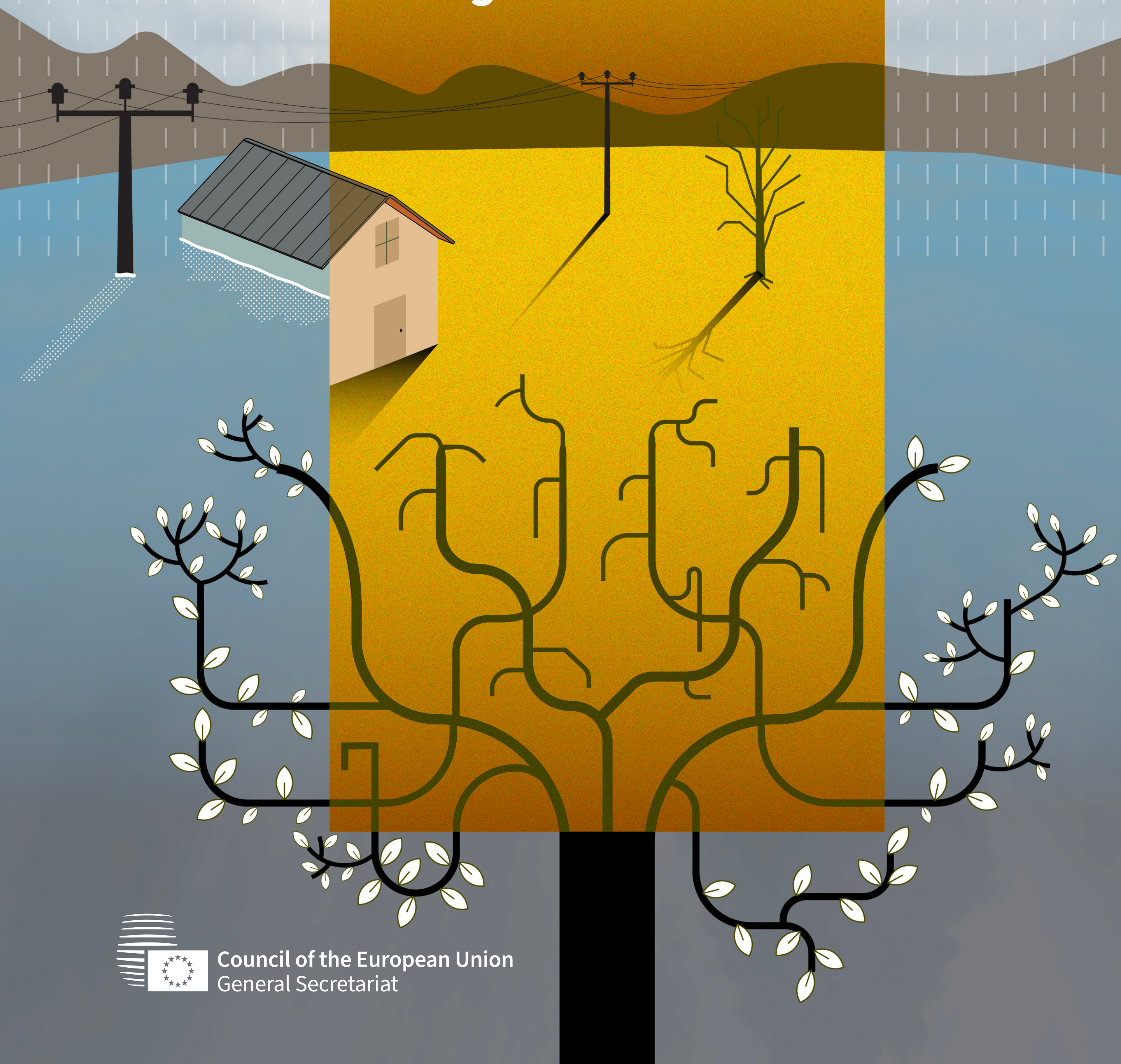
ART — Analysis and Research Team

RESEARCH PAPER

Bridging Water Extremes

Can Floods Alleviate Droughts?



Council of the European Union
General Secretariat

DECEMBER 2025

‘The extremes of too much or too little water are connected by a simple truth: we cannot solve our water challenges without protecting the ecosystems that regulate them’[1]

Introduction

The EU is facing a growing ‘**water paradox**’: at times the sudden arrival of too much water causes floods that put lives, infrastructure, homes and farmland at risk, while at other times too little water during prolonged dry periods threatens agriculture, ecosystems and human health. This can occur across regions or within the same region at different times. Climate change – with **Europe the fastest-warming continent**, at roughly twice the global average since 1980[2] – is accelerating the hydrological cycle[3], altering precipitation patterns and river flows and making water supplies not only more unequal across regions and seasons but also more unpredictable[4]. The result is **a widening gap between when and where water is available**, and when and where it is most needed, leading to an increasingly difficult dilemma for policymakers. More frequent and severe extremes are putting enormous strain on civil protection, both in terms of resources and approach. Public concern is also rising[5], manifested in local initiatives[6] and occasionally heated public debates[7] over water storage, reuse and efficiency, adding political momentum to a more integrated flood–drought management approach.

Flood and drought events are not separate crises but rather **two sides of the same climate coin**, yet they are often addressed separately. This paper asks **whether excess water could be transformed into a resource**: captured, stored and, where feasible, mobilised to compensate for scarcity elsewhere. **Water is a strategic asset**: as hydrological volatility affects critical infrastructure and food, energy and transport systems, often linking countries and regions that share river basins and aquifers, coherent flood–drought management becomes a question of preparedness, including resilience and stability, and it can also support competitiveness by reducing outages and limiting economy-wide knock-on losses.

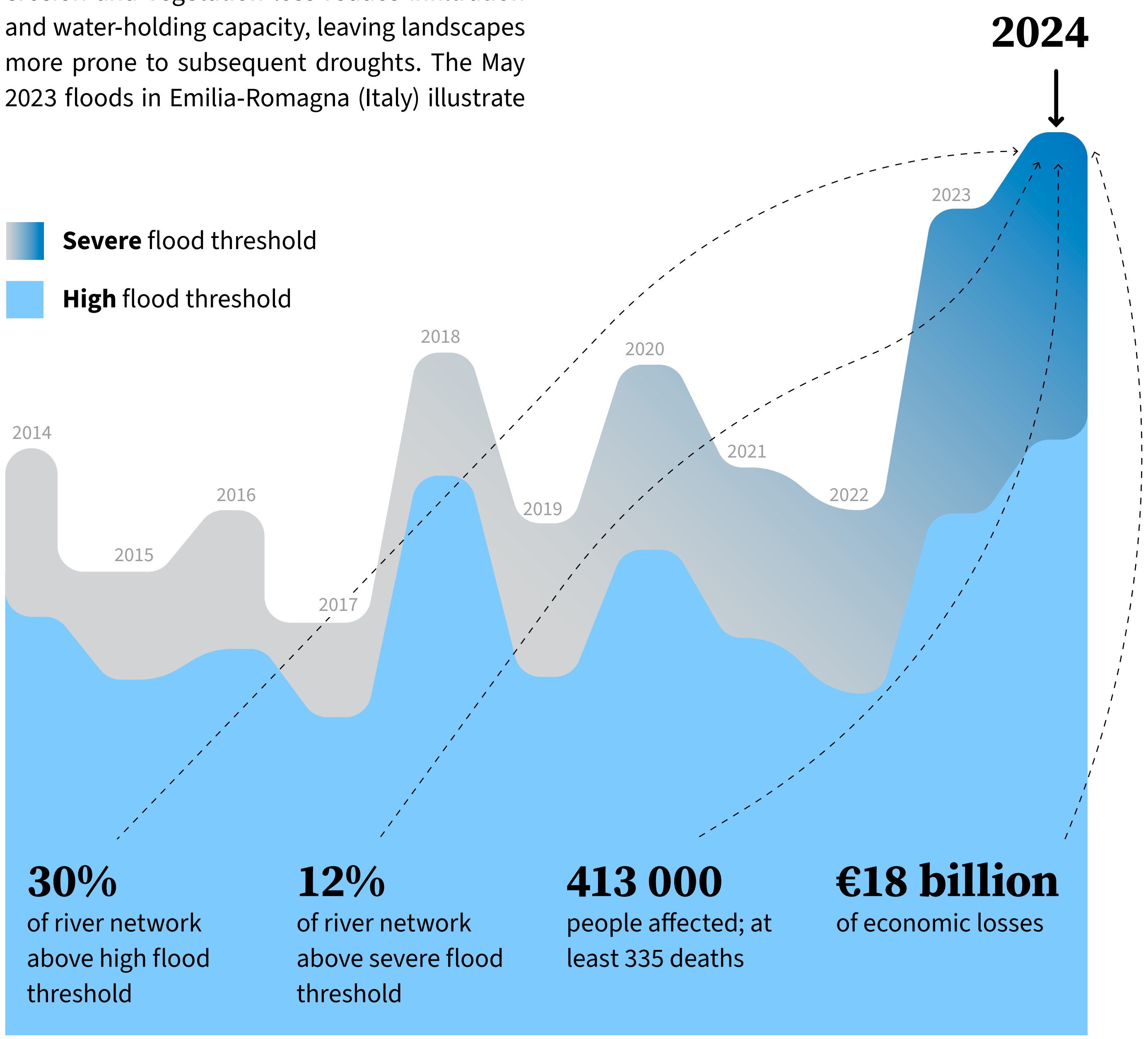
There is **no one-size-fits-all solution for flood-to-drought potential**. Feasibility hinges on local hydrogeology and topography, among other factors, so options must be tailored on a case-by-case basis. After reviewing recent flood and drought events in the EU, the resulting economic and social costs and emerging trends, this paper considers potential solutions and practices, using examples from across the EU. It also identifies conditions and constraints, showing where turning extremes into reserves can strengthen the EU’s water resilience and where it cannot, so that that adaptation choices are effective, economically viable and ecologically responsible.

Floods and droughts in the EU: Trends, risks and impacts

Climate change increases the frequency and intensity of both water extremes: persistent drought on the one hand and heavier, more intense downpours on the other. Rising temperatures accelerate evaporation and reduce soil moisture, intensifying drought conditions, but they also allow the atmosphere to retain more water vapour[8], loading storms and raising the risk of heavier rainfall and flooding. **These two extremes can reinforce each other**: after prolonged drought, dry soils absorb less moisture, and thus a heavy storm produces more runoff and higher flood peaks; in turn, flood-driven erosion and vegetation loss reduce infiltration and water-holding capacity, leaving landscapes more prone to subsequent droughts. The May 2023 floods in Emilia-Romagna (Italy) illustrate this reinforcing effect: after months of drought, exceptional rainfall led to widespread river overtopping and hundreds of landslides, with severe human and economic losses[9].

Recent patterns across the EU

In recent years the resulting 'water paradox' has been particularly striking throughout the EU. 2024 was the warmest year on record, both for Europe and the world as a whole[10], and the first calendar year in which the global average temperature exceeded 1.5°C above pre-industrial levels[11]. Continuing a two-decade trend, surface soils were drier than the overall



average, but with a distinct east–west contrast: there were wetter-than-average conditions in the west and widespread drier-than-average conditions and drought in the east[12]. **2024 saw the most widespread flooding in a decade**, with roughly 30% of the river network exceeding the 'high' flood threshold and 12% surpassing the 'severe' flood threshold. Storms and floods affected an estimated 413,000 people and caused at least 335 deaths that year, with economic losses of roughly €18 billion[13].

