SUPPORTING THE DEVELOPMENT OF AN IRRIGATION STRATEGY FOR SERBIA

A brief on the technology and infrastructure needs assessment for sustainable and profitable irrigation development in the Republic of Serbia

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Contents

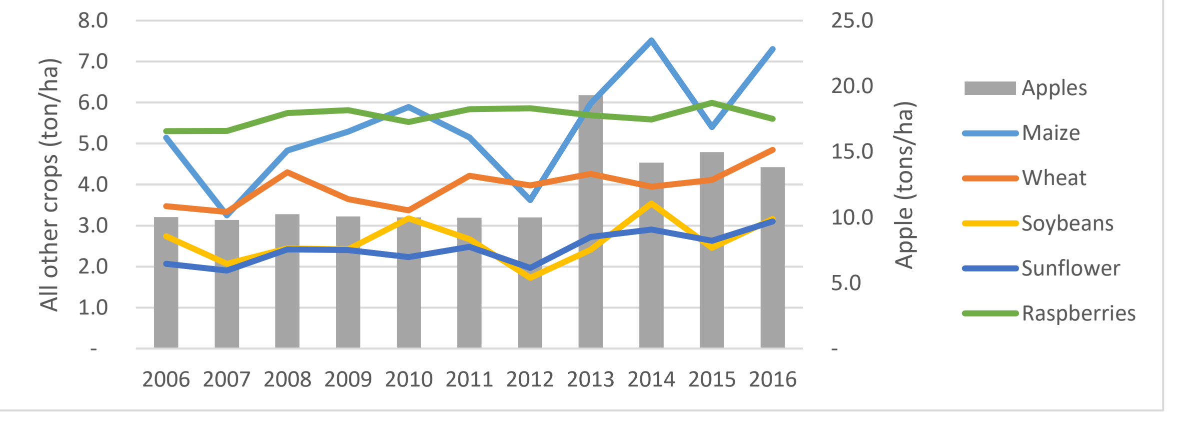
1. Aim of the brief

The aim of this brief is to outline the irrigation technological aspects of irrigation and irrigation infrastructure needs for sustainable and profitable irrigation development in Serbia.

With relatively good soils and favorable weather conditions the vast majority of farming in Serbia is rain-fed, with very little use of irrigation, surveyed at less than 3% cultivated farmland [1].

However, it is expected that climate changes, such as precipitation patterns and temperatures, will increase the need for irrigation especially during extending periods of consecutive dry days. In Vojvodina, mean annual air temperatures are expected to rise by 1.3°C in 2040 and 2.4°C in 2080, according to a number of GCMs and the SRES A2 scenarios, compared with 1985 - 2005. Spring crops are more vulnerable to an increased number of crop drying days and projected higher temperatures in the late spring and summer. According to the results obtained, during the spring crops growing season a temperature increase of 4.9 - 8.9% for 2040 and of 10.8 - 16.6% for 2080 is projected [2].

The following table [3] demonstrates Serbia's yield volatility for selected rain fed crops, and climate changes are expected to increase that:



The low and unstable yields obtained in the crop production in Serbia are the result of insufficient and unfavorably distributed seasonal rainfall. In last 60 years, 48 were dry and 30 of those were very dry. [4]

An analysis of the last nine decades (as of 1924) has revealed precipitation deficits for most cultivated crops in about 80% of years during July and August. [5]

In addition to yield increase, irrigation contributes significantly to yield stabilization at a high level regardless of rainfall amount and distribution. Without irrigation, even the high-value crops such as vegetables, forage crops, flowers and industrial crops have a low production volume when grown on a large area. Droughts are particularly intensive in the northern, eastern and southeastern parts of the Republic, i.e., in the lowlands with most productive soil types. [6]

The following brief is from the Irrigation technologies and infrastructure needs prospects.

[1] 2018 Serbia Ag Census
[2] Lalic and Mihailovic, 2011
[3] 2018 Serbia Ag Census
[4] Babovic et al; Irrigation Effects in Plant Production in Serbia & Montenegro; Novi Sad Institute of Field and Vegetable Crops
[5] Dragovic et al., 2008
[6] Babovic et al; Irrigation Effects in Plant Production in Serbia & Montenegro; Novi Sad Institute of Field and Vegetable Crops

2. Analysis of existing situation in Serbia

The following different configurations of irrigation systems already exist in Serbia to certain levels:

Irrigation infrastructure	Individual	Other 1	Other 2
Water abstraction	**On** farm	**Off** farm	**Off** farm
Water delivery	**On** farm	**On** farm	**Off** farm
Distribution & application	**On** farm	**On** farm	**On** farm

Individual irrigation systems are the most common configuration in Serbia and we know of a few existing irrigation projects with significant water conveyance (we hope to gather further information about it); e.g. Stari Banovci where expansion of an existing irrigation system would eventually allow irrigation of up to 33000 Ha, compared to 22000 Ha before, through the pumping stations for and pressurized pipelines for irrigation.

The existing individual irrigation systems are managed and maintained by the owners, which is driven and justified through economic gains.

Configuration 'Other 1' usually involve surface-water delivery through neighboring farms and therefore not so common, but relatively more common in Vojvodina in farms without direct access to surface water.

Some ongoing projects, including by the Abu Dhabi Fund, would add more projects of 'Other 2' configuration.

The share of 12% of all farm holdings applied irrigation on 3% of utilized agricultural area [7]. According to the Census, the following facts are notable:

- Of the all sown areas and regarding groups of crops, mainly irrigated are areas under vegetables, watermelons and strawberries (open-air grown), 64%.
- As the main source of water for irrigation, 61% agricultural holdings declared ground water at holdings.
- 65303 holdings apply surface irrigation, 13174 holdings apply sprinkler irrigation, and 29323 holdings apply drip irrigation method.
- Bosilegrad is the municipality with the largest share of holdings (73%) that irrigate utilized agricultural area.

2.1. Irrigated farm land

The size of agricultural land in Serbia ranges from a ¼ of hectare to about 50 hectares in private hands, and up to 10,000 ha owned by agricultural companies.

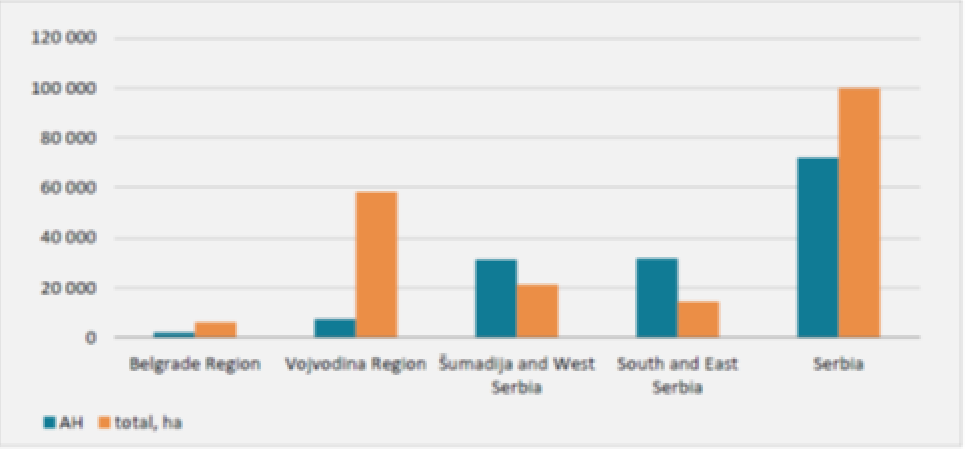
Serbia's usage of irrigation varies between Central Serbia and Vojvodina in terms of number of farms and irrigated hectares. The average irrigated area, per farm, in Vojvodina is 7-8 times larger than in central Serbia:

Irrigating farms in Serbia: [8]

	Farms irrigating		
Crop group/Crop	**No. farms**	**% of farms**	**Av. area**
Central Serbia	166,000	89 %	0.5 ha
Vojvodina	20,000	11 %	3.7 ha
Grand Total	**186,000**	**100 %**	**0.9 ha**

More agriculture holdings (AH) apply irrigation in Vojvodina then in other areas of Serbia [9]:

