IRRIGATION PROSPECTS IN SERBIA

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Summary: *Prospects of irrigation In Serbia is mostly limited with available and required water having in mind that irrigation consumes a lot of water. Aim of the paper is to show potential for irrigation on catchment bases, introducing into analysis all potential sources of water, namely: directs abstraction from rivers and channels, abstraction from groundwater and using existing and/or planned reservoirs for water supply and flood protection as multipurpose systems for irrigation.*

Key words: *Irrigation, water requirements,water availability*

1. INTRODUCTION

Aim of this paper is to determine prospects of irrigation development in Serbia in terms of natural water related factors, namely Irrigation water requirements (IWR) and Irrigation water availability (IWA).
Republic of Serbia is not classified as a country with lack of water resources, but on the other hand there is a problem of unfavourable temporal and spatial distribution of available water.
Unlike the water abstracted for the water supply and industry, majority of the irrigation water is irreversible (consumed by plants), while only the small percentage is returned to the streams. Having on mind that irrigation consumes a lot of water (70% of a water withdrawal in the World is used for irrigation), it is necessary to make detailed water balance calculations that will include spatial and temporal distribution of IWR and IWA for all major catchments in Serbia that contain potential areas for irrigation.

2. IRRIGATION WATER REQUIREMENTS

Irrigation water requirement is calculated with simplified soil water balance equation:

$$IWR = ET_c - P_e \tag{1}$$

where P_e is monthly effective rainfall and ET_c is crop potential evapotranspiration. P_e as part of the cumulative monthly rainfall (P) that remains in the soil is calculated based on

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USDA methodology [2] and ET_c is calculated based on the estimated cropping pattern (K_c) and calculated reference evapotranspiration (ET_0):

$$ET_c = K_c ET_0 \tag{2}$$

Reference evapotranspiration is calculated on monthly bases using the following monthly meteorological data: average of daily minimum (T_{min}) and maximum temperatures (T_{max}), average relative humidity – RH, iInsolation – n, average wind velocity at 2 meters above terrain. The Penman Monteith equation [1] was used for calculating the reference evapotranspiration ET_0 (mm/day).

For the purpose of preliminary analysis, with a main goal of giving an indication of the spatial and temporal distributions of IWR for the whole country, K_c is calculated with uniform cropping pattern adopted: 25% wheat, 30% maize, 15% vegetables, 15% fruits, 15% industrial crops and 10% second harvest.

In this analysis, data from 437 meteo stations have been used, among which 26 of them are with detailed monthly meteorological data necessary for calculation of the reference evapotranspiration ET_0 according to Penman-Monteith method, while the rest contain only the data of monthly precipitation. Since the complete set of meteorological data necessary for calculation of ET_0 is available only for 26 main stations, it was necessary to recalculate ET_0 for the rest of 411 stations where only precipitation is measured. For those stations, ET_0 is calculated by interpolating the meteorological data from 26 main stations, using the weighting factors related to 4 nearest main stations in 4 quadrants, that are computed through the inverse distance method.

Having on mind that temperature data have the strongest impact on ET_0 and they change with the altitude, those data are primarily rescaled with respect to the elevation of the actual precipitation station, using the standard factor -0.65 oC / 100 m of altitude rise.

Results of ET_0 calculation are presented for 8 out of 26 main meteorological stations with full set of available meteorological data (Figure 1). Results are presented as average monthly values based on 71 years long period: 1949-2019. Clearly, results are similar for most stations, except for Valjevo where ET_0 peak, occurring in August, has approximately 15% lower value. Distribution of monthly ET_0 values over a year follow mostly the same pattern: about 80% of ET_0 is related to the vegetative period of 6 months, from April to September, while about 50% of annual sum is for summer months (June, July and August).

Irrigation water requirement (*IWR*) is calculated on monthly bases for all 437 meteorological stations for period of 71 year. Results are synthetized in the form of: monthly average values for each station, annual sum for each station, monthly values for fictive drought year.

Fictive drought year is calculated based on the statistical analysis, under the assumption that monthly *IWR* values for the period of 71 years follow the normal distribution. Recurrence Interval RI = 5, meaning drought that occurs once in 5 years is adopted as standard for design of irrigation systems.

