

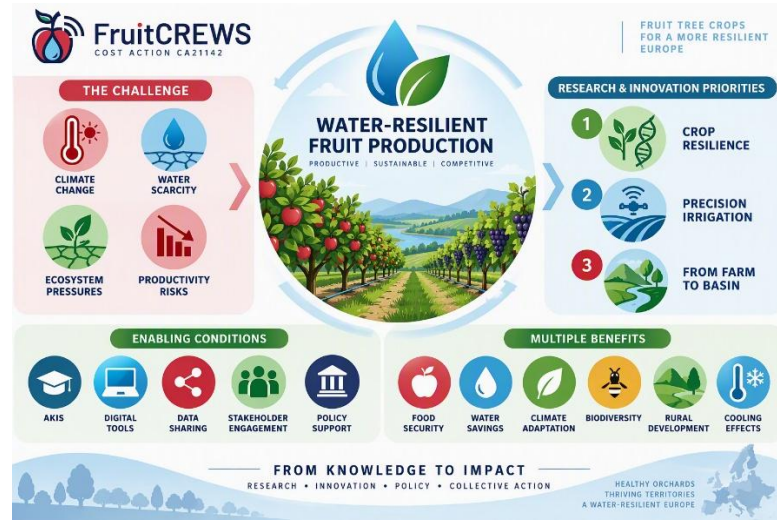
FruitCREWS Position Paper on Research, Innovation and Policy Priorities for Improving Water Productivity and Resilience in Fruit Tree Crops

Prepared by the Working Group Leaders and the Management Committee of COST Action CA21142 (FruitCREWS)

<https://doi.org/10.20350/digitalCSIC/29284>

Summary

Water resilience must become a strategic priority for European fruit production. Increasing water scarcity, more frequent droughts and heatwaves, growing competition among water users, and the impacts of climate change are placing unprecedented pressure on irrigated perennial cropping systems.



This Position Paper reflects the collective vision of the FruitCREWS COST Action participants and outlines key priorities to strengthen the resilience of fruit production systems to future water challenges. It calls for a transition from a narrow focus on irrigation efficiency towards a broader water-resilience framework that integrates productivity, environmental sustainability, ecosystem services, socio-economic viability, and adaptation to climate change. To achieve this transition, three strategic research and innovation priorities have been identified:

1. Enhancing crop resilience to water-related stresses (Section 2.1).
2. Accelerating the deployment of precision water management (Section 2.2).
3. Scaling impacts from farm to basin level (Section 2.3).

The FruitCREWS community also identified several cross-cutting policy priorities.

- Agricultural Knowledge and Innovation Systems should be strengthened.
- Data governance frameworks should promote secure, transparent, and trusted data-sharing mechanisms.
- Policies should recognize the potential additional ecosystem services provided by well-managed irrigated fruit tree crops.

Looking ahead, European and national funding programmes and policy instruments, including the Common Agricultural Policy, should support both the generation of new knowledge and the large-scale deployment of proven innovations.

1. Introduction

Improving water use efficiency and productivity¹ has become a strategic priority within the framework of the [European Water Resilience Strategy](#) as water security increasingly threatens the sustainability and even the long-term persistence of agricultural production and indeed food security. Climate change is increasing water scarcity and raising the frequency and intensity of extreme weather events, causing irregular rainfall patterns, droughts and floods. In addition, water pollution further limits the surface water and groundwater available for use. This affects farming cycles, yields, and the livelihoods of farmers and rural communities. Strengthening water resilience, combined with innovative water management practices can support climate adaptation and contribute to long-term food security in Europe.

This overall scenario is even more relevant for perennial tree crops since orchards and vineyards represent long-term endeavors, characterized by a high initial investment by the grower followed by an early unproductive phase lasting a few years, before entering full production. Their long lifespan (several decades) makes these crops highly vulnerable to climate change as the multiple stressors generated by abiotic constraints can impact the quantity and quality of the production and revenue both at short (seasonal) and long (entire orchard life) time scales. In fact, because of their perennial character, tree responses to stress conditions have a multi-season component influencing both the given response when the stress is applied, and possible carry-over effects in the long-term. Fruit growers cannot shift their yearly production cycle and crop choice based on changing conditions and foreseen seasonal stressors, as often done for annual crops. In addition, fruit trees, grapes and olives are high value “cash” crops whose market acceptance depends on specific quality standards (i.e. size, sweetness, taste, oil content) that are strongly sensitive to tree physiological status as well as how different varieties respond to different soils and climates. These constraints, typical of perennial crops, put them at serious risk and require measures to be taken to help the adaptation of the sector to the challenges ahead.

