Integrated Water Management

Climate Resilience, Environmental Governance, and Agricultural Water Security in North Macedonia

Defining IWRM Standards

The standard definition comes from the **Global Water Partnership:**

*"IWRM is a process that promotes the coordinated development and management of water, land and related resources to **maximize economic and social welfare** equitably without compromising ecosystems."*

UNEP uses essentially the same definition to align global environmental governance.

Practical IWRM Implementation

In practice, integrated management means planning and managing these critical sectors **together**, because decisions in one part inevitably affect the others:

- Surface & Groundwater
- Irrigation & Drinking Water
- Industry & Environment
- Floods & Droughts

Coordinated planning ensures that water use in one sector does not compromise the security of another.

For irrigation, integrated water management means:

Resource Assessment: knowing how much water is available in rivers, reservoirs and groundwater;

Monitoring & Control: using monitoring, water permits, pricing and records to control water use;

Sustainable Allocation: deciding how much can safely be used for agriculture without damaging other users or ecosystems;

Infrastructure Maintenance: maintaining dams, canals and drainage systems properly;

Stakeholder Coordination: coordinating water allocation among farmers, municipalities, industry and nature;

Climate Resilience: preparing for droughts, floods and climate change;

Efficiency Gains: improving irrigation efficiency so less water is lost in canals, pipes and fields;

Inclusive Decisions: involving farmers, water users, institutions and local communities in decisions.

Critical Perspective on IWRM

Although the concept of **Integrated Water Resources Management** (IWRM) has been recognized for over six decades, scholarly debate persists regarding the operational feasibility and definitive scope of its multi-sectoral application.

Core Challenges: Critics argue that while the framework provides a foundation for holistic resource governance, its implementation often suffers from ambiguity and a tendency to prioritize water-sector interests over land-use and energy planning.

Furthermore, the conceptual malleability of the framework—often described as an *"all things to everyone"* approach—has facilitated its global adoption while simultaneously complicating coherent policy analysis.

Part I: The National Hydrology

Analyzing North Macedonia's physical water assets, transboundary basins, and the vulnerabilities driven by climate stress.

Hydrological Profile & Basins

River Basins & Topography

North Macedonia is divided into three primary transboundary river basins. The Aegean Basin dominates 87% of the territory, primary fed by the Vardar River network.

The remaining regions fall under the Adriatic Basin (Black Drim) and Black Sea Basin, causing high dependency on regional hydro-cooperation.

Internal Generation Advantage

An estimated 84% of water resources are generated internally. However, spatial and seasonal distribution is highly uneven.

The eastern plains experience intense, chronic water stress, while the western mountain chains possess significant glacial and sub-alpine runoff potential.

System Inefficiencies & Losses

65%

Maximum Non-Revenue Water Losses

Infrastructural Obsolescence

Much of the water distribution and agricultural irrigation infrastructure is severely outdated, with the majority of systems built prior to the 1990s.

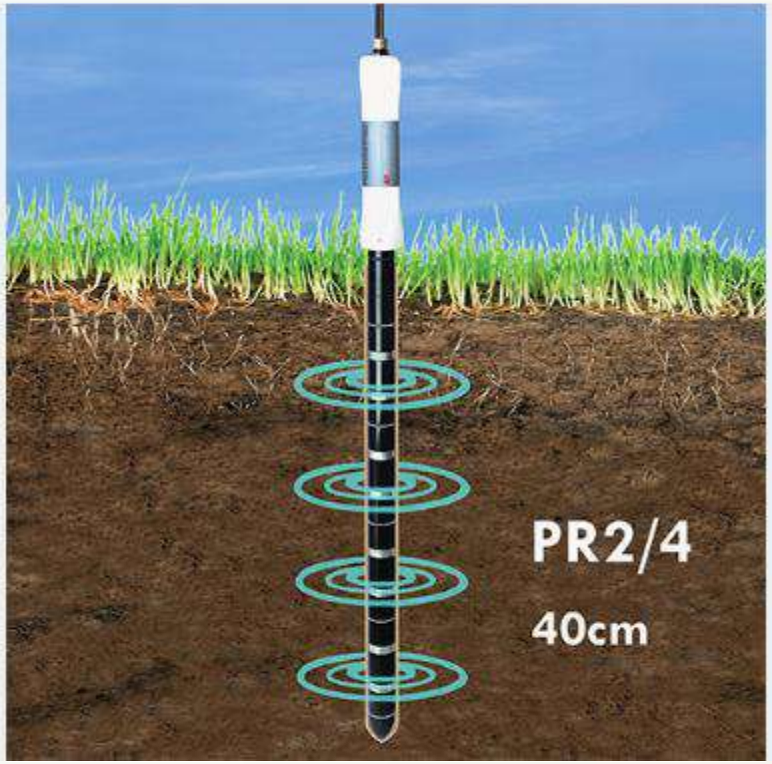
Losses due to physical pipe leaks, ruptured irrigation canals, and unmonitored connections range from 40% to 65% nationally, severely draining municipal and agricultural economic capacity.

Part II: The Agricultural Nexus

Evaluating water consumption trends, farming dependencies, and the critical need to modernize irrigation delivery across Macedonian plains.

Irrigation System Challenges

- **Network Deterioration:** Siltation, structural damage, and complete abandonment of historical lateral channels.
- **Low System Utilization:** Outdated formal networks force farmers to establish independent, unsanctioned groundwater wells.
- **Severe Evaporative Losses:** Continued reliance on traditional open dirt furrow irrigation methods across major production zones.
- **Soil Preservation Need:** Soil erosion risks rise without carefully monitored, targeted root hydration.



Core Strategic IWRM Pillars

Governance

Overcoming institutional fragmentation. Creating robust channels of cooperation between the Ministry of Environment and the Ministry of Agriculture.

Modern Monitoring

Deploying advanced hydrographic and cosmic ray soil telemetry to acquire real-time, non-invasive regional moisture flux measurements.

AMP Modernization

Design agricultural modernization pathways to rebuild main dams, clean arterial canals, and restore economic reliability.

Irrigation Tech Comparison

Irrigation Methodology	Efficiency Rating	Water Conservation Benefit	Macedonian Adoption Priority
Traditional Furrow & Flooding	40% – 50%	✕ Negligible	Phase Out Completely
Mechanical Sprinklers	70% – 80%	! Moderate	High (Grain / Forage Fields)
Drip & Micro-Irrigation	90% – 95%	✓ Exceptional	Critical (Vineyards, Fruit, Tobacco)
Precision Telemetric Drip	95% +	✓✓ Maximum	Strategic Pilot Areas (Vardar Valley)

Climate Change & GDP Outlook

Macedonian Economic Loss Projection: Climate and water shocks represent an escalating systemic risk, with cumulative damage modeled to reach up to 4.0% of National GDP by 2050 if structural water adaptations are deferred.