Droughts were equally stark. In 2024 average summer **river flows were 'notably' or 'exceptionally' low** in 35% of Europe's rivers, especially in the southeast, which experienced extreme dryness[14]. In 2022 Europe saw its worst drought in 500 years[15], with more than a quarter of its territory affected, and '**unprecedented stress on water levels in the entire EU**'[16]. Reservoirs were severely depleted, agricultural yields fell, and low river flows disrupted inland shipping and hydropower generation, with the latter decreasing by 20%[17].

The **future outlook is troubling**. While floods and droughts are natural phenomena, their occurrence and magnitude have increased over time and are **likely to increase further** due to climate change. As temperatures climb, heat and drought intensify; overall rainfall can decline, while precipitation extremes increase, raising the risk of severe flooding[18]. According to the Intergovernmental Panel on Climate Change (IPCC), even an extra +0.5°C of warming is expected to produce statistically significant increases in extremes[19]. The heaviest downpours (those lasting just minutes or hours) tend to intensify by roughly 6.5% for every °C of warming, although this varies by region[20]. Floods are the most common natural disasters in **Europe**, and the continent **is among the regions with the greatest projected increase in flood risk**[21]. That risk is compounded by ageing flood protection infrastructure and by urban planning in flood-prone areas that has often prioritised development over disaster preparedness, leaving communities exposed[22]. Unless there is a change of course, the damage from river flooding in Europe could rise seven to tenfold by 2100, driven primarily by the increase in population and assets located in flood-prone areas, and further amplified by climate change[23].

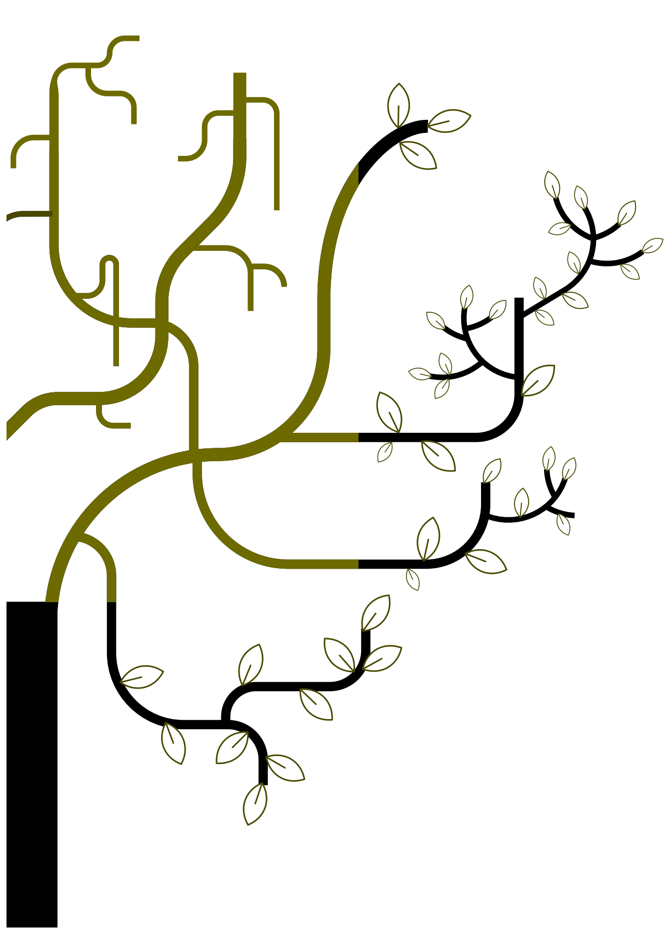
At the same time, **water scarcity and unpredictability are also rising.** Studies point to changes in river flows – including lower flows in parts of major basins such as the Danube and the Tisza – which could make supplies less reliable[24]. Drought risk is also mounting: anthropogenic warming has already increased the frequency and severity of droughts, which in turn raise wildfire risk by drying soils and vegetation. This trend is set to continue, with a **regional disparity**[25]: southern and western Europe are projected to experience more frequent, intense and prolonged droughts, while conditions are expected to ease somewhat in northern and north-eastern regions.[26]

Cascading impacts

Floods and droughts hit human and natural systems in overlapping but distinct ways. They impose both **direct damage** (destroyed crops, reduction of crop yields and quality, inability to plant due to water-logged soils, damaged buildings and infrastructure, costs of emergency response) and **indirect losses** that ripple through the economy (fodder and livestock shortages due to crop loss, supply chain breaks, transport delays, power cuts and health impacts). Floods are sudden and locally concentrated, with obvious immediate damage but also protracted effects (for example, when businesses, disrupted by factors such as forced closures or damaged infrastructure, transmit economic shocks to their suppliers and buyers[27]). Droughts are gradual and spatially diffuse and can persist for months and span multiple regions, thus their indirect effects are often undercounted or omitted from loss databases.

The **human and financial stakes are large** and reflect a long-term trend: between 1980 and 2023, floods caused 4 226 deaths and displaced 320 000 people across the EU, with annual damages averaging €7.8 billion, reaching a peak of €48.2 billion in 2021[28]. Globally, flooding has caused more than $1 trillion in losses since 1980[29]. Meanwhile, droughts over the past decade have cost Europe an average of €9.4 billion per year, with €50 billion lost in 2022 alone[30].

The European Central Bank (ECB) estimates that euro-area banks have ~€1.3 trillion in loans to sectors that are highly exposed to water scarcity (agriculture, manufacturing, mining, construction), and that severe droughts could cut euro-area output by nearly 15%[31]. Impacts on ecosystems and social well-being are more difficult to quantify but no less real.



Critically, the **losses are uneven**: poorer communities often suffer the greatest welfare damage, even when the recorded hit to gross value added is small[32]. Globally, water-related conflicts and political instability are on the rise[33], as intensified floods and droughts can displace large numbers of people, potentially leading to migratory movements.

Challenges to effective water management

Managing water extremes in silos makes it harder to effectively respond to their impacts. In practice, risk assessments often emphasise past direct damage, while future cascading losses, co-occurring events and flood-drought feedbacks are only partially captured, if at all. This can leave **policies and budgets misaligned across the two risks**. On an operational level, there is already an EU toolbox to support the Member States, which combines early warning, coordinated response and solidarity[34] and is anchored in the EU's Solidarity Clause (Article 222 of the Treaty on the Functioning of the European Union – TFEU[35]). These operational instruments, however, function at different rates: rapid activation for floods versus slower, planning-oriented support for droughts, which can complicate integrated budgeting and joint operations. Despite overall progress, recent events suggest that many European countries are not yet fully prepared for extreme events as regards comprehensive risk management. Prevention, preparedness and implementation lag behind rapidly rising risk levels[36].

The challenge is further amplified by the **fragmented management of transboundary water resources**[37]: throughout the world, hundreds of shared river basins and aquifer systems carry a large proportion of the freshwater flow between many countries, while similar challenges exist between regions and within countries. Over 60% of river basins in Europe

are transboundary[38]. Effective cross-border cooperation (including data sharing, joint monitoring, early warning, coordinated operations and agreed benefit sharing), is essential to better quantify and prevent losses[39].

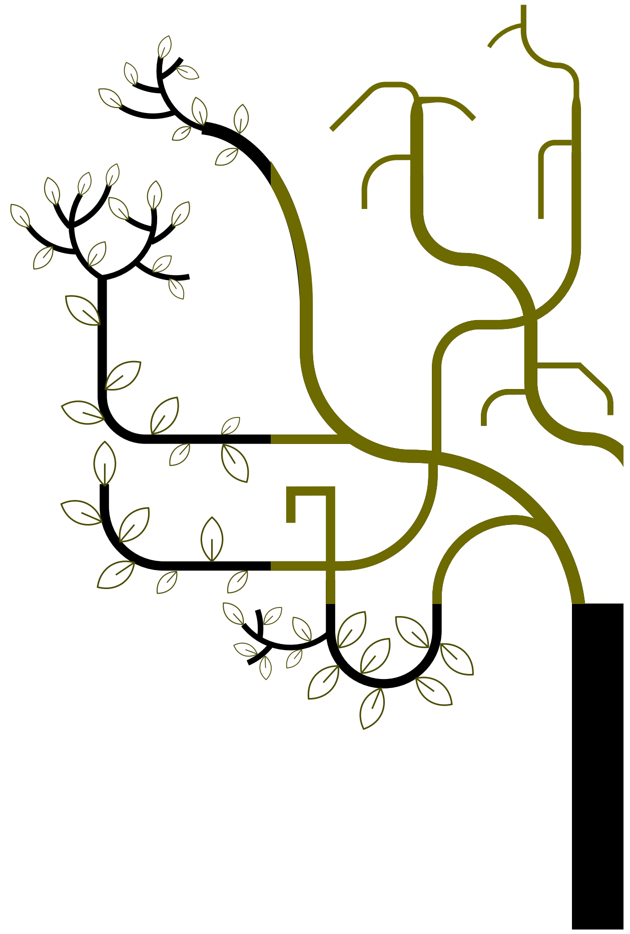
Land, cities and shared responsibility

Room for action spans sectors and actors, from households and farms to municipalities and regions. **Agriculture**, for instance, is both **highly exposed** to floods and droughts and **structurally influential**, possessing an extensive arsenal of tools for long-term mitigation – tools that can both keep more of the flood surplus in the landscape and help lower water demand in dry spells. These range from wetland/floodplain restoration and soil protection and rehabilitation to crop and tillage choices, irrigation efficiency and landscape retention. On-farm ponds, field-edge wetlands and controlled drainage can catch non-polluted, high-flow water and help it soak into the ground. However, uptake is dependent on **viable economics**: broad adoption is more likely when upfront costs, cash-flow risks and maintenance are addressed via workable business models and incentives that reward water-resilient outcomes.

Cities have a parallel role. Many continue to miss opportunities to capture and **reuse stormwater** before it joins rivers or infiltrates, while outdated, **leaky water networks leave them underprepared for extremes**[40]. Updating water infrastructure, reducing hard, fast-runoff surfaces and rolling out blue-green measures (rain gardens, green roofs, parks that flood safely, rainwater harvesting, and non-potable reuse in buildings) could curb flood damage and aid drought resilience by boosting infiltration and stretching supplies.

Private action is also significant: some estimates indicate that improved private, building-level precautionary measures could reduce flood risk in Europe by 15%[41] (e.g. installing flood barriers, adopting rainwater harvesting systems, raising utilities above floodwater levels, using flood-resilient landscaping and incorporating permeable pavements). Moreover, both municipal-level and private residential flood resilience measures offer a range of **co-benefits that can significantly enhance quality of life**. In the case of municipal-level measures, co-benefits include improved urban biodiversity, reduced heat island effects and better water quality. At the private residential level, they can help reduce energy costs, prevent property damage and improve overall well-being by creating safer and more resilient homes.

