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TECHNICAL AND ECONOMIC PARAMETERS FOR SELECTION OF THE OPTIMAL VARIANT OF THE REGIONAL IRRIGATION SUBSYSTEM

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ABSTRACT

A model of the water management system is developed by connecting the technical and economic parameters that best represent the regional irrigation subsystems. The following technical parameters were analyzed: the location of water intake, configuration, and dimensions of the primary canal network, pipelines, and the number and location of pumping stations. Economic parameters depend on the technical ones and they are necessary investments for construction (€), unit investments (€/ha), investments for replacement of equipment during the period of exploitation (€), annual irrigation costs, and fixed irrigation costs (€/ha, €/m^3), energy consumption and cost (kW, yearly h, yearly €), economic price of irrigation (€/ha, €/m^3), break-even point analysis. The model was tested on the future regional subsystem "Telečka" with an area of about 25,145.00 ha, which will be part of the regional system "Severna Bačka" (AP Vojvodina, Northern Serbia). Based on the specified parameters, 6 potential variants for construction have been proposed. By ranking the stated quantitative parameters, the best effects are achieved in the 4.1 variant of the technical solution with the following values: total investments for the construction of 42.05 million €, unit investments of 1,670.00 €/ha, investments for equipment replacement of 4.20 million € every 10 years, costs of irrigation on the water intake 130.00 €/ha, fixed costs of irrigation 86.00 €/ha, economic price of irrigation 203.00 €/ha (for d.r. 6%). For the calculation of these parameters, data from the technical part of the plan was used, in which a large number of experts from different professions were involved. An improved planning methodology (using a simulation model) as well as the obtained technical and economic data can be used for comparison with other regional subsystems that are in similar conditions (e.g. climatic, soil, available water resources).

Keywords: investment, costs, effects, simulation, ranking.

INTRODUCTION

Numerous mathematical and econometric models, based on the methods of system analysis, operational research, and econometrics, are used to select the most favorable water management solution for the regional irrigation system/subsystem. Given that these systems occupy a large arable area that extends over several municipalities, it is necessary to separate lands suitable for irrigation. There are also several water sources (rivers, already built canals and reservoirs, wells) for the water supply of this subsystem. Other restrictions should be taken into account: roads of the first and second order, railways, bridges, energy networks, facilities, etc. Due to all these parameters, the planning and design of such systems is a complex research task in which experts of various profiles from agriculture, hydrotechnics, mechanical engineering, energetics, economics, law, and ecology participate (Potkonjak et al., 2008; Rudić et al., 2019). Therefore, systems are divided into subsystems, but this division does not reduce the difficulty of the task. There are numerous methods and models that can be used for planning and selecting the optimal variant of the regional hydrosystem/subsystem (Holy, 1993; Raju & Kumar, 2006; Srđević & Srđević, 2016). Depending on the set task and goal of the research, as well as the complexity of the system in the technical-technological sense and the degree of detail, a suitable model is compiled (Potkonjak et al., 2013; Đurin & Baić, 2016; Srđević & Srđević, 2016) which best represents the specific system.

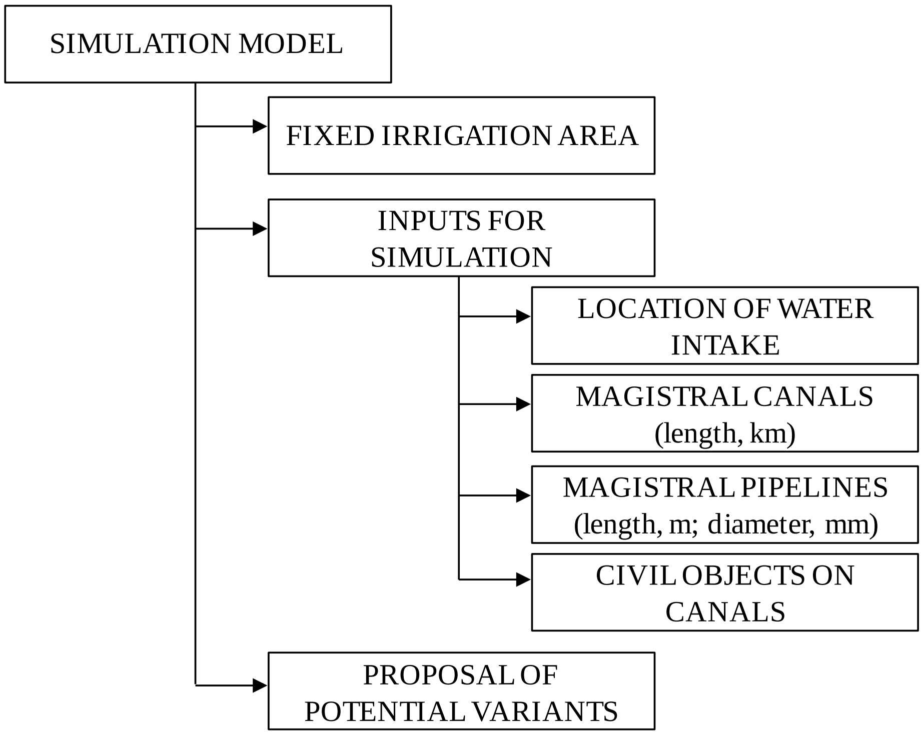
The paper presents only a part of the results of the extensive research that was related to the planning of the development of this subsystem. The developed simulation model contributed to proposing 6 potential variants for construction that could be implemented at this location. The inclusion of economic parameters (investments, costs, water price) contributed to distinguishing the variant with the best techno-economic effects.