Summary of Irrigation Water Management

Republic of North Macedonia — focus on water use, users, efficiency and management priorities

18,370 ha
Hydrosystem irrigated area, 2021

253.8 Mm^3
Delivered irrigation water, 2021

13,816 m^3/ha
Actual use, 2021

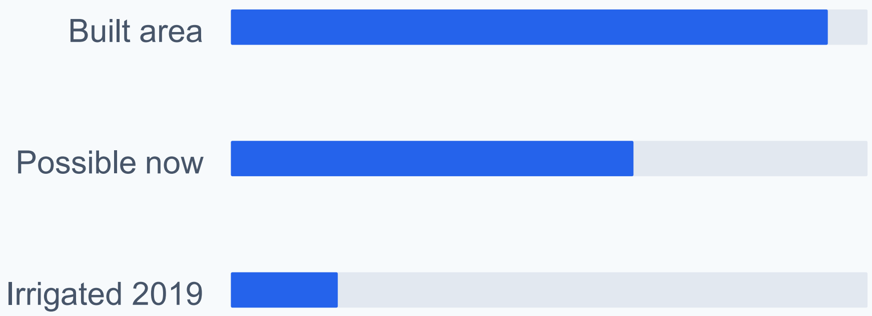
36,715
Contracted users, avg. 2019–21

Core message: the national irrigation system has valuable infrastructure, but weak measurement, low utilization of built capacity, inconsistent water-use figures and limited incentives for efficient irrigation.

1. Executive summary

Only about one quarter of the technically possible hydrosystem area is actually irrigated in recent data.
Water-use data show very large year-to-year variation: 7,339–34,650 m³/ha during 2019–2021.
Most water users are individual farms; contracted hydrosystem users average 36,715 per year.
Billing is mostly area/crop based, not measured volumetrically, which weakens incentives to save water.
Priority reforms: measure water, modernize delivery, maintain assets, improve registers, and build user capacity.

Infrastructure utilization, ha



The problem is not only "more water". It is also how water is measured, allocated, priced, maintained and used at farm level.

Source: "Report on the Status of Irrigation in the Republic of North Macedonia", second draft, 5 Sept 2022

2. Water resources and governance context

Irrigation is part of wider national water management

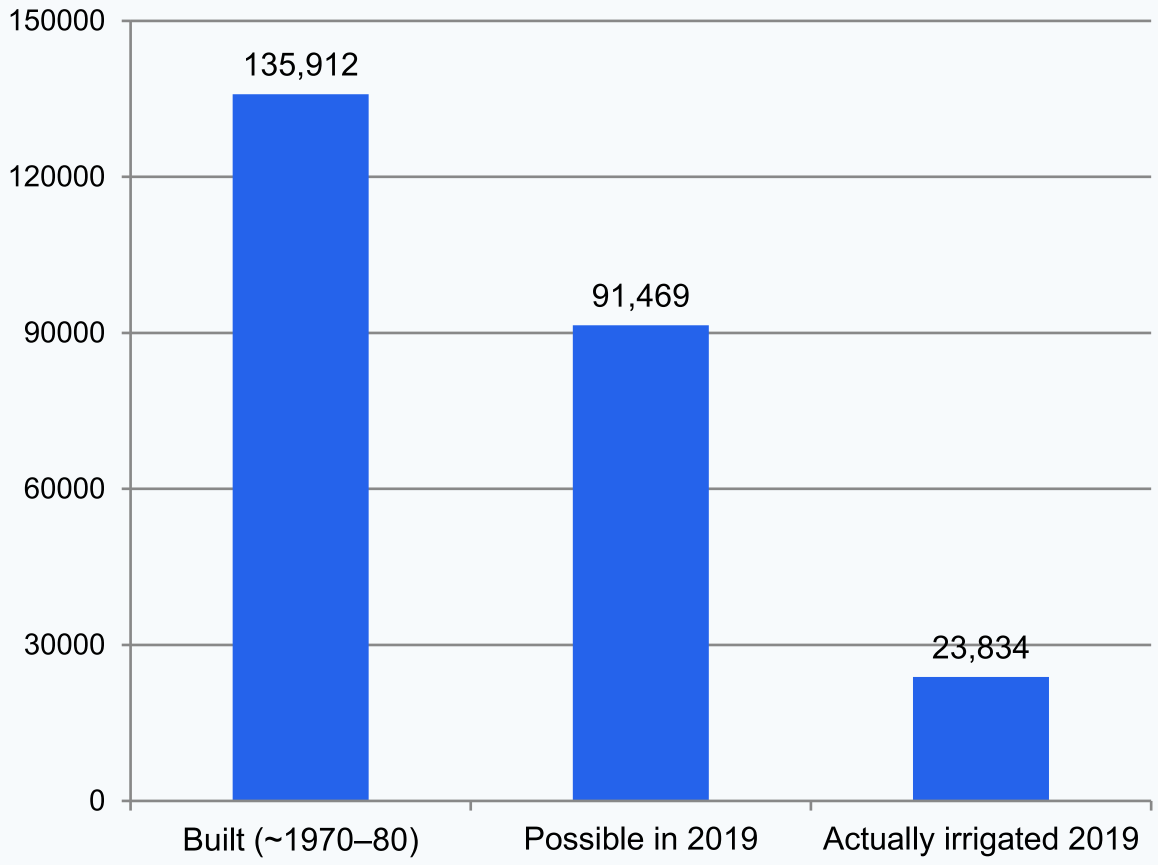
6,374 Mm³/year	27	AD Water Economy	95,000 ha by 2027
Surface water resources	**Large dams listed**	**Main operator**	**Policy target**
Vardar 72%, Crn Drim 26%, Strumica 2%	multi-purpose storage and regulation	14 regional branches	NSARD target for irrigated area

Water Law frames rational and efficient use of water resources.
Water Economy Law centralizes operation and maintenance through AD Water Economy and public enterprises.
The water-service tariff law does not yet regulate irrigation prices, so irrigation remains outside modern tariff-setting logic.
Strategic documents emphasize new infrastructure, rehabilitation, efficient use and institutional reform.

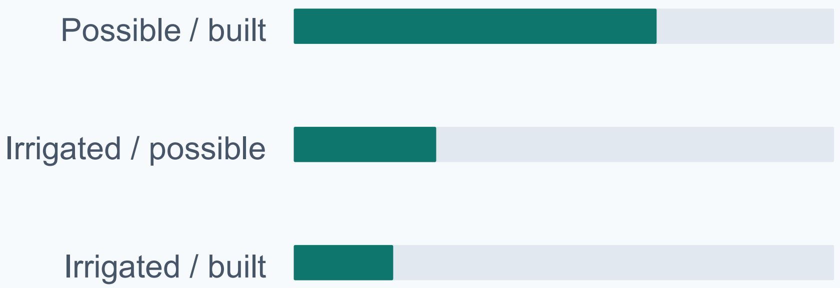
Source: "Report on the Status of Irrigation in the Republic of North Macedonia", second draft, 5 Sept 2022

3. Irrigation infrastructure: large potential, low utilization

Hydrosystem area in hectares



Utilization ratios, %



Interpretation: about one third of built irrigation area is no longer functionally available; of the area that could be irrigated, only around 26% was actually irrigated in 2019.

