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CROP IRRIGATION TECHNIQUES AND TECHNOLOGICAL INNOVATIONS: A COMPARATIVE STUDY BETWEEN FRANCE AND ROMANIA

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Abstract. *In the face of climate change, increasing water scarcity, and growing pressure on agricultural systems, irrigation has become an essential tool for maintaining crop productivity and ensuring food security. This article presents a comparative analysis of irrigation methods used in France and Romania, focusing on their main characteristics, advantages, limitations, and suitability under different climatic and agricultural conditions. Particular attention is given to traditional irrigation techniques and modern systems, including surface irrigation, sprinkler irrigation, and drip irrigation, which differ in terms of water-use efficiency, operational costs, and environmental impact. The study also explores recent technological innovations in agricultural water management, such as connected soil moisture sensors, automated irrigation systems, remote sensing, and decision-support tools designed to support precision agriculture. By providing real-time information on soil moisture, weather conditions, and crop water requirements, these technologies enable farmers to make more informed irrigation decisions, reduce unnecessary water consumption, and improve resource allocation. Their adoption can contribute to increased irrigation efficiency, improved crop performance, and reduced environmental pressures. Furthermore, the comparison between France and Romania highlights the importance of adapting irrigation strategies to local conditions, infrastructure availability, economic constraints, and the effects of climate variability. While both countries face challenges related to water availability and sustainable agricultural development, their approaches to irrigation modernization reflect different regional needs and opportunities. The objective of this study is to identify effective irrigation practices and innovative solutions that can contribute to a more resilient agricultural sector. Ultimately, the findings aim to emphasize the role of efficient irrigation management and digital technologies in balancing agricultural productivity, responsible water use, and long-term environmental sustainability.*

Keywords*: Irrigation, water management, smart technologies, sustainability, precision agriculture, France, Romania, agricultural innovation*

INTRODUCTION

Agriculture is one of the sectors most directly affected by climate variability and increasing water scarcity. In many regions of Europe, prolonged drought periods, irregular precipitation patterns, and rising temperatures have intensified the need for efficient water management strategies. Irrigation has therefore become a key factor in maintaining agricultural productivity and ensuring food security.

France and Romania are among the largest agricultural producers in Europe, but they differ considerably in their climatic conditions, cropping patterns, and irrigation needs. France cultivates approximately 26.7 million hectares of utilised agricultural area (EUROSTAT, 2023), making it one of the European Union's leading agricultural economies. Although much of the country benefits from relatively regular rainfall, recurring summer droughts, particularly in the southwest and Mediterranean regions, have increased the importance of irrigation for maintaining crop yields. As a result, irrigation is primarily concentrated on high-value crops such

as maize, vegetables, orchards, and vineyards, while a large proportion of French agriculture remains rainfed.

Romania possesses approximately 12.5 million hectares of agricultural land, including extensive arable areas located in the Romanian Plain, Dobrogea, and the Danube Basin. These regions experience a more continental climate characterized by hot summers, lower precipitation during the growing season, and a higher frequency of drought events. Consequently, irrigation plays a crucial role in ensuring stable agricultural production, particularly for cereals (CONSTANTIN ET. ALL, 2025) and oilseed crops. Historically, Romania developed large irrigation schemes during the communist period, many of which were designed to support agricultural production over vast areas; most of this infrastructure was built before 1990.

Despite these differences, both countries face increasing pressure from climate change, which is expected to intensify water scarcity and increase the occurrence of droughts. Consequently, irrigation has become an essential tool for securing agricultural productivity in both France and Romania. However, the way irrigation is implemented differs between the two countries, reflecting variations in agricultural structure, historical infrastructure development, and water management strategies. The comparison of irrigation techniques therefore provides valuable insights into the respective levels of modernization and efficiency of their irrigation systems.