MATERIALS AND METHODS

The research in this paper refers to the "Telečka" subsystem, which will be part of the RHS "Severna Bačka" (AP Vojvodina). Most of the research, in this case, took place in the field (geodetic surveys and hydraulic measurements). In the area of the 3 municipalities where this subsystem will be located, other relevant data were collected (land, existing sowing structure, processing facilities, and already built water management facilities). After that, the General Project (Nikoletić et al., 2020), as well as the Preliminary Study of justification for the same subsystem (Potkonjak et al., 2020) were prepared. Calculation of investments and costs, for all variants, were calculated based on the prices and quantities shown in the General project. The data from these studies were used in this paper in order to improve the methodology of planning regional hydrosystems/subsystems. In this case, a simulation model was developed and presented, which was tested on this subsystem. The simulation model included technical (mainly hydrotechnics) and economic parameters obtained in previous calculations in the mentioned studies which were compared and ranked (Scheme 1). The future area of the subsystem was a fixed size, and the technical parameters for the simulation were:

- different locations of water intakes for supplying water to canals and pipelines,
- dimensions of magistral canals (km),
- dimensions of magistral pipelines (lengths and diameters),
- positions of construction facilities on pipelines.

The output of the simulation model is 6 potential variants for the realization of this subsystem. Technical, technological, and economic data were calculated for each potential variant, which is presented in tables and graphics.



Scheme 1. Simulation model for proposal of potential variants

RESULTS AND DISCUSSION

Based on hydro-technical calculations, which took into account the proposed dispositions of the locations of pumping stations, canals, and pipelines, as well as the facilities on them, the basic parameters of the simulation for 6 potential variants were obtained (Table 1).

Technical and economic parameters of calculations by variants

The water intake locations for all 6 variants have the same flow rate of 7.32 m^3/s, which represents the capacity of all pumping stations on the primary network of the subsystem (Table 1). Based on this data, and taking into account the already built water facilities on the future "Telečka" subsystem, using appropriate programs for all 6 variants, channel lengths and pipeline lengths (m) with diameters of 1200, 1350, and 1400 mm were calculated (Table 2). The proposed diameters of the pipelines depended on the area (ha) to be supplied with water.

Table 1. Potential location of water intake (pumping stations)

Variants	Locations of water intake	The capacity of pumping stations, Q, m^3/s
Var.1.1	Žarkovac	7.32
Var. 1.2	Žarkovac	7.32
Var.2	Mali Stapar	7.32
Var.3	Sivac	7.32
Var.4.1	Žarkovac and Sivac	4.91+2.41
Var.4.2	Žarkovac and Sivac	4.91+2.41

Table 2. Technical data as a result of the simulation

Variants	Length of channels, m	Length of pipelines, m (d=1200 mm)	Length of pipelines, m (d=1350 mm)	Length of pipelines, m (d=1400 mm)
Var. 1.1	55,648.00	6,714.00	0	0
Var. 1.2	55,648.00	3,999.00	11,088	0
Var. 2	58,356.00	4,674.00	8,412	0
Var. 3	47,000.00		0	5,385.00
Var. 4.1	56,402.00	6,022.00	0	5,370.00
Var. 4.2	56,402.00	12,044.00	0	5,370.00

In Figure 1 on the example of variant 4.1. the configuration of the channel network and pipelines with accompanying facilities is shown.

Based on the obtained parameters of the primary network on the "Telečka" subsystem, the necessary investments for construction were calculated. The calculation also included: construction facilities on canals, mechanical equipment of pumping stations and dam, electrical equipment and power supply, initial investments (design, supervision, consent, and fees), expropriation costs, and irrigation fees.

