Scientific Papers. Series E. Land Reclamation, Earth Observation & Surveying, Environmental Engineering. Vol. XIV, 2025
Print ISSN 2285-6064, CD-ROM ISSN 2285-6072, Online ISSN 2393-5138, ISSN-L 2285-6064

ADAPTING ROMANIA'S IRRIGATION INFRASTRUCTURE TO CLIMATE CHANGE: OPPORTUNITIES AND CHALLENGES

Mihai Teopent CORCHEȘ

"1 Decembrie 1918" University of Alba Iulia, 5 Gabriel Bethlen Street, 510009, Alba Iulia, Romania

Corresponding author email: mihai.corches@uab.ro

Abstract

In the context of climate change, where Romania faces increasingly frequent droughts, significantly impacting water availability in several regions, the issue of efficient water resource management is becoming more pressing. The phenomenon of drought is having a growing impact on agriculture, necessitating the development of new irrigation systems and the modernization of existing ones, which may need to be more efficient in water use, such as drip irrigation, subsurface irrigation, or sprinkler irrigation, which can also be equipped with smart irrigation technologies (soil moisture sensors, automatic control, remote monitoring and management, aerial surveillance of agricultural crops, etc.). This study analyzes the opportunities for adapting irrigation infrastructure in the current context, focusing on the possibility of implementing best practices and modern technologies used worldwide in Romania. It also critically examines the challenges Romania faces in the development of irrigation systems, as well as the solutions adopted by other countries to overcome these challenges.

Key words*: climate change, irrigation, water management.*

INTRODUCTION

Climate change represents one of the most complex and pressing challenges of the 21st century, having a profound impact on the dynamics of extreme meteorological phenomena. The increasing frequency and intensity of floods, because of climate change, put pressure on existing infrastructure and risk management capacity (IPCC, 2021). Global climate changes and the intensification of climate risk events, such as changes in precipitation patterns and intensity, combined with modifications in land use practices and improper management of agricultural lands, have a significant impact on soil (Sestras et al, 2023). This reality necessitates not only the modernization and expansion of irrigation systems but also their integration into a unified water management strategy, including effective flood prevention measures. Such a holistic approach is essential for reducing risks associated with extreme climatic events and minimizing damages caused by sudden variations in the hydrological regime. In this regard, a fundamental shift in planning and implementing adaptation strategies is necessary so that irrigation infrastructure and flood prevention works are designed in correlation with future climate risks, based on scenario analyses and advanced predictive models. At present, there are a number of climate models, some of which are global, such as CMIP6 (Coupled Model Intercomparison Project, Phase Six) and HadGEM3 (Hadley Centre Global Environment Model version 3), which are used to simulate long-term climate change. There are also regional climate models, such as REMO (The Regional Climate Model REMO) developed at the Max Planck Institute for Meteorology, currently managed and further developed by the Climate Service Center Germany (GERICS) in Hamburg, Germany; the CNRM-ALADIN model (Aire Limitée Adaptation dynamique Développement InterNational), developed at the National Centre for Meteorological Research in France; or the COSMO-CLM model (Consortium for Small-scale Modeling – Climate Limited-area Model), managed by the European Consortium COSMO. At the European Union level, data can be accessed through the European Climate Adaptation Platform Climate-ADAPT, which was created through a partnership between the European Commission and the European Environment Agency (EEA), with the aim of

supporting Europe's adaptation to climate change.
In this context, adapting irrigation infrastructure to new climatic realities becomes an urgent necessity. This involves not only modernizing existing systems but also adopting innovative strategies that consider uncertainties and future risks (Jongman et al., 2012). Thus, the modernization of irrigation infrastructure in Romania represents not only a complex challenge but also a significant opportunity to strengthen the resilience of the agricultural sector to climate change. The implementation of appropriate policies and the efficient use of available financial resources are essential for establishing a sustainable irrigation system that meets both current and future agricultural needs.
In light of intensifying climate change, reducing the national water footprint has become imperative for all countries, including Romania (Sandu & Vîrsta, 2021).