After analyzing the scientific and technical work carried out within the different working groups of the [FruitCREWS COST Action](#) that deeply analyzed sensors, models and irrigation scheduling research for fruit tree crops ([Züde-Sasse et al. 2026](#)), the Management Committee for the action identified some gaps and research needs regarding water use efficiency that should be of high priority for the near future. The initial draft of this Position Paper was subsequently endorsed by the entire FruitCREWS community, whose members were invited to provide feedback through a survey. A total of 24 contributions were received and integrated.

¹ For precise definitions of these terms, please refer to the study by Fernández 2023. <https://doi.org/10.1016/j.agwat.2023.108548>

The identified needs range from basic research to better understand tree physiology and agronomic performance, mainly under heat and water stress, to innovation that improves on-farm water efficiency by accounting for orchard variability in space and time. Finally, the upscaling and integration of specific on-farm solutions to the basin and regional levels is required to achieve tangible impacts on water conservation.

2. Specific research and innovation gaps

Three key research and innovation priorities have been identified that should be further considered in international research and innovation programs.

2.1 Enhancing crop resilience to water-related stresses

Research is needed to understand physiological, morphological and genetic traits driving adaptation processes of woody crops to climate extremes including drought, salt stress and heat waves. In addition, research efforts should focus on exploiting the untapped genetic diversity found in local cultivars and crop wild relatives, which represent rich sources of drought-resistance genes and adaptive alleles that can be introgressed into breeding programs to enhance crop resilience and sustainability. The knowledge generated through this research should subsequently be translated into practical management strategies and validated across species, production systems, and climatic conditions through robust performance indicators. In this sense, the combination of appropriate choice of irrigation strategies with proper orchard management and irrigation technology should improve irrigation scheduling protocols and decision support systems specifically developed under conditions of water quantity and quality (i.e., salinity and sodicity) constraints.

2.2 Accelerating the deployment of precision water management

Many technologies and agronomic practices have been developed for precision, smart, on-farm irrigation and fertilization management (sensors, models and decision support systems). It is therefore possible nowadays to perform precise irrigation scheduling based on the average demand at the farm level. However, within a field, there is important variability in water and nutrient needs due to soil heterogeneity, differences in climatic conditions and also in the plant material used. Integrating satellite and ground-based Earth observations with atmospheric, precipitation, soil-moisture and plant water status information could support earlier detection of areas within an orchard more prone to develop water stress and drought. The next step for precision fertigation is to take into account the plot variability (both in time and in space) to adjust the irrigation and nutrient

needs to the possible existing differences within a field. In this manner, hydraulic modelling, remote sensing, and geospatial analytics can be integrated to delineate management zones within orchards and vineyards. While this concept has been developed for mobile sprinkler irrigation systems such as center pivots, the technology governing drip irrigation, the most efficient watering methodology, is currently not conducive to spatial management, requiring solutions to this innovation gap to enable precision irrigation.

2.3 Scaling impacts from farm to basin level

The connection between the on-farm and off-farm aspects of water management and the upscaling from the single farm to the whole basin or region have not yet been assessed together. This is required for sustainable long-term integrated water management to be conducted at a water basin scale while properly quantifying the local source-demand balance under different climate change scenarios. New remote sensing technologies coupled with artificial intelligence tools could provide more accurate and spatially explicit estimates of crop water consumption so that the water balance can be better quantified. Using collected data, water and fertilizer management can be adjusted to the available resources, particularly when reused water is employed, considering potential limitations in external water and nutrient inputs. When upscaling the results from the single farm to the whole basin, it is not only necessary to increase water use efficiency and productivity, but also critical to obtain net savings in consumptive water and nutrient use by plants. This will help to reduce the mid-term pressure on water resources and to be better prepared for severe droughts. The approaches for reducing water consumption while maintaining crop productivity could include advanced irrigation systems such as the subsurface application of water and nutrients in addition to agronomic practices such as regulated deficit fertigation or improved canopy management and orchard design. All of this, coupled with the use of improved genetic material with higher intrinsic water use efficiency, could result in net water savings at large scales and increased water productivity at the plot level. In the long-term, this approach could promote more sustainable regional water management.