Source: “Report on the Status of Irrigation in the Republic of North Macedonia”, second draft, 5 Sept 2022

4. Where the irrigated area is concentrated

2016 structural survey vs hydrosystem reporting

84,434 ha
National irrigated land, 2016
all sources, not only AD systems

26.3%
Share of usable agricultural land
irrigated / used land

113,017
Actually irrigating farms, 2016
all farm structures

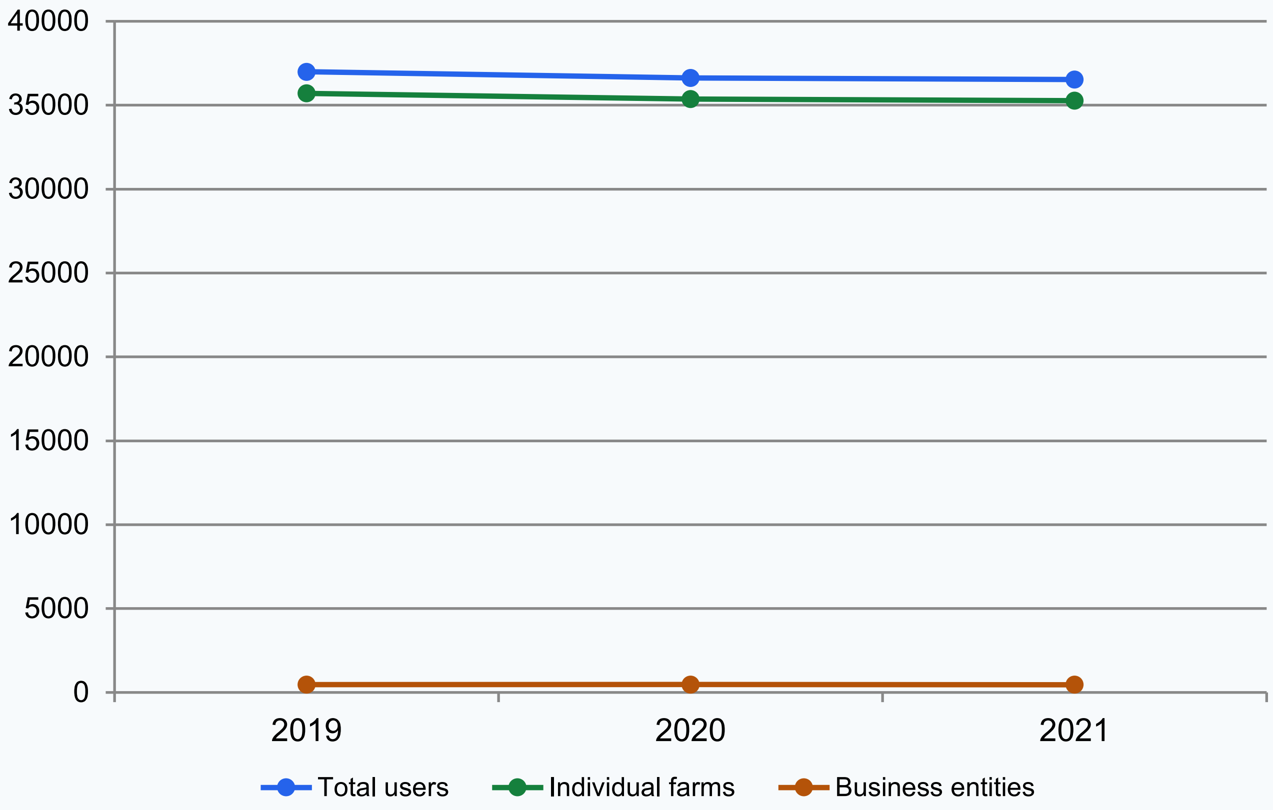
36,715
Contracted hydrosystem users
avg. 2019–2021

Two datasets tell different but complementary stories: national farm surveys capture all irrigation sources, while AD Water Economy data capture contracted hydrosystem users.
This gap indicates the need for integrated land, user and water-use registers across public systems, private wells and local/community systems.
For management, the “served area” must be linked to actual users, crops, volumes and payment records.

Source: “Report on the Status of Irrigation in the Republic of North Macedonia”, second draft, 5 Sept 2022