MATERIALS AND METHODS

This study analyzes the current state of irrigation infrastructure in Romania, highlighting both the main deficiencies and limitations, as well as the existing opportunities for attracting investments and developing sustainable solutions. In this regard, aspects related to available funding sources are addressed, both at the national level through government funds and at the European level through support mechanisms offered by the European Union, such as the National Strategic Plan 2023-2027, which was approved by the European Commission through Commission Implementing Decision C(2022) 8783 of December 7, 2022, under which Romanian farmers can benefit from up to €15.83 billion to improve outcomes and enhance the performance of Romanian agriculture. Additionally, major challenges that may arise in the implementation process of irrigation projects, such as soil and biodiversity impact, are identified.
The study is based on an analysis of recent research in the specialized literature that highlights these aspects. Furthermore, certain considerations such as the energy efficiency of pumping systems, the use of modern irrigation technologies to reduce water losses, and the necessity of an integrated water resource management approach are also discussed.
For the creation of maps, the open-source software QGIS was used, along with publicly available vector datasets from the website https://geo-spatial.org/vechi/download/romania-seturi-vectoriale.

RESULTS AND DISCUSSIONS

Water Resources of Romania

According to data presented by the National Institute of Statistics (INS, 2025), Romania possesses considerable water resources; however, their distribution shows significant regional variability. As shown in the figure below, Romania's water resources are unevenly distributed across the country, being more abundant in the northern half, while the southern regions face a significantly lower level of water availability. This variation directly affects irrigation needs, as the southern areas - being more water-scarce - require more extensive and efficient irrigation systems to support agricultural activities and cope with frequent drought conditions. Moreover, the southern part of Romania is characterized by larger expanses of arable land compared to the north, making it a key agricultural zone. This combination of extensive farmland and limited water resources further intensifies the pressure on irrigation infrastructure, highlighting the need for targeted investments and climate-resilient water management strategies in the region.
In 2023, the total volume of available water resources, based on the level of infrastructure development, was estimated at 50,150 million m³/year. The volume of water for each hydrographic basin, according to the source, was graphically represented in Figure 1.
Surface waters contributed approximately 37,644 million m³/year, while groundwater sources provided 12,506 million m³/year. The distribution analysis reveals that the southern and eastern regions are more vulnerable to drought, primarily due to low precipitation levels and high water demand for irrigation and industry.
These regional discrepancies highlight the necessity of implementing efficient water resource management strategies, including optimizing storage and distribution infrastructure and promoting sustainable water use practices in key economic sectors.

Print ISSN 2285-6064, CD-ROM ISSN 2285-6072, Online ISSN 2393-5138, ISSN-L 2285-6064

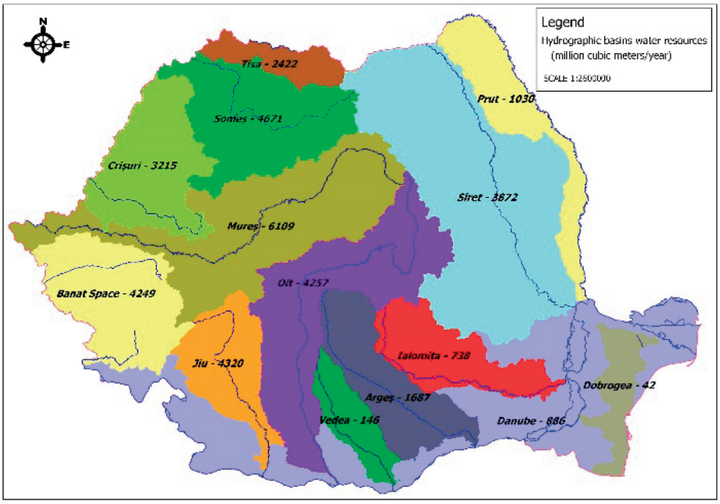

Figure 1. Water resources ensured, according to the development level, in 2023 (original)