Long-term outcomes depend on **how consistently water-resilient practices are supported and sustained across sectors**, with a coordinated approach that involves government at all levels, civil society and industries (also known as the whole of government, whole of society approach), following



the principles of the EU's Preparedness Union Strategy, which aims to achieve comprehensive risk management and resilience building. **Stable incentives and planning**, alongside **infrastructure renewal**, would help maintain rural and urban buffers, reducing losses at source.

Floodwater as opportunity — Turning extremes into reserves?

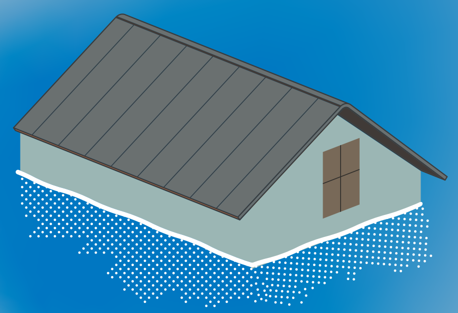
From flood defence to dual-purpose flood-to-drought solutions

To answer whether floodwater can be used for drought relief, it is helpful to reframe the question: **can the tools we use for flood management be made to serve two purposes** – **mitigating flood risk** and protecting people and assets when waters rise, **while also securing water for periods of scarcity**?

EU policy[42] has moved towards this type of integration, creating the conditions required to connect flood management with drought preparedness. This section explores that linkage: how measures designed to moderate floods could, in suitable settings, also serve as drought buffers. In practice, turning floodwater into a strategic reserve is **not a single solution**, but **a range of context-dependent options**. The approach that is selected **must be tailored to the specific circumstances**, as the feasibility of capturing, storing and releasing water to balance flood protection and drought resilience always depends on local conditions.

Not all floods are equal

Crucially, **not every flood can be used as a resource**, and whether it can, depends first on the type and dynamics of the event. Three common types of flood are **fluvial** (rivers overtopping their banks), **pluvial** (intense rainfall and surface runoff), and **coastal** (storm surge). **Flash floods**, which can be fluvial, pluvial, or both, are characterised by very rapid onset. In these fast, high-energy events and in extreme fluvial peaks, **public safety and emergency response take absolute priority**. In such situations the floodwater is often heavily contaminated with sediments, sewage and debris. Studies also document sudden bursts (or pulses) of toxic chemicals that are harmful at any concentration, as well as high concentrations of antibiotics during flash floods [43], and this also threatens the safety of drinking water. As the July 2021 flash floods in Germany and Belgium and the October 2024 Valencia floods showed[44], such events are highly destructive and hazardous, and in such cases it is neither realistic nor desirable to repurpose floodwater. Coastal floods are also generally unsuitable



due to their rapid onset, salinity and contamination with debris and sediments.

In contrast, **certain fluvial and pluvial events** offer the **most favourable opportunity**. In the case of fluvial floods, the option of salvaging and storing water for later use arises during **predictable seasonal high flows**, moderated peaks on controlled reaches (river segments with gates or dams, where flows can be

managed), and the receding phase of a flood, when water levels begin to fall (the so-called 'falling limb of a flood hydrograph'). During this period, water quality can be monitored, and routing decisions can be made deliberately. Pluvial floods, especially in urban areas, can also offer potential: in cities, **capturing and storing stormwater runoff from heavy rainfall** could, if properly managed, also provide benefits during dry periods. This requires suitable infrastructure and careful water quality management to ensure that it can be safely redistributed. In short: not all floods can be repurposed, but some types of fluvial floods and pluvial events, in the right locations and conditions, can offer valuable resources. The choice depends on the frequency and intensity of each flood type, existing infrastructure and water quality considerations. While fluvial floods may offer larger volumes of water for capture, the water quality and logistical challenges associated with their management, such as contamination from sediments and pollutants, can complicate reuse efforts. In contrast, pluvial floods, though typically involving smaller volumes, often occur in areas with existing infrastructure for water capture and storage, making them more immediately actionable for reuse purposes.

Impact of floodwater repurposing in the EU

The potential for repurposing floodwater in the EU depends on three interacting factors:

1. a shifting hazard profile as climate change alters the variation and timing of fluvial and pluvial events;

2. the condition and operation of existing systems;

3. the choices made regarding renewal and investment to enable dual flood-to-drought use.

Southern regions, for example, can experience both intense pluvial and fluvial events and also prolonged seasonal droughts; while ageing and leaky urban water networks add further pressure, underscoring the need for renewal and smarter operations. In these areas, investment in pluvial floodwater capture could provide a source of water for irrigation, cooling, and some domestic uses, especially during the hotter and drier months.

At the EU level, the addressing of floodwater reuse hinges on coordinated **policies that align flood management with water scarcity concerns**, rather than treating them in silos. **Greater coherence with relevant sectoral planning and funding frameworks** – particularly where land, agriculture, urban development and water operations intersect – could help ensure that retention, infiltration, reuse and drought preparedness are, where appropriate, considered together. Progress also depends on interoperable monitoring and forecasting, shared operating rules, and decision support tools (e.g., digital twins and real-time control). Cross-border and inter-regional collaboration is vital for routing and storing usable surplus where it adds most value. The EU's role in fostering research and innovation and in supporting the dissemination of results, alongside funding for both nature-based solutions and smart technologies, would be key to scaling up floodwater repurposing efforts across Member States.

Why this matters now

The EU is entering a **new cycle of priority-setting** and funding as climate and ecosystem-restoration commitments[45] move from target to delivery. Dual-use flood-to-drought measures can meet political tests across different portfolios: potentially, they can help curb the financial burden caused by disasters and narrow insurability gaps, favour energy-sensible storage, and provide visible urban health benefits during heat. They could also **underpin competitiveness** by reducing outages and helping stabilise production in industry, agriculture, inland shipping and energy systems, while turning EU strengths in blue–green infrastructure, managed aquifer recharge and smart water management technologies into exportable capabilities. More broadly, this approach connects climate adaptation and competitiveness, aligning with the European Council's emphasis on advancing competitiveness, resilience and the green transition together[46], including through nature-based and resource-efficient solutions.

At the same time, since many rivers and aquifers are shared, coherent and coordinated action can also **serve security objectives** by protecting critical infrastructure and bolstering water security in times of need through solidarity mechanisms and stronger cross-border basin cooperation. The recent debate on rewetting wetlands and peatlands in specific locations for defence purposes illustrates the emerging intersection between climate adaptation and security, with studies stressing that such ideas should remain aligned with ecological standards[47].

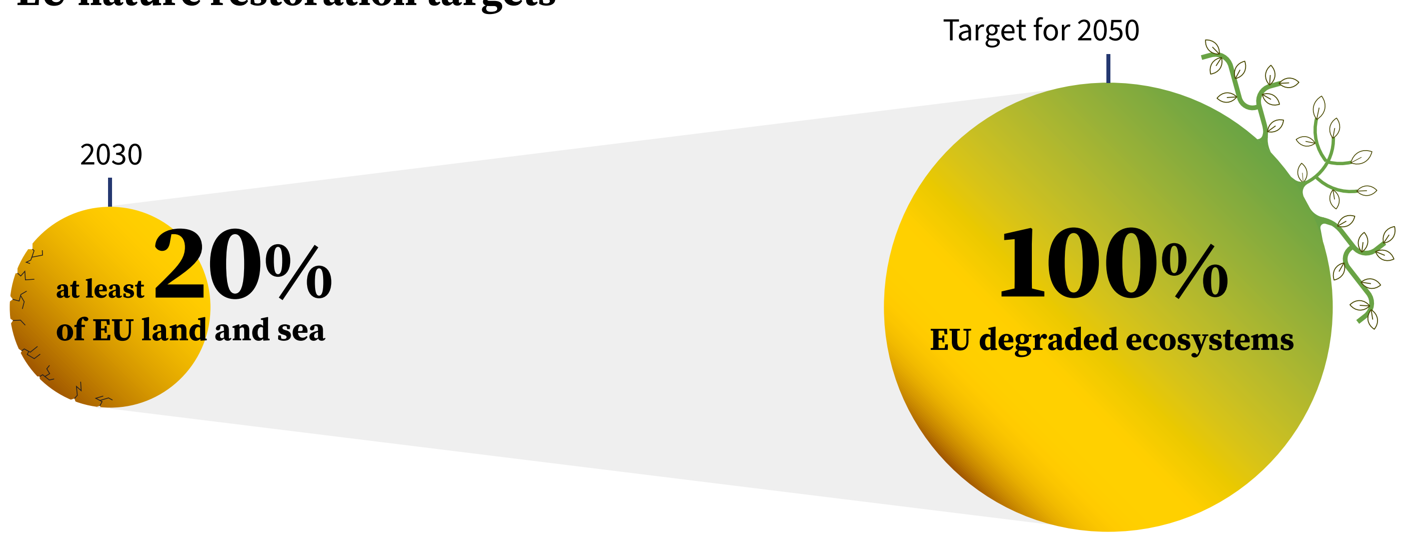
In short, flood-to-drought measures offer a **cross-cutting approach** that aligns environment, agriculture, cohesion, industry, crisis management and civil protection under one investment logic. This framing is consistent with the Council's recently adopted conclusions on the European Water Resilience Strategy, which call for restoring the water cycle, integrating flood and drought management, strengthening security and early-warning systems and scaling both nature-based and technical solutions.

Europe's lost buffers

Historically, Europe relied on **natural ecosystems such as wetlands, floodplains, and aquifers to regulate water flow and mitigate extremes**. These natural buffers absorbed water during floods, slowly released it during dry periods, and provided crucial ecosystem services. Since the mid-20th century, however, much of this natural infrastructure has been lost, mostly due to urbanisation and intensive agriculture and, in some cases, the conversion of wetlands to forests. Draining wetlands, river straightening and the conversion of floodplains into farmland have increased land use and productivity, but often at the cost of vital water storage and natural flood control. **Today only a fraction of Europe's historic floodplains remains**, and their hydrological connectivity largely determines the flood protection and water quality they can still deliver[48].

Recent EU policy places greater emphasis on **restoring and reconnecting natural water retention systems.** The Nature Restoration Regulation (2024)[49] sets binding targets across wetlands, rivers, lakes and peatlands, with the overarching goal of restoration measures on at least 20% of EU land and sea by 2030, and all ecosystems in need by 2050, backed by National Restoration Plans. The Council Conclusions on resilience against flooding (2024)[50] call for retention and infiltration, groundwater recharge, and nature-based, multi-purpose infrastructure. Meanwhile, the European Water Resilience Strategy and the corresponding Council conclusions (2025)[51] establish the restoration of the water cycle – via wetlands, rivers and groundwater – as the basis of resilience against both flooding and drought and call for both nature-based and technical measures to be scaled up in order to deliver this. Additionally, the Common Agricultural Policy (CAP), with its 2021 reforms, supports increased funding opportunities for practices such as rewetting and paludiculture, supporting the restoration of wetlands and peatlands[52]. This aligns with the broader EU Green Deal (2019)[53] and the EU Biodiversity Strategy for 2030[54], and sits within international commitments: EU Member States are Parties to the Ramsar Convention on Wetlands (1971)[55], and the UN Decade on Ecosystem Restoration (2021–2030)[56] underscores the urgency of this issue[57]. The remaining challenge – and opportunity – is **to explicitly link restoration to drought resilience**, so that rebuilt floodplains, wetlands, soils and aquifers not only moderate floods but also buffer dry spells when conditions allow. Restoring lost natural storage could therefore be a major lever for strengthening dual flood–drought resilience.