5. Number and type of irrigation users

Contracts with hydrosystems, 2019–2021



36,715
Average total
users/year

35,481
Average individual farms
users/year

469
Average businesses
users/year

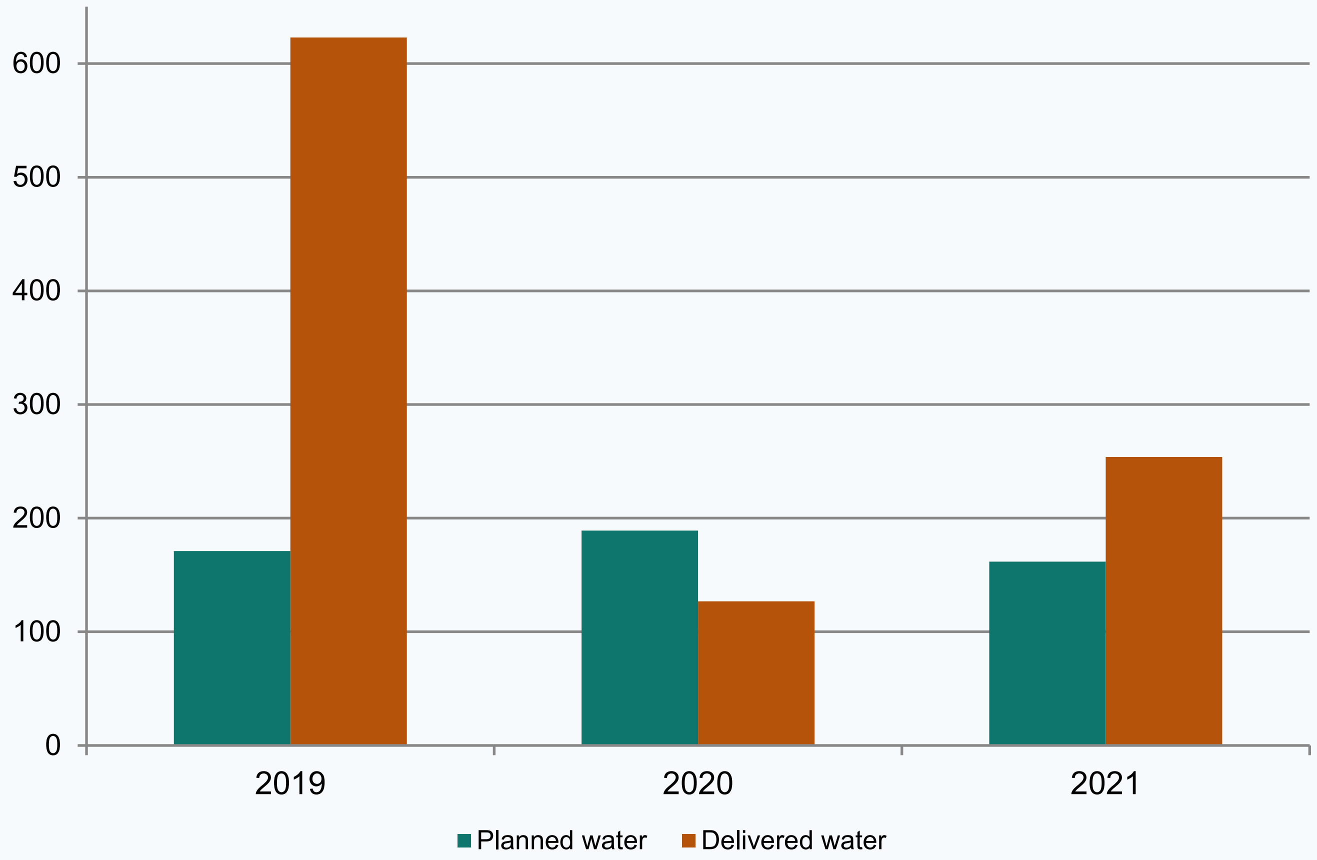
8
Average cooperatives
users/year

Management implication: advisory, billing and monitoring systems must be designed primarily for many small individual farmers, while still tracking larger legal entities separately.

Source: “Report on the Status of Irrigation in the Republic of North Macedonia”, second draft, 5 Sept 2022

6. Total water use: reported delivery is unstable

Reported planned and delivered water, million m³



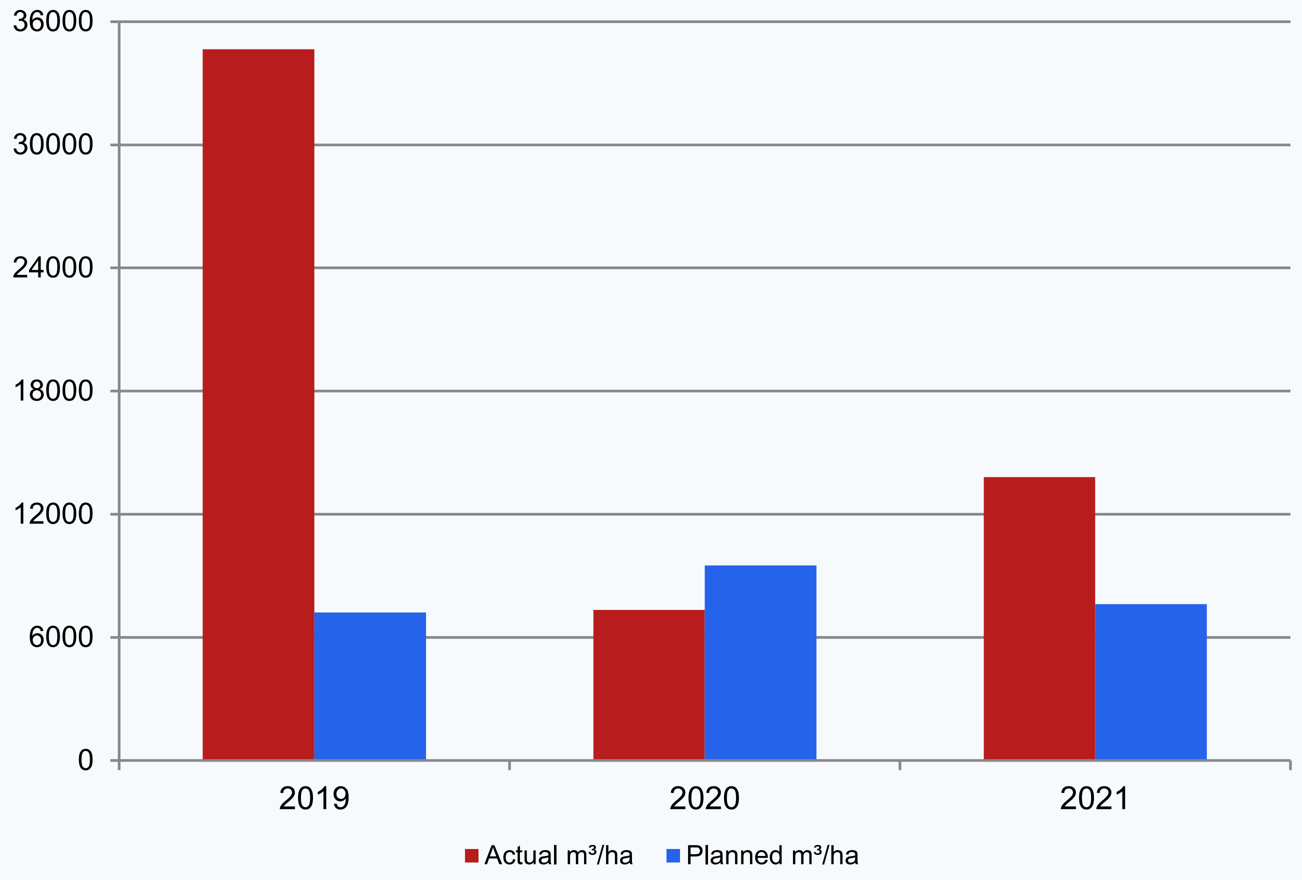
2019: delivered water is reported at 622.9 Mm³ — 364% of planned volume.
2020: delivered water falls to 126.8 Mm³ — 67% of planned volume.
2021: delivered water rises to 253.8 Mm³ — 157% of planned volume.
The spread suggests weak measurement, inconsistent reporting, or very different operational conditions.

For proper water management, annual water delivery must be measured at system, branch, distributary and farm/turnout level.

Source: "Report on the Status of Irrigation in the Republic of North Macedonia", second draft, 5 Sept 2022