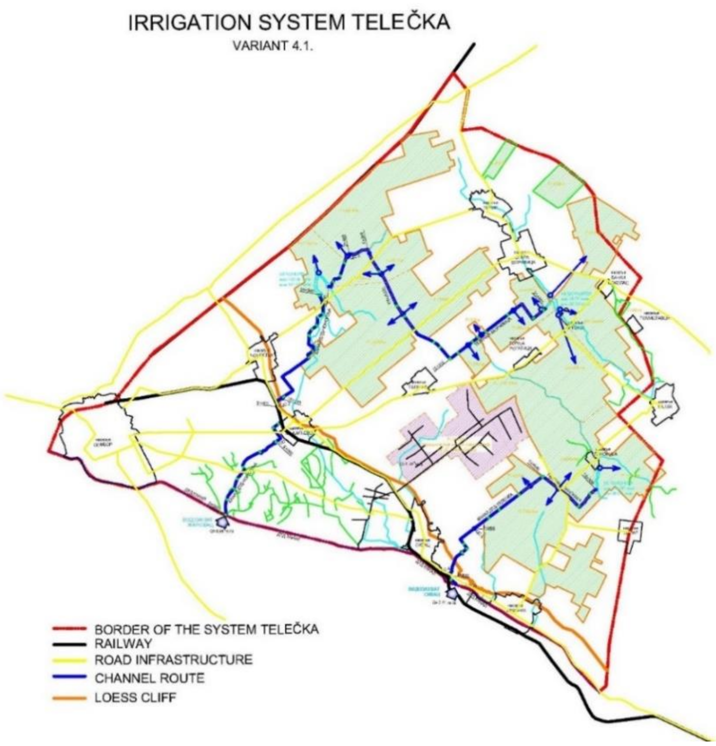


Figure 1. Configuration of canals and pipelines for 4.1. variant

Considering the area of the subsystem of 25,145.00 ha, unit investments were calculated. They are the lowest in variant 1.1., 1,522.70 €/ha, and the highest in variant 2, 2,275.70 €/ha (Table 3).

Table 3. Parameters for ranking

Parameters	Var.1.1	Var.1.2	Var.2	Var.3	Var.4.1	Var.4.2
Unit investment, €/ha	1522.7	1585.3	2275.7	1740.5	1672.5	1625.2
Using costs, €/ha	115.82	116.3	153.9	125.7	129.7	132.02
No. of permanent workers	17	17	17	24	24	24

Apart from investments, the annual costs of exploiting the subsystem with the mentioned facilities, equipment, and related costs are also an important indicator for ranking and proposing potential variants. Here, it is necessary to include as many costs as possible to make the analysis more reliable. The costs that were calculated for all 6 potential variants were depreciation, maintenance, insurance, labor, energy, and irrigation fee. Special attention is paid to the calculation of energy costs. The power for driving the pumps, the annual number of working hours, and the annual consumption (kWh), as well as the annual energy costs, were calculated (Table 4).

Table 4. Yearly consumption and energy costs

Variants	Power, kW	Hours of work, h	Consumption, kWh	Costs, €/yearly
1.1	4,050.00	2,196.00	8,893,800.00	889,380.00
1.2	4,800.00	2,196.00	10,540,800.00	1,054,080.00
2	4,800.00	2,196.00	10,540,800.00	1,054,080.00
3	3,850.00	2,196.00	8,454,600.00	845,460.00
4.1	4,280.00	2,196.00	9,398,880.00	939,888.00
4.2	4,900.00	2,196.00	10,760,400.00	1,076,040.00

Summarizing the mentioned costs by variants, the lowest unit price of water on the primary network of the subsystem according to the monomial tariff was for variant 1.1, 115.82 €/ha, and the highest for variant 2, 153.86 €/ha (Table 5).

Table 5. Yearly costs of irrigation (EUR)

No.	Costs, €	Var. 1.1.	Var. 1.2.	Var. 2	Var. 3	Var. 4.1.	Var. 4.2.
I	Fixed costs	1,872,258	1,719,493	2,663,902	2,169,755	2,170,884	2,092,774
1	Amortization	1,214,461	1,106,676	1,765,183	1,379,800	1,372,919	1,321,332
2	Maintenance	460,068	421,410	663,137	520,947	523,920	502,921
3	Insurance	95,729	89,407	133,582	107,008	112,045	106,521
4	Labor power	102,000	102,000	102,000	162,000	162,000	162,000
II	Variable costs	1,040,25	1,204,95	1,204,95	996,330	1,090,75	1,226,910
1	Energy	889,380	1,054,08	1,054,08	845,460	939,888	1,076,040
2	The fee for water	150,870	150,870	150,870	150,870	150,870	150,870
III	Total (I+II)	2,912,50	2,924,44	3,868,85	3,166,08	3,261,64	3,319,684.0
	Unit price of water, €/m^3	0.066187	0.066458	0.087921	0.071950	0.074121	0.07544
	Unit fixed costs, €/ha	74.45	68.38	105.91	86.28	86.33	83.22
	Unit price for the irrigated area, €/ha/year	115.82	116.30	153.86	125.91	129.71	132.02