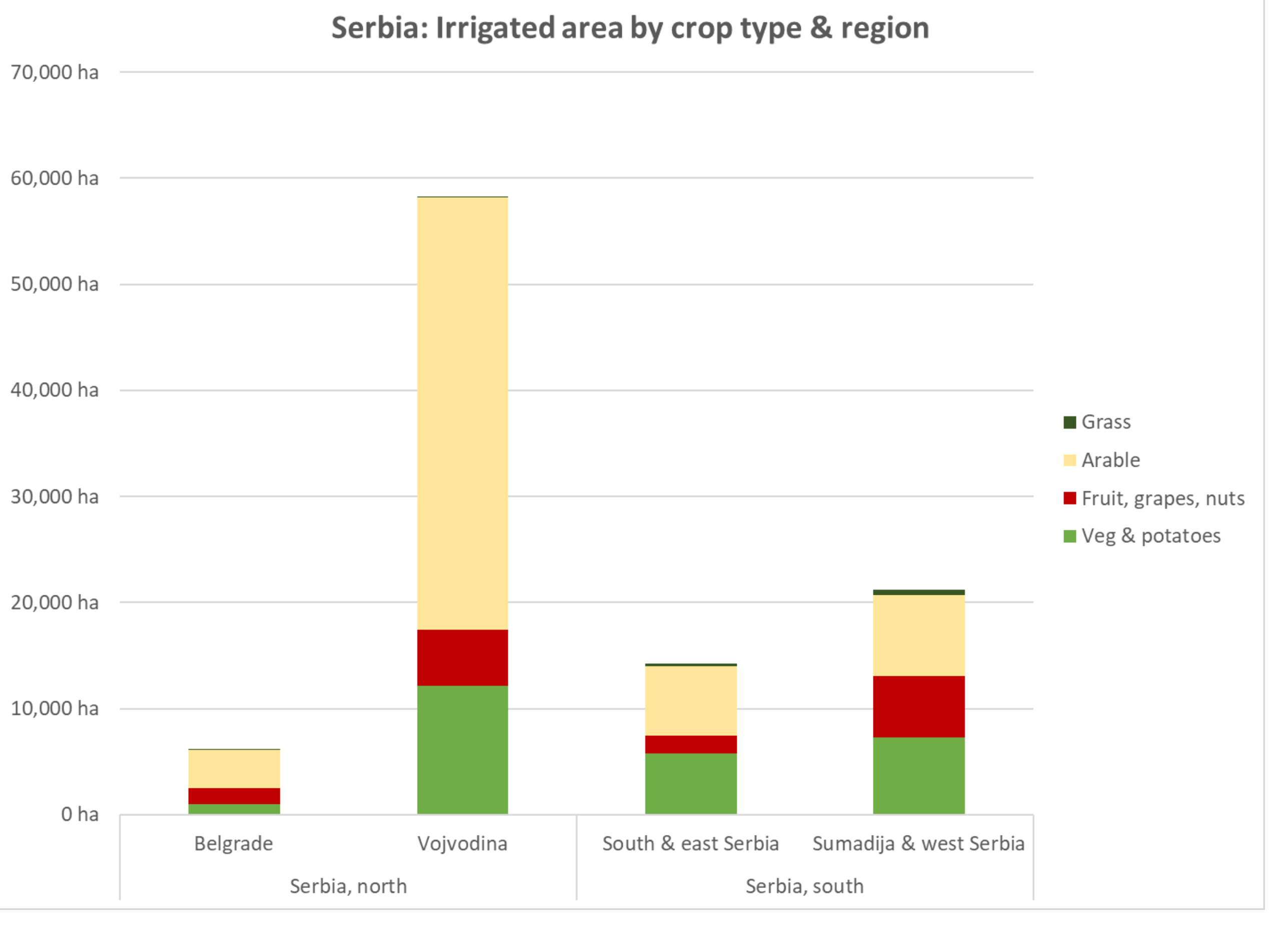
[7] 2012 Ag Census
[8] 2018 Ag Census
[9] 2012 Ag Census



The significant difference in the size of average irrigated area per farm is mainly because in Vojvodina 57% of the irrigated area is for Arable & fodder crops compare to only 32% in Central Serbia.

2.2. Irrigated crops

The most irrigated crops are arable, more in Vojvodina, and vegetables and potatoes [10]:

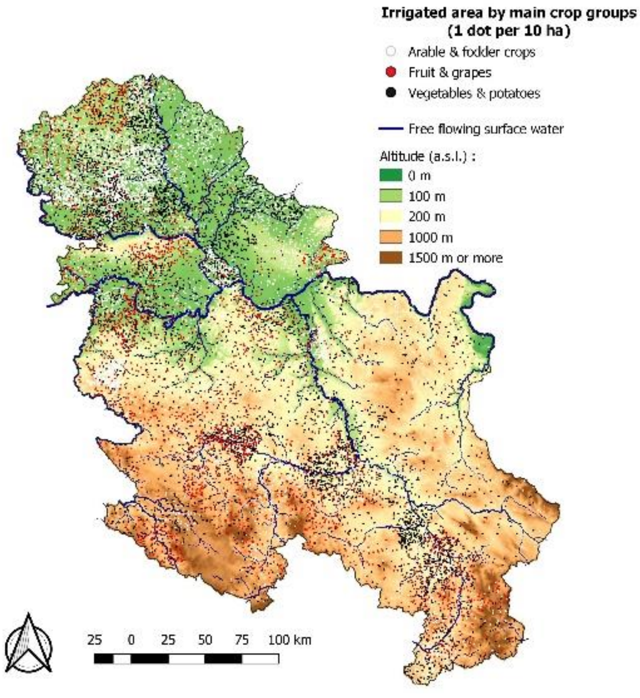


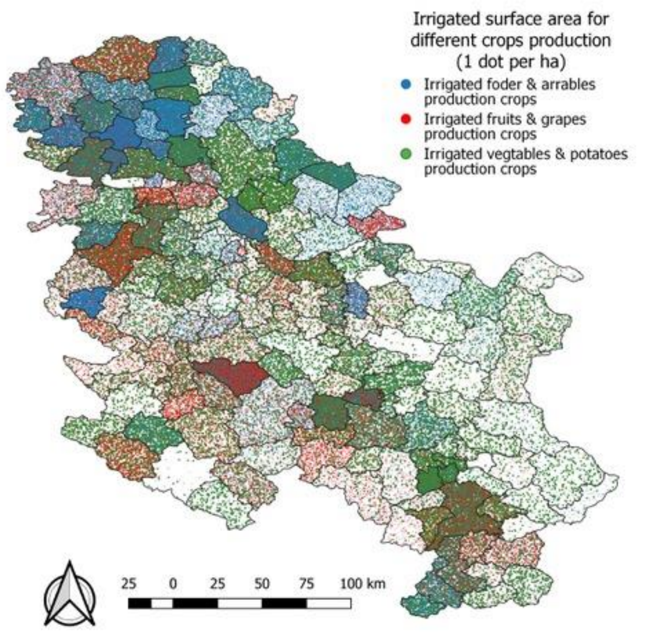
Though the share of Maize and perennials is high among irrigated crops, still very little of these crops are irrigated out of the total cultivated:

Crops	Out of all irrigated land	% irrigated of this crop
Maize	30%	3%
Vegetables	24%	35%
Perennial fruits, grapes & nuts	22%	8%
Potatoes	9%	25%

[10] 2012 Ag Census

Most irrigated arable crops are in Vojvodina while vegetables and fruits are in other regions: [11]

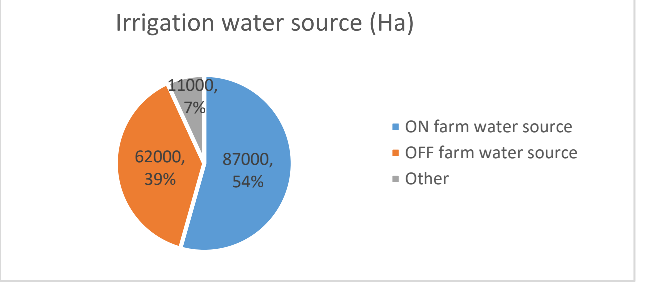




While in Vojvodina's farms are relatively large, they mainly grow arable crops, and in Central Serbia farms are mostly small or of medium size but they grow more HVCs.