7. Water use per unit area

Actual irrigation water use per hectare



18,714 m³/ha

Weighted actual average

2019–2021

7,339 m³/ha

Best-looking year

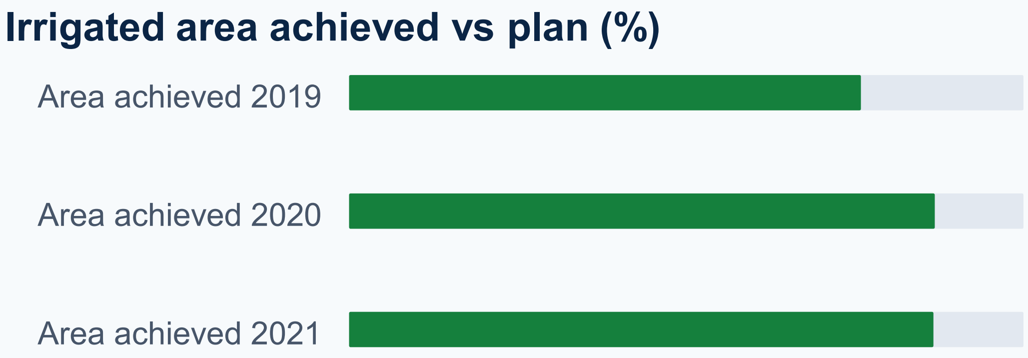
2020, close to plan

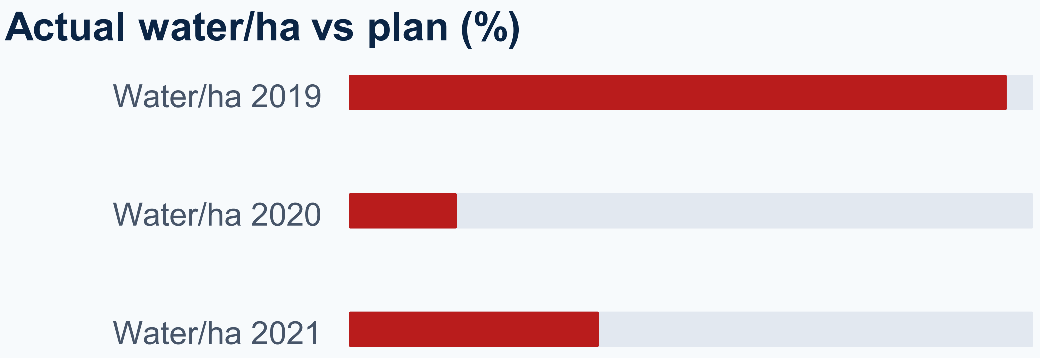
The 2019 and 2021 values are high enough to raise a management alarm: losses, over-irrigation, rice dominance, data problems, or a mix of these factors should be investigated.

Source: “Report on the Status of Irrigation in the Republic of North Macedonia”, second draft, 5 Sept 2022

8. Efficiency signal: planned vs actual

Area delivery and water intensity do not move together





Area realization is relatively stable, mostly 76–87% of plan.
Water intensity realization is extremely unstable: 77–481% of plan.
This is a stronger warning than area alone: planning hectares without measuring water does not ensure efficient irrigation.

Source: “Report on the Status of Irrigation in the Republic of North Macedonia”, second draft, 5 Sept 2022

9. Financial incentives and collection

High collection does not necessarily mean efficient water use

>80–95%	Верово 6.16%	Area + crop	variable
Many branches	**Important exception**	**Billing basis**	**Legal entities**
collection from physical users	very low collection listed	not direct volume	e.g. 33–100% in table

Because water is commonly billed by crop and area, farmers do not directly pay for every cubic meter used.
This weakens incentives to adopt deficit irrigation, scheduling, drip irrigation and soil-moisture monitoring.
High collection rates are positive for financial discipline, but volumetric measurement is needed for water productivity.

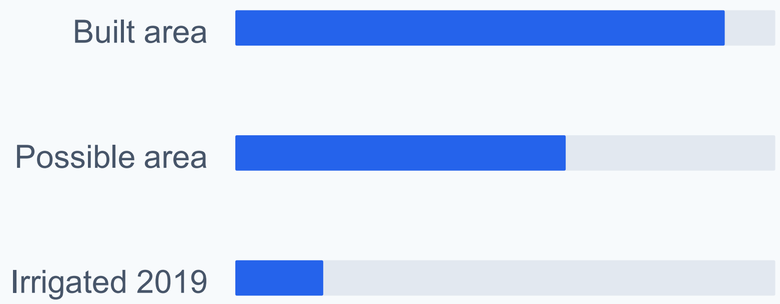
Source: “Report on the Status of Irrigation in the Republic of North Macedonia”, second draft, 5 Sept 2022

10. Infrastructure condition and maintenance

Low functional area reflects ageing systems and maintenance gaps

Several systems have much lower “possible” area than originally built area, indicating deterioration, missing assets or non-functional sections.
Maintenance includes canal cleaning, hydromechanical equipment, dam safety and rehabilitation of damaged structures.
Rehabilitation should prioritize sections with the highest water losses, highest demand and greatest economic return.
New construction should not substitute for maintenance of existing high-value systems.

Area in thousand ha



Asset management needs a live inventory: canals, pipelines, gates, pumps, meters, drains, dams, reservoirs and critical safety components.

Source: “Report on the Status of Irrigation in the Republic of North Macedonia”, second draft, 5 Sept 2022

11. Monitoring, control and data gaps

The weakest link is not technology, but routine measurement

Measurement of irrigation water quantity is not a routine practice in AD Water Economy reporting.
Water quality monitoring is important, especially where groundwater salinity can deteriorate soil properties.
Water permits, water rights, land registers and billing records need to be linked into one management database.
Monitoring should cover abstraction, storage, conveyance losses, delivery, farm application and drainage impacts.

Measure

Record

Decide

Verify

Improve

Recommended operating logic: every irrigation season should close with a water balance, not only with hectares and invoices.

Source: “Report on the Status of Irrigation in the Republic of North Macedonia”, second draft, 5 Sept 2022

12. Key risks for proper water management

Issues that directly affect allocation, efficiency and resilience

High	High	High	Rising
Over-irrigation risk	**Allocation risk**	**Maintenance risk**	**Climate risk**
area-based billing + weak scheduling	no reliable real-time balances	ageing infrastructure	drought and variable supply

If water is not measured, it cannot be fairly allocated among users during drought years.

If losses are not mapped, rehabilitation may be poorly targeted.

If users do not receive scheduling advice, farm-level efficiency remains weak even after infrastructure investments.

If data systems are fragmented, national targets such as 95,000 ha remain difficult to manage and verify.

Source: "Report on the Status of Irrigation in the Republic of North Macedonia", second draft, 5 Sept 2022

13. Priority actions

A practical reform package

1. Install and operate water meters at reservoir outlets, main canals, branch canals and farm turnouts where feasible.
2. Create one integrated registry linking land parcels, users, crops, contracts, water permits, volumes and payments.
3. Move gradually from area-based billing toward a mixed tariff: fixed service fee + measured/estimated volume.
4. Prioritize rehabilitation using water-loss audits and service reliability indicators, not only political demand.
5. Introduce irrigation scheduling support: crop water needs, soil moisture monitoring, critical stages and deficit irrigation.
6. Publish annual water-management dashboards for transparency: hectares, users, volume, m^3/ha, collection and losses.

Implementation principle: do not wait for a perfect national system. Start with pilot branches and scale the tested model.