Irrigation Network in Romania

The irrigation network in Romania is a complex system, primarily developed during the communist period (1960-1989) to support agriculture by ensuring water availability for crops during drought periods. This infrastructure was built in key agricultural areas of the country, such as the Romanian Plain, the Banat Plain, the Crișuri Plain, and other regions in southern and eastern Romania. Currently, the irrigation network is undergoing rehabilitation and modernization, with support from European funds, to address climate challenges and increase agricultural productivity. During the communist period, Romania invested heavily in irrigation infrastructure, constructing a network covering over 3 million hectares. These systems included canals, pipelines, pumping stations, reservoirs, and dams, designed to capture, store, and distribute water from natural sources such as rivers and lakes. The primary goal was to ensure food self-sufficiency and support intensive agriculture. After the 1989 Revolution, many of these systems were neglected or abandoned due to a lack of funding and changing economic priorities. Currently, the area prepared for irrigation is approximately 1,606,847.97 hectares, according to data published on the ANIF website. Of these, the contracted irrigation area is 1,047,301.55 hectares, and the filled irrigation canals total 2,827.33 km, serving an area of 827,404.19 hectares (ANIF, 2024).

According to ANIF data, the total area designated for irrigation in Romania is 2,989,390 hectares, and the primary irrigation infrastructure includes (ANIF, 2024):

- 10,422 km of adduction and distribution canals;
- 24,547 km of buried pipeline networks;
- 2,568 pumping stations, both floating and fixed.

Adapting irrigation infrastructure to climate change

Adapting irrigation infrastructure to climate change is a complex process requiring significant investments, strategic planning, and cooperation at all levels. This adaptation is essential for ensuring agricultural sustainability and food security. To achieve this objective, the following steps are necessary:

1. ***Assessing vulnerability and climate risks***

The first step in ensuring the resilience of irrigation infrastructure in the face of climate change is assessing the vulnerability of existing systems. This involves conducting detailed studies to identify agricultural areas most exposed to extreme climatic events, such as droughts or floods. Current climate models indicate that many regions will experience more intense and frequent precipitation, which may exceed the design capacity of existing infrastructure (Kundzewicz et al., 2014). Vulnerability assessment allows for the prioritization of investments and adaptation measures. It is necessary to develop detailed climate forecasts for all regions of the country to support decision-making.

2. ***Modernization and optimization of existing infrastructure***:

A crucial first step is conducting a detailed inventory of the existing infrastructure using GIS spatial analysis to determine the condition and design capacity of the systems. The use of advanced satellite imagery is essential for monitoring climate change and managing water resources, minimizing uncertainty, and helping to establish optimal mitigation measures (Burghila D., et al 2015). Understanding this information enables the proper design of irrigation works, considering the agricultural areas that require irrigation and the available water resources. Additionally, a quantitative assessment of losses in existing systems is essential to establish a plan for their reduction.

The design of rehabilitation and expansion works for irrigation systems should be based on studies and hydrological simulations to estimate the climate impact on water sources. Rehabilitation should include measures to optimize water consumption, such as:

- using buried pipes or covered channels to reduce evaporation losses;
- implementing drip irrigation;
- utilizing IoT sensors and artificial intelligence to monitor water flow, soil moisture, and optimize water consumption.

3. ***Diversification of water sources for irrigation***:

Climate change and the increasing frequency of drought periods require the diversification of water sources for irrigation to enhance agricultural resilience.

Currently, irrigation in Romania relies primarily on water from rivers and reservoirs but exploring efficient and sustainable alternatives is necessary. Exploring and utilizing alternative water sources, such as constructing rainwater collection basins or reusing treated wastewater, can reduce dependence on traditional sources and ensure a stable water supply for irrigation. However, these water collection systems are suitable mainly for small land areas and using wastewater for irrigation - although beneficial for recycling nutrients and improving soil fertility - requires modern treatment plants, advanced purification technologies, and continuous water quality monitoring to prevent potential health risks if not treated properly.

4. ***Implementation of sustainable agricultural practices***:

Sustainable agricultural practices play a crucial role in conserving water resources, ensuring the long-term viability of agriculture, and protecting the environment. Implementing efficient water management methods not only improves productivity but also reduces negative impacts on aquatic ecosystems. Promoting soil water conservation techniques, such as conservation agriculture - which focuses on minimizing soil disturbance and mulching (Bojariu et al., 2021) and crop rotation can reduce irrigation needs and enhance crop resilience to variable climate conditions.

