Seminar 1

Introduction to water management under climate change: challenges from technical, legal, economic and social perspectives

The first seminar of the UNITA project "Social, Economic and Legal Challenges in Water Governance for a Climate-Resilient and Sustainable Future", brought together researchers from different disciplines to discuss how climate change is transforming water governance and management. The event was designed as the starting point of a broader interdisciplinary collaboration focused on understanding water challenges through economic, social, legal and technical perspectives, while exploring the role that the principles of the circular economy can play in building more sustainable and resilient water systems.

A key message emerging from all presentations was that water management under climate change can no longer be viewed solely as a technical issue. Changes in precipitation patterns, increasing droughts and floods, water scarcity, growing demand, environmental degradation and social inequalities require integrated responses involving governance, economics, law, social justice and technological innovation. Climate change therefore affects not only water resources themselves but also the institutions responsible for governing and managing them.

The keynote presentation by PhD Alan Nicol (International Water Management Institute) focused on the concept of water governance and its increasing importance in an era of climate uncertainty. He argued that climate change should be understood primarily as a governance challenge because it amplifies existing vulnerabilities, increases uncertainty and places pressure on institutions that were designed for more predictable environmental conditions. Water governance concerns questions such as:

- Who has access to water?
- Who pays for water services and infrastructure?
- Who makes decisions?
- Who bears the risks associated with scarcity, droughts or floods?

Governance extends beyond water management itself and includes policy frameworks, institutional arrangements, financing systems, participation mechanisms, information systems, power relations and issues of justice and equity. Climate change makes these dimensions even more important because technical solutions alone cannot guarantee sustainable outcomes. Several illustrative examples were presented. Transboundary river basins, such as the Nile basin, demonstrate how climate stress, infrastructure development and competing national interests create complex governance challenges. Decisions regarding dam construction, water allocation and river basin management involve political and economic considerations as much as hydrological ones. Thus, determining governance scales, whether local, regional or international, often means determining the distribution of both resources and political power.

Another important topic was the concept of Just Water Partnerships, proposed by the Global Commission on the Economics of Water. These partnerships aim to place justice, equity and

inclusion at the centre of water investments and financing decisions. The discussion stressed that governance reform is often more critical than infrastructure investment because financial resources alone cannot solve water challenges if institutions remain weak or unequal. In this sense, governance is ultimately inseparable from questions of finance and social justice. Finally, the role of emerging technologies, particularly Artificial Intelligence (AI) and digital twins was discussed. AI-based tools can support governance by processing information, collecting feedback from citizens, and helping decision-makers identify challenges more effectively. However, technological innovation must complement rather than replace institutional capacity and accountability.

PhD Samara López-Ruiz examined the economic dimensions of water governance under climate change. Her main argument was that climate change transforms water governance into a financial governance problem because utilities and regulators must increasingly allocate costs and risks under conditions of deep uncertainty. Historically, water utilities operated under the assumption of relatively stable climatic conditions. Investment planning relied on predictable water availability and demand patterns. Climate change undermines these assumptions and exposes utilities to growing risks associated with droughts, floods, and changing consumption patterns. Nearly half of the world's water utilities already face some degree of drought-related risk, and future climate change is expected to increase that vulnerability.

A major challenge concerns the adaptation financing gap. While many technical adaptation measures are available, including leakage reduction, increased storage capacity and desalination, implementing them requires substantial long-term investments. Adaptation projects are often politically difficult to justify because their benefits are preventive and occur over long-term horizons. Consequently, investments tend to be delayed despite their importance for future resilience.

Adaptation costs are frequently underestimated because analyses focus mainly on infrastructure expenditures while neglecting governance, institutional and coordination costs. Moreover, droughts generate economic impacts far beyond water utilities, affecting agriculture, industry and regional economies. Adaptation therefore requires an integrated understanding of economic risks across sectors.

A second major issue is the tension between resilience and affordability. Utilities require financial resources to adapt to climate change, but increasing tariffs may generate social resistance and undermine public trust. If prices remain too low, adaptation investments become impossible; if prices increase too quickly, affordability problems emerge. Water pricing is therefore not only an economic instrument but also a mechanism through which governments maintain legitimacy and public acceptance. The fundamental question becomes who should bear the costs: households, agricultural users, industries or taxpayers. Samara López-Ruiz concluded that the key economic challenge is creating regulatory and financial systems capable of mobilising long-term investment while maintaining affordability, fairness, and political legitimacy.

Professor PhD Greta Balliu addressed the social dimensions of water governance and emphasised that water crises should be understood as socio-ecological rather than purely technical problems. Water distribution reflects power relations, institutional arrangements and social inequalities as much as physical water availability. Drawing on theories of political ecology, commons

governance and environmental justice, the presentation examined how climate vulnerability frequently overlaps with poverty, marginalisation and unequal access to resources. Climate change tends to affect vulnerable populations disproportionately, reinforcing existing inequalities. Several forms of inequality were discussed, namely:

- Global inequalities between countries and regions.
- Urban-rural disparities in access to water services.
- Gender-based inequalities related to water collection and household water management.
- Affordability challenges and water poverty.
- Exclusion of disadvantaged groups from decision-making processes.