3. Stakeholder perspective and needs

Following the identification of the above research and innovation gaps, and after a major stakeholder workshop held in Brussels in June 2026 at the European Parliament, additional stakeholder-driven and cross-cutting priorities emerged. These priorities complement the scientific and technological challenges identified by FruitCREWS and highlight the enabling conditions required to accelerate the transition towards more water-resilient fruit production systems.

3.1 Infrastructure and enabling conditions

- Promote investment and accessible financing mechanisms that enable farmers to adopt digital technologies and agrifood infrastructure, with tailored financial options for smallholders, cooperatives, and agrifood entrepreneurs.
- Investments in water infrastructure are essential before advanced water management solutions can be effectively implemented, including collective water governance and the sustainable use of non-conventional water resources.
- Digitalization efforts are often constrained by poor connectivity in rural areas.
- Energy grid limitations represent a major bottleneck for the deployment of digital and irrigation technologies.
- Agricultural Knowledge and Innovation Systems (AKIS) need to be strengthened to improve knowledge transfer and innovation uptake, particularly among small-scale farmers.
- Increased resources should be allocated to research and innovation to support the transition towards more resilient water management systems.

3.2 Water efficiency and performance indicators

- There is a need to move beyond measuring water use alone and focus on water-use efficiency and water productivity.
- However, indicators and metrics for water efficiency are not yet sufficiently defined or standardized.
- Economic efficiency should be integrated into water-efficiency assessments.
- Long-term indicators are needed to measure improvements and progress over time.
- Research organizations can support the development of common standards, labels, and frameworks for assessing water resilience and efficiency.
- Greater involvement of consumers and stakeholders throughout the value chain is needed to promote and support water-efficiency initiatives.

3.3 Adoption of digital tools and decision support systems

- Greater support is required for the implementation of Decision Support Systems (DSSs).
- Technologies should be designed around farmers' and advisors' real needs, experience, and technical capabilities.
- Farmers are often reluctant to share farm data, creating barriers to data-driven water management solutions. Technologies such as blockchain could offer opportunities to enable secure, transparent, and traceable data sharing among stakeholders across the agricultural value chain.
- Current digital tools are frequently too complex. "Super-applications" tend not to work well in practice; simple and user-friendly solutions are preferred.
- The key challenge is bringing technology closer to the farmer experience rather than expecting farmers to adapt to highly technical systems.

3.4 The role of farmers

- Farmers must be at the center of water-resilience strategies and should be recognized as stewards of natural resources.
- Foster public awareness initiatives demonstrating that allocating water resources to agriculture does not solely serve to support agribusinesses, but underpins a network of farmers responsible for food security. In addition, water is essential for preserving irrigated orchards, which not only produce fruit that is vital for human health but, when properly and efficiently managed, also provide key ecosystem services.
- Successful innovation requires active farmer participation in the design and implementation of solutions.
- Younger farmers should be specifically engaged, as most investment decisions occur between the ages of 45 and 55. Beyond that stage, willingness to invest in new technologies often declines.

3.5 The role of technology providers and extension services

- To achieve greater on-the-ground impact, it is essential to actively involve private companies that supply innovative equipment, digital tools, and data-driven services. Their engagement can facilitate technology adoption, provide technical support, and ensure that solutions are tailored to farmers' needs.
- Independent advisory services are also essential to facilitate knowledge exchange among farmers. This role could be strengthened by public extension services, whose importance and support have declined in many European countries.

3.6 Aligning farm and system-level needs

- There is often a mismatch between on-farm needs and off-farm constraints, such as regulations, water allocation policies, or watershed-level management objectives.
- Advances in technology now allow monitoring of water requirements at extremely detailed scales, even at the level of a single leaf.
- However, an important question remains: is this level of information useful and actionable for farmers?
- Even if detailed information is available, it must be considered alongside water availability and practical decision-making needs.

3.7 Water resilience and sustainability

- Water resilience should be the guiding framework moving forward.
- However, agricultural production cannot be fully decoupled from water use. Crops inherently require water to grow.
- Water also plays a critical role in mitigating drought stress and heat stress.
- Irrigated agriculture is fully integrated into the water cycle, and irrigated orchards in particular deliver key ecosystem services, such as acting as green firebreaks against wildfires, which ultimately helps to mitigate desertification.