Calculated *IWR* are the net ("on field") irrigation water requirements, while the gross irrigation water requirements (*GIWR*) are the actual water quantities withdrawn from different sources (rivers, reservoirs or groundwater). *GIWR* depends on the distribution system and the irrigation method, where both impacts are included in the efficiency coefficient (n). Having on mind the assumption that the future development of irrigation in Serbia will be based mostly on sprinkler and drip irrigation methods that are the most water saving, it is reasonable to adopt value n=0.85. Finally, the *GIWR* can be expressed as the following:

$$GIWR=IWR/n \tag{3}$$

Finally irrigation design modulus (q), that indicates a maximum dayli water requirement is calculated based on the maximal monthly *GIWR* value during the drought year with recurrence interval RI = 5 years:

$$q = 0.116 \times max\{GIWR(RI = 5)\}/30 \tag{4}$$

where 0.116 is the factor transforming units from [mm/day] into the $l/(s \text{ x } h_a)$.

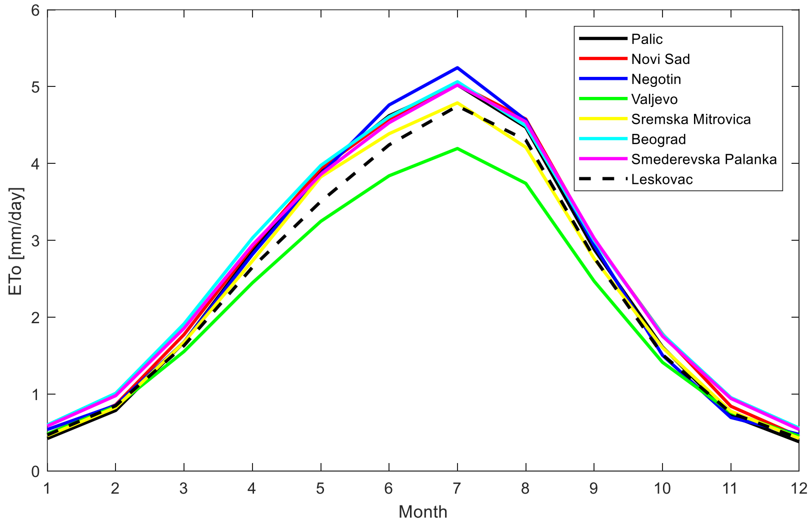

Figure 1. Average monthly ET_0 values for eight meteorological stations

Detailed results for selected meteorological station Novi Sad, are presented on the following figure (*Figure 2.*).

Based on previous results spatial distribution of ET_0 and *IWR* for Serbia is calculated. Two maps showing the spatial distribution of the cumulative annual ET0 and IWR are created. In total maps are created from 437 points, and results are presented on on the following figure (*Figure 3.*).

There are several important facts that can be concluded from the presented analysis:

- GIWR are in the range of 300-360 mm/year for an average year, except for the south west parts of Serbia that have lower GIWR (< 250 mm/year).
- GIWR rise about 50% for drought year with recurrence interval RI = 5 years.
- Design irrigation modulus is about 0.45 - 0.55 l/(s ha), except for the south west areas where it takes values lower than 0.4 l/(s ha).

It should be emphasized that these are the global estimations, while local variations are expected mostly due to different local cropping patterns, as well as the local climate conditions and soil characteristics. Therefore, detailed IWR calculations are obliged for each project individually.

In order to analyze trends in the cumulative annual *IWR* values, Standardised Irrigation Water Requirement Index (*SIWRI*) is calculated for 8 selected meteorological stations as:

$$SIWRI = \frac{IWR - \overline{IWR}}{\sigma_{IWR}} \tag{5}$$

SIWRI describes how much the *IWR* value deviates from the multi-year average.