5. ***Strengthening institutional capacity and legislative framework***:

Better cooperation between central authorities, local authorities, farmers, and other water users is necessary to efficiently manage available water resources and ensure a more coherent and effective approach. The development of centralized irrigation infrastructure reduces the burden on farmers to secure their own irrigation water resources and can lead to more efficient water use and conservation.

Developing policies and regulations that support climate change adaptation, including financial incentives for farmers adopting sustainable practices and efficient irrigation technologies, is essential. Promoting financing programs or subsidies for the implementation of efficient irrigation systems could encourage farmers to adopt solutions that reduce water consumption.

Adapting these steps to the specific context of each region can lead to a more resilient and efficient irrigation infrastructure, capable of addressing the challenges posed by climate change. Educating farmers and engaging local communities are essential for the success of adaptation measures. Farmers must be aware of the risks posed by climate change and be prepared to take preventive measures.

Opportunities for the rehabilitation and construction of irrigation infrastructure in Romania

Funding for irrigation infrastructure is crucial for modernizing and expanding existing systems, particularly in the context of climate change and the need to support sustainable agriculture.

Available funding sources for irrigation projects include the National Strategic Plan 2023-2027, which allocated €400 million for the 2024 funding session under the DR-25 intervention: "Modernization of Irrigation Infrastructure". The public support was 100% non-reimbursable for eligible costs. This plan also includes an additional €1.5 billion for modernizing the primary irrigation infrastructure, managed by the National Agency for Land Improvements.

Challenges in the rehabilitation and construction of irrigation infrastructure in Romania

Developing irrigation infrastructure can impact biodiversity, bringing both benefits and risks to ecosystems. The Natura 2000 network in Romania (Figure 2), covering approximately 23% of the country's territory, is an extensive system of protected areas aimed at conserving biodiversity and protecting natural habitats, as well as significant flora and fauna species at the European level.

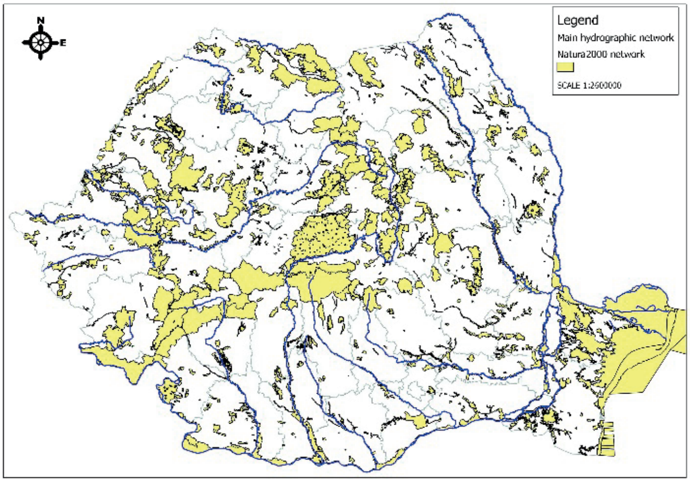

Figure 2. The Natura 2000 network in Romania (original)

Some areas, such as the Danube Delta, are globally recognized for their biodiversity and are also included in other protection programs, such as the Ramsar Convention (on wetlands).

To ensure effective conservation, conservation objectives have been established for all sites, and for some of them, management plans have been developed, outlining conservation measures for the habitats and species present in these sites.

A significant portion of these sites, designated for the protection of aquatic and water-dependent habitats and species, overlaps with watercourses and other wetlands. Therefore, the implementation of irrigation projects should consider the measures set in the conservation objectives and management plans. Carrying out such projects in these areas could significantly impact the conservation status of habitats and species of community interest, as well as the ecological condition of watercourses, which is a key parameter for the preservation of these habitats and species.

1. ***The positive impact of irrigation on biodiversity***

Irrigation can support biodiversity in arid or semi-arid areas by providing the water necessary for plant and animal survival and improving soil fertility. Recent studies show that drip irrigation significantly impacts soil properties, both on the surface and deeper within the profile, influencing soil conditions and plant development (Tsurkan O. et al., 2021). As demonstrated by Olinic et al. (2024), the development of plant root systems plays a crucial role in improving soil structure and enhancing its water retention capacity, especially when integrated with geosynthetic materials for erosion control.

