SECTION 3. ECONOMICS OF ECONOMIC SECTORS

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3.1 Rational water use in agriculture as a prerequisite for food security and sustainable development: global lessons for Ukraine

Water is a key resource for ensuring food security, and its use is indispensable at every stage of production — from field irrigation to processing and transportation of final products. In addition, water is essential for meeting personal and household needs, energy production, industrial processes, and the maintenance of vital ecosystems. According to FAO projections, by 2050 many regions — particularly in North Africa and South Asia — will face severe water shortages, leading to increased competition for water that will constrain agricultural development. Furthermore, a significant share of the world's population growth by 2050 is expected to concentrate in cities of developing countries, intensifying urban demand for water and food and increasing the risk of land and water resource loss for smallholder farmers in peri-urban areas. These trends demand urgent attention and proactive responses, including the implementation of environmental measures to mitigate climate change effects and the preservation and rational use of natural resources to ensure food security and sustainable development.

Globally, the rate of water withdrawal has outpaced population growth. Over the past 100 years, water use has increased sixfold, while the global population has tripled. This disproportionately high growth is largely attributed to industrialization, agricultural sector expansion, improved living standards, and high levels of water loss. Agriculture remains the largest water consumer, accounting for more than 70% of global water withdrawals. According to FAO data, as of 2022, 268 million hectares, or 74% of equipped irrigated land worldwide, were actually irrigated. The global water stress level stands at 18%, with overall water use efficiency estimated at USD 21.5 per cubic meter, while irrigation water efficiency is just USD 0.7 per cubic meter. The volume of renewable freshwater resources globally exceeds 5,300 m^3 per person per year.

Moreover, agriculture continues to be one of the main drivers of deforestation, water pollution, and biodiversity loss. In contrast, the implementation of regenerative agricultural practices can halve methane emissions, reduce energy consumption by more than one-third, and lower water use by up to 30%. Therefore, studying global best practices in rational water use in agriculture and climate change adaptation strategies provides a foundation for developing effective approaches to sustainable water resource management, tailored to Ukraine's current challenges and needs.

The relevance of such approaches is also supported by international commitments, particularly Sustainable Development Goal 6, which aims to ensure availability and sustainable management of water and sanitation for all. This goal once again underscores the urgency of addressing water scarcity. One of the key indicators of progress toward this goal is "water stress" is defined as the ratio between the total freshwater withdrawn by all major sectors of the economy and the total available renewable freshwater resources, accounting for environmental water flow requirements. The following thresholds are used to classify water stress levels:

- up to 25% – no water scarcity;
- 25–75% – low to medium water stress;
- 75% and above – high water stress;
- over 100% – critical level of water stress.

According to FAO data for 2021, 26 countries worldwide experienced low to medium levels of water stress, while 25 countries faced high or critical levels.

Also the SDG indicator is water use efficiency, which in Ukraine is among the lowest in Europe. In 2022, it amounted to only USD 11.8 per cubic meter — 28, 11, 8, and 5 times lower than in Denmark, Germany, France, and Poland, respectively. Ukraine also demonstrated a critically low efficiency of irrigation water use — USD 0.03 per cubic meter. Only Finland reported a lower figure, although its irrigation needs are significantly reduced due to favorable climatic conditions and sufficient rainfall (Table 1).

Table 1

Water Use Indicators in EU Countries[1] and Ukraine, 2022

Country	Agricultural water withdrawal as % of total renewable water resource, %	Ratio of irrigated areas using groundwater to those using surface water, times	SDG 6.4.1. Water Use Efficiency, USD/m³	SDG 6.4.1. Irrigated Agriculture Water Use Efficiency, USD/m³	Water stress, %	Desalinated water volume, km³/year[2]	Area equipped for irrigation with treated wastewater, thousand ha
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Austria	0,2	4,3	157,4	2,2	8,7		
Belgium	0,2	1,4	93,4	1,6	52,8		
Bulgaria	3,4	-	9,7	0,2	40,2		
Croatia	0,1	-	50,5	0,9	1,5		
Czechia	0,3	-	132,9	1,4	22,0		
Denmark	8,4	48,9	332,3	1,4	25,3		
Estonia	0,04	0,2	20,2	0,7	13,1		
Finland	0,9	0,2	78,8	0,02	7,1		
France	1,2	-	94,7	3,1	21,4	0,01	4,2
Germany	0,7	4,6	126,3	2,5	35,4		3,0
Greece	11,9	-	18,1	0,6	20,3	0,01	4,7
Hungary	0,5	-	26,0	0,5	8,1		
Ireland	0,1	0,25	280,5	-	8,1		
Italy	8,9	0,5	50,0	0,93	29,8	0,2	4,0
Latvia	0,1	0,1	155,0	0,04	1,02		
Lithuania	0,2	-	151,9	0,1	2,2		
Malta	42,3	229	237,5	4,0	72,6		0,3
Netherlands	0,3	-	96,5	21,5	16,7		
Poland	2,1	0,1	55,4	0,2	32,5	0,01	
Portugal	4,4	1,2	32,0	0,5	12,3		
Romania	1,4	-	24,8	0,4	7,6		