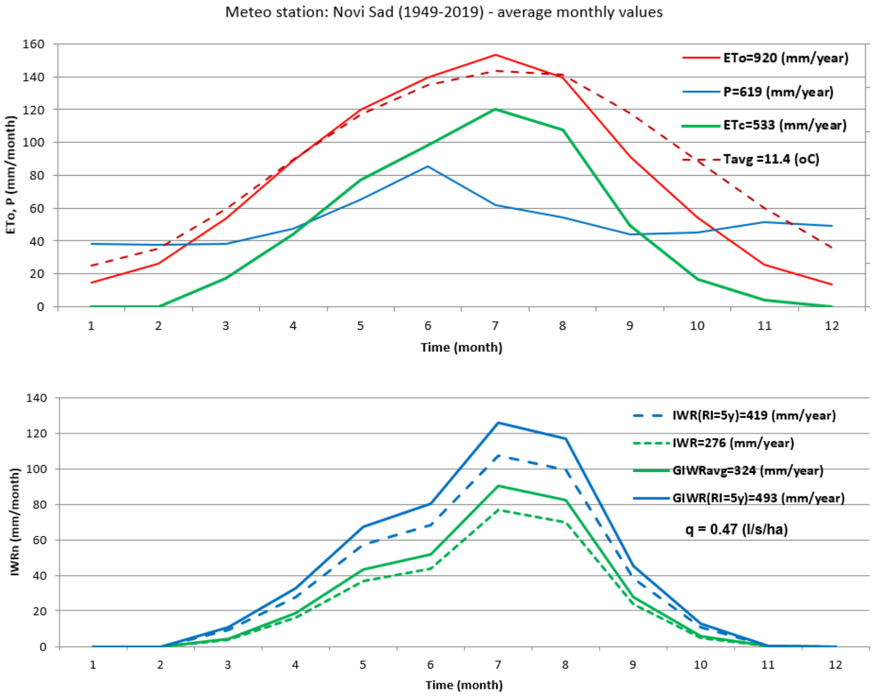

Figure 2. Results for meteorological station Novi Sad

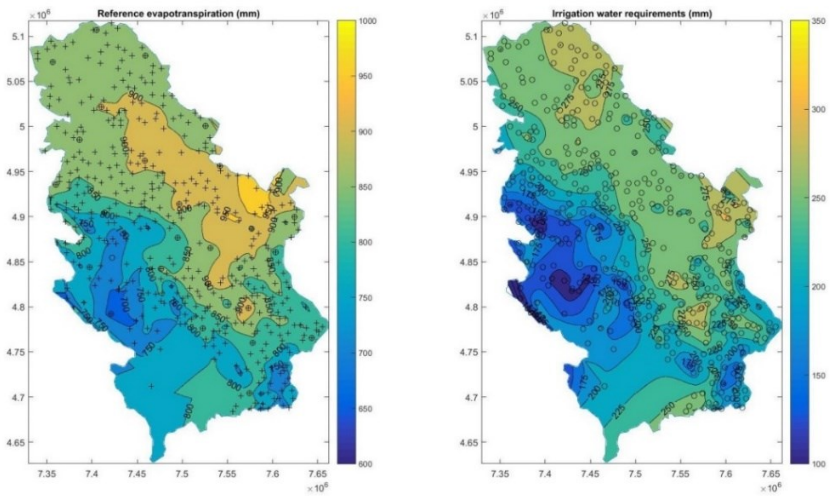

Figure 3. Maps representing the spatial distribution of the cumulative annual ET_0 (left) and IWR (right) values

Hence, *SIWRI* = 0 is related to average *IWR*, while *SIWRI* = ±1 indicates dry/wet year with the *IWR* value that deviates from average by one standard deviation. *SIWRI* values higher than 0.84 indicate droughts with recurrence interval (*RI*) of 5 years or more.

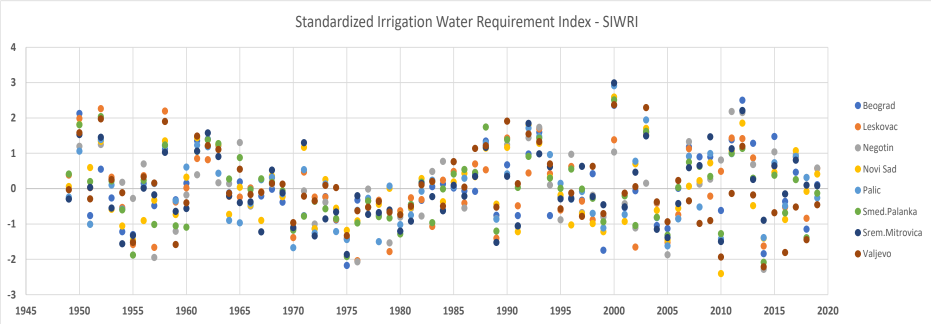

Figure 4. Change of SIWRI for 8 main meteorological stations over period of 71 year

Results on *Figure 4* shows that for the period before 2000 there is a certain long term trend with sequences of multiple wet or drought years in a row, while after the year of 2000 extremely rainy and drought years take turns more frequently than before. It is well known that years 2000 and 2012 were extreme droughts, which is confirmed by the results presented. Based on the *SIWRI* values, the recurrence interval for the year 2000 reaches almost 100 years in case of some stations (e.g. Belgrade).

3. IRRIGATION WATER AVAILABILITY

The following water sources are considered:

- Surface water – irrigation water abstraction directly from rivers and channels
- Groundwater – irrigation water abstraction from groundwater bearing layers
- Reservoirs – irrigation water abstraction from reservoirs.

3.1. Surface water - direct abstraction from rivers

In order to estimate possible water withdrawal for irrigation from rivers, 35 hydrological stations were selected based on the spatial distribution and data availability. Analyzed discharge data cover the period from 1990 to 2019. Available water for irrigation is calculated based on the average monthly discharge values. Locations of analyzed stations are shown in Figure 5.