For projects that have only one product for sale, in this case, irrigation water, a suitable indicator for ranking is the parameter obtained from break-even analysis i.e. break-even point (BEP). The same was calculated for all 6 variants and shown in table 6. The highest water price elasticity is with variant 1.2. (47.19 %). The minimum irrigated area (Fmin, ha) to cover the annual costs of the subsystem is for variant 1.2. (11,868.39 ha), and the minimum unit costs (Jmin, €/ha) of irrigation from the primary network are for variant 1.1. (115.82 €/ha).

Table 6. Comparison of break-even point (BEP), minimum irrigated area (Fmin), and minimum unit costs (Jmin) by variants

Parameters	Var.1.1	Var.1.2	Var.2	Var.3	Var.4.1	Var.4.2
BEP, %	52.47	47.19	51.13	52.86	53.98	53.74
Fmin, ha	13195.14	11868.39	12858.53	13292.08	13574.70	13513.39
Jmin, €/ha	115.82	116.30	153.86	125.91	129.71	132.02

In the example of variant 4.1, the BEP calculation is shown graphically (Figure 2).

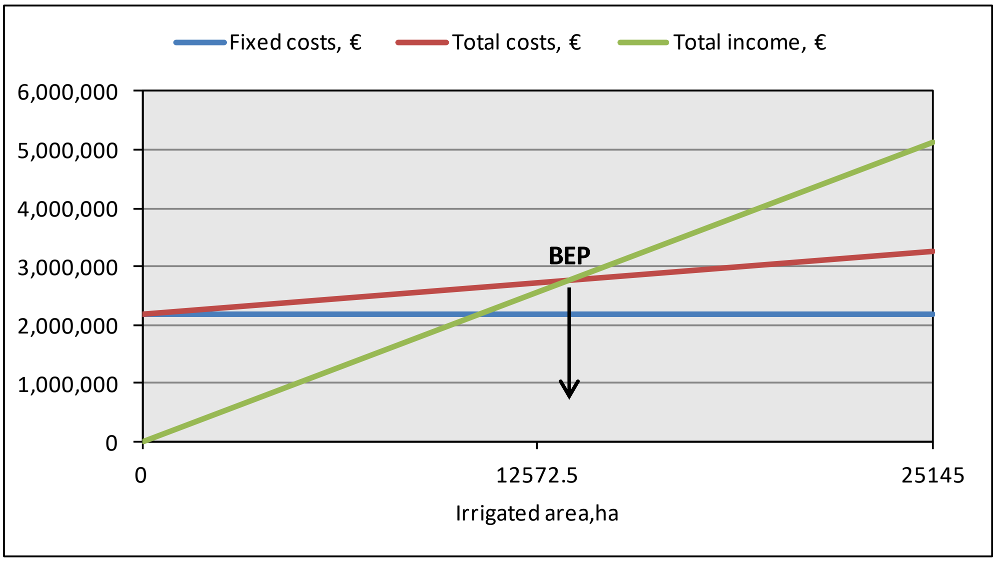


Figure 2. Break-even point (BEP) for variant 4.1.

Many more indicators can be important parameters for ranking and choosing the optimal variant of the subsystem. In the literature, dynamic indicators of efficiency are more respected, such as the net present value of the project, financial and economic rate of return, economic price of water (ILRIC method), and others (Potkonjak & Mačkić, 2014).

In these studies, the economic evaluation of this subsystem was performed based on ILRIC methods. This method is based on the comparison of discounted costs (where they are included in initial investments and equipment replacement and exploitation costs in €) with the total discounted area for irrigation on the "Telečka" subsystem. The costs include total investment and exploitation costs for the operating period of the subsystem for 30 years with discount rates (d.r.) of 0%, 3%, 6%, and 8% per year (Table 7).