[1] The table presents data for the EU-27 (excluding Cyprus and Luxembourg) and Ukraine.
[2] 2021 data.
[3] 2021 data

Continuation of table 1

1	2	3	4	5	6	7	8
Slovakia	0,1	-	158,2	1,8	2,4		
Slovenia	0,01	0,6	55,8	9,7	5,6		
Spain	17,0	-	40,8	0,5	43,3	0,42	
Sweden	0,1	0,4	249,0	4,2	3,6		
Ukraine	0,6	-	11,8	0,03	6,3		

Source: compiled and calculated by the author based on FAO data [66].

As shown in Table 1, Malta, Spain, and Greece have the highest share of agricultural water withdrawals relative to their total renewable water resources − ranging from 42.3% to 11.9%. However, unlike Spain and Greece, where actual irrigation volumes are substantial (3.1 million ha and 1.0 million ha, respectively), Malta (with only about 4,000 ha of irrigated land) does not withdraw large volumes of water for agricultural purposes. The high percentage is instead explained by the country's extremely limited water resources. Malta is considered the most water-scarce country in Europe, with a water stress level exceeding 72%. The primary water source is desalinated seawater, which supplies over 60% of national water needs. Water-saving irrigation methods, water reuse, and alternative water sources are widely adopted for irrigation. Households and the tourism sector are the largest water consumers, far exceeding agriculture. Thus, although the absolute volume of agricultural water use in Malta is relatively low, its relative share of total renewable resources is the highest in Europe − 42.3%.

Several EU countries (e.g., France, Greece, Italy, Spain) also use desalinated and treated wastewater for irrigation. In France, for instance, in 2018, households and industries generated 14.7 million m³ of wastewater daily, which was subsequently treated at over 3,000 local facilities. The resulting sludge − 1.1 million tons − was reused mainly in agriculture (81%), incinerated (14%), or used for other purposes (2.6%). Additionally, 0.1% of treated water was reused for irrigation. France invests significantly in water infrastructure modernization, with annual per capita investment reaching EUR 66 — 61% above the European average.

Countries outside Europe, such as ***Israel and Egypt***, also stand out due to their high water stress levels and reliance on alternative water sources for agriculture. In Israel, where water stress reached 130% in 2022, 0.5–0.6 km³ of seawater is desalinated annually, and 0.28 km³ of treated wastewater is used for irrigation. In 2021, actual irrigated area in Israel totaled 240,000 ha, over 70% of which was under drip irrigation. Vegetable crops accounted for 22.5% of this area. About 40,000 ha were irrigated with treated wastewater. Irrigation water efficiency is high − USD 2.6 per m³ − and over 60% of total water withdrawals come from groundwater due to limited surface water availability. Overall, water use efficiency in Israel is around USD 141/m³ − twelve times higher than in Ukraine.

Egypt's water stress is even higher − 141.2%. National water policy includes both desalination and wastewater reuse, with respective annual volumes of 0.20 km³ and 0.29 km³. Treated wastewater irrigates 35,500 ha. Egypt's actual irrigated area is 3.4 million ha (out of a potential 4.4 million ha), including 932,000 ha of forage crops, 927,000 ha of maize, and 452,000 ha of rice. However, water use efficiency remains critically low − USD 5.7/m³, and irrigation water efficiency is USD 0.8/m³. This calls for urgent improvements in water use practices in both agriculture and domestic sectors.

