REVISTA IBEROAMERICANA DE CIENCIA, TECNOLOGÍA Y SOCIEDAD
PRIMERO ONLINE

# *Science-policy Dialogue on Drought Risk Management. Drinking Water Emergency in Uruguay* *

# Diálogo ciencia-política sobre gestión del riesgo de sequía. Emergencia de agua potable en Uruguay

# Diálogo entre ciência-política sobre gestão do risco de seca. Emergência de água potável no Uruguai

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*Drought is one of the environmental hazards of greatest global concern, with consequences that challenge decision-makers around the world. This article analyses the case of Uruguay regarding the drinking water availability issue, in the context of the drought that affected the region from 2019 to 2023. Through a process of co-production of knowledge based on social learning, and involving actors from public policy and academia, strategies for integrated drought risk management are outlined. Improvements in governance, starting with the formalization of an integrated intersectoral participatory setting, as well as in communication and targeted research in water resources to find resilient systems that could adapt to current climate variability, were identified as the most important needs to be addressed. Binding political commitments are required to move from discourse on the need for change to structural change in regulatory frameworks and water management practices. Recommendations are presented to strengthen governance and improve resilience facing future droughts.*

**Keywords:** *climate services; co-production; governance; SISSA; social learning*

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La sequía es uno de los riesgos ambientales de mayor preocupación mundial, con consecuencias que desafían a los responsables de la toma de decisiones a nivel mundial. Este artículo analiza el caso de Uruguay en relación con la disponibilidad de agua potable, en el contexto de la sequía que afectó a la región entre 2019 y 2023. Mediante un proceso de coproducción de conocimiento basado en el aprendizaje social, con la participación de actores de políticas públicas y la academia, se describen estrategias para la gestión integral del riesgo de sequía. Se identificaron como necesidades prioritarias mejoras en la gobernanza, comenzando por la formalización de un entorno participativo intersectorial integrado, así como en la comunicación y la investigación específica sobre recursos hídricos para encontrar sistemas resilientes que puedan adaptarse a la variabilidad climática actual. Se requieren compromisos políticos vinculantes para pasar del discurso sobre la necesidad de cambio a un cambio estructural en los marcos regulatorios y las prácticas de gestión del agua. Se presentan recomendaciones para fortalecer la gobernanza y mejorar la resiliencia ante futuras sequías.

**Palabras clave:** aprendizaje social; coproducción; gobernanza; servicios climáticos; SISSA

A seca é um dos riscos ambientais de maior preocupação global, com consequências que desafiam tomadores de decisão em todo o mundo. Este artigo analisa o caso do Uruguai em relação à disponibilidade de água potável, no contexto da seca que afetou a região entre 2019 e 2023. Por meio de um processo de coprodução de conhecimento baseado em aprendizagem social, com a participação de atores de políticas públicas e da academia, são descritas estratégias para a gestão integral do risco de seca. Foram identificadas necessidades prioritárias de melhorias na governança, começando pela formalização de um ambiente participativo intersetorial integrado, bem como na comunicação e na pesquisa específica sobre recursos hídricos para encontrar sistemas resilientes que possam se adaptar à variabilidade climática atual. Compromissos políticos vinculantes são necessários para passar do discurso sobre a necessidade de mudança para uma mudança estrutural nos marcos regulatórios e nas práticas de gestão da água. Recomendações são apresentadas para fortalecer a governança e melhorar a resiliência a futuras secas.

**Palavras-chave:** aprendizagem social; coprodução; governança; serviços climáticos; SISSA

## Introduction

### Risk management framework for droughts

Drought is one of the environmental hazards of greatest global concern. It is a complex, climate-driven phenomenon with consequences that challenge decision-makers around the world and are therefore the subject of national drought policies. Wilhite (1996) has advanced a drought management methodology for use in political settings that can be adapted to different spatial scales, i.e., local, state, regional and national. This design consists of ten steps, the first five involving the assessment of available resources to support the development of the plan and tactics for gaining public support for the process. In order to develop and implement the plan, it then indicates moving on to the identification of research needs and institutional deficiencies, as well as the development of multi-level educational and training programmes. Finally, it advocates the development of procedures for the evaluation of the drought management plan, aiming at continuous improvement through modifications as necessary (Wilhite, 1996; Wilhite and Easterling, 1987). These steps were then the basis on which the World Meteorological Organization (WMO) together with the Global Water Partnership (GWP) developed the document "National policy guidelines for drought management. A template for action" (Wilhite, WMO-GWP, 2014).