2. ***The negative impact of irrigation on biodiversity***
Irrigation infrastructure can have significant adverse effects, including:
Dams and irrigation channels can disrupt natural water flow, affecting aquatic ecosystems. A study examining the ecological impact of dam construction on river environments, using intertidal nematode communities as bioindicators, found that interrupting longitudinal connectivity and accumulating contaminants upstream altered nematode structures, affecting abundance, diversity, dominant genera, and community compositions (Tran et al., 2022).
A recent study (Cabodevilla et al., 2022) highlights a significant impact of irrigation systems and associated land-use changes on bird communities in an arid Mediterranean ecosystem. The study found that 55% of bird species responded negatively to irrigation (with a reduced probability of occurrence), while only 11% showed a positive response. These changes led to a 24% overall decline in species richness at the site level. The impact was particularly pronounced in ground-nesting bird species, followed by those associated with shrubs and forests, suggesting that the effects of irrigation on biodiversity may be more extensive and complex than initially assumed. The implementation of irrigation, combined with landscape transformations, changes in agricultural practices (such as monoculture), and the intensive use of agrochemical products, can induce substantial modifications in the composition and dynamics of local bird communities. Another study (Poff et al., 2010) indicates that alterations in river flow regimes can lead to the loss of aquatic habitats and the decline of species.
Excessive irrigation can cause soil salinization, reduce fertility and harm native plant species (Qadir et al., 2014).

A crucial aspect to consider when designing irrigation systems is energy efficiency, as these systems can significantly increase operating costs.

CONCLUSIONS

In the context of increasingly evident climate change in recent years in Romania, adapting irrigation infrastructure to new climate realities is a strategic priority for ensuring food security and agricultural sustainability. One of the most cited global examples of irrigation and technological reform comes from Israel, a country with limited water resources and uneven water distribution, which has become a world leader in efficient irrigation systems. In the 1960s, the Israeli company Netafim pioneered drip irrigation. The use of this irrigation method on over 75% of agricultural crops, combined with the reuse of treated wastewater for irrigation at over 86%, rainwater harvesting, seawater desalination, the construction of numerous reservoirs for storing irrigation water, controlling the consumption behavior of the population through media and online campaigns, and the use of IT solutions, has made Israel a global example to follow (Kaplan, 2022). The increasing frequency of extreme weather events, such as prolonged droughts or intense rainfall, necessitates urgent and effective measures to modernize and expand irrigation systems, optimize water resource use, and reduce the agricultural sector's vulnerability.

REFERENCES

ANIF – National Agency for Land Improvements. (2024). *Despre noi*. Retrieved March 7, 2025, from https://www.anif.ro/despre-noi/

ANIF – National Agency for Land Improvements. (2024). *Irigatii*. Retrieved March 7, 2025, from https://www.anif.ro/irigatii/

Bojariu, R., Nedealcov, M., Boincean, B., Bejan, I., Rurac, M., Pîntea, M., Caisin, L., Cerempei, V., Hurmuzachi, I., Baltag, G., & Zaharia, N. (2021). *Ghid de bune practici întru adaptarea la schimbările climatice și implementarea măsurilor de atenuare a schimbărilor climatice în sectorul agricol*. Chișinău: S.n. Retrieved March 7, 2025, from https://www.researchgate.net/publication/357649368_Ghid_de_bune_practici...