2.3. Abstraction and delivery infrastructure

Most Serbian farms are using on farm water, both underground and surface water, for irrigation compared to off farm water, and this is common across all farm sizes: [12]



Both High Value Crops and Low Value Crops are currently served by irrigation: [13]

	Land share by crop type			
Water source	**HVCs**		**LVCs**	
On farm water	60,000 ha	*68%*	26,000 ha	*38%*
Off farm water	22,000 ha	*24%*	40,000 ha	*57%*
Vodovod	3,000 ha	*3%*	1,000 ha	*2%*
Other	4,000 ha	*5%*	3,000 ha	*4%*
Total	**89,000 ha**	***100 %***	**71,000 ha**	***100%***

2.3.1. On farm water

On-farm water abstraction in Serbia includes:

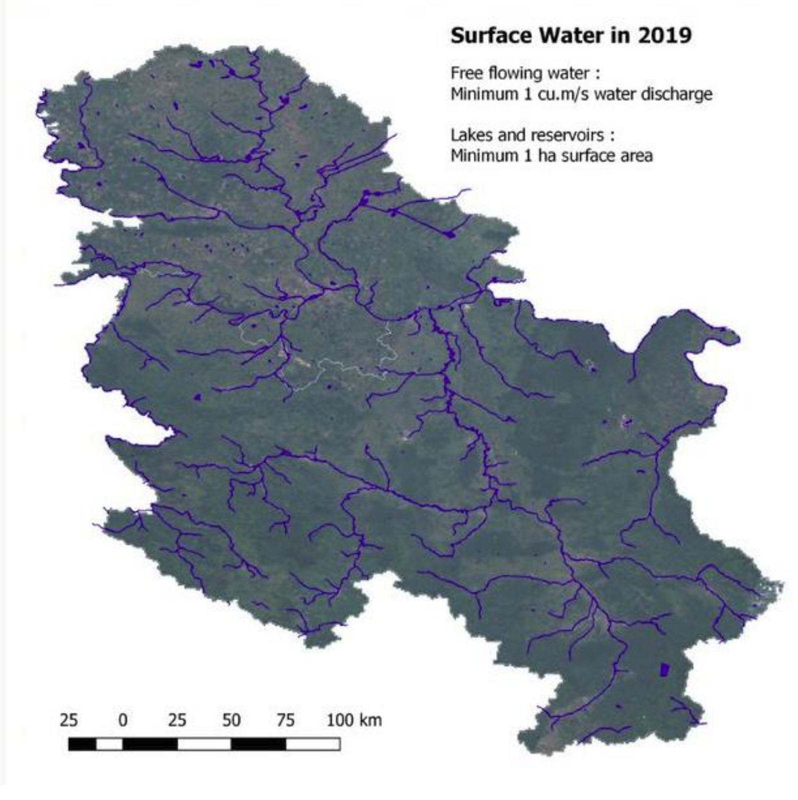
- Underground water (boreholes) which is the most common
- Surface water

[11] 2012 Ag Census
[12] 2018 Farm Structures Survey
[13] 2018 Farm Structures Survey

In both cases, there is no need for public investment as it is under responsibility of the farm, including investment and operation. As such, there is little centralized information and monitoring of water gauging and about the energy used for pumping.

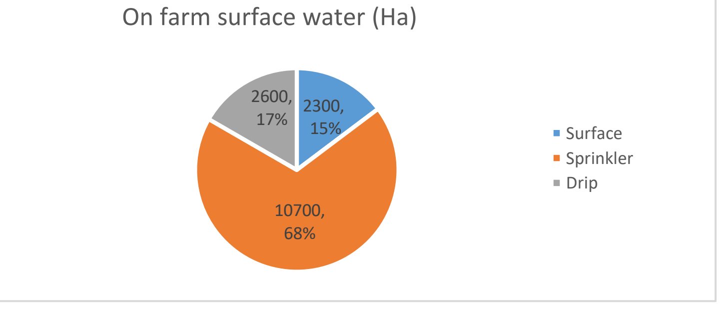
	Underground water in Serbia: [14]
1	Supplying 71000 Ha, about 45% of the irrigated farm
2	Used by 51% of irrigating farms
3	Supplying 60% of irrigated HVCs
4	Used less by large farms (16% of irrigating large farms) and more by small and medium sized farms (around 55% of those farms that are irrigating)
5	Used for sprinkler irrigation (48%) and drip irrigation (42%)

Surface water, especially in Vojvodina and the DTD hydro-system, is applicable in all lowlands and to a certain extent in hilly areas.



	Surface water in Serbia: [15]
1	Supplying 16000 Ha - 10 % of all irrigated farm land
2	Equally used for HVC and LVC
3	Equally used by Small and Medium farms, less by Large farms
4	Mainly under sprinklers - 68%

How on-farm surface-water is applied for irrigation:



The vast majority of Serbia's irrigators of on farm surface water are using sprinklers irrigation, which is less sensitive to water quality than drip irrigation.

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[14] 2018 Ag Census
[15] 2018 Ag Census

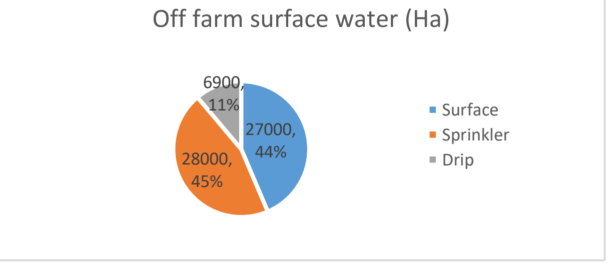
SWOT for On-farm water abstraction in Serbia:

Strengths	*Weaknesses*
All responsibility for irrigation infrastructure is on-farm	Capital cost
Water availability is secured	Energy cost
Little or no need for water storage	Requites setting-up capacity
Minimized water losses with little or no water conveyance	Requires knowledge and manpower for O&M and for water quality monitoring
Flexibility for applying fertilizer through the irrigation system with no risk to other farms	Unmonitored abstraction
Flexibility to choose a preferred irrigation method to meet specific requirements and operation capacity	
Irrigators would manage O&M in order to assure operation of the irrigation system	
Opportunities	**Threats**
Increased irrigation efficiency with modern irrigation methods	Lack of capital investment
Increased overall farm productivity, with more hectares under HVC	Lack of setting-up capacity
Increased knowledge and expertise among irrigators	Lack of operation know-how

2.3.2. Off farm surface water

Three large rivers flow through the Vojvodina Province, the Danube, Sava and Tisza, with several smaller watercourses draining into them. Hydro system DTD includes 960 km of main canals (BCN - basic channel network), and 21.500 km of small canals (DCN - detailed channel network)[16].

	Off-farm water abstraction in Serbia:
1	Supplying 62000 Ha - 39 % of all irrigated farm land
2	Around 60% of it under LVC
3	Only 10% under drip with the rest equally under surface and sprinklers



SWOT for Off-farm water abstraction in Serbia:

Strengths	*Weaknesses*
Individual on farm irrigation infrastructure	Capital cost
With no need to rely on external water supply, water availability is secured	Energy cost
Little or no need for water storage.	Requites setting-up capacity
Optimized efficiency with little or no water conveyance, and cost, minimizing water losses	Requires knowledge and manpower for O&M and for water quality monitoring
Individual irrigation systems have full control and flexibility for applying fertilizer through their irrigation system with no risk to other farms	