Potential area that can be irrigated with the water abstracted directly from the river can be determined based on the estimated potential river discharge and the previously computed irrigation water requirements (IWR). For the purpose of this analysis, which is done on the strategic level for the whole territory of Serbia, estimation of the available surface water for irrigation is based on the average monthly discharge data. However, more detailed analysis related to a specific areas requires a catchment water management model which uses the average daily discharge values, since the water is abstracted directly from the river and not retained in reservoirs. This is especially important for

smaller rivers, where daily discharge values can differ significantly from the monthly average.
Irrigation water availability (Q_{irr}) is determined based on the difference between (monthly) river discharges with 80% probability of occurrence and that with 90%, multiplied by factor $f < 1$, where $Q_{80\%}$ and $Q_{90\%}$ values are estimated based on the statistical analysis of monthly discharge values, which is explained later on.

$$Q_{irr} = f(Q_{80\%} - Q_{90\%}) \tag{6}$$

Discharge value $Q_{90\%}$ is adopted as the downstream minimum which indicates that irrigation should be stopped when the river discharge is lower than $Q_{90\%}$. Downstream minimum is a water management category that depends on the downstream water use (Q_{dwns}) and the ecological water requirements (Q_{ecol}), and it is estimated as a maximum of those two values - $max(Q_{ecol}, Q_{dwns})$.
There are different criteria for estimating Q_{ecol}, but the most common one is to use discharge with probability of occurrence of 95% ($Q_{ecol} = Q_{95\%}$). However, this value is calculated based on the average daily discharges for a whole year, and not on the average monthly values for vegetation period. Another reason why probability of 90% is used instead of 95% is to leave enough water for other potential downstream water requirements (Q_{dwns}) that are not taken into account here. However, abstraction of water for other purposes are much lower compared to the irrigation requirements, especially having on mind that more than 80% of water abstracted for water supply and/or industry is returned to streams and is available for downstream users, which is not the case with irrigation. Based on the comparison between the adopted $Q_{90\%}$ and the estimates of Q_{ecol} for several hydrological stations, it has been concluded that $Q_{90\%}$ is an adequate value of a downstream minimum, and as such it can used for further analysis.
Finally, in order to remain on the safe side, it is adopted that only two thirds of gross available water ($Q_{80\%}$ - $Q_{90\%}$) is for irrigation ($f = 2/3$), while the remaining reserve is used as a compensation for:

- the fact that calculation is not done using daily, but monthly discharge data that are lower (not on the safe side);
- the possibility of a significant rise in water demand by other users, or a climate change scenarios that can significantly lower the water availability in the future.

The presented methodology for calculating the water quantity available for irrigation is implemented on 35 hydrological stations, for each month of vegetation period (April to September). In order to determine $Q_{80\%}$ and $Q_{90\%}$, different probability distributions of average monthly flows have been analyzed for a 30 years long period (1990 – 2019). Weibull empirical distribution has been compared with log-normal and log-Pearson III distributions for different hydrological stations. Finally, log-normal distribution is adopted as the relevant one, and it is further used for determination of $Q_{80\%}$ and $Q_{90\%}$.
By introducing obtained discharge values into Eq. (6) together with $f = 2/3$, monthly Q_{irr} values are calculated. Further analysis showed that August is most often a critical month when both hydrological and agricultural droughts coincide (*GIWR* is high and Q_{irr} has lowest values).
After estimating Q_{irr} for each hydrological station based on the statistical analysis, these values were assigned to the corresponding catchment areas and the potential irrigation

areas can be determined based on the previously calculated design irrigation modulus q, as:

$$A_{irr} = Q_{irr}/q \tag{7}$$

Južna morava, zapadna morava and velika morava subcatchments

These three subcatchment areas are presented in Figure 5 with the relevant downstream stations bolded in the corresponding table. Since Juzna and Zapadna Morava are the two main tributaries of Velika Morava river, it is clear that Q_{irr} = 7.45 m^3/s ("Ljubicevski Most" - the most downstream station on Velika Morava) is the cumulative Q_{irr} for the three subcatchment areas. Based on Q_{irr} values for the downstream stations on Juzna and Zapadna Morava subcatchments, Q_{irr} = 2.40 m^3/s and Q_{irr} = 3.43 m^3/s are adopted as the corresponding irrigation discharges, respectively, leaving Q_{irr} = 7.45 – 2.40 – 3.43 = 1.62 m^3/s for the Velika Morava subcatchment. Based on the design modulus q, which is about 0.5 l/(s ha) for the central part of Serbia, gross potential irrigation area A_{irr} for the whole Velika Morava catchment, with direct abstraction from rivers, is about A_{irr} = 7.45/0.5x1000 ≈ 15000 ha, while A_{irr} for Južna, Zapadna and Velika Morava subcatchemnts are about 5000, 7000 and 3000 ha, respectively.