EU nature restoration targets



The flood-drought toolbox: infrastructure and operational pathways

This section sets out the main infrastructure and practical routes for capturing, storing and, where feasible, mobilising excess water. It reviews four pathways: grey assets that slow, store and steer high flows; nature-based (green/blue-green) measures that make space for water and promote infiltration; hybrid subsurface storage via managed aquifer recharge (MAR); and smart, forecast-led operations that optimise timing and use. For each, it outlines enabling conditions and notes examples of both success and limited uptake. The appendix offers additional EU cases, summarised under their respective goals, their roles in floods and droughts, the key enablers and common limits.

→ **Grey infrastructure**

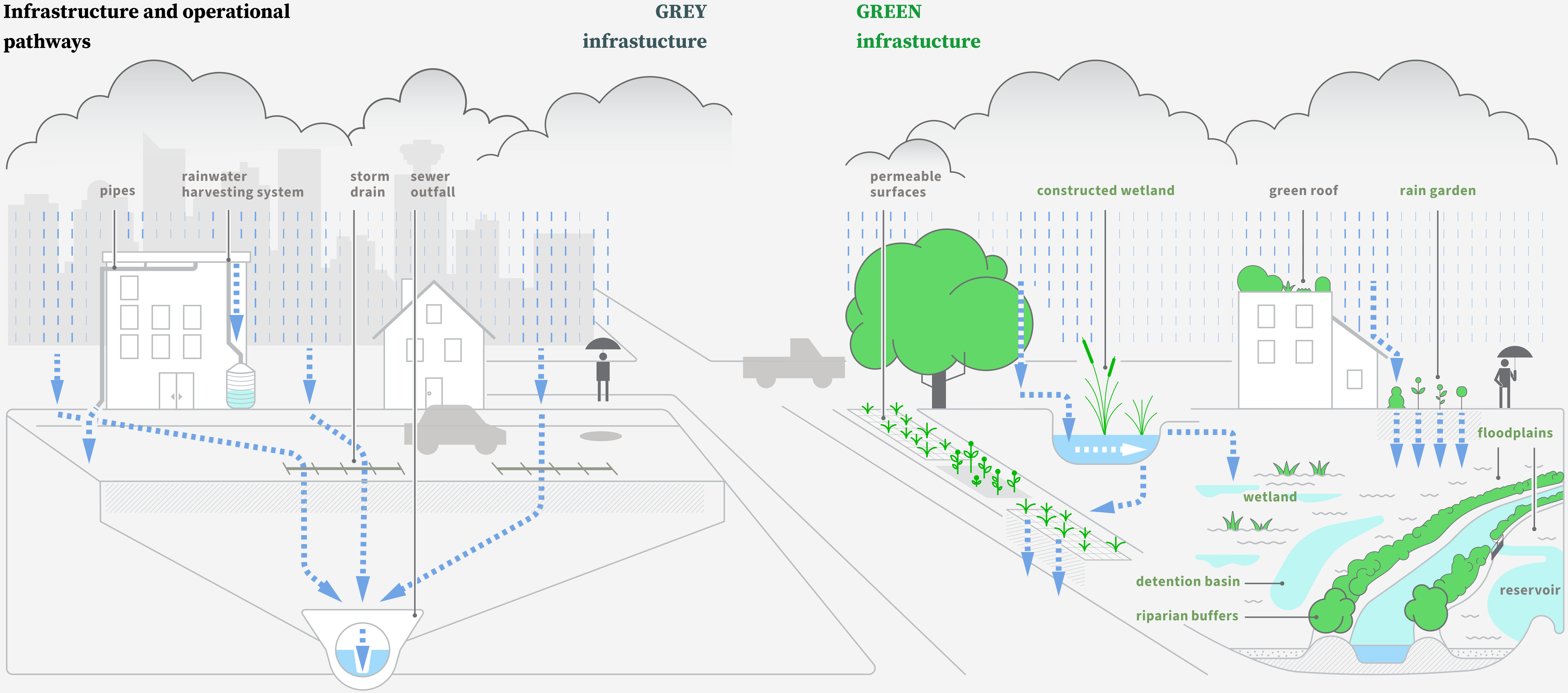
Grey infrastructure refers to the 'classic', **engineered flood control systems**[58], including pipes, ditches, pumps, diversion channels, dams, retention basins and reservoirs, which slow, store and steer high flows to cut flood peaks and protect people and assets. Reservoirs are also

a critical component of the drought resilience infrastructure due to their ability to enhance low flows[59]. Using forecasts, operators can create space before a surge and release water gradually afterwards[60] to support navigation, ecosystems, irrigation or, where the terrain permits, short, low-energy transfers within a basin. Grey assets **provide timing and volume control** that can sometimes help bridge wet hours into dry weeks. Their effectiveness depends on siting, rules and maintenance; poorly designed or maintained systems can shift risk downstream or underperform under very extreme events. Moreover, because large grey infrastructure projects in the EU generally require environmental assessment[61] and public participation, delivery is also dependent on permitting and public acceptance, which can affect timing and cost.

→ **Conveyance and reallocation (inter-/intra-basin transfers)**

One subcategory within grey infrastructure plays a specific role in **moving water** from one place to another: interbasin water transfers move water **from surplus basins** (often flood-prone or heavily regulated) **to deficit areas** via pipelines, canals or tunnels. They can provide **a strategic**

Infrastructure and operational pathways



means to balance needs across regions, especially where fluvial high flows are moderated and linked to storage, or where pluvial volumes are aggregated locally, so that water captured in one place helps alleviate drought elsewhere. Trade-offs include high capital and lifetime energy use, environmental impacts in donor and receiving rivers, and complex allocation and compensation across jurisdictions. Short, gravity-assisted intra-basin links tied to local storage tend in practice to fare better than long, pumped inter-basin schemes.

Grey assets are generally **capital-intensive and relatively inflexible**: they are often designed based on past climate conditions, and thus it can be expensive and complex to update them to cope with new and more extreme weather patterns. As climate extremes shift, these older systems may become less effective[62], which is also why they are **increasingly paired with nature-based solutions**. In urban settings, both **retrofits** and **integration in new developments** (for example, detention/retention features and staged release points in new residential, commercial and utility buildings) can also capture short, intense rainfall surges and—where basic quality checks are in place—hold non-potable volumes for later use.

*In the **Oder basin** (Poland), the **Racibórz Dolny** dry flood reservoir – developed in response to the 1997 floods and completed in 2020 – helped reduce peak flows during the September 2024 flood event in south-western Poland[63]. The scheme was a **major financial and social undertaking** costing roughly PLN 2 billion, which is approximately EUR 480 million, **co-financed by the EU and the World Bank**[64], and required the **resettlement of two villages**. Despite these costs, the reservoir has **proved its worth**, reducing flood impacts for **more than 2.5 million residents** across **the Silesian, Lower Silesian and Opole provinces.***

*In contrast, the May 2023 **Emilia-Romagna** (Italy) floods saw widespread embankment breaches[65] and overtopping across multiple rivers, causing landslides and leaving tens of thousands of people displaced. Post-event analyses point to a **compound set of vulnerabilities**: prolonged drought, which reduced soil infiltration, **ageing and unevenly maintained grey infrastructure**, and **the exposure of assets in floodplains**, which together **cascaded into systemic failure**.*

→ Green infrastructure

Nature-based (green or blue-green) infrastructure uses **restored or enhanced natural systems** – including **floodplains** and **wetlands**, re-meandered rivers, seasonal polders and riparian buffers – to absorb, slow and store water, lowering flood peaks while recharging soils and aquifers for dry periods. These solutions **make space for water, spread and delay flood waves, and promote infiltration rather than rapid runoff**. In cities, sustainable drainage systems[66] (or SuDS, an umbrella term for techniques that capture rain where it falls, slow it and clean it, such as permeable paving, rain gardens, green roofs) provide source control and treatment, cutting both flows and pollution. As they are linked to suitable storage and basic quality checks, SuDS can also transform some urban runoff into a reusable, non-potable water resource for dry periods (e.g., irrigation or cooling) without changing their primary flood function. When applied at city scale, they can serve as the building blocks of a comprehensive, strategic implementation plan for urban water management, alongside wider blue–green planning (e.g., floodable parks and squares), to create '**sponge cities**'. Because they operate using natural processes, well-sited schemes deliver **co-benefits** (habitat, cooling, water quality), remain adaptable as climates shift and are cost-effective[67]. As a result, they are increasingly paired with grey assets in integrated plans.

*In **Barcelona** (Spain), parks-scale **sustainable drainage systems** (SuDS) such as Parc Joan Reventós[68] **capture pluvial surges on-site**, filter and store the water, and **reuse it to irrigate** park vegetation in dry periods, reducing pluvial flooding and alleviating the demand for potable water demand. The approach, which has been deployed across multiple sites since the 2000s, couples storm buffering with non-potable reuse, and is cited in the **city's broader transition toward water-sensitive urban design**[69].*

*Along the Rhône River, a **flagship floodplain restoration initiative** under the Plan Rhône aimed to reconnect side channels and increase temporary storage. After several years of local negotiation and institutional debate, the scheme was ultimately not taken forward. Contributing factors included **overlapping competences**, a limited formal mandate for the lead body, and the **absence of clear compensation arrangements** for affected landowners. Overall, the episode reflects the complexity of multi-actor restoration projects[70].*

→ Hybrid approach: subsurface storage

Managed aquifer recharge (MAR)[71] – a hybrid approach using **a natural store (the aquifer) with engineered structures, pre-treatment, controls and monitoring** – means deliberately topping up groundwater so it can be used later or support rivers and wetlands. Surplus water gathered at safe moments (e.g. high river flows, stormwater after basic treatment, recycled water, even desalinated water) is routed to infiltration basins/galleries or injection wells, turning suitable aquifers into natural, low-evaporation reservoirs. MAR stores water without the extensive evaporation losses of surface reservoirs and alleviates the mismatch between wet periods and dry demand. It is a low cost, low-energy water supply option that **can also improve groundwater quality**[72] under the right conditions. Nature-based MAR (NaBa-MAR[73]), goes a step beyond: it is an innovative and dynamic model that combines often site-specific traditional MAR methods with groundwater flow systems to manage water replenishment at a regional or landscape level. MAR can also store stormwater, provided only pre-treated amounts are routed to the aquifer.