Source: “Report on the Status of Irrigation in the Republic of North Macedonia”, second draft, 5 Sept 2022

2. Crop water needs of main crops in the Western Balkan

South Eastern Europe
SWG RRD
Regional Rural Development Standing Working Group

Table 1. Irrigation water requirement by group of crops

Country/Crop	Irrigation water requirements by season (mm)	Applied irrigation techniques	Irrigation efficiency	Irrigation application rate (mm)	No. of applications during the season
Bosnia and Herzegovina/Maize	302	Sprinkler	60-70%	50	6
Bosnia and Herzegovina/Vegetables	115-160	Sprinkler/drip/furrow	~70%	/	>20
Bosnia and Herzegovina/Orchards (apple, pear)	185-320	Drip irrigation	~70%	/	>21
Bosnia and Herzegovina/Vineyards	70-140	Drip irrigation	/	/	/
Montenegro/Maize	345	Sprinkler	60-70%	50-60	6-7
Montenegro/Vegetable (tomato)	389	Drip irrigation	70-90%	15	25
Montenegro/Orchards	264	Drip irrigation	70-90%	20	13
Montenegro/Vineyards	133	Drip irrigation	70-90%	15	9
Kosovo*/Maize	285	Sprinkler	80-85%	60	5
Kosovo*/Vegetable (tomato, pepper)	360	Sprinkler/drip	80-95%	10-12	20-40
Kosovo*/Orchards -apple, plum, cherry	380	Drip irrigation	80-95%	18	20
N. Macedonia/Maize	420	Sprinkler	60-70%	60-70	6-7
N. Macedonia/Vegetable (tomato, pepper)	360	Drip irrigation	70-90%	12	30
N. Macedonia/Orchards (apple, pear)	390	Drip irrigation	70-90%	18	20
N. Macedonia/Vineyards	277	Drip irrigation	70-90%	18,5-13,9	15-20
Serbia/Maize	210±70	Sprinkler		20-40	0-8
Serbia/Vegetable	130±60	Sprinkler/drip/furrow	~70%		>20
Serbia/Orchards-apple, pear, cherry	295±80	Drip irrigation	~70%		>22
Serbia/Vineyards	76±40	Drip irrigation			

Irrigation water requirements in WBC vary from country to country, than applied irrigation techniques, technology of production, season of production etc.

The highest irrigation requirements should be provided in rice and alfalfa production, followed by maize, fruit production vegetable crops (tomato, pepper) etc.

South Eastern Europe
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Advantages of irrigation scheduling

Proper organization of irrigation practice among various fields and minimization of crop water stress-increase crop yields.

Reduce the farmers water costs and labor as result of proper irrigation, maximal use of soil moisture.

Reduce of fertilizer costs by holding surface runoff and deep percolation (leaching) of fertilizer to the ground water-protect the environment.

Increase net returns by increasing crop yields and crop quality

Tanaskovik (2009) report higher WUE (30-60%) in treatments with irrigation scheduling in comparison with traditional irrigation practices in pepper crop.

SAVING WATER

improve irrigated agriculture practice by irrigation scheduling based on soil moisture monitoring

Methods based on climate characteristics (indirect methods)

Table 2. Irrigation scheduling for different crops (rough estimation)

Type of crops		March	April	May	June	July	August	Sept.
ETo rough estimate (mm/day)		1.5 - 2	2.5-3	3.5-4.5	4.5-5	5-6	5-6	3-3.5
Vegetable Root zone 0.3m	Irr. Appl. Rate (mm/m^2) Irrigation Intervals (days)	10-15 5-7	10-15 4-5	15-20 4-5	20-25 3-4	20-25 3-4	20-25 3-4	15-20 4-5
Field crops Root zone 0,6 m	Irr. Appl. Rate (mm/m^2) Irrigation Interval	20 10	20 6-7	30 6-7	30-40 6-8	30-40 6-8	30-40 6-8	20 6-8
Orchards (drip) Root zone 0,5 m Norms*(mm/m^2)	Irrigation Interval**	4-5	2-3	1-3	1-3	1-3	1-3	2-3

*Sandy 7 (mm/m^2); Loamy 15 (mm/m^2); (mm/m^2) Clayey 25 (mm/m^2) **lower value suit to sandy soil

South Eastern Europe SWG RRD Regional Rural Development Standing Working Group

Methods based on plant condition monitoring

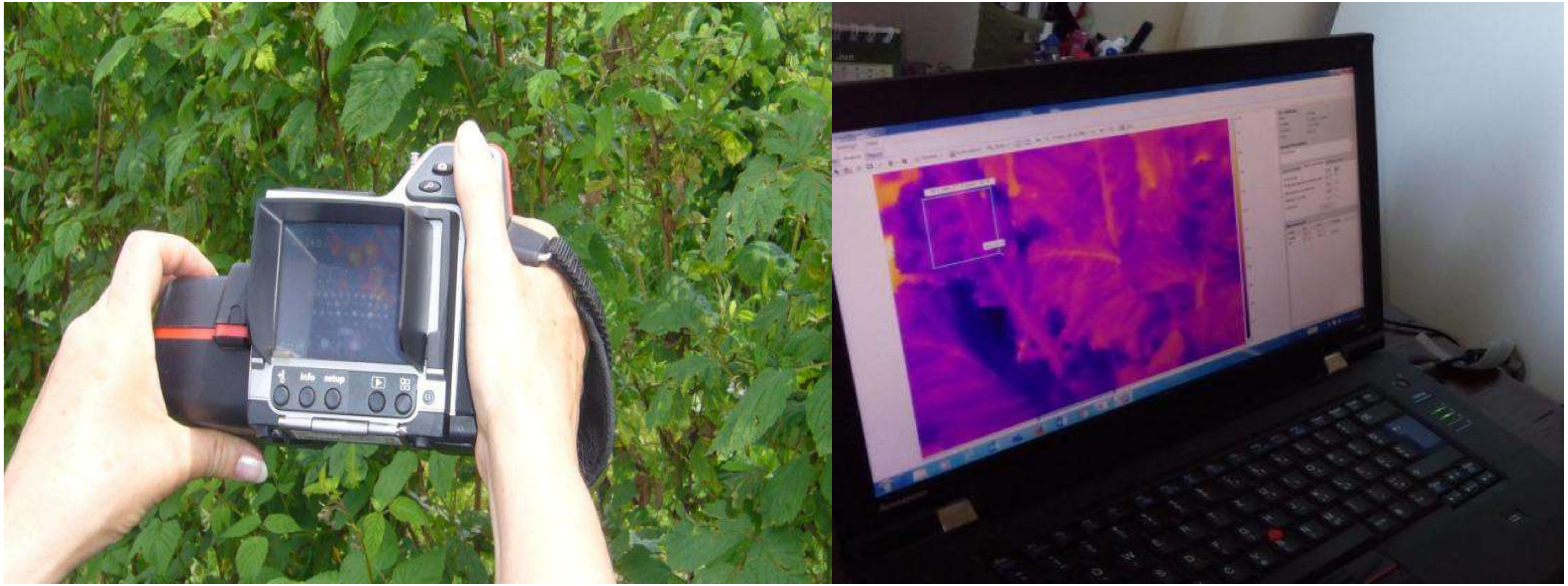


Figure 10. Measurement of infrared thermometry of the canopy (Stričević, R. own archives)

Drip irrigation system in a pomegranate farm in central Albania, Sources: Zruli P.