Table 1. Available irrigation water in Velika Morava catchment

Catchment	StationID	River	Station name	A (km2)	August	Qirr (m3/s)
Južna Morava	47295	IBAR	LOPATNICA LAKAT	7818	1.91	2.40
	47590	**JUŽNA MORAVA**	**MOJSINjE**	**15390**	**2.40**	
	47570	JUŽNA MORAVA	ALEKSINAC	14284	2.07	
	47530	JUŽNA MORAVA	VLADIČIN HAN	3052	0.47	
	47665	VETERNICA	LESKOVAC	500	0.08	
	47740	JABLANICA	PEČENjEVCE	891	0.04	
	47640	VLASINA	VLASOTINCE	879	0.21	
	47528	JUŽNA MORAVA	VRANjSKI PRIBOJ	2775	0.17	
	47920	NIŠAVA	PIROT	1745	0.60	
	47990	NIŠAVA	NIŠ	3870	0.96	
	47880	TOPLICA	PROKUPLjE	1774	0.18	
Zapadna Morava	47350	MORAVICA	ARILJE	830	0.34	3.43
	47120	ZAPADNA MORAVA	MILOČAJ	4658	1.22	
	47195	**ZAPADNA MORAVA**	**JASIKA**	**14721**	**3.43**	
Velika Morava	**47090**	**VELIKA MORAVA**	**LJUBIČEVSKI MOST**	**37320**	**7.45**	1.62
	47040	VELIKA MORAVA	BAGRDAN	33446	6.52	
	47010	VELIKA MORAVA	VARVARIN	31548	6.00	
	47075	JASENICA	SM.PALANKA (JASENICA)	496	0.03	
	47076	KUBRSNICA	SM.PALANKA (KUBRSNICA)	743	0.04	

Kolubara catchment

The approach presented assumes the relevant hydrological station is located downstream enough (close to the junction with Sava) so that the corresponding Q_{irr} can be assigned to the whole (sub)catchment area. However, this is not the case with Kolubara catchment, since the most downstream station Beli Brod covers only 52 % of the whole catchment area. Therefore, the corresponding Q_{irr} = 0.42 m^3/s is increased proportional to the catchment area, giving Q_{irr} = 0.42/0.52 ≈ 0.8 m^3/s. Based on q = 0.4 l/(s ha) value adopted for the western Serbia, A_{irr} estimated for Kolubara catchment is about 0.8/0.42x1000 ≈ 2000 ha.

Table 2. Available irrigation water in Kolubara catchment

StationID	River	Station name	A (km2)	August	Qirr (m3/s)
45905	KOLUBARA	VALjEVO	340	0.08	0.8
45910	KOLUBARA	BELI BROD	1896	0.42	

Mlava, Pek & Timok catchments

In this section, results for the three independent catchments (Mlava, Pek and Timok catchments) located in the east part of Serbia, are presented. Like for Kolubara catchment, due to fact that the downstream hydrological stations do not cover the whole catchment areas in case of Timok and Mlava catchments, the corresponding Q_{irr} values are increased proportionally to their areas. Results are summarized below (q = 0.52 l/(s ha) is adopted for this region):

- Mlava catchment - Q_{irr} = 0.39 m^3/s; A_{irr} = 0.39/0.52x1000 ≈ 750 ha
- Pek catchment – Q_{irr} = 0.19 m^3/s; A_{irr} = 0.19/0.52x1000 ≈ 360 ha
- Timok catchment – Q_{irr} = 0.47 m^3/s; A_{irr} = 0.47/0.52x1000 ≈ 900 ha

Results clearly show there is not enough water for irrigation of large areas, and the only way for increasing potential areas for irrigation would be construction of reservoirs.