*In the **Algarve** (Portugal), projects on the Campina de Faro / Rio Seco aquifer divert **surplus surface water from strong rain events** (alongside treated wastewater) into **infiltration basins and wells**, raising groundwater levels, improving groundwater quality and building a **drought buffer** for irrigation and supply[74]. Reviews indicate MAR can be scaled at relatively low environmental impact and cost compared to the alternatives, provided pretreatment and monitoring, illustrating a clear **flood-to-drought pathway**: storm surplus captured and banked underground for dry periods.*

*In **Malta** a **pilot Managed Aquifer Recharge** (MAR) scheme is being developed for the Pwales coastal aquifer, using treated wastewater, **to improve the quality of groundwater** that suffers from seawater intrusion. The project serves as a pilot for the development of further MAR schemes in Malta[75]. Lessons learned on monitoring, basic field investigations, simple modelling, staff training and understanding costs are intended to be transferable to other EU settings, helping others judge where MAR could work and how to set it up[76].*

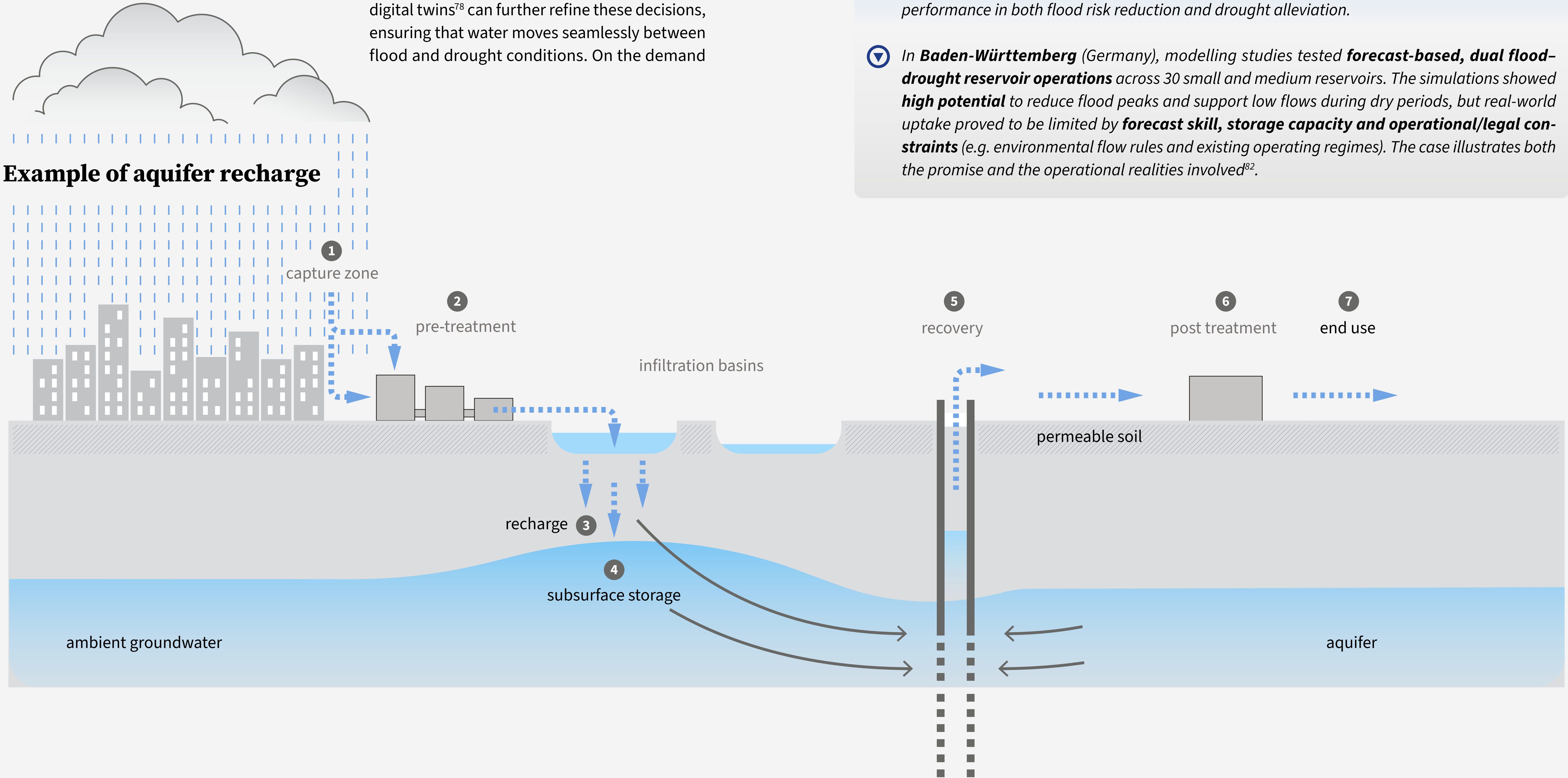
→ Smart Technology & Emerging Operations

New operations and digital tools, including the use of AI[77], make the toolbox smarter, **optimising the timing and efficiency** of the above systems. Weather and river forecasts permit operators to lower water levels before a surge and gradually release water afterwards. Smart gates and pumps can regulate water flow based on real-time data, ensuring that the appropriate amount and quality of water is stored, used or released depending on seasonal needs. Basin-level digital twins[78] can further refine these decisions, ensuring that water moves seamlessly between flood and drought conditions. On the demand side, digital tools improve how stored water is used. In agriculture, **smart irrigation** guided by soil moisture and temperature sensors can help **apply water only when and where it is needed**, while farm software, drones and variable rate equipment **target applications to local conditions**[79]. Similar operational gains exist in cities and utilities, where real-time control and monitoring **optimise storage, reduce losses and prioritise non-potable uses** when appropriate. These digital capabilities are also aligned with the EU's sovereign digital transition by enabling interoperable data sharing, stronger incident response and generally enhancing operational efficiency.

*Under Flanders' (Belgium) **Sigma Plan**[80], the Demer valley combines green–grey measures with real-time **model predictive control**[81] **(MPC**, a feedback method that uses a system model to predict upcoming levels/flows and set gates in advance) to coordinate gates and controlled flood areas. The system **flattens fluvial peaks** to protect towns and habitats and, in line with the plan's objectives, also **retains water for dry periods**. In practice this **forecast-led control** enhances performance in both flood risk reduction and drought alleviation.*

*In **Baden-Württemberg** (Germany), modelling studies tested **forecast-based, dual flood–drought reservoir operations** across 30 small and medium reservoirs. The simulations showed **high potential** to reduce flood peaks and support low flows during dry periods, but real-world uptake proved to be limited by **forecast skill, storage capacity and operational/legal constraints** (e.g. environmental flow rules and existing operating regimes). The case illustrates both the promise and the operational realities involved[82].*

Example of aquifer recharge



In practice (as the examples in the appendix will further show), most measures lean either flood-first or drought-first, but some can serve both when conditions align: usable water quality (typically a slice of the cleaner high-flow window), storage that is ready to receive the excess water (ponds, suitable aquifers), and clear operating rules that safeguard minimum river flows. The **strongest results come from locally tailored combinations** that pair classic infrastructure (bypasses, basins, reservoirs) with nature-based retention (floodplains, wetlands) and, where the geology permits, subsurface storage via managed aquifer recharge. **Well-maintained grey–green hybrids have long service lives and can be permanent assets**. Smart operations (forecast-led drawdown, basin-level decision support) enhance performance, while on the demand side, soil and groundwater stewardship and efficient irrigation stretch stored volumes. Taken together, these form a **configurable toolbox for dual flood-to-drought use**.

Conditions and constraints

Turning floodwater into reserves depends on science, engineering and institutions: it works best where **topography, storage pathways and governance align**. Where key conditions are missing, such as poor water quality, steep terrain, limited land or disproportionate financial, carbon or ecological costs, or where inter-regional tensions arise, the case weakens, and the risks may outweigh the benefits.

While the EU has established the overarching legal framework (the Floods Directive and the Water Framework Directive), planning and implementation lie with Member States, often at regional/local level, so **flood-defence systems vary widely across the bloc**. Thus, there is **no one-size-fits-all solution**: using floodwater for drought relief should be viewed as a toolbox to be applied selectively to each different context, depending on the following major conditions and constraints:

- **Water quality**: only a portion of high fluvial flow is fit for capture; peaks often carry sediment and pollutants. Pluvial sources vary: roof rainwater is typically cleaner; mixed urban runoff requires screening and pre-treatment. Usable surplus depends on monitoring, pre-treatment capacity and shut-off rules that protect aquifers and ecosystems. Quality gates should match intended use (firefighting, irrigation, non-potable urban, potable after advanced treatment).

- **Temporal mismatch**: flood peaks are short; droughts linger. Fluvial opportunities tend to arise in predictable seasonal windows or managed 'falling limbs'; pluvial events provide smaller but more frequent locally available surges. Bridging the gap requires inter-seasonal storage (surface or subsurface) and clear operating rules that control releases while safeguarding environmental flows.

- **Energy and carbon footprint**: gravity-driven systems work best where topography permits. In areas with significant elevation differences, pumping can become costly and energy-intensive, with considerable carbon footprint and implications for future sustainability. Pluvial systems can often move water short distances to nearby ponds, tanks or suitable aquifers using gravity alone.

- **Land use and space constraints**: for fluvial retention, solutions such as seasonal polders or floodplain restoration require space, which can displace existing uses. Pluvial capture competes for urban space but can be integrated into streetscapes, parks and buildings. Feasibility hinges on land-tenure arrangements, compensation/easements and incentives that make space for water without putting disproportionate burdens on farmers or municipalities.

- **Environmental impact**: shifting flood routing can alter environmental flows, affecting downstream ecosystems and potentially worsening water quality issues. Any intervention should be carefully designed with local hydrogeology in mind and be consistent with the Water Framework Directive's 'no deterioration principle', in order to avoid unintended consequences. For fluvial measures, maintaining minimum downstream ecological flows and avoiding habitat loss is key; for pluvial solutions, rainwater capture should be balanced with infiltration so that there is always enough groundwater to sustain small rivers and watercourses during dry periods.

- **Governance and equity**: managing water resources involves a complex web of responsibilities across local, national and cross-border jurisdictions. Fragmented governance can hinder integrated planning and finance, while issues of ownership and equity, such as cost-bearing and benefit-sharing, remain sensitive. Solidarity in water allocation, particularly in transboundary regions, remains a contested area. The effective management of fluvial and pluvial water systems requires clear frameworks for allocation and cooperation, particularly in transboundary regions and especially when resources are scarce or in emergencies. This requires well-defined rules on water allocation, benefit-sharing, compensation and dispute resolution.

Potential questions for further reflection:

- How can existing planning frameworks — including flood risk management plans, river basin management plans, and relevant land use, agricultural and urban planning strategies — be better aligned so that retention, infiltration, reuse and drought preparedness are, where appropriate, considered together?

- What practical steps could strengthen day-to-day cross-border coordination in shared basins — for example through shared monitoring, hydrological forecasting, early warning protocols, and interoperable data and modelling tools?

- How can economic incentives, funding instruments and risk sharing models be structured to support the adoption and maintenance of water-resilient practices across farms, municipalities and industries of different sizes?

- What approaches could help mainstream water-resilience considerations across sectors, for instance in new housing developments, infrastructure renewal cycles and spatial planning, so that future land use decisions already anticipate a more volatile hydrological regime?

- If surplus water is treated as a strategic buffer, what allocation and compensation arrangements might guide cross-regional or cross-border releases in scarcity conditions, particularly when priorities differ?

- How can existing critical infrastructure protection and security frameworks83 be better integrated with water management to reduce systemic risks and ensure the continuity of essential services?

Using floodwater for wildfire response?