Burghila, D., Bordun, C. E., Doru, M., Sarbu, N., Badea, A., & Cimpeanu, S. M. (2015). Climate change effects – where to next? *Agriculture and Agricultural Science*

Procedia, 6, 405–412. https://www.sciencedirect.com/science/article/pii/S2210784315002405

Cabodevilla, X., Wright, A. D., Villanua, D., Arroyo, B., & Zipkin, E. F. (2022). The implementation of irrigation leads to declines in farmland birds. *Agriculture, Ecosystems & Environment, 323*. https://www.sciencedirect.com/science/article/pii/S0167880921004059

INS – National Institute of Statistics. (2025). *Romanian Statistical Yearbook* (ISSN 1220-3246). Retrieved March 5, 2025, from https://insse.ro/cms/sites/default/files/field/publicatii/anuarul_statistic_al_romaniei_carte_ed_2024_en.pdf

IPCC. (2021). *Climate Change 2021: The Physical Science Basis*. In V. Masson-Delmotte et al. (Eds.), *Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change* (2391 pp). Cambridge University Press. https://www.ipcc.ch/report/ar6/wg1/downloads/report/IPCC_AR6_WGI_FullReport.pdf

Jongman, B., Warda, P. J., & Aerts, J. C. J. H. (2012). Global exposure to river and coastal flooding: Long-term trends and changes. *Global Environmental Change, 22*, 820–835. https://www.researchgate.net/publication/329415777_Global_exposure...

Kaplan-Zantopp, M. (2022). How Israel used innovation to beat its water crisis. Retrieved April 11, 2025, from https://www.israel21c.org/how-israel-used-innovation-to-beat-its-water-crisis/

Kundzewicz, Z. W., Kanae, S., Seneviratne, S. I., Handmer, J., Nicholls, N., Peduzzi, P., Mechler, R., Bouwer, L. M., Arnell, N., Mach, K., Muir-Wood, R., Brakenridge, G. R., Kron, W., Benito, G., Honda, Y., Takahashi, K., & Sherstyukov, B. (2014). Flood risk and climate change: Global and regional perspectives. *Hydrological Sciences Journal, 59*(1), 1–28. https://www.tandfonline.com/doi/full/10.1080/02626667.2013.857411

Olinic, T., Olinic, E. D., & Butcaru, A. C. (2024). Integrating geosynthetics and vegetation for sustainable erosion control applications. *Sustainability, 16*(23), 10621. https://doi.org/10.3390/su162310621

Poff, N. L., & Zimmerman, J. K. H. (2010). Ecological responses to altered flow regimes: A literature review to inform the science and management of environmental flows. *Freshwater Biology, 55*, 194–205. https://pofflab.colostate.edu/wp-content/uploads/2019/08/Poff_2010_LitreviewtoEflows.pdf

Sandu, A. M., & Vîrsta, A. (2021). The water footprint in context of circular economy. *AgroLife Scientific Journal, 10*(2), 170–177. https://agrolifejournal.usamv.ro/index.php/agrolife/article/view/318/317

Sănduleac, P., Sevastel, M., Roșca, S., Bilașco, S., Sălăgean, S., Dragomir, L. O., Herbei, M. V., Bruma, S., Sabou, C., Marković, R., & Kader, S. (2023). GIS-based soil erosion assessment using the USLE model for efficient land management: A case study in an area with diverse pedo-geomorphological and bioclimatic characteristics. *Notulae Botanicae Horti Agrobotanici Cluj-Napoca, 51*(3), Article 13263. https://www.notulaebotanicae.ro/index.php/nbha/article/view/13263

Tran, T. T., Nguyen, M. Y., Quang, N. X., Hoai, P. N., & Veettil, B. K. (2022). Ecological impact assessment of irrigation dam in the Mekong Delta using intertidal nematode communities as bioindicators. *Environmental Science and Pollution Research, 29*, 90752–90767. https://link.springer.com/article/10.1007/s11356-022-22135-4

Tsurkan, O., Burykina, S., & Leah, T. (2012). Methodological approaches for assessing the drip irrigation impact on the pedo-ecological state of irrigated soils. *Scientific Papers. Series A. Agronomy, LXIV*(2), 81–86. https://agronomyjournal.usamv.ro/pdf/2021/issue_2/Art11.pdf

Qadir, M., Quillérou, E., Nangia, V., Murtaza, G., Singh, M., Thomas, R. J., Drechsel, P., & Noble, A. D. (2014). Economics of salt-induced land degradation and restoration. *Natural Resources Forum, 38*, 282–295. https://www.researchgate.net/publication/267571092_Economics_of_salt-induced_land_degradation_and_restoration