Several irrigation techniques are used in both countries. Surface irrigation, sprinkler irrigation, and drip irrigation are the main methods employed (INRAE, 2022). Each has its own advantages and limitations in terms of water-use efficiency, installation cost, and environmental impact. At the same time, the emergence of smart technologies, such as soil moisture sensors, automated systems, remote sensing, and decision-support tools, helps optimize water use and improve the sustainability of farms (INRAE, 2022, EUROSTAT, 2023).

The objective of this study is to compare the different irrigation methods and the technological innovations currently used in France and Romania. This analysis aims to highlight the most effective practices for sustainable water management in the context of climate change.

MATERIAL AND METHODS

This study is based on a comparative literature review focusing on irrigation practices and technological developments implemented in France and Romania. Relevant scientific articles, technical reports, and agricultural databases (EUROSTAT, 2023), ANIF (ANIF, 2021), SDES (INSEE, 2020) were analyzed to identify the most common irrigation methods and recent innovations in water management.

The comparison was conducted according to several criteria:

- Water-use efficiency;
- Installation and operational costs;
- Adaptability to local climatic conditions;
- Environmental impact;
- Technological integration;
- Contribution to sustainable agriculture.

Particular emphasis was placed on the evaluation of precision irrigation technologies, including sensor-based monitoring systems, automated irrigation scheduling, Geographic Information Systems (GIS), and remote sensing tools. Their contribution to improving irrigation management and reducing water consumption was analyzed and compared between the two countries.

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RESULTS AND DISCUSSIONS

Traditional and Modern Irrigation Systems:

Surface irrigation remains one of the oldest and most widely used irrigation techniques. Although it requires relatively low investment costs, its efficiency is generally limited due to evaporation losses and uneven water distribution (Figure 1). Sprinkler irrigation systems provide better control of water application and can be adapted to various crop types. These systems are extensively used in both France and Romania, particularly for cereal crops and large agricultural fields (Figure 2). Drip irrigation is recognized as one of the most efficient irrigation methods. Water is delivered directly to the root zone, minimizing losses through evaporation and runoff. This technique is increasingly adopted in horticultural production, vineyards, and high-value crops (Figure 3). In France, sprinkler systems cover 87% of the irrigable area, compared with 8% for micro-irrigation and 5% for surface irrigation (Figure 4) (Rusu et all., 2016, Team France-Export, 2025). In Romania, 89.1% of the 2.989,379 ha equipped for irrigation are equipped for sprinkler irrigation, against 9.2% for furrow irrigation and 1.7% for irrigation by submersion (Figure 8) (ANIF, 2021).

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Figure 1. Surface (furrow) irrigation of a prepared field, with water distributed by gravity along the furrows



Figure 2. Sprinkler irrigation of a vegetable crop, with water applied as artificial rainfall



Figure 3. Drip irrigation delivering water directly to the root zone of a plant (source: aquaportail.com).

Comparison between France and Romania crop irrigation methods

Sprinkler irrigation is the predominant irrigation method in both France and Romania. In France, it accounts for 87% of the irrigable area (2.47 million ha; Figure 4) (INSEE, 2020), while in Romania it represents 89.1% of the area equipped for irrigation (2.66 million ha; Figure 8) (ANIF, 2021). This similarity indicates a strong reliance on pressurized irrigation systems in both countries, reflecting the suitability of sprinkler technology for large-scale field crops. Nevertheless, Romania exhibits a slightly greater dependence on this method, both in relative and absolute terms.

A notable difference emerges in the use of surface irrigation techniques. In France, gravity irrigation represents only 5% of the irrigable area (129,000 ha) (INSEE, 2020), whereas furrow irrigation in Romania accounts for 9.2% (276,271 ha) (ANIF, 2021). The Romanian share is therefore almost double that of France. This suggests that traditional irrigation systems remain

more important in Romania, likely reflecting the continued use of infrastructure developed during earlier periods of agricultural modernization.