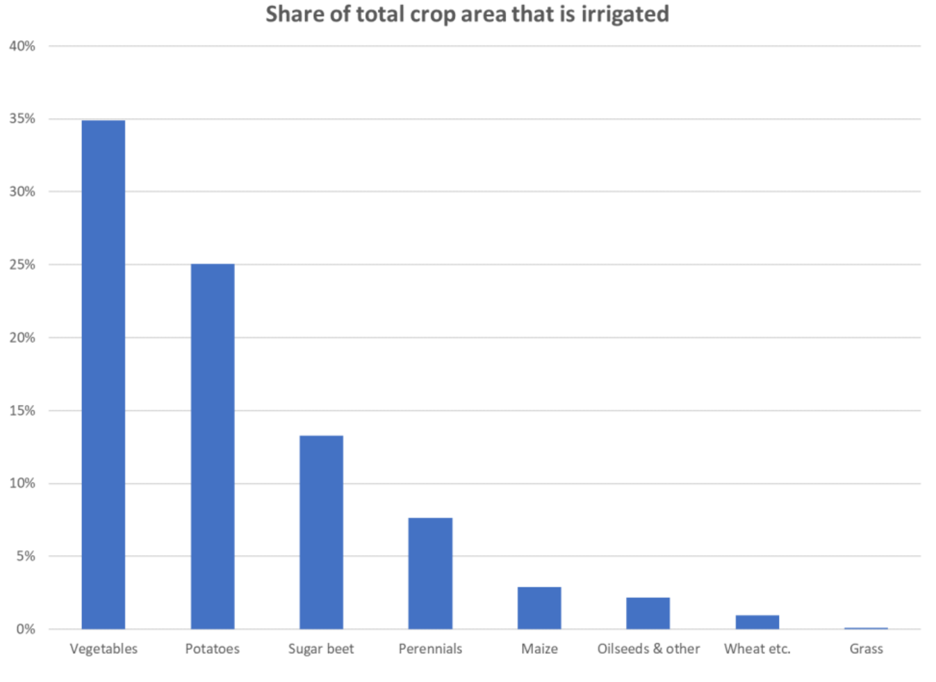
[16] www.vodevojvodine.rs

With full individual control on water volume, pressure, and quality, irrigators would have full flexibility to choose their preferred irrigation method to meet their requirements and operation capacity	
Irrigators would manage O&M in order to assure operation of the irrigation system	
Opportunities	**Threats**
Increased irrigation efficiency with modern irrigation methods	Lack of capital investment
Increased overall farm productivity, with more hectares under HVC	Lack of setting-up capacity
Increased knowledge and expertise among irrigators	Lack of operation know-how

2.4. Existing irrigation methods

Most of the need for irrigation in Serbia, around 60-70%, is during the months of July and August, depending on the precipitation in each year. As such, the irrigation infrastructure and systems are curtail for the gains of irrigation. Unlike in dry countries, in Serbia such complementary irrigation in between rain, enables the flexibility among irrigation methods.

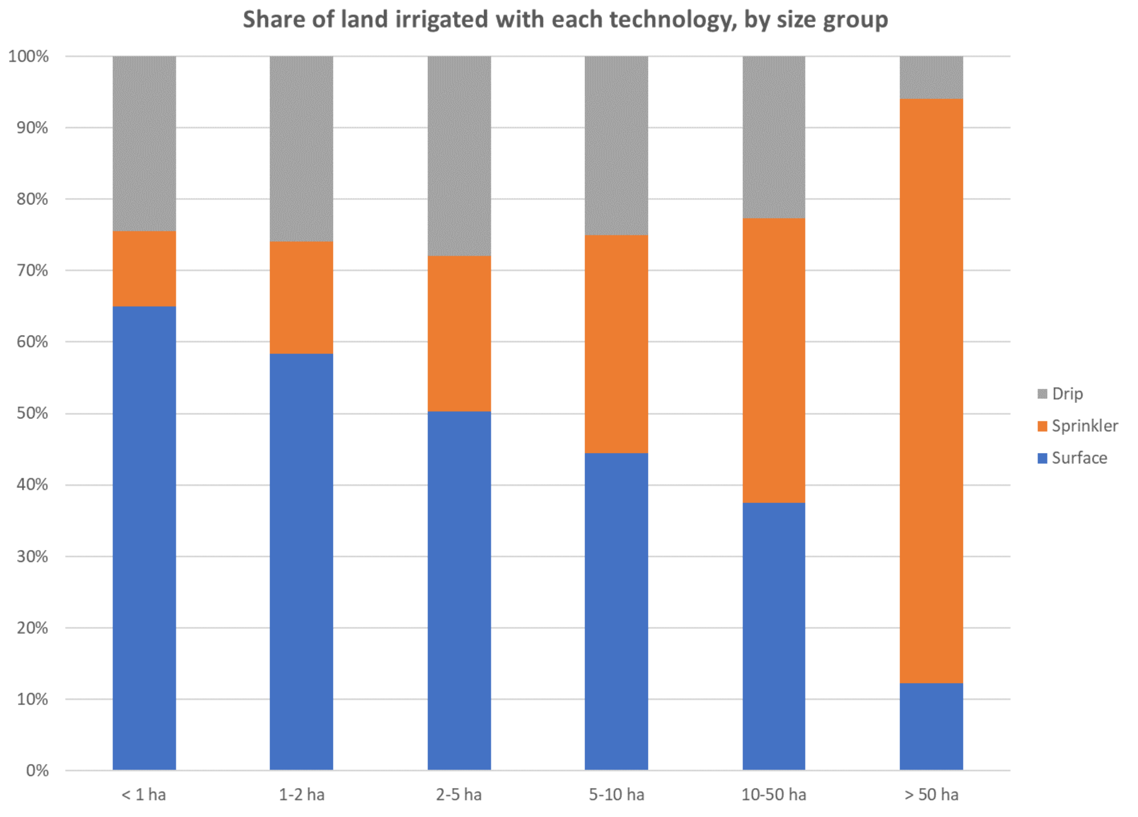
Share of total crop area that is irrigated: [17]



Irrigation by water source and irrigation method: [18]

Source	Application method (estimated areas)							
	Surface		Sprinkler		Drip		All methods	
Groundwater on farm	7,100 ha	*10%*	34,300 ha	*48%*	29,800 ha	*42%*	**71,200 ha**	***100%***
Surface water on farm	2,300 ha	*15%*	10,700 ha	*68%*	2,600 ha	*17%*	**15,600 ha**	***100%***
Surface water off farm	27,000 ha	*44%*	28,000 ha	*45%*	6,900 ha	*11%*	**61,900 ha**	***100%***
Vodovod	100 ha	*3%*	2,600 ha	*71%*	1,000 ha	*26%*	**3,700 ha**	***100%***
Other	1,900 ha	*27%*	3,400 ha	*47%*	1,900 ha	*26%*	**7,200 ha**	***100%***
Total	**38,500 ha**	***24%***	**79,000 ha**	***49%***	**42,100 ha**	***26%***	**159,600 ha**	***100%***

[17] 2012 Ag Census
[18] 2018 Farm Structures Survey



Although Maize is currently the single most irrigated arable crop in Serbia followed by Soy, and together they represent 61% of all 71,000 Ha of irrigated arable crops, more irrigation equipment is currently sold for irrigating fruits and vegetables. [19]

In Vojvodina, large farms tend to irrigate more than small farms, while in Central Serbia it is mainly the medium size farms that are irrigating.

Arable & fodder are the most irrigated crops followed by vegetables and potatoes: [20]

Crop group	Irrigated area	Out of total irrigated area
Arable & fodder	71,000 ha	44 %
Vegetables & potatoes	56,000 ha	35 %
Fruit & grapes	33,000 ha	20 %
All crops	**160,000 ha**	**100 %**

2.4.1. Surface irrigation

Surface irrigation (including variations of it such as furrow-irrigation, flood-irrigation, basin-irrigation and border-irrigation) is the most common form of irrigation throughout the world, and has been practiced in many areas of the world, virtually unchanged for thousands of years. However, as it inefficient compared to modern precise irrigation methods, it is not expanding as modern irrigation methods, and mostly continue to be used in place where already existed. Surface irrigation in Serbia, mainly furrow, occupies 24% of all irrigated farm land in Serbia with 38500 Ha, nearly half of it using off-farm surface water and only 10% of it using on-farm groundwater.

With surface irrigation slopes should be uniform with a minimum slope of 0.05% in order to provide adequate drainage, and the maximum slope should be of 0.5%-2%, depending on type of surface irrigation, in order to limit problems of soil erosion. With surface irrigation either the entire field is flooded (basin irrigation) or the water is fed into small channels (furrows) or strips of land (borders). Good design should consider the slope, the soil type, the stream size, the irrigation depth, the cultivation practice and the field length, in order to achieve gains.