Conflicts between competing water uses were highlighted as another major social challenge. Agriculture alone accounts for approximately 70% of global freshwater withdrawals, creating increasing competition among domestic, agricultural and industrial users under conditions of scarcity. A key concept presented was social resilience, which extends beyond infrastructure and includes trust, social networks, community participation and institutional effectiveness. Community-based forms of water management can strengthen societies' capacity to adapt to climate change while promoting social inclusion and equity. The discussion also reinforced the importance of recognising water as a human right and incorporating climate justice considerations into adaptation policies.

The legal session examined how regulatory frameworks must evolve to address climate-related water challenges. Professor PhD Vera Parisio focused on water supply services and governance models. Different approaches adopted by municipalities, including direct public management, in-house companies and outsourcing arrangements were discussed. According to European Union law, there is no universally preferred model. Instead, local authorities should select governance arrangements according to their specific circumstances and objectives. The important principle is maintaining the flexibility to adapt institutional models when conditions change.

Particular attention should be given to mechanisms that integrate climate adaptation and circular economy principles into water service governance. In fact, future water systems may increasingly incorporate greywater reuse, nature-based solutions, rainwater harvesting, urban drainage innovations and alternative water sources. These sustainability criteria could also become part of procurement and public tender processes.

Professor PhD Flaminia Stârc-Meclejan presented legal challenges from the perspective of the Romanian experience as a case study. Romania has transposed many European environmental directives into national law, but implementation remains problematic. Major issues include inadequate wastewater treatment, deficient infrastructure, water losses, diffuse agricultural pollution and insufficient enforcement capacity. Only around 57% of the Romanian population is connected to public water supply systems, the lowest rate in the European Union.

Conflicts between environmental protection and development objectives were discussed, including controversies surrounding hydropower projects. Climate litigation is emerging as another important trend, exemplified by the lawsuit filed by the NGO Declic against the Romanian government, alleging insufficient climate action and adaptation efforts. Such cases demonstrate the growing role of courts in shaping environmental governance. In conclusion of the legal session, circular economy principles were presented as an opportunity to improve

compliance, reduce pollution and increase resource efficiency through wastewater reuse and nutrient recovery.

The technical session demonstrated how scientific knowledge and technological innovation can contribute to climate-resilient water management. Professor PhD Stefania Tamea focused on the relationship between climate change, agriculture and water availability. Climate change affects precipitation patterns, snow accumulation, evapotranspiration and soil moisture, particularly in mountain regions that function as natural water reservoirs. Rising temperatures are reducing snow storage capacity and altering seasonal water availability. At the same time, growing food demand increases agricultural water requirements. Although rainfall patterns may not show dramatic declines everywhere, irrigation needs continue to rise because higher temperatures increase evaporation and reduce soil moisture, causing significant pressure on water resources. The following priorities were identified:

- Improved monitoring systems.
- Better measurement of water and soil moisture.
- Decision-support systems and digital twins.
- Increased water storage capacity.
- Aquifer recharge strategies.
- Water reuse and adaptation measures.

Professor PhD Pedro Dinis Gaspar presented innovative technological solutions aimed at increasing water-use efficiency and resilience. Examples included clay-based low-energy irrigation systems capable of substantially reducing water consumption, AI-supported monitoring systems for agriculture, and digital platforms facilitating the exchange of reclaimed wastewater between suppliers and users. Additional research explored advanced water treatment methods using ultraviolet radiation and non-thermal plasma technologies to remove pathogens and improve water quality. These examples demonstrated that innovation can play an important role in addressing water challenges, provided technologies are adapted to local contexts and supported by effective governance structures.

In summary, the seminar demonstrated that climate change is reshaping water management across multiple dimensions. Water governance can no longer focus exclusively on infrastructure and engineering solutions but must incorporate economic sustainability, social justice, legal adaptability and technological innovation. Across all presentations, several recurring themes emerged: the importance of governance, the need for institutional reform, the challenge of financing adaptation, the centrality of justice and participation, the growing relevance of circular economy approaches and the potential of technological innovation. Climate change is not only altering hydrological systems but also exposing weaknesses in governance structures, increasing uncertainty, intensifying competition for water resources, and creating new demands for adaptation. Addressing these challenges requires more than technological solutions; it also requires effective institutions, adequate financing, inclusive governance and regulatory frameworks capable of responding to rapidly changing environmental conditions. Effective responses to climate change require interdisciplinary cooperation among researchers, policymakers, utilities, businesses and communities.

As the first seminar of the UNITA project, the event successfully established a shared interdisciplinary framework for understanding the challenges of water management under climate change, and highlighted the importance of integrating technical, economic, social and legal perspectives within a common research agenda.

The seminar also demonstrated the value of cross-disciplinary dialogue in identifying common challenges and potential solutions. Themes such as climate resilience, water justice, adaptation financing, circular economy approaches, digitalisation, stakeholder participation and institutional reform emerged as cross-cutting priorities that connect the different dimensions of water governance. By bringing together researchers and practitioners from diverse fields and countries, the event laid the foundation for future collaboration, the development of joint research initiatives, and the production of policy-relevant knowledge. In this sense, the seminar represented not only an academic exchange but also an important step towards building an international research community committed to developing resilient, equitable and sustainable water governance systems for an increasingly uncertain climate future.