- Just as there are planetary limits to water use, there are also limits to resilience. Adaptation strategies must acknowledge these biophysical constraints. Current approaches to water resilience often fail to adequately incorporate economic and social dimensions.

3.8 Drought, climate impacts, and ecosystem services

- Physiological impacts of drought on crops may occur before hydrological drought becomes evident.
- There is a hysteresis effect in drought responses, meaning that crop recovery and ecosystem responses do not always immediately follow improvements in water availability.
- Irrigated agricultural areas can deliver important environmental services, including the provision of green spaces and localized cooling effects for nearby urban environments. Nevertheless, unsustainable irrigation practices may lead to aquifer depletion, salinization, nutrient losses, and ecosystem degradation. As such, assessments of irrigated agriculture should account for both its benefits and potential adverse impacts.
- These wider ecosystem and climate-regulation services should be considered when evaluating the value of irrigation and water management.

4. Conclusions

The transition towards a more water-resilient fruit production sector requires a systemic approach that combines scientific advances, technological innovation, enabling infrastructure, and active stakeholder engagement. While significant progress has been achieved in understanding crop water requirements and in developing precision irrigation technologies, several critical gaps remain that limit the effective adoption and scaling of these solutions.

At the scientific level, a deeper understanding of the physiological, morphological, and genetic mechanisms underlying tree responses to drought, heat, and other climate-related stresses is needed. This knowledge should be translated into practical management strategies and decision-support tools capable of improving water productivity while maintaining yield and fruit quality under increasingly variable climatic conditions.

The future of precision irrigation lies not only in improving field-scale efficiency but also in accounting for spatial and temporal variability within orchards through variable-rate irrigation, advanced sensing technologies, and integrated modelling approaches. However, technological sophistication alone is insufficient. Solutions must remain accessible, affordable, and easy to use, ensuring that they respond to farmers' actual needs and decision-making processes.

Stakeholders highlighted that investments in water infrastructure, rural connectivity, energy systems, and Agricultural Knowledge and Innovation Systems (AKIS) are indispensable prerequisites for successful digital and water transitions. In parallel, greater efforts are required to develop common standards and indicators that adequately capture water-use efficiency, resilience, economic performance, and long-term sustainability outcomes.

A recurring message throughout the discussions was that farmers must remain at the center of the transition. Water resilience strategies should build on farmers' knowledge and their stewardship role, while actively involving younger generations who are more likely to invest in innovation and technological change. Trust-building mechanisms will also be required to address concerns related to data ownership and data sharing.

Looking beyond the farm scale, improving water-use efficiency must ultimately translate into measurable reductions in water consumption and enhanced resilience at basin and regional level. Achieving this objective requires stronger integration between farm-level management decisions and watershed-scale planning, supported by remote sensing, artificial intelligence, and scenario-based assessments of future water availability under climate change.

Finally, water resilience should be recognized as a multidimensional concept encompassing environmental, economic, and social aspects. Future policies and research programs should move beyond a narrow focus on water savings and acknowledge the broader ecosystem services provided by irrigated agriculture, including climate adaptation, drought mitigation, landscape sustainability, and local cooling effects. Strengthening these connections will be essential to ensure the long-term sustainability, competitiveness, and resilience of European fruit production systems.

In addition to research funded under the next European research and innovation work programmes, dedicated funding within the Common Agricultural Policy (CAP) should be allocated to support the deployment of innovation on the ground, for example by continuing and strengthening EIP-AGRI Operational Groups. Initiatives of this kind are essential for bringing together researchers, innovators, advisors, farmers, and other end-users to jointly refine technical solutions and, most importantly, demonstrate their effectiveness under real farming conditions.

How to cite: FruitCREWS (2026). FruitCREWS Position Paper on Research, Innovation and Policy Priorities for Improving Water Productivity and Resilience in Fruit Tree Crops. COST Action CA21142, October 2026. DOI: <https://doi.org/10.20350/digitalCSIC/29284>

This publication is based upon work from COST Action CA21142 FruitCREWS (Fruit tree Crop Responses to Water deficit and decision support Systems applications), supported by COST (European Cooperation in Science and Technology). www.cost.eu