India, with a water stress level of 66.5% in 2022, had a total water use efficiency of USD 3.4/m³ (41 in industry, 0.5 in irrigation). Experts predict that by 2030, demand will exceed supply by 50%, potentially reducing GDP by 6% by 2050. India, therefore, prioritizes sustainable water management — reducing withdrawals, rational pricing, and community-based governance. Informal water markets are widespread but understudied. With over 66 million ha of irrigated land (8% in wheat and rice), agriculture consumes 90% of freshwater, 65% of which is sourced from groundwater. Electricity subsidies for pumps exacerbate groundwater depletion. Although water pricing is encouraged, regulatory disparities across regions and per-acre rather than volumetric charges hinder progress. Better regulation, monitoring, and environmental-economic mechanisms are essential, especially concerning informal water markets.

In ***Ethiopia***, the water stress level is 32.3%. Despite having substantial groundwater potential, most agricultural output relies on rainfed farming, making the country highly vulnerable to climate change. Climate-smart agriculture (CSA) is essential to reduce these risks and support food security. After a major drought in 1980–1985, small-scale irrigation development began. However, political and institutional instability hindered progress until 2010. The expansion of irrigation areas became part of national agricultural policy, with the Ministry of Water, Irrigation and Energy (MoWIE) establishing an Irrigation Development Commission and implementing three five-year development plans. Small-scale systems were prioritized for their cost-efficiency, ease of implementation, greater farmer involvement, and improved coordination. By 2021, around 5% of cultivated land was equipped for irrigation. In 2022, 858,000 ha were under irrigation — one-third of the potential. Irrigation water efficiency was USD 0.2/m³; overall water use efficiency was USD 5.9/m³.

Despite growing attention to irrigation, Ethiopia's system remains underperforming. Many projects do not operate at full capacity, and others suffer from poor maintenance. Key challenges include: lack of technical and financial resources; weak institutional capacity among contractors and clients; insufficient planning data; limited stakeholder involvement; lack of monitoring and evaluation; frequent project changes causing cost overruns and delays; and the absence of advisory services in irrigation.

The unregulated use of groundwater in Africa remains a major concern, threatening long-term sustainability. Groundwater-based irrigation is energy-intensive, thus alternative energy sources such as solar pumps are essential. Studies confirm the profitability of solar-powered irrigation for crops like onions and tomatoes. However, to prevent aquifer depletion and ecological degradation, standards must be enforced: comprehensive groundwater monitoring systems, permit-based withdrawal, and local community involvement in water management and equitable resource allocation are all critical. These are key prerequisites for sustainable water use and improved decision-making in local water governance.

In ***Ukraine***, the water issue is gaining strategic importance due to increasing climate challenges, growing needs of the agricultural sector, and the consequences of military operations. The ongoing military conflict has led to a dramatic decline in water use, particularly in the land reclamation sector, where water consumption dropped by 80% between 2021 and 2023. Overall, total water use in Ukraine decreased nearly threefold between 2010 and 2023, while the reduction in irrigation water was more than sevenfold. In particular, in 2010, 1,377 cubic meters of water were used for irrigation, of which 87% was the share of Kherson region and the Autonomous Republic of Crimea. The destruction of the Kakhovka Hydroelectric Power Plant dam effectively eliminated irrigation systems in Kherson, Zaporizhzhia, and parts of Dnipropetrovsk regions. Notably, in 2021, the volume of irrigation water used in Kherson oblast alone was twice as high as the total amount used for irrigation across the entire country during 2022-2023 (Table 2).

Table 2

Dynamics of Water Resource Use in Ukraine, million m³

	2010	***2020***	***2021***	***2022***	***2023***	***2023/2010, %***
Used fresh water	9817	7238	6161,3	3401,3	3576,5	36,4
Used fresh water for needs irrigation	1377	1452	970,5	143,2	192,3	14,0
including Dnipropetrovsk	16	32	21,3	21,6	14,7	91,9
Zaporizhzhia	32	172	89,5	2,7	1,5	4,7
Mykolaiv	25	106	53,6	4,7	36,8	147,2
Odesa	71	180	107,1	73,0	89,8	126,5
Poltava	-	8	10,5	5,7	6,8	-
Kherson	695	898	648,4	0,9	0,3	0,0
Cherkasy	5	27	18,3	22,0	26,6	532,0

Source: compiled and calculated by the author based on data [72, 73].