The global framework for Climate Services established by the World Meteorological Organization (WMO) encourages support to governments and decision-makers, aiming to meet climate information needs in a way that helps people and organizations to make decisions (WMO, 2015). Climate services are the provision and use of climate data, information and knowledge and require a commitment between the recipient of the service and its provider, together with an effective access mechanism to enable timely action (WMO, 2013; 2023).

The Drought Information System for Southern South America (SISSA for its Spanish acronym) operates at the regional level and its role is to provide tools and information on droughts and their impacts to governments, non-governmental and private institutions and individuals in general, in line with the concept of climate services (WMO, 2023). It operates within the framework of the Regional Climate Centre for Southern South America (CRC-SAS for its Spanish acronym), and involves the Meteorological Services of Argentina, Brazil, Paraguay, Bolivia, Uruguay and Chile. The pillars of SISSA are monitoring and forecasting, risk categorization and sectoral impacts, planning, preparedness, mitigation and contribution to national drought policies (SISSA, 2024).

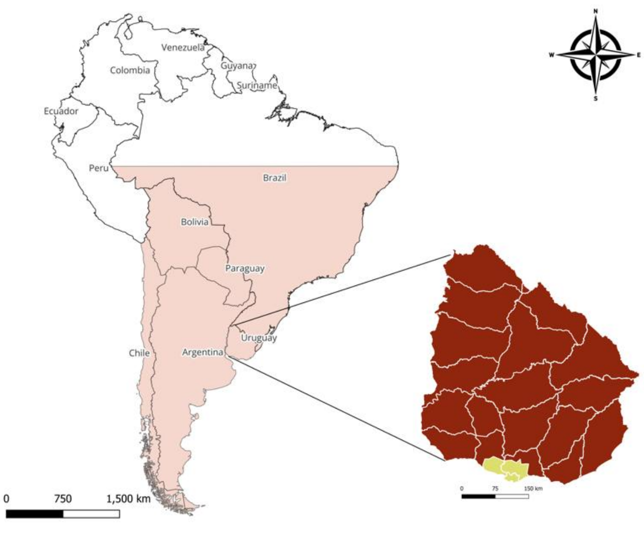
Within this framework, this article focuses on the case of Uruguay to analyze drought risk management and proposes inter-institutional actions aimed at comprehensive management, with an emphasis on drinking water supply, which was revealed to be the most vulnerable sector in the 2020-2023 drought. The energy sector is presented as a successful example to understand how recent changes have enabled the latest water crisis to be overcome. This case study is also seen as a contribution to the development of climate services at regional level in the context of SISSA and the CRC-SAS.

### Water resources and droughts in Uruguay and the region

Droughts originate from a deficiency of precipitation that results in water scarcity for some activity. There are many natural and human factors that ultimately affect the availability of water for society. As drought occurs with varying frequency in all regions of the world and in all types of economic systems, the approaches taken to defining drought also reflect regional differences (Wilhite and Glantz, 1985). For analytical purposes, definitions of drought are grouped into four types: meteorological (period of abnormally dry weather), agricultural (shortage of precipitation that adversely affects agricultural production), hydrological (period of below-average water content in streams, reservoirs, groundwater aquifers, lakes) and socio-economic (shortage of water for human consumption or related to an economic resource). The fundamental importance of drought lies in its impacts and implies that water scarcity is not the unique characteristic of droughts as a drought can propagate through the economy and society (Smakhtin and Schipper, 2008; Wilhite and Glantz, 1985).

The drought experienced in southern South America from 2019 to 2023 was regional in nature, negatively affecting all countries in the region (**Figure 1**), with different impacts depending on the territorial, productive, demographic and economic characteristics of each country. This drought manifested across all scales and dimensions: meteorological, agricultural, hydrological and socio-economic (Rivera, 2024; Geirinhas *et al*., 2023; Naumann *et al*., 2021). Due to its prolonged duration and severity, it had negative impacts on ecosystems, economies and populations in the La Plata River Basin. These included difficulties in the supply of drinking water, increased forest fires, losses in artisanal fisheries, reduced agricultural and livestock yields, difficulties in river transportation and a reduction in hydroelectric power generation, with a consequent increase in the cost of electricity in Brazil and Argentina, countries highly dependent on this energy source (Naumann *et al*., 2021).