Table 3. Available irrigation water in Mlava, Pek And Timok catchments

StationID	River	Station name	A (km2)	August	Qirr (m3/s)
42730	PEK	KUSIĆE	1220	0.19	**0.19**
42527	MLAVA	VELIKO SELO	1124	0.23	**0.39**
42921	BELI TIMOK	KNjAŽEVAC	1242	0.15	**0.47**
42929	BELI TIMOK	ZAJEČAR	2150	0.23	

Drina catchment

Drina is trans boundary river with catchment area of 17720 km^2 that extends on 3 countries: Montenegro, Serbia and Bosnia & Herzegovina, each of them having about 1/3 of the catchment area on their territory. Estimated value of Q_{irr} is about 9.3 m^3/s, equal to the sum of Q_{irr} for Radalj station (9.18 m^3/s – Drina river) and Q_{irr} for Lesnica station (0.14 m^3/s – Jadar river. Available water has to be divided between Bosnia & Herzegovina and Serbia, so it is assumed that Q_{irr} for Serbia is about 9.3/2=4.65 m^3/s.
Main potential irrigation areas are situated at the most downstream part of the river Drina (Mačva in Serbia and Semberija in Bosnia & Herzegovina/Republika Srpska). It should be noted that the channel and gate for water withdrawal for irrigating Semberija is already constructed, while the Semberija irrigation system is designed and partly build (designed area of Semberija irrigation system is about 8500 ha).
Having on mind q = 0.45 l/(s ha) is adopted for this region, A_{irr} = 4.65/0.45x1000 ≈ 10300 ha is an approximate area that can be irrigated with water directly withdrawn from Drina.

Table 4. Available irrigation water in Drina catchment

StationID	River	Station name	X	Y	A (km2)	Zo (m.a.s)	August	Qirr (m3/s)
45865	DRINA	BAJINA BAŠTA	7383425	4871075	14797	211.47	8.38	**9.3**
45882	DRINA	RADALj	7352959	4921062	17490	129.47	9.18	
45837	LIM	PRIJEPOLjE	7390050	4805150	3160	443.37	1.14	
45892	JADAR	LEŠNICA	7363500	4944625	959	103.47	0.14	

Sava catchment

Sava is a trans boundary river and an international waterway. Estimated Q_{irr} for Sava catchment is based on the data from hydrological station Sremska Mitrovica. Having on mind that Drina river is a tributary of Sava, based on the water balance approach Q_{irr} = 35.9 m^3/s for Sava catchment is estimated as a difference between Q_{irr} for Sremska Mitrovica (45.2 m^3/s) and Q_{irr} for Drina catchment (9.3 m^3/s). Determined Q_{irr} value is close to the discharge value already planned for abstraction within the two technical documents related to two potential irrigation regions located on the left and right bank of the river Sava: General design for Irrigation of Srem region & General design for Irrigation of Macva region. By assuming q = 0.46 l/(s ha) for this region, the potential irrigation area that can be supplied with water directly withdrawn from Sava is about A_{irr} ≈ 35.9/0.46x1000 ≈ 78000 ha.

Table 5. Available irrigation water in Sava catchment

StationID	River	Station name	X	Y	A (km2)	Zo (m.a.s)	August	Qirr (m3/s)
45090	SAVA	SREMSKA MITROVICA	7390175	4981125	87996	72.22	45.17	**35.90**

Note there is a potential conflict of interest in water management between water withdrawal for irrigation and water transport in hydrological drought years, due to fact that Sava is an international waterway.

Dunav, Tisa & DTD system

Highest potential for irrigation is located in the north part of Serbia. Potential is identified according to: water availability and also in terms of irrigable land. Hidrosystem DTD is designed and partly built to be used for irrigation as well as for other water management tasks (drainage, flood protection, water transport and ecological water requirements). Most of irrigation water that could be directed toward DTD channel network could be withdrawn from Dunabe river (Bezdan and Bogojevo hydro profiles). Estimated available water for irrigation from Dunabe is 164 m^3/s, so that potential irrigation area is estimated to about 300000 ha. It should be noted that existing structures in hydro nodes Bezdan and Bogojevo and downstream channels, presently do not have enough capacity for abstracting maximum potential water for irrigation. Also, there is a potential conflict in water management during drought periods, because Dunabe is international waterway so that international obligations and priorities in water management rules should be established.

Another hydro node for abstraction for irrigation purposes is Dam on the river Tisa. Estimated available water for irrigation from Tisa is 37.3 m^3/s so that potential irrigation area is estimated to about 70000 ha.

Again there is potential conflict in water management with water transport in hydrological drought years, having in mind that Tisa is also international waterway.

Additional 3000 ha could abstracted from river Tamiš for irrigation.

Table 6. Available irrigation water abstracted from Dunav, Tisa and Tamiš

StationID	River	Station name	X	Y	A (km2)	Zo (m.a.s)	August	Qirr (m3/s)
42010	DUNAV	BEZDAN	7334254	5081102	210250	80.64	144.6	**164**
42020	DUNAV	BOGOJEVO	7350350	5044540	251593	77.46	163.9	
44020	TISA	SENTA	7430200	5087875	141715	72.8	37.3	**37.3**
42401	TAMIŠ	JAŠA TOMIĆ	7489150	5031950	5334	73.46	1.54	**1.5**

3.2. Groundwater – abstraction from river alluvium

Ground water for irrigation purposes can be abstracted only from river alluvium layers. There are several reasons for this limitation:

- the main reason is written in Water law, where is stated that high quality groundwater that could be readily used for water supply, cannot be used for other purposes.
- water supply is priority, so that springs, especially in karst regions, cannot be used for irrigation.