4. Irrigation techniques and agricultural production under climate changes

Use drip irrigation instead of furrow irrigation - improve WUE and crop production **(Tanaskovik et al., 2011)**

Treatments	D.M. yield kg/ha	ETP m^3/ha	WUE kg/m^3	Comparison with T5 (%)	Comparison with T4 (%)
T1	9990[a]	4270	2.34[a]	187.2	127.2
T2	9500[a]	4425	2.15[b]	172.0	116.9
T3	8710[b]	4501	1.94[c]	155.2	105.4
T4	8160[c]	4425	1.84[d]	147.2	100.0
T5	7300[d]	5825	1.25[f]	100.0	

DF1 - Drip irrigation according to daily evapotranspiration with application of water every 4 days and conventional fertilization (spreading of fertilizer on soil)

T5 - Furrow irrigation according to daily evapotranspiration with application of water every 7 days and classic fertilization (spreading of fertilizer on soil)

Improving WUE
by
changing irrigated practice

Application of surge flow irrigation in furrow irrigation.

Use of siphons or gated pipe in furrow irrigation

Use LEPA or micro-sprinklers in Sprinkler irrigation

5. Drip Fertigation

Use drip fertigation instead of spreading of fertilizer on soil - improve WUE and crop production

Table 6. WUE in pepper crop under different irrigation and fertigation regimes (Tanaskovik et al., 2016)

Treatment	WUE (kg/m³)	NFUE (%)	Pepper Yield (t/ha)
DF1	2.50	67.02	71.11
DF2	2.47	63.45	68.40
DF3	1.99	48.48	62.61
ØB	1.54	32.61	54.74

DF1 and 2 - Drip Fertigation according to daily evapotranspiration with application of water and fertilizer every two and four days

ØB - Drip irrigation according to daily evapotranspiration with application of water every 6 days and conventional fertilization (spreading of fertilizer on soil)

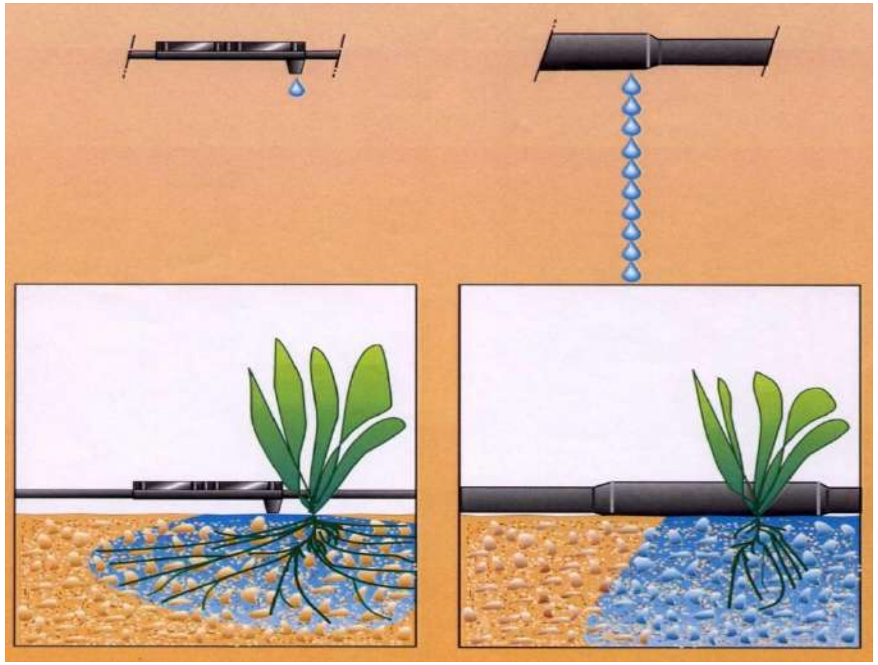
6. Improving WUE
by
Using SLECI or other ultra low irrigation techniques

Key benefits of SLECI in practice:

- Water Conservation: The results show that significant improvements in water productivity and water use efficiency can be achieved without compromising yield.
- Energy Efficiency: It is a low-energy system that operates using natural physical principles rather than mechanical pumps or electronic controls.
- Sustainable Materials: Made from biodegradable and renewable resources.
- Simplicity: The system's design, production, and installation are simple.

SLECI offers a practical pathway for climate-resilient agriculture that is simultaneously accessible to smallholders and commercial producers seeking to reduce costs and carbon footprints.

Figure 24. SLECI installation in sweet cherry orchards in FGI Plovdiv (Malchev et al., 2022)



7. Smart irrigation and automation

Advantages of smart irrigation:

- Water conservation: Reduces unnecessary water use by applying precise amounts.
- Lower costs: Cuts expenses through automation and efficiency.
- Fertilizer efficiency: Reduces unnecessary fertilizers use by applying precise amounts.
- Improved plant health: Maintains optimal soil moisture for better growth.
- Greater sustainability: Preserves water resources and supports eco-friendly farming.
- Yield: Improved yield production

Disadvantages of smart irrigation:

- High initial costs: Equipment and installation can be expensive.
- Connectivity issues: Dependence on stable internet or network connections.
- Complex setup: Requires technical knowledge for proper installation and calibration.
- Maintenance Requirements: System equipment need regular upkeep to avoid false readings.

Figure 25. Smart irrigation and fertigation management in real time (Stričević, R., own archives)

Deficit irrigation practice
SAVE WATER AND IMPROVE WUE

The main objective of deficit irrigation is to increase the WUE of a crop by eliminating irrigations that have little impact on yield.

The results show that yield reduction may be small compared with the benefits gained through diverting the saved water to irrigate other crops.

RDI is usually applied during periods of rapid growth and maturation, when less water can be supplied to the crop, or irrigation can be omitted.

RDI can be applicable for almost all crops (maize, cotton, sunflower, tomato, potato, and especially on vineyards and fruit tree crops).

9. Deficit irrigation practice DI

Table 7. Effect of DI on water savings and yield reduction of several staple crops grown in WBC

Country/region	Crop	Deficit irrigation %	Water saving	Yield reduction
N. Macedonia[1]	Pepper	80	19	No reduction
Serbia[2]	Pepper	80 and 60	9 and 24	20 and 56
	Bean	80 and 60	4.4 and 8.7	4,2 and 16
	Maize	50	50	25-29
	Tomato	50	24-33	21
BiH[3] Banja luka	Maize	50	13	22
Sarajevo	Maize	50	21	2,6

[1]Tanaskovik et al., 2015 ; [2]Cosić et al., 2015; Lipovac et al., 2022, Pejić et al., 2011; Đurović et al., 2016; [3]Čereković et al., 2024

MULCHING
SAVE WATER AND IMPROVE WUE

Mulching is the practice of covering the soil surface with organic or synthetic materials to create a protective layer.

This technique helps manage the crop environment, leading to reduced water loss, weed suppression, temperature regulation, and improved soil health.

The most effective use of mulching depends on the type of crop, climate, and available materials.