[19] 2020 October private irrigation companies survey
[20] 2018 Ag Census

2.4.2. Sprinkler irrigation

79000 Ha makes sprinkler irrigation the most common irrigation method in Serbia (49% of all irrigated farm land) with a wide range of sprinkler-system configurations, the most common in Serbia are:

- Center pivot
- Linear (lateral move)
- Rendžer (ranger)
- BK / kišno krilo (rain wing)
- Tifon (reel machine)

As detailed in the following SWOT, sprinklers are popular because of good uptake derived from precise irrigation and fertigation incorporation. It is mostly popular for seasonal crops, mainly arable crops in Vojvodina, but sprinkler irrigation is suited for most row, field and tree crops, where the simplicity of setting up and operation allow covering almost any size of plot of reasonably variable topography, and is adaptable to most soils. In common-practice the average application rate from the sprinklers (in mm/hour) is designed to be just under the basic infiltration rate of the soil.

2.4.3. Drip irrigation

Drip is already used in around 26% of Serbia's total irrigated hectares.

Small & medium farms are more likely to use drip for irrigating High Value Crops and in most cases would be suing underground water.

A recent survey [21] indicate that 80% of drip users are choosing drip mainly for its accuracy and water saving, as well as for accurate fertigation. Drip is currently the most common irrigation method in Serbia with 43% of irrigation sales, followed by sprinklers.

The gains of using drip in Serbia are proven for a variety of crops, e.g. Onions: [22]

Table 2. Yield, yield components and morphological characteristics of onions

Variant	Replicates	Yield (t ha^{-1})	Plant height (cm)	Number of leaves per plant	Bulb weight (g)	Dry matter in bulbs (%)
Surface drip	1	23.02	57.0	7.2	59.9	14.5
	2	20.90	57.0	6.9	60.6	14.1
	3	21.60	56.6	7.3	60.1	14.9
	Average	**21.84a**	**56.9a**	**7.1a**	**60.2a**	**14.5a**
Subsurface drip (5 cm)	1	23.91	55.6	7.9	69.8	15.0
	2	20.79	56.5	7.7	68.7	14.5
	3	20.55	57.2	7.8	70.2	13.9
	Average	**21.75a**	**56.4a**	**7.8a**	**69.6b**	**14.5a**
Subsurface drip (10 cm)	1	24.96	60.4	8.6	73.5	13.0
	2	23.19	56.3	7,4	67.6	14.5
	3	23.52	57.1	7.9	69.8	13.5
	Average	**23.89a**	**57.9a**	**8.0b**	**70.3b**	**13.7a**
Non-irrigated	1	15.57	46.8	7.2	53.1	14.5
	2	16.89	46.2	7.0	51.1	14.0
	3	16.83	49.0	7.6	48.6	13.5
	Average	**16.43b**	**47.3b**	**7.3a**	**50.9c**	**14.0a**

Watermelons:[23]

Drip irrigation significantly influenced yield and fruit characteristics of watermelon in temperate climatic conditions of the Vojvodina region. The yield in irrigation conditions (37.28 t/ha) was 3.7 times higher (9.98 t/ha) as compared with control without irrigation.

Potatoes: [24]

Potato yield in the variant with drip irrigation was 48.31 t ha-1 or 88.3% higher than in the variant without irrigation.

[21] October 2020 - Serbian private irrigation companies survey
[22] Pejić et al.; Effects of surface and subsurface drip irrigation in the yield, vegetative growth and water productivity of onions
[23] Pejic et al; Water yield relations of drip irrigated watermelon
[24] Pejic et al; Response of Potato to Water Stress in Southern Serbia

2.5. Summary

- Irrigation is needed in more than 70% of years, especially in the northern part of Serbia, while in the east of the country the need for irrigation is felt in more than 90% of the years. Percentage of dry to extremely-dry years for July-August recorded between 1924 to 2007: [25]

mm	July		August		Category
	No	%	No	%	
0-25	13	15.50	17	20.25	Extremely dry
26-50	31	36.90	24	28.55	Very dry
51-75	17	20.20	19	22.60	Dry
75-100	9	10.70	11	13.10	Moderately dry
	70	83.35	71	84.50	Total dry
101-125	7	8.35	10	11.90	Moderately rainy
>126	7	8.35	3	3.60	Rainy
Total	84	100.00	84	100.00	

- The effect of irrigation ranges from several percent in years with relatively favorable amounts and distribution of rainfall, up to 100% in dry years. In extremely dry years, irrigation increases crop yields 2-3 times in relation to rain fed conditions. [26]
- Given Serbia's climate, irrigation systems can assure watering during critical growth stages of the crops; As an example, if maize does not receive the required amount of water during the flowering stage, it would not help getting 300 or even 400 mm of rain at a later stage, as the yield loss would not be recovered.
- Some irrigation technologies, namely drip, offers another key success factor which is the ability to provide the nutrients in a small portions along the growth of the crop, optimizing the yield per amount of nutrients. This is a key factor even in year with good precipitation as it is possible to apply the fertilizer through the drip irrigation system synchronized with rainfall.

Summarizing what is most common for Serbia's existing irrigation:

In terms of irrigated hectares
Using sprinklers
Arable crops
Vojvodina

In terms of number of irrigating farms
Using drip
Central Serbia

Water source
Mainly on-farm boreholes

[25] Dragovic et al 2003; Impact of irrigation for Sustainable Food Production on Climate change

[26] Dragovic et al 2003; Impact of irrigation for Sustainable Food Production on Climate change

3. Investment options for irrigation infrastructure and irrigation technology

3.1. Scenarios for irrigation infrastructure: Individual and Multi-user irrigation systems

The following levels would be reviewed:

1. Water abstraction/catchment level;
   An average Serbian farm (depending on crop, soil, climate etc.) would require about 300mm during the irrigation season, most of it during July and August and that might increase by 20-50% during drought, the . Below are some indicative water volumes for any planned expansion of irrigation:

Planned Expansion (ha)	Required for irrigation (m3)
1000	3,000,000-4,500,000
5000	15,000,000-22,500,00

   The required energy for irrigation is estimated at average engaged power of 0.64 Kw/ha. [27]
2. Water Delivery/conveyance level; when using off-farm water
3. Distribution & application level

While the distribution & application level is always part of on-farm private infrastructure, the abstraction and delivery levels maybe either on-farm (and therefore private), or off-farm, private or public infrastructure.

Individual vs Multi-user irrigation systems:

Level \ Irrigation system	*Individual*	*Multi-user*
Water abstraction/catchment	On farm	Off-farm
Water Delivery/conveyance	On farm	Off-farm*
Distribution & application	On farm	On farm

* Water delivery to the farm-gate is shared by multiple users; requires ongoing operation-management and maintenance and are therefore subject to significant overhead in order to maintain efficient service level

Note: All the technologies reviewed in this chapter are applicable for Serbia following local assessment by regions, types of soil, crops, and climate conditions.

Individual irrigation systems:

Strengths	*Weaknesses*
All responsibility for irrigation infrastructure is on-farm	Capital cost
Water availability is secured	Energy cost
Little or no need for water storage	Requites individual setting-up capacities
Minimized water losses with little or no water conveyance	Requires individual knowledge and manpower for O&M and for water quality monitoring
Flexibility for applying fertilizer through the irrigation system with no risk to other farms	
Flexibility to choose a preferred irrigation method to meet specific requirements and operation capacity	
Irrigators would manage O&M in order to assure operation of the irrigation system	
Opportunities	**Threats**
Focus on monitoring of multi-individual systems applying strategy and policies	Lack of capital investment
Enable centralized management of water sources by applying technology and criteria	Poor/little cooperation from individual irrigators
Governance of irrigated water with restricted public sector spending	

[27] NAP UNDP 2015

Multi-user irrigation systems:

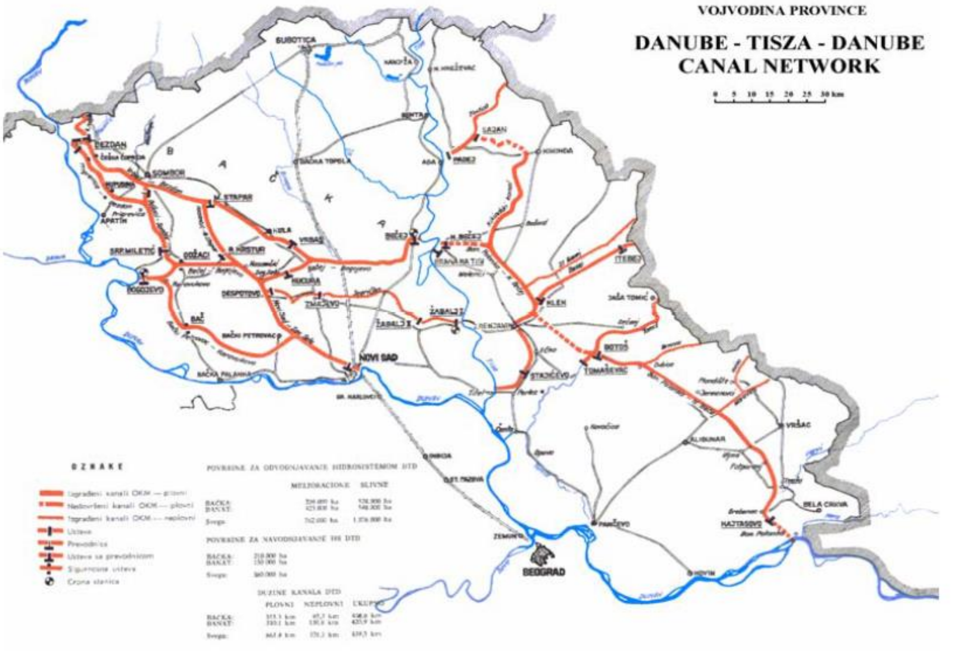
Strengths	*Weaknesses*
Serve farms without access to water	Capital costs
Governed water usage	O&M costs
Monitored water quality	Requires expertise for O&M
Infrastructure sharing	
Opportunities	*Threats*
Faster adaptation of irrigation	Poor level of service, e.g. insufficient water to meet demand
Standardize water pricing and policy	Farmers would decide 'not to use'
	Inefficient/costly O&M

3.2. Potential water abstraction/catchment options

3.2.1. For Serbia's lowlands

Vojvodina's extensive river and canal system with its many branched canals already reach many farming areas, and can be further extended.

Another potential consideration can be using the existing Danube-Tisza-Danube canal network, that currently mainly serve flood protection, also for irrigation purposes.



Irrigation from river/canals already exist to some extent in the DTD system, e.g Mali Iđoš but water delivery/conveyance is rare with Negotinsksa nizija as an exception.

The following options are proposed for further detailed evaluation:

i. Usage of existing flood protection reservoirs for irrigation – 'dual-purpose'.
   E.g. in Fruška gora mountain Srem Irrigation system.
   This can be done by direct pumping or via transferring additional water from nearby rivers.
   Following the flood of 2014 some flood protection dams and reservoirs are currently being designed, e.g. Kolubara, Pambukovica and Kamenica, which will also be used for irrigation.
   Would allow the use of both drip and sprinkler irrigation methods, which can be assessed depending mainly on water quality and typical farm size in each region.
   As drip systems are more sensitive to water quality than sprinklers, sprinklers might be preferred if water quality in such reservoirs cannot be maintained.

ii. Construction of new reservoirs, combined with flood-protection or dedicated to irrigation.
   Feasible should be carefully studied. E.g. in Republic Srpska - Bosnia & Herzegovina for the World bank - "Irrigation system Potkozarje - municipality Gradiška".

iii. Abstraction from underground water, preferably wells/boreholes that are near rivers, with very high transmissivity and are in immediate contact with surface water e.g. “Resavska celina” project.
In order to minimize and optimize the infrastructure proven technologies can be applied such as:
    - Air valves that by releasing air out of the water pipes reduce the use of energy.
    - Pressure regulating hydraulic valves that simply the design of the piping system by maintain the required/specified water pressure at all farm gates, including the farms near the pumping.
    - Flow sustain hydraulic valves that maintain pre-designed flow of water even when the demand along the pipe is changing.
    - Wireless water gauging devices that are useful for both monitoring as well as for alerting of abnormalities in the supply of water.

iv. Tertiary treatment of urban sewage, combing the need to protect environment from contamination of surface and underground water with waste, and at the same time make more water available for irrigation. This can serve farms surrounding major urban areas where the infrastructure for sewage collection and treatment would be installed. Such national-level programs are already in place in some countries, e.g. Israel and Spain, with accumulative data and methodologies.

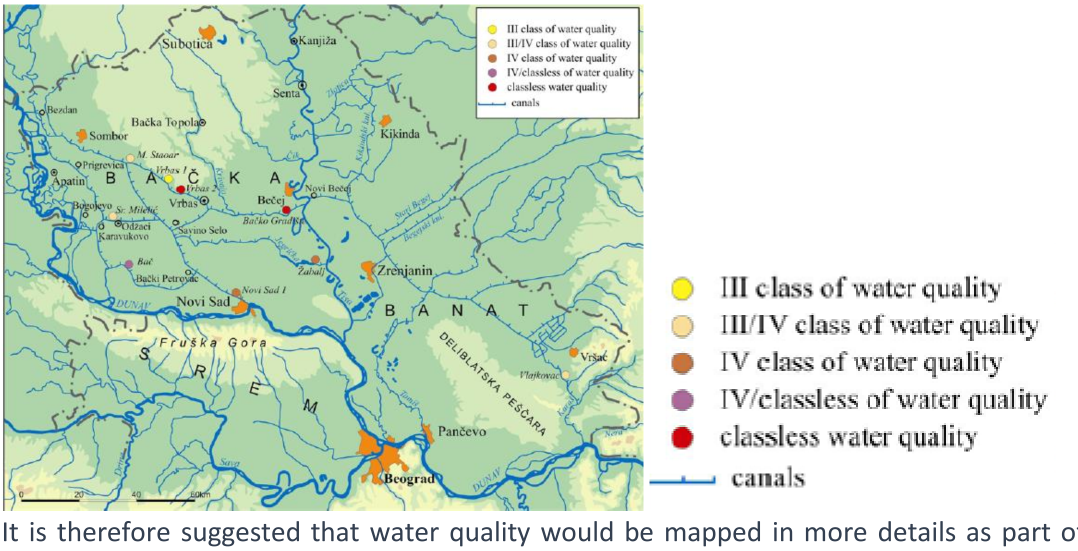
3.2.2. For Serbia’s hilly areas

i. Construction of new reservoirs, which could be combined with flood-protection or dedicated to irrigation.
ii. Rain-harvesting through water storage, with or without further conveyance. An interesting option for farms in areas without access to surface water or areas with deep groundwater, e.g the Zlatibor district in the hilly and mountainous area there are rainwater reservoirs/pools used for irrigating to 1-2 ha each.

3.2.3. Water quality

Water quality monitoring of surface water would be essential especially from canals with slow-flow and weak aeration, e.g. Vrbas and Novi Sad, where increased organic load is registered, increased concentration of mineral forms of nitrogen (on Novi Sad route), and sometimes phenolic elements: Hg, Mn, Cu and Fe. Another example is the inflow of waste untreated water of settlements in Vrbas, Crvenka and Kula, where the water quality is completely degraded (‘classless’).

Water quality of hidro – system Danube – Tisza – Danube: [28]



It is therefore suggested that water quality would be mapped in more details as part of expansion of irrigation, taking into consideration the aspects of climate changes and other water users.

[28] Milijašević et al; Water Quality State in the Hydro – System Danube – Tisza – Danube

3.2.4. Summary

The following summarize water catchment infrastructure and technologies that are recommended for region/zone and for project assessment:

#	Water catchment	Infrastructure	Applicable technology
1	Rivers and canals (e.g. Vojvodina DTD, Macva)	- Water-volume monitoring and potential gauging - Water delivery to farm-gate - Water quality monitoring	- Precise wireless water gauging devices that are useful for both monitoring as well as for alerting of abnormalities in the supply of water. - Air valves that by releasing air out of the water pipes reduce the energy requirements. - Pressure regulating hydraulic valves that simply the design of the piping system by maintain the specified water pressure at all farm gates, including the farms near the pumping. - Flow sustain hydraulic valves that maintain pre-designed flow of water even when the demand along the pipe is fluctuating. - Energy-less RAM pumps that can serve small farms nearby surface water - Filtration systems
2	Water reservoirs including rain-harvesting (both lowlands and hilly areas)	- Water storage - Water delivery to farm-gate - Gauged allocation - Water quality monitoring	- Precise wireless water gauging devices that are useful for both monitoring as well as for alerting of abnormalities in the supply of water. - Air valves that by releasing air out of the water pipes reduce the energy requirements. - Pressure regulating hydraulic valves that simply the design of the piping system by maintain the specified water pressure at all farm gates, including the farms near the pumping. - Flow sustain hydraulic valves that maintain pre-designed flow of water even when the demand along the pipe is fluctuating. - Energy-less RAM pumps that can serve small farms nearby surface water - Filtration systems
3	Abstraction of underground water (all Serbia)	Individual on-farm catchment, delivery and emitter equipment **OR** Water delivery to farm-gate with individual on-farm emitter equipment	- Pumping stations and piping - Filtration systems

3.3. Water delivery scenarios and technologies

3.3.1. Applicable scenarios

Delivering irrigation water 'the last mile' to farms far from surface water or with deep groundwater is recommended after per-project assessment that would include feasibility.