- 80% of water supply in Serbia relies on groundwater, so it can be abstracted for irrigation purposes only from water bearing layers that can be replenished during the non-irrigation period. Note that using water from deep groundwater bearing layers is considered groundwater mining, and is not in accordance to sustainable development.

Based on everything mentioned, it is clear that alluvium layers of large rivers are the only possible source of groundwater for irrigation purposes, since the abstraction from these sources is delayed abstraction from the river itself. In such case, the aquifer is used as a retention basin that is gradually refilled with water in periods without irrigation.

Furthermore, there are certain pre conditions to be satisfied and proved in the technical documents before groundwater is used for irrigation:

- detailed investigations and modelling proving that the abstraction of groundwater for irrigation purposes will not affect present and future development of water supply in the region.
- detailed investigations and modelling proving that groundwater is able to replenish during non-irrigation season, so that irrigation will not have a permanent effect on groundwater balance.
- detailed investigations and modelling proving that irrigation will not have a long term effect on groundwater quality.

Available abstractions from groundwater (so called dynamic reserves) are estimated based on the previous investigations, studies and projects that are summarized and presented in the *Strategy of water resources management in Serbia until 2034 ("Sl.glasnik RS", br. 3/20172017).* Data on potential groundwater abstraction for irrigation purposes presented here should be considered as a global approximation.

Due to the uncertainties that are involved in the approximate data presented here, detailed investigation is required for each project (area) individually. First of all, it is unclear whether the data acquired from the Strategy document are related to the maximal or the average capacity of well fields that can be used for irrigation. Also, the probability of occurrence of a potential well field capacity in drought months and years is unknown. That is why the presented results concerning the potential abstraction from groundwater should only be considered as a rough estimate.

Based on the estimated dynamic reserves, and the adopted value of q = 0.5 l/(s ha), a global approximate estimation of the available irrigation water abstracted from river alluviums is made:

- Danube alluvium – Qirr ≈ 5 m3/s, Airr ≈ 5/0.5x1000 = 10000 ha
- Sava alluvium - Qirr ≈ 3.5 m3/s, Airr ≈ 3.5/0.5x1000 = 7000 ha
- Morava alluvium - Qirr ≈ 2 m3/s, Airr ≈ 2/0.5x1000 = 4000 ha

3.3. Reservoirs for irrigation

There are not many existing reservoirs that are used for irrigation, and none of them is a single purpose reservoir designed for irrigation only. Usually reservoirs are built primarily for flood protection, but could also be used for irrigation. Most off the reservoirs with volumes above 2 Mm^3 are located in Srem region, on the streams that go from Fruška gora mountain. Building dams and creating large reservoirs that will be a part of the regional irrigation system is probably not a realistic goal at this moment, having on mind that it would be difficult to prove feasibility of these projects. On the other hand, multipurpose reservoirs with clearly defined operation rules are of great importance in the future water resource management in Serbia.

Flood protection reservoirs
For example, after the flood event that happened in 2014 more than 20 reservoirs are planned for flood protection in Kolubara catchment. Initially, these were planned as a single purpose reservoirs for flood protection only, but with adequate operation rules that would include early warning system for flood protection and adequate design of dam drawdown facility providing conditions for fast removal of stored water before potential flood event, these reservoirs could become multipurpose reservoirs used also for irrigation. This is especially important for Kolubara catchment, where is shown that with direct abstraction from rivers only about 2000 ha can be irrigated.
As an example, results of recent analysis for reservoirs Pambukovica and Kamenica, primarly aimed for flood protection, has shown their potential for irrigation: Pambukovica (10.6 Mm^3) – A_{irr} = 2500 ha and Kamenica (11.1 Mm^3) – A_{irr} = 1800 ha.
The rough estimate is there is possibility for irrigation of up to 20000 ha from planned flood protection reservoirs in Kolubara catchment.

Water supply reservoirs
Moreover, it is known from previous analysis that reservoirs for water supply have potential to be used for irrigation. Reservoirs for water supply are planned as a part of the regional water supply systems with volumes determined based on projections of demographic and industrial growth and specific consumptions done back in 80's. Obviously, most of those projections were over estimations.