Wildfires are also rising in frequency and intensity across southern and central Europe. By 30 September 2025, 2,128 fires were detected, and more than 1 million hectares had burned across the EU[84]. Like floods, wildfires are **sudden, high-impact shocks**. They also **raise flood risk afterwards**: burned slopes lose vegetation and can develop water-repellent soils, so the first heavy rains generate fast runoff, debris flows and flash flooding[85]. A severe fire season can therefore set the stage for a severe flood season.

The main question posed by this paper leads to a practical follow-up: can floodwater and/or stormwater runoff be captured and later used to support wildfire response? As in the case of drought relief, the answer is 'sometimes and to a certain extent': particularly as a **supplementary water source** in areas where access to traditional supply is limited. The temporal mismatch is significant: floods generally peak in cool, wet months, whereas fires peak in hot, dry ones. Bridging that gap requires inter-seasonal storage, including multi-purpose ponds (serving both as reservoirs for firefighting and as mitigation measures for flood control), small mountain or hill reservoirs, or (where geology allows) managed aquifer recharge to bank water underground with minimal evaporation. Additionally, **rainwater harvesting**[86] (capturing precipitation at source before it contacts the ground) can also supply water for firefighting that has been stored in tanks, ponds or reservoirs.

Since firefighting does not require potable water, stormwater, captured floodwater and rainwater are all well-suited for this purpose, as long as the storage system is properly maintained to prevent the contamination or clogging of equipment. This includes ensuring that water quality is monitored, in order to avoid issues with pollutants or debris. When planning such systems, the quality of the water and the logistics of accessing it should align to ensure efficient and effective firefighting operations.

Once stored and settled, that water becomes **tactical supply**: designated dip points for helicopters and refill points for fire engines. At the town–forest edge, stormwater and floodwater storage ponds can double as 'fire ponds' that can feed hydrants or portable tanks during incidents. Proximity is crucial – smaller, distributed sources (farm ponds, municipal basins, urban retention lakes) often serve the wildland–urban interface better than a single distant reservoir, provided that access and draft points are designed in advance. **Stored water also supports prevention**, as it makes it possible to water green areas around important buildings to stop fires from spreading, create wet lines for controlled burns, and keep vegetation along rivers moist during high-risk periods.

Conclusions

The EU's water future will be shaped by its **capacity to manage growing volatility** across the hydrological cycle. **Floods and droughts** are not separate crises, but interlinked pressures that **expose vulnerabilities in infrastructure, ecosystems and economies**. While untreated floodwater is often unsuitable for reuse, in certain contexts measures that mitigate flood risk can also help retain water for periods of scarcity. The **feasibility of** such **dual-use flood-to-drought approaches is highly context-dependent**, resting on hydrogeology, topography, water quality, land availability, economic viability, ecological safeguards and governance arrangements that enable **shared decision-making and stewardship of common resources**.

Where conditions align, combining traditional flood defences with nature-based retention, managed aquifer recharge and smart, forecast-led operations can strengthen both flood protection and drought preparedness. This does not mean that there is no need for robust emergency response or long-term demand management, but it **can expand the toolbox available to regions with both too much and too little water**. A key insight is that **restoring and maintaining the natural systems** that hold and filter water — soils, floodplains, wetlands and aquifers — remains one of the most effective levers for **increasing resilience across extremes**.

Responsibility is shared. Rural landscapes shape retention and infiltration, but cities, industry and utilities are equally influential. Reducing network leakages, integrating blue–green solutions into urban planning, supporting regenerative land and soil management, and enabling efficient agricultural and industrial water use can all help maintain buffers throughout the year. Uptake depends on **viable economics**, including **incentives, compensation arrangements and risk-sharing** models to make water-resilient practices practical for farms, municipalities and firms of different sizes.

Because many European rivers and aquifers are shared, **coordination across borders and regions** matters. Harmonised operating principles and cooperative basin governance can help **avoid the transfer of risk from one area to another**. This relies as much on trust and **public consent** as it does on engineering: water resilience is stronger when communities, sectoral actors and water experts are involved early, and when allocation and benefit-sharing rules are clear and transparent.

Looking ahead, **mainstreaming water resilience across sectors** – agriculture, land use planning, housing, infrastructure, industry and civil protection – will be central to safeguarding stability and competitiveness in a more variable climate, with stronger civil protection capacity developing in parallel. Enhancing dual flood-to-drought potential is one component of that broader shift. As the EU enters a new phase of implementation in climate adaptation, ecosystem restoration and economic renewal, **embedding water resilience in strategic planning, financial cycles and spatial decisions** could help ensure that Europe is better prepared to withstand the extremes ahead, while sustaining the ecosystems and communities that depend on reliable, healthy water.

Appendix

Tool	EU example	Goals	Role during floods	Role during drought/low flows	Key enablers	Limits and risks
Floodplain reconnection and bypasses *Hybrid (green-led)*	**Room for the River** (NL)	Create space for Rhine–Meuse rivers to pass high water safely while improving landscape quality and nature; add resilience for periods of low water.	High. Moves dikes back, lowers floodplains, and adds side channels to spread and speed safe conveyance, reducing peak water levels and load on defences, cutting breach risk.	Moderate. Side channels and restored floodplains support cooler habitats and local groundwater, help maintain navigation depths and ecological connectivity; limited direct "banked" supply.	National, programmatic approach; stable funding; multi-agency coordination; land acquisition tools; co-benefits (parks, cycling paths, nature) that build public support; adaptive design and monitoring.	Land-use trade-offs and occasional resettlement needs; sediment build-up, residual risk beyond design events; competing spatial claims (housing, farming); benefits are mostly indirect for drought supply.
Retention basin / polder / Floodplain restoration *Hybrid (grey-green)*	**Integrated Upper Rhine Programme** (DE-FR transboundary)	A system of 13 flood-retention areas to reduce Rhine flood peaks and preserve and /or restore the Upper Rhine floodplains.	High. Temporarily stores part of the flood, reducing peak water levels downstream and slowing the flood wave; coordinated across the Franco-German reach to protect cities and industry.	Moderate. Mainly a flood-risk tool with co-benefits: stored areas can keep groundwater-fed river flow (baseflow) and support ecological resilience through dry spells, providing new habitats for a wide variety of flora and fauna.	Available floodplain land, advanced operation, minimum flow rules for river ecology.	Cross-border coordination complexity, land-use trade-offs, habitat impacts if misoperated.
Diversion channel / bypass *Hybrid urban (grey-green-smart technologies)*	**New Danube** relief channel and Danube Island, Vienna (AT)	Flood relief channel next to the Danube, helps Vienna avoid large floods while keeping the main river open for navigation and turning the intervening strip (Danube island) into public green space.	High. Gated inlets/weirs - with real-time hydraulic control to activate the bypass channel safely - divert part of the flow into a parallel channel, spreading the flow across two channels, thus lowering peak water levels through the city; Danube Island adds a physical barrier.	Low. Mainly a flood-risk tool with some co-benefits (not designed as a drinking-water source for drought): in normal times the New Danube and Danube island serve mainly recreation; targeted releases help nearby floodplain wetlands; increased biodiversity, hydropower plant on the Danube supplies electricity.	Gravity-friendly topography, long-term planning, integrated engineering-landscape design; controllable structures; water-quality safeguards; big public asset offering valuable amenities.	High capital and upkeep costs, multi-agency coordination complexity, sediment management and habitat/recreation trade-offs, design limits – residual risk in case of beyond design flood event.
Multi-purpose reservoirs *Hybrid (grey-led, with smart technologies)*	**Seine Grands Lacs** (FR)	Four main reservoir-dams to reduce Paris flood peaks, manage water flows year-round, strengthen preparedness; forecast-led drawdown.	High. Hold back part of the flood in upstream reservoir lakes and designated storage areas, so peak water levels through Paris are lower and the flood wave arrives more slowly; coordinated warnings and emergency plans guide operations to create storage ahead of peaks, coordinated gate releases.	Moderate-high. Controlled releases help keep the river navigable, dilute pollution, and support ecosystems during dry spells, by maintaining minimum river flow.	Forecast-led storage and early warning systems, dedicated basin-authority (Sein Grands Lacs), broad multi-stakeholder coordination.	Residual risk beyond the design event (very high potential damages if a centennial-scale flood hits); sediment/ecology trade-offs; institutional fragmentation and complexity of existing tools; sustained funding needs for upkeep and upgrades.

Tool	EU example	Goals	Role during floods	Role during drought/low flows	Key enablers	Limits and risks
Short-haul intra-basin transfer *Hybrid (grey-green with managed aquifer recharge)*	**Marchfeld Canal** (AT)	Secure regional water supply (including for irrigation), stabilise and improve groundwater, restore/reroute near-natural flows, provide local flood protection, biodiversity and recreational opportunities.	Moderate. Takes controlled Danube inflows, a sensitive system of weirs, pumps and renovated banks manage high water locally and lower flood risk.	High. Delivers reliable water to farms and towns; stabilise groundwater and improve groundwater quality (the Marchfeld plain is home to Austria's largest contiguous groundwater reservoir).	Gravity-assisted, large underlying aquifer, sophisticated monitoring and operative system controlled by specialists.	Benefits mainly regional, energy, operation and maintenance needs, dependence on Danube flow/ quality, sediment management, ecological impact if mis-managed.
Dune infiltration *Hybrid (subsurface storage)*	**Amsterdam water supply dunes** (Amsterdam, NL)	Secure drinking water by storing surface water in dune aquifers .	Moderate. Takes safe high-flow water surplus from the Rhine river and after pre-treatment infiltrates it into coastal dune sands, which act as natural filter and further purifies the water.	High. Banks surplus water in low-evaporation underground storage for dry periods, helps hold back salinity, potable-supply.	Suitable geology with permeable protected dunes, strict quality monitoring.	Clogging/quality failures, ecological constraints in dunes, energy for pumping and water treatment.
Floodplain reconnection and river restoration *Green / blue-green*	**Mura-Drava-Danube** 5 country UNESCO Biosphere Reserve	Flagship project to reconnect rivers with their floodplains to reduce flood risk while restoring habitats and river dynamics across AT–SI–HR–HU–RS.	High. Lets water spread into safe areas, slowing the flood wave and trimming local peaks; improves distribution via reopened side channels.	Moderate. Healthier soils and wetlands retain moisture, give a small lift to nearby groundwater, and support cooler, resilient habitats: helpful in dry spells but does not provide on-demand storage. Drought buffering strengthens if paired with complementary measures (e.g., small off-channel ponds, farm ponds, or managed aquifer recharge where geology allows.	Cross-border coordination; targeted reconnection of side channels; long-term monitoring of flows, habitats, and groundwater; community buy-in, land agreement with farmers.	Needs space and can compete with intensive land uses; modest direct effect on regional water supply without added storage, outcomes depend on maintenance and ecological flow management.
Hybrid adaptation *Hybrid (green-grey)*	**Upper Vistula** flood protection measures (PL)	Hybrid adaptation measures including renaturalisation of reservoirs and wetland restoration, modernization of river embankments; restoration of dike functionalities; and reconstruction of water pump stations and water discharge channels to reduce flood risk, increasing retention and strengthening protection of urban areas.	High. Restores wetlands/ reservoirs to temporarily hold high water, enlarges and raises embankments, and upgrades pumps, together lowering local peaks and overflow risk and protecting towns.	Moderate; co-benefits rather than a designed supply source: restored wetlands and more natural river sections can help keep soils wetter and support local groundwater and habitats through dry spells.	Inclusion in River Basin Management Plans; strong local mandate after 2010–11 floods; broad stakeholder participation; major financing (≈€217 m, incl. World Bank).	Land acquisition changes; need to monitor and mitigate habitat impacts during works; coordination across agencies; residual risk beyond the design event.