**Figure 1. Map of South America: SISSA member countries (Argentina, Bolivia, part of Brazil, Chile, Paraguay and Uruguay) affected by the 2019-2023 drought in pink. Uruguay enlarged with Montevideo and metropolitan area in yellow.**




The hydrological drought of 2019-2023 in the La Plata River Basin, the second largest river basin in South America and the fifth largest in the world, was caused by a precipitation deficit in the Paraná, Paraguay and Uruguay rivers, in response to an unusual multi-year La Niña event. During this period, minimum water levels have been reported, unprecedented in the last 50 years (Rivera, 2024; Geirinhas *et al*., 2023; Naumann *et al*., 2021).

In Uruguay, in particular, the social impacts of the drought under study began in 2020 in the agricultural sector, except for rice cultivation, which, in the 2022-2023 harvest, had record high yields (MGAP, 2023a) due to irrigation systems established decades ago. The 2022–2023 drought was the most severe in the last three decades, with direct gross losses of USD 1.883 billion, equivalent to 3% of GDP and almost 39% of agricultural value added (Cortelezzi et al., 2023; MGAPb) The sectors most affected were rainfed agriculture (USD 1.098 billion, mainly due to losses in soybeans (USD 832 million) and corn (USD 266 million), beef cattle (USD 287 million), forestry (USD 162 million), lost pastureland (USD 145 million), and dairy farming (USD 136 million) (Cortelezzi *et al*., 2023; MGAP, 2023b). The impact on production and exports was equally severe. In the 2022–2023 harvest, soybeans—the main summer crop since 2003–2004—registered a production of just 648,000 tons with a yield of 641 kg/ha, one of the lowest values in the crop's history in Uruguay. Corn, with 188,000 hectares cultivated, reached an average productivity of only 1,415 kg/ha, more than 50% below the historical average (Uruguay XXI, 2024). In macroeconomic terms, agricultural GDP registered a 2.9% drop in 2022, and by the end of 2023, agro-industrial exports stood at around USD 8.2 billion, a 28% decrease compared to the record set in 2022 (MGAP, 2023b). Within those exports, agricultural goods totalled USD 983 million in 2023, a year-on-year reduction of 61%, driven mainly by the collapse in soybean sales, which fell from USD 1,917 million in 2022 to just USD 411 million in 2023 (Uruguay XXI, 2024).

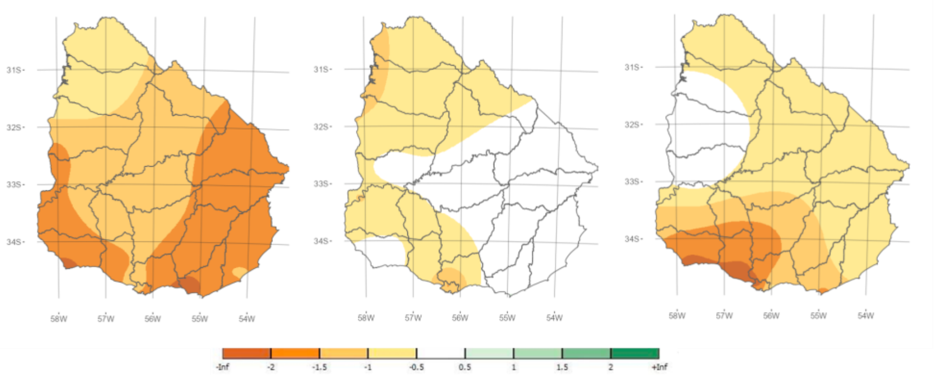
In 2017, with the aim of adaptation the impacts of climate variability on the agricultural sector, the Uruguayan Parliament approved amendments to the 1997 Law on Irrigation for Agricultural Purposes (IMPO, 2017). This generated resistance from civil society and part of academia (Ryfisch *et al*, 2026; Díaz and Schiavone, 2025), halting the implementation of these amendments. The sources consulted point to historical tensions regarding water privatization in Uruguay (Ryfisch *et al*., 2026; Dias *et al*., 2023; Meerhoff and Bernardi, 2018), tensions that have not yet been resolved.