Table 6. List of water supply reservoirs that could be used for irrigation purpose

Reservoir	River	Year built	Type	Height (m)	Width (m)	Volume (10^6 m^3)
Bovan	Moravica	1978	Z	52	151	59
Gruža	Gruža	1984	L	52	288	65
Barje	Veternica	1991	K	75	326	41
Prvonek	Banjska	2005	K	88	250	20
Stuborovni	Jablanica	2018	K	74	430	52

Conservative estimate is that 12000 ha can be irrigated from selected reservoirs. However, it should be emphasized that reservoirs for water supply could be used for irrigation only if detailed investigations and modelling prove that it is possible to establish adequate water management rules that: 1. will not affect present and future development of water supply in the region, 2. will not significantly increase the risk of the water supply deficit in drought years, 3. will not have a long term effect on water quality in reservoirs.

4. CONCLUSION

Potential for irrigation in terms of irrigation water requirement and water availability in Serbia has significant spatial differences.
Even though north part of Serbia (e.g. Vojvodina), has low precipitation rate, there is huge potential for irrigation with water that can be abstracted mainly from Dunabe and

Tisa rivers and directed through DTD system of channels to individual irrigation systems. Also, there is potential for water withdrawal from Sava river for irrigation of Srem region in Vojvodina. Based on presented analysis, total potential irrigation area can be estimated to about 450000 ha. It should be noted that there is potential conflict in water management in drought periods due to fact that Dunav, Tisa & Sava are international water ways. Also it is necessary to invest in DTD system for reconstruction of channels and hydro nodes in order to fulfill it's irrigation potential.

South from the Sava river there is much less potential for irrigation in terms of water availability. Mačva region can be irrigated with water abstracted from Drina, Sava and groundwater, which is in fact alluvium that those two rivers had created. Due to fact that Drina is transboundary river, potential abstraction from Drina has to be divided between Srbija & Bosna and Herzegovina. Based on presented analysis, potential irrigation area with water from Drina and its alluvium is more than 17000 ha.

In Kolubara catchment, the water availabile for direct abstraction from rivers is very scarce. It is estimated that only about 2000 ha could be irrigated in that way. In order to extend potential irrigation area it is necessary to build reservoirs. About 20 reservoirs for flood protection are planed to be build in Kolubara catchment area. With proper design and water management rules, some of these reservoirs could be used for irrigation. That would increase potential area for irrigation to more than 20000 ha. Moreover, Kolubara catchment has reservoir Rovni, that is build as part of the regional water supply system Kolubara, and it could be potentially used as additional source for irrigation.

Velika Morava has potential for irrigating of up to 15000 ha. If irrigation area is divided with its main contributors: Juzna & Zapadna Morava, then potential areas that could be irrigated with direct withdrawal from rivers is 5000 ha for Južna Morava, 7000 ha for Zapadna Morava and 3000 ha for Velika Morava. Additional 4000 ha could be irrigated from groundwater. Additionaly, 4 water supply reservoirs with volumes above 20 milion m^3, exist in the Velika Morava catchment: Gruža, Bovan, Barje and Prvonek, and with proper water management rules are potential source for irrigation.

Regions in the East part of Serbia, that are located in the catchments of rivers Mlava, Pek and Timok and far from Dunabe river, are with least potential for irrigation due to scarce water availability for direct abstraction from rivers. Potential irrigation area is up to 2000 ha and it could be increased only with building multi purpose reservoirs, where irrigation would be one of the users. In terms of water availability, there is almost unlimited potential for irrigation in the East parts of Serbia that are close to the Dunabe river (e.g. regions near Kladovo and Negotin).

REFERENCES

[1] Allen L et.all 1998. Crop Evapotranspiration: Guidelines for Computing Crop Water Requirements. FAO Irrigation and Drainage Paper 56. Rome, Italy: Food and Agriculture Organisation.
[2] USDA (1993) National Engineering Handbook, Part 623, Irrigation Water Requirements

ПЕРСПЕКТИВЕ НАВОДЊАВАЊА У СРБИЈИ

Резиме: *Могућности наводњавања у Србији су ограничене расположивошћу водних ресурса и потребама за водом, имајући у виду да наводњавање захтева велике количине воде. Циљ рада је да се покаже потенцијал за наводњавање по сливним подручјима, процењујући све потенцијалне изворе воде: захватање директно из реке, захватање подземне воде и коришћењем постојећих или планираних резервоара које се користе за снабдевање водом и/или заштиту од полава као вишенаменске водопривредне објекте.*

Кључне речи: *Наводњавање, потребе за водом, расположивост водних ресурса*