A comparison of current irrigation water use with 1990 levels reveals a sharp decline − more than 36-fold. This downward trend is driven by a combination of factors, including the collapse of the land reclamation system, chronic underfunding of the sector, deteriorating infrastructure, a lack of economic incentives to maintain irrigated areas, and, more recently, the consequences of military aggression and the destruction of critical water management infrastructure. This trend is illustrated in Figure 1.

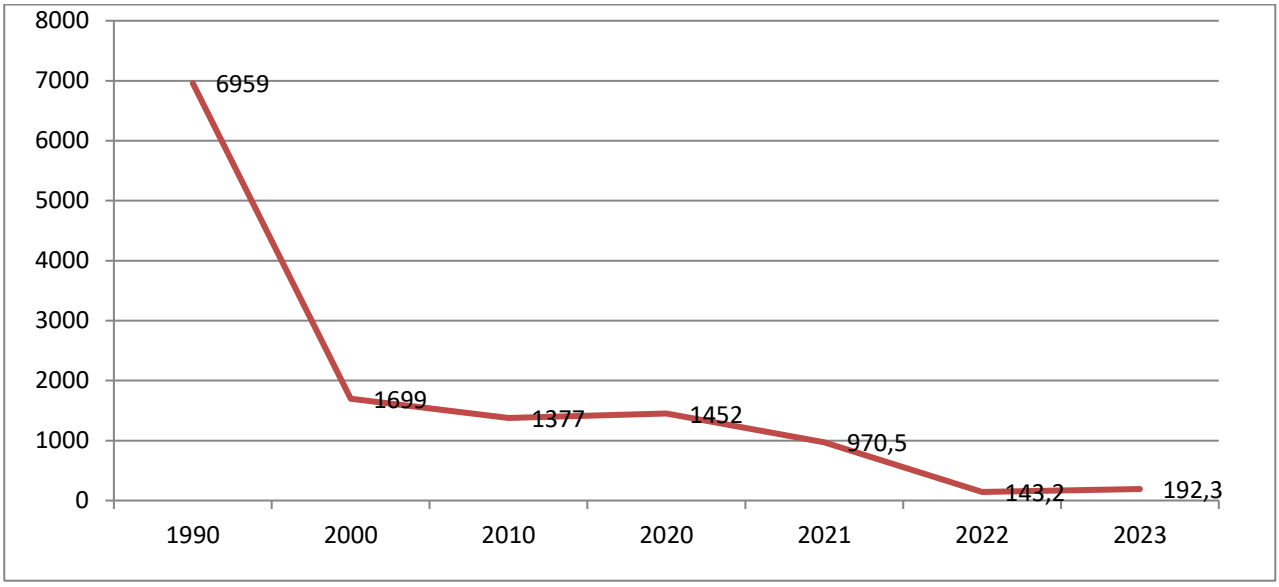

Figure 1. Dynamics of freshwater use for irrigation in Ukraine, million m³
Source: compiled by the author based on data [73].

However, in the face of climate change and increasing water scarcity, ensuring sustainable irrigation is a key factor for restoring Ukraine's agricultural potential and strengthening its food security.

In conclusion, ensuring adequate water supply for agricultural production − a strategic resource for food security − is critically important amid population growth and climate change. A global trend has emerged where water demand growth outpaces population growth. This imbalance forces countries to explore new approaches to water use optimization. Global experience in rational water use and water scarcity mitigation in agriculture highlights diverse strategies and technologies aimed at efficient resource utilization, loss reduction, and climate change adaptation. Ukraine, while experiencing a national water stress level of 6.3%, faces challenges from uneven water distribution,

irregular rainfall, and an outdated land reclamation system, all of which hinder agricultural efficiency and call for adaptive management strategies.

This underscores the importance of climate-smart agriculture and water-resilient farming practices, including reduced water consumption, adoption of drip irrigation, and greater reuse of irrigation water. Ukraine lags behind European countries in water use efficiency − USD 11.8/m³ for general use and only USD 0.03/m³ for irrigation. Therefore, it is crucial to revise water management approaches, modernize infrastructure, implement fair and economically justified water tariffs, enhance stakeholder participation, and promote research and innovation in agrotechnologies through professional training and institutional support.