Agricultural droughts in Uruguay have been the subject of study in recent times (Cruz *et al*., 2021; Cruz *et al*., 2018; Lanfranco, B.; Rava, C., 2009; De Torres *et al*., 2007), and their occurrence and impacts have been reported historically (Barrán and Nahum, 2010), in the press and other local media due to their major impact on the country's economy (Giuliano *et al*., 2024), although the particular analysis of the 2020-2023 agricultural drought would deserve a study in itself.

In addition to the agricultural impact, the 2020–2023 Uruguayan drought was exceptional because it was urban-rural in nature, and also because of its duration and intensity. This situation exhibited territorial heterogeneity and variations over time, with a background drought alternating with periods of rainfall that were insufficient to restore the hydrological cycle.

The precipitation deficit is typically assessed using indicators such as the Standardized Precipitation Index (SPI), which quantifies precipitation anomalies relative to a historical reference series and expresses them in standardized units, allowing for the identification of dry or wet conditions at different time scales (e.g., 3, 6, or 12 months). The persistence of negative values at these scales constitutes an early sign of meteorological drought. The SPI for 12 months (January- December) indicates that the year 2020 was very dry (severe drought) in almost the entire country, while 2021 was slightly dry and affected the western and central-southern coasts. While the year 2022 was dry in almost the entire national territory with severe drought in the south and southwest (INUMET, 2024) (**Figure 2**).

**Figure 2. 12-month standardized precipitation index, 2020 to 2022 from left to right (INUMET, 2024)**



This situation, beyond its relatively low frequency of occurrence revealed the weaknesses of some institutions as regards emergency management, as well as strengths in other cases, showing that it is possible to develop resilient management systems.

The most salient impacts of this latest drought in Uruguay relate, for the first time, to the provision of water for human consumption in the metropolitan area (Kruk *et al.*, 2025), with Montevideo being the first capital city in the 21st century to run out of drinking water, a city where 50% of the country's population resides. In 2014 this also happened in the city of São Paulo (Mannan *et al.*, 2022; Reis Deusdará-Leal, 2020; Millington, 2018), which although not a capital city, concentrates more than 21% of Brazil's population. In Uruguay, the national Constitution establishes that 'access to drinking water and sanitation constitute fundamental human rights' and that 'the principle by which the provision of drinking water and sanitation services must be carried out prioritizing social reasons over economic ones. The impacts on the agricultural sector were also severe and prompted policy support measures (Cortelezzi et. al., 2023) as in previous years (Cruz *et al.*, 2018). In the energy sector, the consequences did not have a major impact on the population, in contrast to a drought in 1988-1989 that was like the urban-rural drought we analyze, although of shorter duration (Caffera *et al.*, 1989). In 1988-1989 the greatest impacts were in the agricultural sector, and at the urban level in the energy sector (Cruz *et al.*, 2018). One of the reasons why the 2019-2023 drought had minor impacts on the energy sector is that in recent decades there have been major transformations in Uruguay's energy matrix.

As in the case of South America and particularly Uruguay, various countries and regions of the world face the problem of water resources management (Motsumi *et al.*, 2023; Hagenlocher *et al.*, 2023; Vignola *et al.*, 2018). Specilized literature points to the strong need for case study-based research and to the development of climate services addressing the challenges of climate change adaptation, and in particular for urban water management (Cantone *et al.*, 2023; Ray *et al.*, 2022; Boon *et al.*, 2022), so this work is also a contribution in this regard.

## Co-production of knowledge and multi-level social learning

As the production of scientific information does not guarantee its use in decision-making, it is essential to advance in the appropriation of science by society. In this sense, it is crucial to address communication between scientists, decision-makers and laypeople that allows articulations and adjustments of results, translation and transfer of information and knowledge of potential impacts and viable guidelines for action, as well as the exploration of new institutional forms (Cantone *et al*., 2023; Hidalgo and Natenzon, 2014). These aspects link to the demand for public participation in policy decisions in two ways: contributing to policy decisions in which science plays a contributing role, such as in natural resource management (e.g. water); and in decisions on scientific research priorities and agendas (Motsumi *et al*., 2023; Cantone *et al*., 2023; Ray *et al*., 2022; Hidalgo and Natenzon, 2014).