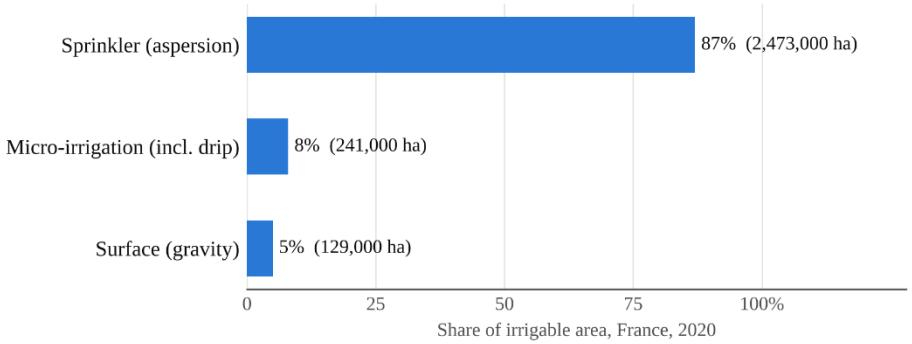


Figure 4. Irrigation techniques used in France in 2020, as a share of the irrigable area (source: SDES, 2024, based on the 2020 Agreste agricultural census (INSEE, 2020)

The greatest contrast concerns the adoption of efficient irrigation technologies. Micro-irrigation, including drip irrigation, covers 8% of the irrigable area in France (241,000 ha) (INSEE, 2020), making it the second most important irrigation method. In Romania, by contrast, the remaining category is submersion irrigation, which represents only 1.7% of the equipped area (49,701 ha) (ANIF, 2021). The ANIF statistics do not report micro-irrigation separately and may not capture systems installed privately by farms; these figures therefore indicate a more advanced documented adoption of water-saving irrigation technologies in France, rather than a precise measure of drip irrigation in Romania.

Overall, both countries display a highly concentrated irrigation structure dominated by sprinkler systems. However, France demonstrates greater diversification through the wider use of micro-irrigation, while Romania retains a stronger reliance on surface irrigation methods. This comparison suggests that France has made greater progress toward efficient water management, whereas Romania still possesses significant potential for the expansion of modern irrigation technologies.

Technological Innovations

Both countries are progressively integrating digital technologies into agricultural water management practices. Connected soil moisture sensors provide real-time information regarding soil water content, allowing producers to irrigate only when necessary (Figure 5) (INRAE, 2022). Automated irrigation systems use sensor data and weather information to regulate water application without direct human intervention. This approach reduces labor requirements while improving irrigation precision. Remote sensing technologies based on satellite imagery and drones enable large-scale monitoring of crop conditions and water stress. These tools help identify areas requiring irrigation and facilitate resource optimization (Figure 6). Decision-support systems combine environmental data, crop requirements, and weather forecasts to generate irrigation recommendations (INRAE, 2022). Such technologies represent a fundamental component of precision agriculture and contribute significantly to sustainable water management FAO, 2026).



Figure 5. Connected soil moisture sensor installed in an orchard to monitor soil water content in real time.



Figure 6. Fixed-wing drone used for crop monitoring and water-stress detection over a field

Comparative Analysis Between France and Romania:

France benefits from more extensive irrigation infrastructure and a higher adoption rate of advanced irrigation technologies. Government programs and technical support have encouraged the implementation of precision agriculture solutions and smart irrigation management systems. Between 2003 and 2010, the irrigated share of the utilised agricultural area fell from 7.0% to 5.7% in France and from 2.9% to 1.0% in Romania (Figure 7).

Romania, despite possessing significant agricultural potential, faces challenges related to aging infrastructure and uneven access to irrigation systems. According to Team France Export, only about 16% of the 3.1 million ha of irrigation infrastructure (about 515,000 ha) is used, partly because of outdated pumping systems inherited from the communist era, and a EUR 1.5 billion network rehabilitation programme (PNS 2023–2027) is planned (WORLD BANK GROUP, 2021); the ESA study reports that on more than 75% of the equipped surface the systems are not functional. However, substantial investments and modernization initiatives have accelerated the adoption of innovative irrigation technologies in recent years. Both countries recognize the necessity of improving irrigation efficiency in response to climate change and increasing pressure on water resources. Nevertheless, local environmental conditions, economic constraints, and infrastructure availability influence the pace and scale of technological adoption.