Tool	EU example	Goals	Role during floods	Role during drought/low flows	Key enablers	Limits and risks
Sponge city network *Hybrid urban (blue-green/grey)*	**Copenhagen Cloudburst Plan**	Reduce the impact of flood events as a result of heavy rains and thus protect the city via parks, basins, "cloudburst boulevards," permeable streets, and detention corridors that double as public space.	High (pluvial). Stores, slows, and routes stormwater on the surface to reduce street/ basement flooding and sewer overflows. High socio-economic co-benefits including insurance damage savings and the increase in real-estate value	Low–Moderate. Increases infiltration and soil moisture locally, provides urban cooling, and can support minor groundwater recharge, but not a major water-supply source.	Citywide masterplan; utility funding model; multi-use design (in normal weather amenities, in cloudbursts flood routes); coordinated maintenance; sustainable in the long-term, potential to be replicated / upscaled; innovative;	Limited effect on river/coastal surges; space and retrofit constraints; construction disruption; ongoing operational and maintenance needs
Large multipurpose reservoir and distribution network *Grey*	**Alqueva Dam** (Guadiana River, Alentejo, PT)	Largest reservoir in Europe with an irrigation network of 110000 ha, to provide regional water security and development (irrigation, urban supply, hydropower)	High/Moderate. Holds back peak flows, shaves downstream highs, allows more controlled releases	High. Major irrigation and urban/ industrial supply buffer. Effectiveness rises when paired with efficient irrigation and demand management to stretch stored volumes.	Very large storage and a built distribution grid across the region, energy flexibility from hydropower, cross-border flow arrangements with Spain on the Guadiana river	Controversial: significant benefits are coupled with considerable trade-offs, such as high environmental cost with significant habitat and heritage loss, displacement of communities, low return on investment. High evaporation in hot, dry summers, high energy demand for pumping and distribution.
Large interbasin transfer *Grey*	**Tagus–Segura Inter-Basin Transfer** (ES)	Move water from the Tagus basin (centre) to the Segura basin (southeast) to support cities and irrigation in a chronically dry region	Low. The canal can take some high-flow water when available, but it is not designed as a flood-relief system	High. Provides a strategic supply buffer for the Segura basin and helps ease groundwater over-abstraction when allocations are available	Long-distance conveyance assets; operating rules and permits; coordination between basins; backup sources (desalination/reuse) to smooth variability; energy for lifting/pumping	High energy/carbon costs, strong climate variability in the basins, shrinking donor-basin surpluses inter-regional conflict over "exporting" water; ecological impacts along the donor river; dependency risk for the receiving basin if allocations are cut.

1. Retno Marsudi, Dr. Musonda Mumba, 'Floods and droughts are two sides of the same crisis', United Nations, Africa Renewal. 20 March 2025.
2. Europe is heating faster partly because recent weather patterns lock in longer, hotter summers. Cleaner air since the 1980s means less pollution to block sunlight, therefore more solar radiation reaches the surface. Europe's closeness to the Arctic – which is warming even faster – adds to this effect. Why are Europe and the Arctic heating up faster than the rest of the world? | Copernicus.
3. 'Climate Change and Water', World Meteorological Organisation, 2020.
4. Devika Rao, 'Earth's climate is in the era of 'global weirding', The Week, 13 March, 2025.
5. A 2024 Eurobarometer survey shows high public concern: 78% of respondents favour more EU action on water-related issues, especially to address pollution and scarcity. Across Member States, people see pollution and over-consumption/wastage as the main national threats linked to water; in countries frequently hit by drought, drought itself tops the list (e.g., Spain, Cyprus, Malta). A majority also believe that key sectors (industry, energy, tourism and agriculture) are not doing enough to use water efficiently.
6. A few examples:
France: Bassines Non Merci is a French coalition (citizens, farmers, NGOs) campaigning against large irrigation mega-basins, citing environmental impacts, equity concerns and doubts about their role in climate adaptation; actions range from protests to civil disobedience.
Portugal, Algarve: eGroundwater platform is a management platform that helps local users share data, access consolidated information on aquifers, and coordinate responses during drought. It also serves as a tool to press authorities for faster action during prolonged water scarcity.
Netherlands, Amsterdam: Amsterdam Rainproof is a platform that connects citizens, public servants, and entrepreneurs to collaborate on solutions, products, and initiatives for better managing extreme rainfall. Through this movement, they advocate for political action and work together to build a more resilient city.
Italy, Sicily: RIVER PRO project in Sicily engages local communities to address water management challenges in the Simeto River Valley. By involving residents in monitoring water quality and advocating for sustainable practices, the initiative aims to improve governance and resilience to climate-related water issues.
Bulgaria: Grassroots response under the slogan 'No Water, No Life', with protests against increasingly severe water shortages. The initiative highlights the intersection of climate change, failing infrastructure, and social inequality, including tensions between ethnic groups. It advocates equitable access to water resources and calls for systemic reforms in water governance.
7. 'Drought inflames France's water wars', Politico, 25 July 2023; 'Water war: Why drought in Spain is getting political', Politico, 24 May 2023.
8. For every degree Celsius that Earth's atmospheric temperature rises, the amount of water vapor in the atmosphere can increase by about 7%. 'Steamy Relationships: How Atmospheric Water Vapor Amplifies Earth's Greenhouse Effect', Nasa, 8 February 2022.
9. Emilia-Romagna (Italy), May 2023: months of drought preceded two episodes of intense rainfall, causing 23 rivers to overflow, hundreds of landslides, 17 fatalities, 36.600 evacuees, closure of over 700 roads, multi-billion-euro damage.
Martina Valente, Clara Del Prete, Giulia Facci, Ardigò Martino, Giuseppe Roberto Grilli, Francesca Bravi, Chiara Reno, Luca Ragazzoni, 'The 2023 floods in the Emilia-Romagna Region, Italy: A retrospective qualitative investigation into response strategies and criticalities', International Journal of Disaster Risk Reduction, vol. 116, January 2025.
10. 'The European State of the Climate 2024 report (ESOTC 2024)', Copernicus Climate Change Service (C3S) and World Meteorological Organisation (WMO), 19 May 2025. pp.2-3.
11. 'WMO confirms 2024 as warmest year on record at about 1.55°C above pre-industrial level', World Meteorological Organisation, 10 January 2025.
12. ESOTC 2024., op. cit. p.36.
13. ESOTC 2024., op. cit. p.6.
14. ESOTC 2024., op. cit. p.11.
15. 'Observer 2022: a year or extremes', Copernicus, 29 December 2022.
16. Research Commissioner Mariya Gabriel, as quoted in 'Europe's drought the worst in 500 years – report', BBC, 23 August 2022.
17. Matt McGrath, 'Climate change: Drought highlights dangers for electricity supplies', BBC, 13 August 2022.
18. Lina Adil, David Eckstein, Vera Künzel, Laura Schäfer, 'Climate Risk Index 2025. Who suffers most from extreme weather events?', Published by Germanwatch, 12. February 2025., p.23.
19. IPCC Sixth Assessment Report, Chapter 11: Weather and Climate Extreme Events in a Changing Climate, Intergovernmental Panel on Climate Change, 2023.
20. Imre M. Jánosi, István Zsuffa, Tibor Bíró, Boglárka o. Lakatos, András Szöllősi-Nagy, Zsolt Hetesi, 'The dynamics of lowland river sections of Danube and Tisza in the Carpathian basin', Frontiers Earth Sci., 12 February 2025. Sec. Hydrosphere, vol. 13, p.2.

21. ESOTC 2024., op. cit., p. 5.
22. 'From Crisis to Opportunity & Innovation: Flood Management in Europe', Co-creative Improved Understanding and Awareness of Multi-Hazard Risks for Disaster Resilient Society – C2IMPRESS –, 29 November 2024.
23. Max Steinhausen, Dominik Paprotny, Francesco Dottori, Nivedita Sairam, Lorenzo Mentaschi, Lorenzo Alfieri, Stefan Lüdtke, Heidi Kreibich, Kai Schröter, 'Drivers of future fluvial flood risk change for residential buildings in Europe', Global Environmental Change, vol. 76, September 2022.
24. Jánosi, op.cit. p.2.
25. Corrado Motta, Gustavo Naumann, Diego Gomez, Giuseppe Formetta, Luc Feyen, 'Assessing the economic impact of droughts in Europe in a changing climate: A multi-sectoral analysis at regional scale', Journal of Hydrology: Regional Studies, vol.59, June 2025. p.1.
26. 'JRC PESETA IV Study: Climate change impacts and adaptation in Europe', European Commission, Joint Research Centre.
27. G. Bijnens, M. Montoya, S. Vanormelingen, 'A bridge over troubled water: flooding shocks and supply chains', National Bank of Belgium, 3 October 2024.
28. 'Floods in Europe', European Environment Agency, Climate Preparedness 2025.
29. 'Floods, storm surges, flash floods: Risks are on the rise', Munich RE, May 2025.
30. Droughts in Europe, European Environment Agency, Climate Preparedness 2025.
31. Martin Arnold, Kenza Bryan, 'Droughts are major threat to Eurozone economy, warns ECB', Financial Times, 22 May 2025.
32. Ajit Niranjan, Europe's summer of extreme weather caused €43bn of short-term losses, analysis finds, The Guardian, 15 September 2025.
33. 'Understanding Risk and Investing in Solutions for Water Security', World Resources Institute.
34. The European Flood Awareness System (EFAS) provides early flood forecasts; rescEU provides strategic reserves of response equipment; the Emergency Response Coordination Centre (ERCC) ensures rapid deployment of emergency support and acts as a coordination hub between all EU Member States; the Copernicus European Drought Observatory (EDO) provides drought intelligence; the European Drought Risk Atlas maps hotspots, risks and impacts, while the European Union Solidarity Fund (EUSF) offers financial aid after major disasters.
35. The Solidarity clause, introduced by Article 222 of the Treaty on the Functioning of the European Union (TFEU), provides the option for the EU and EU countries: to act jointly; to prevent the terrorist threat in the territory of an EU country; to provide assistance to another EU country which is the victim of a natural or man-made disaster. EUR-Lex.
36. Adil et al, op. cit., p.23.
37. 'Alistair Rieu-Clarke, 'Hundreds of rivers and lakes cross international borders – countries need to commit to sharing the water', The Conversation, 12, April 2023.
38. 'EU cross-border water cooperation in spotlight on Danube Day', European Commission, 27 June 2024.
39. The Joint Cooperation programme on Applied scientific Research (JCAR) was set up to improve the cooperation on flood and drought management and foster long-term partnerships between European knowledge institutes to inform flood and drought strategies in transboundary regional river basins.
40. Leonie Cater and Giovanna Coi, 'Europe is flushing its water down the drain' Politico, 27 May 2025.
41. M. Steinhausen, op. cit.
42. Council Conclusions on the comprehensive enhancement of the EU's resilience against flooding, ST 16841/24, 12 December 2024; Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions on European Water Resilience Strategy, 4 June 2025; Council Conclusions on the European Water Resilience Strategy, Council of the EU, 21 October 2025.
43. Ghazi Al-Rawas, Mohammad Reza Nikoo, Malik Al-Wardy, 'A review on the prevention and control of flash flood hazards on a global scale: Early warning systems, vulnerability assessment, environmental, and public health burden'. International Journal of Disaster Risk Reduction, vol. 115, December 2024.
44. Severe flash flooding in western Germany and eastern Belgium (Ahr/Erft/Meuse basins) caused over 220 fatalities displaced tens of thousands, and resulted in tens of billions of euros in damage. 'Devastating floods in 2021', European Environment Agency. Torrential rains and flash floods caused at least 219 deaths and left dozens missing, with widespread infrastructure damage. 'Devastating rainfall hits Spain in yet another flood-related disaster', World Meteorological Organization, 31 October 2024.
45. Refers to the EU's Nature Restoration Regulation and related national restoration plans, which set legally binding targets for restoring degraded ecosystems across the Union.

