agricultural land in the Galovica catchment area, only a part of which has been completed due to financial issues, would bring about significant improvements.

There are major differences between the various catchment areas in the Sava's alluvial plain.

The construction of water wells for the Belgrade water supply has considerably improved the condition of the Petrac system. However, most of the area remains threatened due to a lack of adequate maintenance. Poor performance of the drainage system is also evident in the Fenek-Petrac catchment area, because the system has not been completed.

At Zidine, the open canal system has been fully reconstructed based on existing design documents and, as such, its performance has changed to satisfactory. However, regular maintenance of the main canal of this system is required to ensure its optimum performance.

The Boljevci-Progar system is virtually out of commission because it has not been completed and because its pumping station is not in service. As a result, most of the area it covers is threatened by superfluous water. The preparation of design documents for the reconstruction of the Boljevci New pumping station is currently under way.

The critical points in terms of performance of the drainage system in southeastern Srem are the existing structures of the canal network. Secondary network culverts are often too high and their diameters too small. Similarly, the structures of the primary canal network, where canals intersect with railroad lines, are overly elevated. Even though these shortfalls have been noted, no substantial reconstruction of the structures has been undertaken to date.

The application of linear multiple regression methods on monthly data did not yield satisfactory results for the following drainage systems: Galovica, Petrac, Zidine, and Progarsko Donje Polje. Namely, these systems are highly complex and their performance depends on a large number of factors, only four of which were addressed by this analysis. Additionally, these drainage systems are inert and, as such, monthly data are not representative for an analysis of superfluous water evacuation. This does not apply only to the Fenečka Bara drainage system, for which the coefficients of regression suggest a very good dependency between the amounts of evacuated water and groundwater levels. Since the coefficient of multiple linear correlation (R=0.816) for the four assumed independent variables does not differ significantly from the coefficient of simple linear correlation (r=0808) between the amounts of evacuated water and groundwater levels, it is obvious that groundwater levels have a dominant effect on the performance of the Fenečka Bara drainage system. The resulting coefficient of determination shows that 65.0% of the variation in the amount of water discharged by the Stari Fenek Pumping Station is attributed to groundwater level variations. Since this area used to be a swamp, groundwater is obviously a dominant contributor to superfluous water. It is for this reason that the results of the correlation and regression analysis model can only be used for this system to forecast the monthly amounts of pumped water.

Because monthly data are not representative for drainage system forecasts in southeastern Srem (the one exception being the Fenečka Bara drainage system), a correlation and regression analysis was performed using a longer period of time. This part of the analysis addressed the hydrologic year, from 1 October to 30 September of the following year, while another part of the analysis addressed the non-vegetation period – from 1 October to 31 March of the following year.

There is a weir between the Petrac I and Galovica canals, which allows the discharge of water from one canal into the other, or the conveyance of superfluous water either to the Galovica PS or the Petrac PS. As such, the focus of the correlation and regression analysis was placed on the joint operation of the Galovica PS and the Petrac PS. The multiple linear regression analysis, on a hydrologic year basis, showed that a model with two independent variables (average river stage and average groundwater level during the hydrologic year), from a practical perspective, allows for a reliable forecast of the amounts of superfluous water which need to be evacuated. The value of the coefficient of multiple determination of this

model is R^2=0.74, meaning that 74% of the variation in the amount of water evacuated via these pumping stations is explained by the variation in these two independent variables. Therefore, the proposed model can be recommended for the forecasting of the amounts of water to be evacuated during a hydrologic year. Partial coefficients of correlation are also significant: they are 0.772 for groundwater and 0.558 for river stage.

With regard to water logging in southeastern Srem, the non-vegetation period is very important, when there is extensive rainfall and when the crop water demand is low. The results of the correlation and regression analysis for the parallel operation of the Galovica and Petrac pumping stations during the non-vegetation period suggest that a model with three independent variables (total precipitation, average stage of the Sava River and average groundwater level during the non-vegetation period) yields the highest coefficient of linear multiple correlation, R=0.749. The coefficient of multiple determination of this model is R^2=0.56, showing that 56% of the variation in the amount of water evacuated via these pumping stations, is attributed to the variation in these three parameters. Therefore, the proposed model can be recommended for the forecasting of the amounts of water to be evacuated during a hydrologic year. This model yields a highly significant partial coefficient of correlation for the groundwater level - 0.670.