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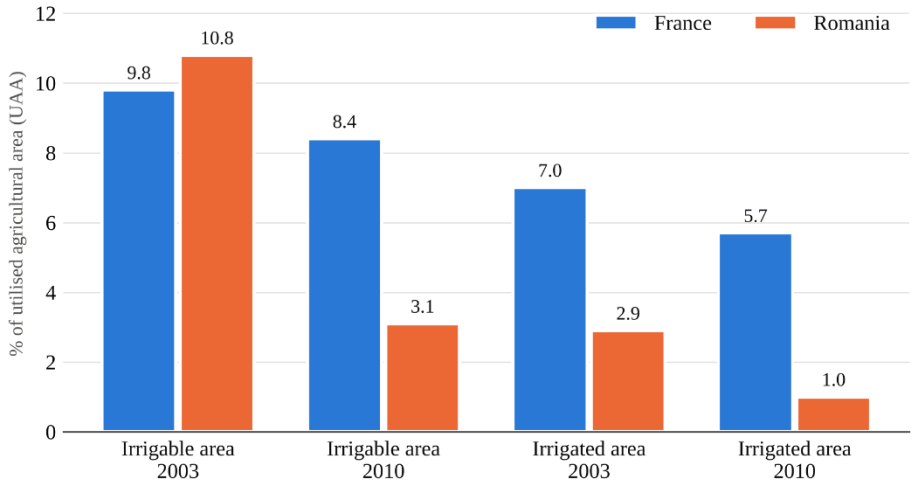


Figure 7. Irrigable and irrigated area as a share of the utilised agricultural area (UAA) in France and Romania, 2003 and 2010 (source: RUSU and SIMIONESCU, 2016, own calculations based on national statistical data; see also Eurostat, 2023)

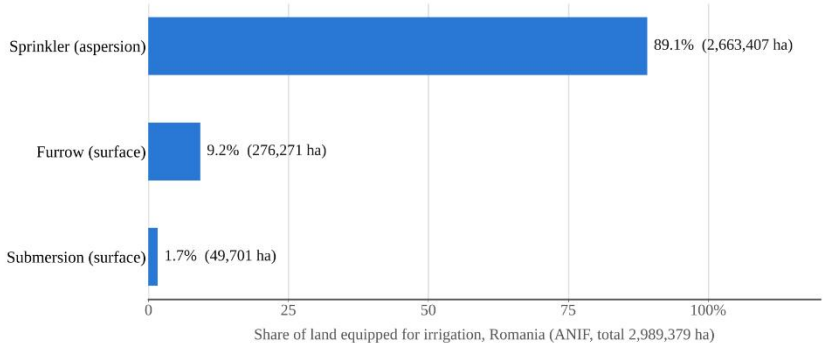


Figure 8. Irrigation methods in the land equipped for irrigation in Romania, as a share of the total equipped area of 2,989,379 ha (source: ANIF, irrigation facilities in Romania (ANIF, 2021)

CONCLUSIONS

Efficient irrigation management is becoming increasingly important for ensuring agricultural productivity and sustainability under changing climatic conditions. The comparison between France and Romania demonstrates that both traditional irrigation methods and modern technologies play significant roles in agricultural water management.

Among the irrigation techniques examined, drip irrigation offers the highest potential for water savings and resource efficiency (INRAE, 2022). Furthermore, technological innovations such as soil moisture sensors, automated irrigation systems, remote sensing tools,

and decision-support platforms contribute substantially to optimizing water use and improving agricultural performance.

Although France currently demonstrates a higher level of technological integration, Romania is making significant progress through infrastructure modernization and the adoption of precision agriculture practices. Continued investment in smart irrigation technologies will be essential for enhancing agricultural resilience, improving water-use efficiency, and supporting long-term sustainable development in both countries.

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