46. European Council conclusions on competitiveness and twin transition, European Council, 23 October 2025.
47. 'Wetland restoration: a nature-based solution for Europe's security?' International Union for Conservation of Nature and Natural Resources – IUCN, 11 June 2025.
48. 'Green infrastructure…' op. cit. p.18.
49. 'Regulation (EU) 2024/1991 of the European Parliament and of the Council of 24 June 2024 on nature restoration and amending Regulation (EU) 2022/869', EUR-Lex.
50. 'Council Conclusions on the comprehensive enhancement of the EU's resilience against flooding', 12 December 2024.
51. 'Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions on European Water Resilience Strategy', 4 June 2025; ;Council Conclusions on the European Water Resilience Strategy', adopted on 21 October 2025.
52. Paludiculture is the productive land use of wet and rewetted peatlands that preserves the peat soil and thereby minimizes CO2 emissions and subsidence. 'Opportunities for Paludiculture in the CAP', Wetlands International Europe, 8 November 2021.
53. 'The European Green Deal', European Commission.
54. 'Biodiversity strategy for 2030', European Commission.
55. 'The Convention on Wetlands', Ramsar.
56. 'UN Decade on Ecosystem Restoration'.
57. 'Why It's Time for Wetland Restoration Now to Secure a Sustainable Future', United Nations, 2 February 2023.
58. 'Nature-based solutions for adapting to water-related climate risks', OECD, p.8.
59. Sarah Quynh-Giang Ho, Uwe Ehret, 'Is drought protection possible without compromising flood protection? Estimating the maximum dual-use benefit of small flood reservoirs in Southern Germany', European Geosciences Union, 23 July 2024. p.1.
60. 'Water reservoirs and large dams', Knowledge for policy, European Commission, May 2025.
61. Under the EU's Environmental Impact Assessment (EIA) Directive (2011/92/EU as amended by 2014/52/EU), major building or development projects in the EU must first be assessed for their impact on the environment. European Commission.
62. 'Nature-based solutions', op. cit, p.9.
63. Monika Scislowska, 'Floodwater reservoir becomes Poland's hero for preventing major flooding', AP News, 1 September 2024.
64. 'Finally safe' European Investment Bank, 10 December 2024.
65. Michela Marchi, Ilaria Bertolini, Laura Tonni, Luca Morreale, Andrea Colombo, Tommaso Simonelli, Guido Gottardi, 'An Extensive Italian Database of River Embankment Breaches and Damages', Water 2025, 17, 2202.
66. 'Sustainable drainage systems', British Geological Survey.
67. 'Green Infrastructure: Cost-effective solutions to flooding', Headwater Economics.
68. 'Sustainable drainage systems (SUDS) – Park of Joan Reventós', Urban Nature Atlas.
69. David Saurí, Laura Palau-Rof, 'Urban Drainage in Barcelona: From Hazard to Resource?', Water Alternatives, vol. 10, issue 2. 2017.
70. Joana Guerrin, 'A floodplain restoration project on the River Rhne (France): analyzing challenges to its implementation', Regional Environmental Change, 2014.
71. Heng Zhang, Yongxin Xu, Thokozani Kanyerere, 'A review of the managed aquifer recharge: Historical development, current situation and perspectives', Physics and Chemistry of the Earth, vol. 118–119, October 2020.
72. 'Hybrid 'Managed Aquifer Recharge' as an adaptation tool to ensure a resilient and healthy groundwater source'. KU Leuven Project.
73. Concept developed by Eotvos Lorant Tudomanyegyetem (ELTE), Budapest. NaBa-AR deszkamodell.
74. Kath Standen, Luís Costa, Rui Hugman, José Paulo Monteiro, 'Integration of Managed Aquifer Recharge into the Water Supply System in the Algarve Region, Portugal', Water 2023, 15, 2286.
75. 'Development of a Managed Aquifer Recharge Scheme in the Pwales Groundwater Body', RBMP Life Malta.
76. 'Pwales - Managed Aquifer Recharge (MAR)', Interreg Europe.
77. Zhewei Liu, Natalie Coleman, Flavia Ioana Patrascu, Kai Yin, Xiangpeng Li, Ali Mostafavi, 'Artificial intelligence for flood risk management: A comprehensive state-of-the-art review and future directions', International Journal of Disaster Risk Reduction, vol 117, 1 February 2025.
78. Yifan Yang, Chen Xie, Ziwu Fan, Zhonghou Xu, Bruce W. Melville, Guoqing Liu, Lei Hong, 'Digital twinning of river basins towards full-scale, sustainable and equitable water management and disaster mitigation', npj Natural Hazards vol. 1, 2024.
79. ART – Analysis and Research Team, 'From Screens to Fields: how digitalisation is transforming agriculture' Consilium, February 2025.
80. Demervallei, Sigma Plan.
81. Toni Barjas Blanco, 1 Patrick Willems, Bart De Moor, Jean Berlamont, 'Flood Prevention of the Demer River Using Model Predictive Control', IFAC Proceedings Volumes, vol. 41, issue 2, 2008, pp. 3629-3634.
82. Quynh-Giang Ho, op. cit.
83. EU frameworks such as the Critical Entities Resilience Directive (Directive (EU) 2022/2557) and the NIS2 Directive on cybersecurity (Directive (EU) 2022/2555) already cover drinking water and wastewater services, requiring operators to undertake risk management and resilience planning against both physical and cyber disruptions.
84. 'Current wildfire situation in Europe', Joint Research Centre.
85. Matilda Bathurst, 'Why do wildfires increase flood risk?' PreventionWeb.
86. 'A Complete Guide to Rainwater Harvesting', Rainwater Management Solutions.

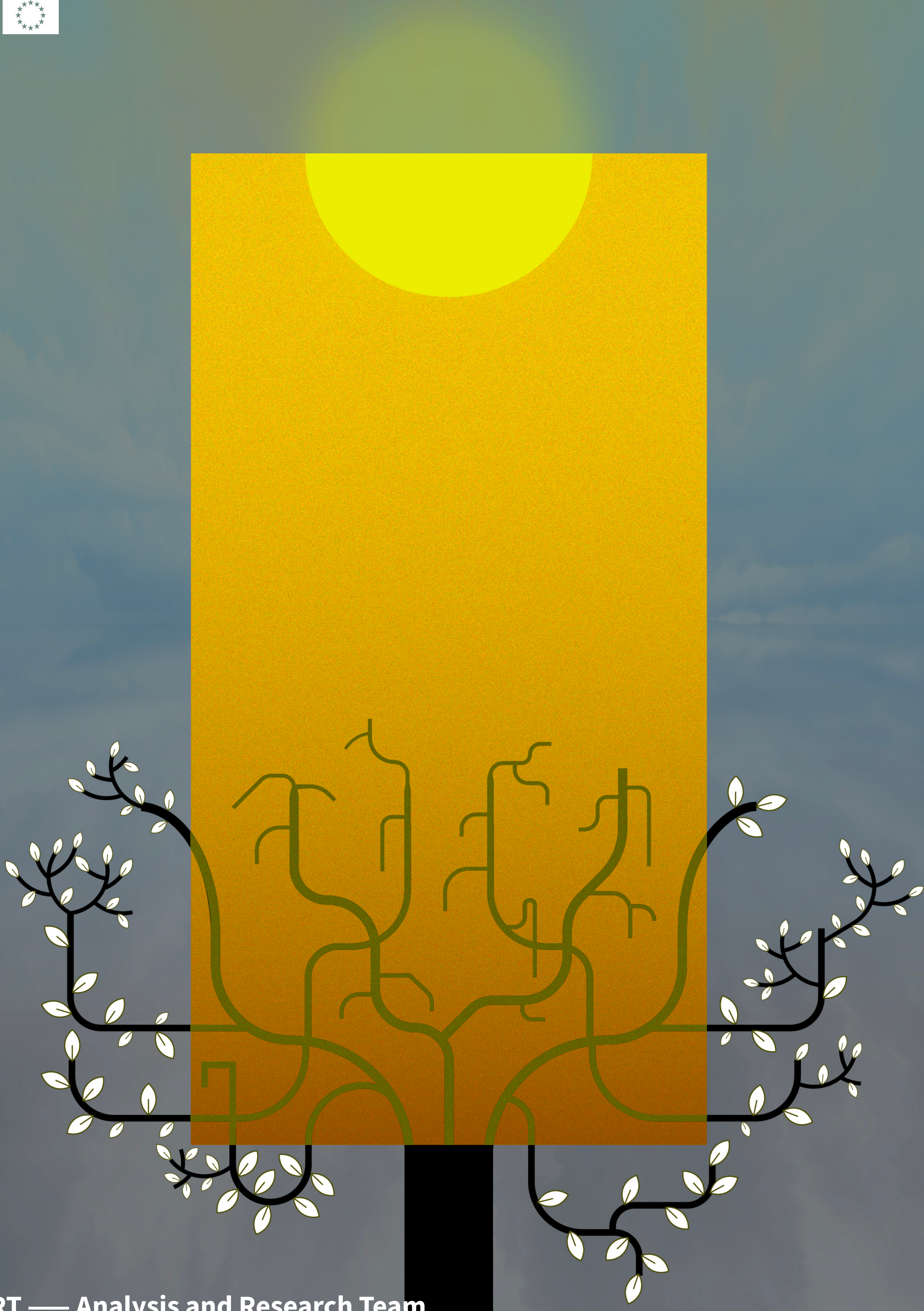
Edition notice

This publication has been produced by the General Secretariat of the Council of the European Union (GSC) and is intended for information purposes only. It does not involve the responsibility of the European Union institutions nor the member states.

For further information on the European Council and the Council of the European Union, please contact the GSC Public Information service:
www.consilium.europa.eu/en/infopublic

PRINT	ISBN 978-92-850-0608-2	doi: 10.2860/0411595	QC-01-25-013-EN-C
PDF	ISBN 978-92-850-0607-5	doi: 10.2860/1717645	QC-01-25-013-EN-N

This ART publication was created with the contribution of the Creative Services (DG COMM) of the General Secretariat of the Council.



ART —— Analysis and Research Team

Produced in collaboration with the Visual Communication and Production Unit