According to Pahl-Wostl (2009), linkages between academia, the policy sector and other societal actors enable the development of collective learning that allows for better coping with an upcoming event. Change is seen as a social phenomenon, in which collective learning evolves in a gradual way and informal networks play a crucial role for collective learning processes (Pahl-Wostl, 2009). The team developing this study forms one of these networks, qualified as informal or adaptive networks. Adaptive networks are groups of interacting people from different sectors of society who develop ideas that influence these sectors to the benefit of the whole Ideas in different sectors of society may evolve separately, but if there is interaction, they can influence each other. However, Smith and Stirling (2010) consider that a key issue is the question of who governs and who is prioritised in the decisions taken in the framework of sustainability. This implies that research should devote more attention to how the informal settings promoted by academics in adaptive governance are linked and embedded in multilevel governance systems (Pahl-Wostl *et al*., 2013). Understanding these linkages becomes essential to move from discourse on the need for change to structural change in regulatory frameworks and management practices. While informal settings provide spaces for experimentation and can lead to revision of assumptions and paradigms, formal policy calls for specific processes to ensure the outcomes of learning and develop binding commitment. Lemos and Morehouse (2005) describe a model of science policy co-production in which the concept of iterativity is central. In this context, iterativity refers to the ability to maintain information flows and participation between science and decision makers, so this may be the way to update political commitments.

In this regard, the following questions arise to be answered in this work: What institutional aspects should be prioritized to avoid future water crises? What knowledge is necessary to create or deepen to improve drought risk management?

## 1. Methods

The methodology adopted in this work included the following steps: 1. Identification of the study problem: the response to drought 2019-2023 stemming from public policies and academia in Uruguay 2. Formation of an interdisciplinary and inter-institutional working team, integrating relevant institutions and relevant actors. 3. Description and analysis of needs and actions to be taken in the short, medium and long term to deal with drought events and prevent future negative impacts, which contributed empirical information to collective reflection (social learning). 4. To outline strategies for integrated drought risk management.

### 1.1. Conceptual framework for knowledge co-production

To approach climate knowledge co-production, the consultative mode described by Meadow *et al*. (2015) was applied, where research aims to solve 'real-life' problems. In this mode,

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interactions between scientists and policy actors occur at specific stages of the research, such as problem formulation, verification of results and dissemination of findings. This interaction is not necessarily continuous throughout the process and inputs may be facilitated by some team members acting as translators/facilitators. Within the consultative mode (Meadow *et al*., 2015) a collaborative process (Cruz *et al*., 2018) that refers to ‘boundary organizations’ (Meadow *et al*., 2015) was carried out. In our case, SISSA would be acting as the boundary organization that connects academia with public policy actors, and the individuals acting as knowledge brokers are some members of the boundary organization who have that specific task.

### 1.2. Institutions involved and co-production process

The research was developed based on face-to-face and virtual meetings from March 2023 to September 2024 with members of institutions that are considered key to assessing the emerging problems of the 2019-2023 drought in Uruguay (Wilhite, 1996), and desk work of documentation and background analysis. In the first virtual meeting, experiences were shared, and future actions were planned in relation to integrated drought risk management. The contribution of members of institutions involved the writing process and data collection. The institutions involved in this work and their mission are summarized in **Table 1**, their structure and administrative level are presented in **Figure 3**.