10. Low cost water saving practices

Table 8. Water consumption (ETP) in pear orchard in Mlado Nagorichane, North Macedonia with different mulch material and ways of maintaining the surface in the row (Tanaskovik et al., 2015)

Treatment	ETP m^3/ha	% of ETP
Black plastic foil	3611	100
Peat as mulch	4062	112,50
Sawdust as mulch	4359	120,71
Straw as mulch	4417	122,32
Geotextile as mulch	4447	123,15
Control treatment without mulch material	4586	127,00

Using organic materials to improve soil water-holding capacity and WUE

This approach builds soil health over time and offers a low-cost, effective way to conserve water and buffer against drought. The primary strategy is to increase the soil's organic matter content, which acts like a sponge, allowing soil to absorb and store significantly more water.

Leaving plant material on the soil surface is the easiest and most accessible method of using organic materials. The residue forms a protective layer that drastically reduces water evaporation from the soil surface.

In addition, is required that no till or minimum tillage should be used to maximises water storage and preserve organic materials.

10. Low cost water saving practices

Table 9. Water-physical properties of the soil before conducting research with cover crops in pear orchard in 2012 (Tanaskovik et al., 2015)

h	Bulk density	Soil water retention at 0,33 bars			Soil water retention at 6.25 bars			Available wate
cm	g/cm^3	Mass %	Vol. %	m^3/ha	Mass %	Vol. %	m^3/ha	m^3/ha
0-30	1.56	15.92	24.85	745.5	10.19	15.89	476.94	268.54
30-60	1.5	18.57	27.86	835.7	12.33	18.49	554.79	280.92
0-60	1.53	17.25	26.35	1581.20	11.26	17.20	1031.74	549.46

Table 10. Water-physical properties of the soil after the completion of research with cover crops in pear orchard in 2015 (Tanaskovik et al., 2015)

h	Bulk density	Soil water retention at 0,33 bars			Soil water retention at 6.25 bars			Available wate
cm	g/cm^3	Mass %	Vol. %	m^3/ha	Mass %	Vol. %	m^3/ha	m^3/ha
0-30	1.52	17.48	26.60	798.0	10.34	15.72	471.50	326.50
30-60	1.50	19.06	28.59	857.7	12.57	18.85	565.65	292.90
0-60	1.51	18.27	27.59	1655.70	11.46	17.30	1037.15	618.55

11. Shade nets for controlling microclimate and saving water

Table 11. Effect of UV net on water consumption in pepper crop grown in plastic house and covered by UV nets with different colours (Tanaskovik et al., 2015)

Treatment	Effect of green UV net on ETP (%)	Effect of white UV net on ETP (%)	Effect of red UV net on ETP (%)
Green UV net	100	/	/
Red UV net	105.8	102.8	100
White UV net	102.9	100	/
Control treatment without UV net	108.7	105.7	102.8

12. On-Farm water harvesting and storage

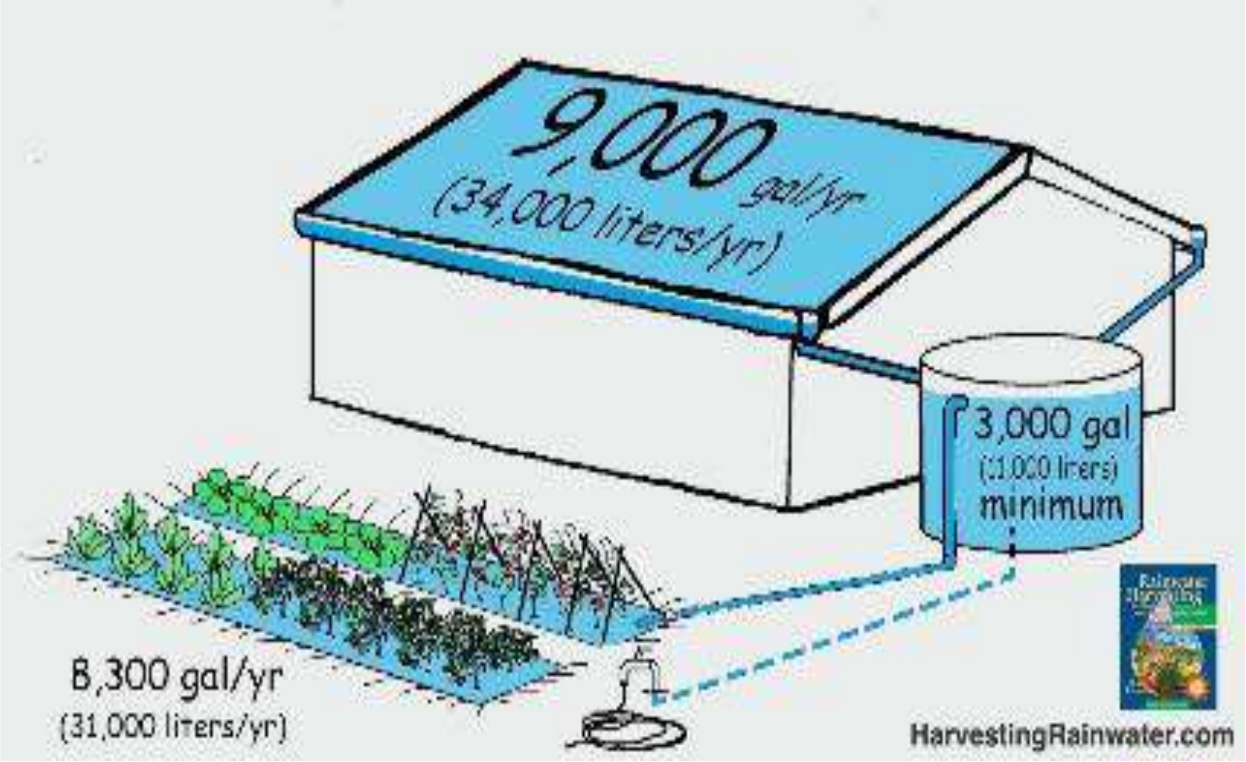
12.1. Roof water collection

Advantages:

- Simple technology that uses existing structures and local materials.
- Water is stored close to where it is needed, reducing cost for transport.
- Can provide water of good quality if treated.
- Reduces pressure on wells and nearby watercourses.

Disadvantages:

- Limited storage and dependence on rainfall; may not cover needs in prolonged droughts.
- Upfront costs for tanks, gutters and fittings can be a barrier for small farms.
- Requires regular cleaning of gutters, filters and tanks to maintain water quality.
- Poorly designed systems can lead to contamination or mosquito breeding.



12. On-Farm water harvesting and storage

12.2. Farm ponds and small reservoirs

Advantages

- Improved water security for crops and livestock during dry period.
- Reduction of peak runoff, soil erosion and downstream flood risk.
- Multiple potential uses, including aquaculture and groundwater recharge.
- Creation of wet habitats that enhance farm biodiversity.

Disadvantages

- Land area occupied by the pond and associated safety zones.
- Investment cost and need for basic technical design and supervision.
- Sedimentation can gradually reduce storage volume if catchment erosion is high.
- Open water is exposed to evaporation and can pose safety risks for children and animals.