- In the north of Serbia it is recommended to assess leveraging Vojvodina's extensive rivers and canals system in favor of irrigation, e.g. Srem. Complementing briefs of this project would detail the potential volume of water and hectares that can be potentially irrigated.

- Delivery of water to the ‘farm gate’ with pressurized delivery piping systems. When used for irrigating high value crops such systems can serve central Serbia’s typically small sized farms.
- Drip systems operating with lower pressure would settle for less pressure from the delivery infrastructure.

3.3.2. Applicable technologies

Following are selective applicable digitized/AI/IoT equipment for pressurized piping delivery systems for brining water from the water source to the farm gate:

- Digital wireless gauging for real-time monitoring systems that serve unlimited number of users/irrigators. It would allow for scheduling, meet water quota and charge for consumed water in the most accurate way. It would also allow efficient O&M detecting failure in real-time as well as effective scheduling water availability vs water demand.
- Wireless leak detectors for real-time indication of water losses. The EU is supporting some innovative ventures that had developed digitized solutions for this.
- Pressure regulating valves in combination with flow-sustain capabilities provide the ability to maintain the pre-design/decided volume and pressure around the clock, which is especially important during peak demand and because of Serbia’s numerous farms in the size of 2-5 Ha, where demand from centralized irrigation systems would fluctuate around the clock and along the irrigation season.
- Air-release valves, which reduces the amount of air out of the pressurized pipes, thus optimize energy use for water delivery in the pipes.
- RAM pumps – especially for Serbia’s smallholder farms, this centuries-old technology is actually quite applicable to farms, which are next to surface water, enabling overnight irrigation tank filling-up, and gravity irrigation during the day. It requires no electricity and is simple to use.
- CROPA - Creative Realization of Precision Agriculture, which is an innovative concept to be considered for experiment.

3.4. Applicable water distribution and application methods

Being a late comer to irrigation can become a huge opportunity for Serbia through application of precise irrigation technologies, mainly drip and sprinklers, combined with fertigation; it can become part of an overall governance of water use.

According to Serbian Irrigation Companies’ survey[29], about 50% of the demand for irrigation comes from 2-5 Ha farms (representing 61% share of the total number of Serbia’s farms)most of these farms (43%) procure drip irrigation technology, and 80% of them mentioned they choose drip technology over other technologies because of water-saving. The survey indicates that 50% of those currently procuring irrigation in Serbia are using surface water and 40% are using wells. As the above figures are different from the recorded information for existing irrigation in Serbia it may be indicating current trends.

3.4.1. Drip irrigation

The global intensive expansion of this irrigation technology would fit Serbia’s HVCs all around the country but especially applicable for Central Serbia’s hilly areas. By delivering water and fertilizers directly to the root zone this irrigation method is demonstrating the most efficient crop per drop method currently available for commercial outdoors farming.

However, it is another aspect of drip irrigation that makes it so relevant for Serbia, and that is scheduling irrigation in synchronization with forecasted rain, so that fertilizers would be applied in small portions. Field trials showed amazing uptake results even in countries with more rain than Serbia (e.g. potatoes grown in Japan between April to June, under over 350mm of rain, showed 50-60% yield uptake, compared to rain fed, and a little more in output value due to more favorable size of the potatoes).

On surface drip irrigation is the most common and simple way for getting all the benefits out of this accurate irrigation method, especially for seasonal crops. More advanced irrigators, especially for

[29] October 2020 - Serbian private irrigation companies survey

Serbia's perennials, might consider installing sub-surface drip systems that require more expertise and advanced farm practices.

Strengths	*Weaknesses*
Precise water and fertilizer application: best for drop per crop and Nitrogen per Kg/crop	High capital cost
Applicable to any size of plot	Energy costs
Applicable to any topography including slopes	Sensitive to water quality
Low application rate of water and using low pressure (and energy); enables parallel irrigation of more hectares	Require setting up and O&M expertise
no leaching, no runoff, evapotranspiration; minimized environmental impacts of irrigation	
Enables synchronizing fertilizer application with rainfall ('technical irrigation')	
Less weeds; decreases usage of herbicides	
Reduce leaf disease and pathogens population which decreases usage of pesticides	
Opportunities	*Threats*
Expand farm production through water saving	Insufficient electricity for pumping when and where needed
Increase productivity under any precipitation	Poor design will reduce gains
Expand updated knowhow	Low water availability
	Poor water quality
	Rats/voles damage
	Lack of Poly-Ethylene recycling engagement

3.4.2. Sprinkler irrigation

This irrigation method would do well for Northern Serbia's lowlands relatively larger farms, compared to Central Serbia. As detailed in the following SWOT, sprinklers are popular because of many goods reasons, such as good uptake derived from precise irrigation which is suitable for most row, field and tree crops, where the simplicity of setting up and operation allow covering almost any size of plot of reasonably variable topography, and is adaptable to most soils.

In common, practice the average application rate from the sprinklers (in mm/hour) is designed to be just under the basic infiltration rate of the soil and in Serbia there should be no problems applying sprinklers in large scale, and sprinkler systems are also compatible with digitized gauging and control equipment.

Mechanized sprinkler systems are most suitable for large farms, as in Vojvodina, while small and medium sized farms can choose any of the many configurations of sprinklers available on the market.

Strengths	*Weaknesses*
Precise water application	Capital cost
Applicable to any farm size	High energy costs
Relatively easy to apply	Less water efficient than drip in terms of drop per crop
Less sensitive to water quality than drip	Environmental impact includes potential Nitrogen leaching and Nitrogen runoff
Simple O&M with little labor	Intensify Pesticides usage for pathogens and leaf disease

	Herbicides usage for weeds
	Less adaptable for slopes
	Wind effecting wetting pattern
	Not suitable for soils which easily form a crust
Opportunities	*Threats*
Expand production through water saving	Insufficient electricity for pumping when and where needed
Incorporate fertigation	Poor design will reduce gains
	Low water availability

3.4.3. Surface irrigation

As it is considered inefficient compared to modern precise-irrigation methods, it is not expanding as the modern irrigation methods, and mostly continue to be used in places where already existed.

- Effective for certain crops, for certain types of soil and for flat terrain
- O&M is simple and low cost, mainly keeping weeds away along the furrows and keeping the slopes
- Doubtful if justifies new infrastructure for Serbia's short irrigation season of 2-4 months a year given the other alternatives

Strengths	*Weaknesses*
Low capital cost	Inefficient use of water
Simplicity of O&M	Leaching and runoff
Require little know-how with 'cheap' labor	Poor flexibility to crop rotation
Little or no pumping	May impact farm practices in order to realize gains
Neutral to water quality	Heavy, clay soils can be difficult
	Only applicable where ground leveling is feasible
	Intensify Herbicides usage for weeds
Opportunities	*Threats*
Rapid expansion of irrigation especially to plots next to surface water	Contamination of underground aquifers
May improve some farm practices	Inflexible for climate change
	Gauging and monitoring are labor intensive
	Soil erosion
	Poor land grading result in waterlogging
	Poor/wrong stream size design result in deep percolation losses

Below is a method for applying the most suitable method for specific soil, subject to zone and project-specific conditions to be assessed: [30]