**Table 1. Uruguayan institutions involved in the study and their area of action (mission)**

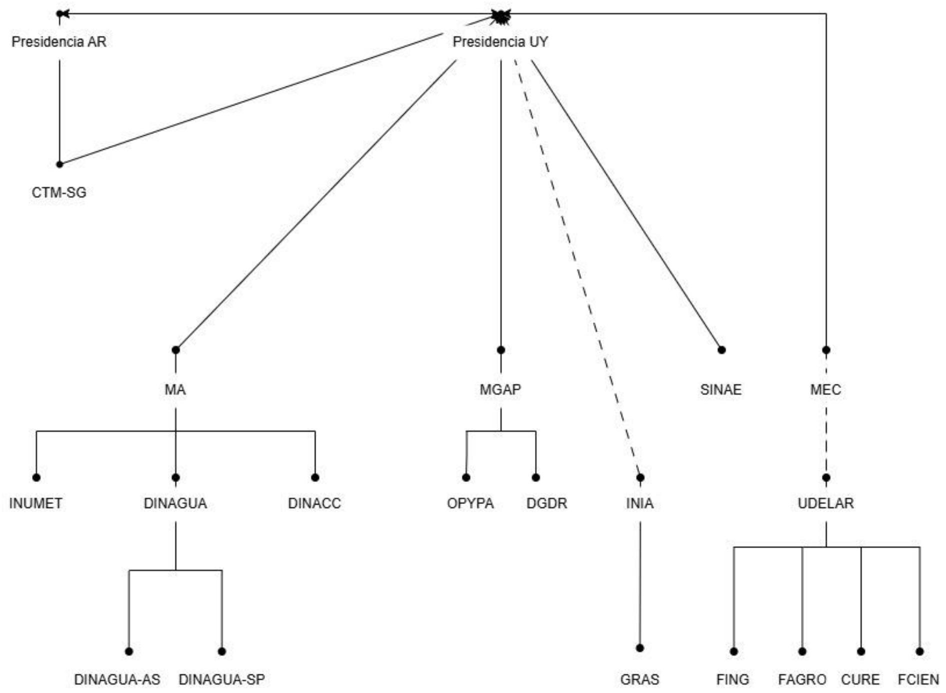
<table>
<tr><td>Instituto Uruguayo de Meteorología (INUMET, Uruguayan Institute of Meteorology)</td><td colspan="2">Provide public meteorological and climatological services to contribute to the safety of people and their property, to the sustainable development of society and to act as meteorological authority in the national territory, in its air and maritime space. Coordinate meteorological activities of any nature in the country and represent the República Oriental del Uruguay in international bodies related to these matters.</td></tr>
<tr><td>Ministerio de Ambiente (MA, Ministry of the Environment)</td><td colspan="2">Implement the national environmental policy, environmental management, sustainable development and conservation and use of natural resources set by the Executive Power.</td></tr>
<tr><td rowspan="2">Ministerio de Ambiente (MA, Ministry of the Environment)<br>Ministerio de Ganadería, Agricultura y Pesca (MGAP, Ministry of Livestock, Agriculture and Fisheries)</td><td colspan="2">Dirección Nacional de Cambio Climático (DINACC, National Directorate of Climate Change)</td></tr>
<tr><td>Dirección Nacional de Aguas (DINAGUA, National Water Directorate)</td><td>Fulfill Uruguay's obligations in the context of the multilateral environmental agreements on climate change and ozone layer protection of which Uruguay is a Party. Support the functioning of the National System of Response to Climate Change and Variability (SNRCC) by coordinating, with eleven Ministries, the Planning and Budget Office, the Congress of Mayors and the National</td></tr>
</table>

<table>
<tr><td rowspan="4"></td><td></td><td colspan="2">Emergency System (SINAE), national climate change policies.</td></tr>
<tr><td rowspan="3">Dirección Nacional de Aguas (DINAGUA, National Water Directorate) Contribute to the permanent development of the agricultural, agro-industrial and fisheries sectors.</td><td colspan="2">Advance in the implementation of integrated water management of national and transboundary basins and aquifers, as well as continue with the implementation of the plans and programs of the national water plan.</td></tr>
<tr><td>Situation and Forecast Room (DINAGUA-SP, Situation and Forecast Room)</td><td>Generate hydrological information and products that enable to know the state of the country's current and future water resources.</td></tr>
<tr><td>Groundwater (DINAGUA-AS, Groundwater)</td><td>Efficient management and sustainable use of groundwater.</td></tr>
<tr><td rowspan="3">Ministerio de Ganadería, Agricultura y Pesca (MGAP, Ministry of Livestock, Agriculture and Fisheries) Sistema Nacional de Emergencias (SINAE, National Emergency System)</td><td colspan="3">Oficina de Programación y Política Agropecuaria (OPYPA, Office of Agricultural Programming and Policy)</td></tr>
<tr><td>Dirección General de Desarrollo Rural (DGDR, General Directorate of Rural Development)</td><td colspan="2">Contribute to the design, implementation and evaluation of public policies for the agricultural, agro-industrial and fisheries sectors, with the aim of generating conditions for the sustainable development of these sectors. Contribute to the generation and systematization of quality, timely and relevant statistical information for decision-making by the different actors involved in agro-industrial chains.</td></tr>
<tr><td>Comprehensive emergency and disaster risk management in Uruguay. To protect the population, significant assets and the environment in</td><td colspan="2">Be a benchmark in the implementation of public policies for Rural Development, through an agile, dynamic and innovative management, promoting relevant interventions adapted to the territories, considering a sustainable production for the improvement of the rural population's living conditions,</td></tr>
</table>