The coefficients of simple linear correlation for the Zidine PS based on hydrologic year data suggest that there is a highly significant link between the amount of superfluous water and the average stage of the Sava during the hydrologic year (r=0.728), based on data for a series of 19 hydrologic years. This is as expected because three sides of the Zidine drainage area are bordered by the Sava River. The coefficient of determination of this model shows that 53% of the evacuated water is attributed to the variation in stages of the Sava during a hydrologic year. Since it is extremely practical to measure only one independent variable, this model can be recommended for the forecasting of the amounts of water to be evacuated during a hydrologic year.

If other water balance factors are included in the correlation and regression analysis, the model which is obtained yields a significant coefficient of multiple linear correlation - R=0.903 ($p<0.03$). It shows that 82% of the variation in the amount of evacuated superfluous water during a hydrologic year is attributed to the variation in the selected independent variables. The independent variables of this model are: total precipitation during the non-vegetation period, the average stage of the Sava, and the

average groundwater level during the same period. Finally, it is noteworthy that the best results of the correlation and regression analysis using data for a hydrologic year were obtained for the Zidine PS. Unfortunately, this model was obtained based on only 9 data points for the sample. As such, its application for water evacuation forecasts cannot be recommended until more data have been collected.

Conclusion

The concept of this paper reflects the need to continue experimental work and theoretical study of the water balance within the scope of applied drainage measures, which the Faculty of Agriculture of the University of Belgrade has been conducting for decades.

The studied region is southeastern Srem, whose surface area is roughly 86,300 ha. It encompasses the following drainage areas: Galovica, Petrac, Zidine and Progarsko Donje Polje, and has for decades been an experimental site of the Faculty of Agriculture. The water balance is extremely important to this area, which is predominantly agricultural; any excessively wet or dry year threatens the entire economy in this area. As such, the effectiveness of the canal network which drains superfluous water, and which is the main topic of this paper, is essential for the functioning and survival of intensive agricultural production in this large area.

The water balance components, including actual amounts of water drained by the canal network, were either measured or computed, and then analyzed applying up-to-date methods. State-of-the-art graphical software was used to analyze spatial data and apply appropriate statistical methods. This has allowed both spatial and temporal simulation of the amounts of superfluous water and insight into hydrologic events which took place several decades ago; it has also provided answers to many important questions concerning water management practices.

The study emphasizes the gloomy prospects of the canal network which is absurdly, being threatened by its very creator – man. Water and soil pollution have already reached significant levels, as evidenced by the register of polluters. It should be noted that soil and water pollution monitoring is still inadequate and that there is a lack of comprehensive assessment of potential solutions to accrued environmental problems. The recommendations made in the study constitute a potential roadmap for the resolution of growing environmental issues in southeastern Srem.

In general, the effectiveness of drainage must be maintained at a high level because that is the only way to optimize agriculture in the researched area. In addition to ensuring an appropriate water balance in southeastern Srem, drainage measures must address sustainable development of the canal network. Future development of the drainage system must be part of comprehensive and integrated water management in southeastern Srem.

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UTICAJ KANALSKE MREŽE NA BILANS VODA JUGOISTOČNOG SREMA

Enike Gregorić[1]

Rezime

U ovom radu prikazani su rezultati istraživanja analize uticaja kanalske mreže za odvodnjavanje na bilans voda na području jugoistočnog Srema. Rad je proizašao iz doktorske disertacije koja je obuhvatala detaljnu analizu ključnih komponenti vodnog bilansa jugoistočnog Srema, uključujući i stvarne količine voda koje se odvode kanalskom mrežom za odvodnjavanje. Primenom modela linearne višestruke regresije uspostavljena je analitička veza između količina evakuisane vode, kao zavisno promenljive, i četiri ključna parametra (suma padavina, suma potencijalne evapotranspiracije, srednji vodostaj Save i srednji nivo podzemne vode) kao nezavisno promenljivih. Ova veza omogućuje prognozu hidroloških pojava na osnovu izmerenih podataka iz prošlosti. Time je dat odgovor na neka pitanja važna za meliorativnu praksu. Efikasnost kanalske mreže za odvodnjavanje je u tesnoj vezi sa njenim održavanjem. U radu je pokazano da održavanje kanala nije zadovoljavajuće, a osnovni uzrok postojeće stanje su finansijski

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Enike Gregorić, Poljoprivredni fakultet, Zemun, Nemanjina 6

problemi. Na pojedinim delovima područja, kanali sistema za odvodnjavanje su postali kolektori otpadnih voda. Zbog toga budući razvoj sistema za odvodnjavanje mora biti u funkciji kompleksnog i integralnog upravljanja vodama na području jugoistočnog Srema.

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