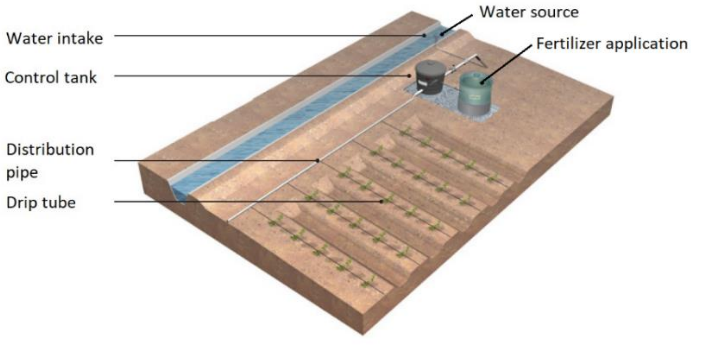
Irrigation depth of application for different soil types and irrigation methods

Soil type	Rooting depth of the crop	Net irrigation depth per application (mm)	Irrigation method
Sand	Shallow	20-30	Short furrows
	Medium	30-40	Medium furrows, short borders
	Deep	40-50	Long furrows, medium borders, small basins
Loam	Shallow	30-40	Medium furrows, short borders
	Medium	40-50	Long furrows, medium borders, small basins
	Deep	50-60	Long borders, medium basins
Clay	Shallow	40-50	Long furrows, medium borders, small basins
	Medium	50-60	Long borders, medium basins
	Deep	60-70	Large basins

[30] FAO Irrigation and Drainage paper

3.4.4. Gravity micro-irrigation

This relatively new and innovative irrigation technology is aiming to provide all the known gains of drip irrigation with little conversion capital and using gravity as the energy for irrigation. It is applicable in farms with immediate access to surface water such as in Vojvodina, for a wide range of soils and for crops with proven uptake when irrigated with drip irrigation.



Pros: providing the proven gains of drip irrigation but with little capital.

Cons: Have not been introduced yet to Serbia.

As of today, about 3% of Serbia's Maize, a major crop of 1 million Ha, is irrigated, resulting high inter-year variability, so such innovative low cost irrigation technologies should be further assessed for farms next to surface water.

Strengths	*Weaknesses*
Using gravity as energy	Only a few years of field experience
Precise water and fertilizer application	Sensitive to water quality
No leaching, no runoff, evapotranspiration; minimized environmental impacts of irrigation	Applicable to flat plots
Enables synchronizing fertilizer application with rainfall ('technical irrigation')	
Less weeds; decreases usage of herbicides	
Reduce leaf disease and pathogens population which decreases usage of pesticides	
Opportunities	*Threats*
Saves the capital cost involved with drip and sprinklers	Poor design will reduce gains
Increase productivity under any precipitation	Low water availability
Expand updated knowhow	Poor water quality
	Rats/voles damage
	Lack of Poly-Ethylene recycling engagement

3.4.5. Supplementary applicable technologies

Review of options for farm level irrigation technologies:

1. 'Digital farming' and 'Sensors':
   The use of Ag-sensors is booming around the world as an effective tool for optimizing the use of important farm resources – water, fertilizers and soil. On-farm sensors for monitoring the crop or the surrounding environment such as soil-moisture, solar-radiation, wind speed and direction, rain, and also off-farm relevant information such as precipitation from the nearest climate station and satellite view for spotting the less irrigated parts of fields.
2. Irrigation Controllers:

Time-based and volume-based irrigation control systems, from simple and standalone pre-programmed irrigation controllers all the way to cloud based multi-zone irrigation control. Considering Serbia's climate, a combination of irrigation controllers with rain-sensors would assure optimized scheduling.

3. PC drippers:
   Pressure-compensating drippers are the most precise irrigation emitters and thus enable precision irrigation in any region with variable topography. This powerful irrigation technology can bring HVCs to Serbia's hilly areas with all the well-proven gains of drip irrigation.
4. Fertigation:
   Automatic-fertigation systems for accurate and efficient fertilizer application saves farm expenditure while avoiding contamination of underground aquifers. Fertigation is a powerful tool for increased productivity, allow crop rotation and reduces leaching and aquifer contamination. The effectiveness of fertigation is often dependent on the effectiveness of the irrigation system and the full advantages of irrigation and fertigation only become evident if the correct irrigation design is employed to meet plant requirements and to distribute water and fertilizer evenly.
   Both Central and Northern Serbia would do well if precise fertigation systems and practices would be applied.
5. RAM pumps:
   RAM pumps, which are self-powered water pumps using gravity imposed water-pressure, can help smallholders start irrigating even without access to electricity for water pumping.
   Many of Vojvodina's farms with immediate access to surface water can apply this simple but effective tool for irrigating areas that are not yet served with electricity.
6. Covered crops:
   Covered-facilities, greenhouses included, with accurate irrigation and fertigation systems enable high yield high quality production of HVCs and over longer production season. Central Serbia's hilly areas can provide great climate conditions for long and productive season for vegetables and fruits if precise irrigation and fertigation is applied.

In addition to the above, which can be field tested and localized by Serbia's extension services, the following complementing tools and knowledge-transfer would support expansion of irrigation:

1. Training courses for irrigation experts and instructors.
2. Demo plots for demonstrating all aspects of applying irrigation.
3. Training programs for small farms irrigators.
4. Training programs for irrigation operators in large irrigating farms.
5. Certification courses for operators of Multi User irrigation systems.

3.5. Low hanging fruits for irrigation infrastructure and technology

#	Action
1	Expanded water delivery systems from existing rivers and canals especially in northern Serbia - providing 'the last mile'
2	Increased abstraction capabilities in hilly areas
3	Expand the electricity 'reach' allowing water pumping
4	Drip irrigation for HVCs, supported by field days and irrigation training using demo plots (extension services)
5	Localize low cost irrigation technologies for arable crops such as Maize - demo irrigation plots of gravity micro irrigation accompanied with training for irrigation
6	Align real-time climate data with control of local irrigation systems
7	Incentivize foreign irrigation manufacturers to act in Serbia
8	Increase the 'practical research' of fertigation and irrigation both in Northern and Central Serbia
9	Familiarize 'digital farming' to Serbian farmers (extension services)

3.6. Major risks for the development of irrigation infrastructure in Serbia

#	Risk	Risk mitigation
1	Poor O&M of multi-user systems	Engage the potential irrigators in the process
2	Farmers will not be using the irrigation system	Provide effective incentives and 'education'
3	Insufficient pumping and storage capacities	Design for XX% success-level and allow to fail every Y years (economic decisions)

4	Poor water quality	Implement national water quality strategy
5	Increased costs of water conveyance / energy	Dual purpose systems, not only for irrigation
6	Change of crops that are currently cultivated	Design for crop flexibility/rotation
7	Pollution of high aquifers from inaccurate fertigation	Encourage precise irrigation and fertigation methods
8	Seasonal changes in water availability due to climate change	Incentivize for more precision technologies

3.7. Summary

#	**Lowlands scenarios**	**Assumption**	**Infrastructure**	**Farm level**
1	Adjacent to rivers & overlying alluvial aquifers	For all crops	- On-farm pumping and irrigation - Potentially regional-monitoring and water-gauging	- Sprinklers, especially for large farms & fields - Drip for small and medium size farms & fields - Surface irrigation
		For arable & fodder	- On-farm pumping and irrigation - Potentially regional-monitoring and water-gauging	- Gravity micro irrigation
2	Already served by drainage canals	For all crops	- Regional monitoring and potential gauging - On-farm pumping and irrigation	- Sprinklers, especially for large farms & fields - Drip for small and medium size farms & fields
		For HVC & for perennials		- Drip - Gravity micro irrigation
3	Above reasonably shallow and plentiful groundwater		- On-farm pumping and irrigation	- Sprinklers, especially for large farms & fields - Drip for small and medium size farms & fields
			- Otherwise: Pressurized piping leading filtered water from well to the farm gate	- Sprinklers, especially for large farms & fields - Drip for small and medium size farms & fields
4	None of the above sources but could be supplied by canals		- Regional monitoring and potential gauging - On-farm pumping and irrigation	- Sprinklers, especially for large farms & fields - Drip for small and medium size farms & fields
5	Near major urban areas	Especially for perennials	Waste water after tertiary treatment	Drip irrigation

#	**Hilly areas scenarios**	**Infrastructure**	**Farm level**
1	Land close to rivers and streams	Pumping stations	Drip or sprinklers
2	Land over reasonably shallow and plentiful groundwater	- Pumping stations - Potentially water storage	Drip or sprinklers
3	None of the above sources	Rain harvesting reservoirs/tanks	Drip