Table 7. The economic price of irrigation to the discount rate (d.r., %)

d.r., %	Var. 1.1 €/ha	Var. 1.2 €/ha	Var. 2 €/ha	Var. 3 €/ha	Var. 4.1. €/ha	Var. 4.2 €/ha
d.r., 0 %	124.18	131.34	166.6	135.27	138.54	140.69
d.r., 3 %	150.90	159.16	206.6	165.83	167.86	169.19
d.r., 6 %	183.26	192.84	255.09	202.86	203.3	203.66
d.r., 8 %	207.39	217.96	291.28	230.47	229.72	229.36

Based on several technical and economic parameters, variant 4.1 is the most favorable. However, for the final decision on the choice of variant for further development, it is necessary to include some other factors: the ownership structure of the land and the size of the plots, the dynamics of the construction of the complete subsystem, the way of financing the secondary and tertiary network as well as the irrigation equipment, environmental factors, social impact.

CONCLUSIONS

A part of the research on the selection of the variant of the "Telečka" subsystem, which in the final stage will be part of the regional hydrosystem "Severna Bačka", is presented. The location of this subsystem has been defined and covers an area of 25,145.00 ha and will be located in the area of 3 municipalities. The required capacity of pumping stations at the water intake is 7.32 m^3/s with partially known locations. The water management solution to this problem was only related to the primary canal network and pipelines, as well as the construction facilities on them. For this purpose, a simulation model was developed based on which 6 potential variants were obtained for implementation. Based on the specified parameters, 6 potential variants for construction have been proposed. By ranking the stated quantitative parameters, the best effects are achieved in the 4.1 variant of the technical solution with the following values: total investments for the construction of 42.05 million €, unit investments of 1,670.00 €/ha, investments for equipment replacement of 4.20 million € every 10 years, costs of irrigation on the water intake 130.00 €/ha, fixed costs of irrigation 86.00 €/ha, economic price of irrigation 203.00 €/ha (for d.r. 6%). For the calculation of these parameters, data from the technical part of the plan was used, in which a large number of experts from different professions were involved. An improved planning methodology (using a simulation model) as well as the obtained technical and economic data can be used for comparison with other regional subsystems that are in similar conditions (e.g. climatic, soil, available water resources).

REFERENCES

Đurin, B., & Baić, L. (2016). The Method of Selecting the Optimal Variant of Irrigation Systems Driven by PV Energy. *American Scientific Research Journal for Engineering, Technology, and Sciences*, *26*(3), 225–243. file:///C:/Users/ksenija.mackic/Downloads/moanassar,+2324-7018-1-LE-1.pdf

Holy, M. (1993). Is irrigation sustainable? *Canadian Water Resources Journal*, *18*(4), 443–449. https://doi.org/10.4296/cwrj1804443

Nikoletić et al. (2020). Generalni projekat regionalnog podsistema za navodnjavanje "Telečka", "Hidrozavod DTD" ad., Novi Sad.

Potkonjak, S., Bajčetić, R., & Škorić, M. (2008). The approach of development planning of regional hydrosystems. *Agrieconomica, 39–40,* 38–45.

Potkonjak, S., Mačkić, K., & Zoranović, T. (2013). Economic value and pricing of water in irrigation in Serbia. *Book of Proceedings of the IV International Scientific Symposium*

"Agrosym 2013", Jahorina, 932–937.
Potkonjak, S., & Mačkić, K. (2014). Assessment of the economic effects of irrigation in the area of the Danube region in Serbia. *Thematic Proceedings of the International Scientific Conference "Sustainable Agriculture and Rural Development in Terms of the Republic of Serbia Strategic Goals Realization within the Danube Region",* Belgrade, 940–956.
Potkonjak, S. (2020). Prethodna studija opravdanosti podsistema za navodnjavanje "Telečka". "Hidrozavod DTD" ad., Novi Sad.
Raju, K. S., & Kumar, D. N. (2006). Ranking irrigation planning alternatives using Data Envelopment Analysis. *Water Resources Management*, *20*(4), 553–566. https://doi.org/10.1007/s11269-006-3090-5
Rudić, Ž., Nikolić, G., Stević, D., Božić, M., Mačkić, K., & Potkonjak, S. (2019). Achieving sustainable irrigation development in agricultural areas of Serbia with limited water resources. *Outlook on Agriculture*, *48*(2), 126–135. https://doi.org/10.1177/0030727019831019
Srđević, B., & Srđević, Z. (2016). *Vodoprivredna sistemska analiza sa primenom u menadžmentu vodnih resursa (Water management system analysis with application in water resources management)*. Poljoprivredni fakultet, Novi Sad. http://polj.uns.ac.rs/sites/default/files/udzbenici/VODOPRIVREDNA-SISTEMSKA-ANALIZA.pdf