| | | |
|---|---|---|
| | the event of the eventual or real occurrence of emergency or disaster situations through the joint coordination of the State with the appropriate use of public and private resources. | small and medium family and non-family producers. |
| Comisión Técnica Mixta Salto Grande (CTM-SG, Salto Grande Joint Technical Commission) | Fulfil and enforce the founding principles of the Salto Grande Joint Technical Commission for the use of the rapids of the Uruguay River in the Salto Grande area (Argentine-Uruguayan binational). | |
| Administración del Mercado Eléctrico de Uruguay (ADME, Uruguayan Electricity Market Administration) | Operate and manage the required demand for energy. Operates and manages the National Load Dispatch, National Interconnected System (S.I.N.) non-state public person. | |
| Instituto Nacional de Investigación Agropecuaria (INIA, Agricultural Research Institute) | Generate and adapt knowledge and technologies to contribute to the sustainable development of the agricultural sector and the country. Legal entity under non-state public law (public-private). | |
| Instituto Nacional de Investigación Agropecuaria (INIA, Agricultural Research Institute) Universidad de la República (UDELAR, University of the Republic) | Área de Sistemas de Información y Transformación Digital (GRAS, Information Systems and Digital Transformation Area) | |
| | Higher public education at all levels of culture, artistic education, the licensing for the exercise of scientific professions and the exercise of the other functions entrusted to it by law. | Promotion, coordination and execution of research projects and other activities related to the development of advanced information systems and support for decision-making in the agricultural sector, for the prevention and management of climate-related risks. As well as leading from INIA the strengthening of the use of Information and Communication Technologies (ICT) in the agricultural sector. |
| Universidad de la República (UDELAR, University of the Republic) | Facultad de Ingeniería (FING, Faculty of Engineering) | |
| | Facultad de Agronomía (FAGRO, Faculty of Agronomy) | Teaching, research, extension in fluids (water and air) for energy, drinking, agriculture and livestock and all uses in general. Train professionals in the areas of engineering. Create original and quality knowledge in engineering |

| | | |
|---|---|---|
| | | and its basic sciences. Contribute to national and social development through its graduates and the direct transfer of knowledge and research. |

**Figure 3. Institutional structure and administrative level of the institutions involved**




The solid lines represent absolute hierarchical dependence and dotted lines represent partial or indirect dependence. The meaning of the acronyms is presented in **Table 1**, with the exception of FCIEN (Facultad de Ciencias; Faculty of Sciences) and CURE (Centro Universitario de la region Este; University Center of the Eastern Region).

Subsequently, semi-structured individual interviews were conducted to 12 stakeholders from the fields of policy and academia: officials from INUMET (2), MA (3), MGAP (1), SINAE (1), CTM-SG (1), ADME (1), researchers from UDELAR (2) and INIA (1) (**Table 1**). The guiding questions for the interviews are presented in **Table 2**.

**Table 2. Interview questions**

| | |
|---|---|
| 1 | What is the main drought-related problems you identify in Uruguay? |
| 2 | Which of these identified problems are being addressed in your institution? |
| 3 | What are the constraints (if any) to overcoming these identified problems? |
| 4 | What are the opportunities or potential strengths related to drought management that you identify in Uruguay? |

| | |
|---|---|
| 5 | Which of these opportunities/strengths are being (or could be) worked on in your institution? |
| 6 | What are the constraints (if any) to taking advantage of the opportunities or enhancing the strengths that are being addressed in your institution? |
| 7 | Would you be willing to participate in inter-institutional (and interdisciplinary) meetings/workshops to outline solutions to problems (or grasp opportunities)? |

In November 2023, a face-to-face workshop was held with the extended participation of all the institutions involved (21 participants), during which each institution made presentations, followed by a plenary discussion. The keynote theme for the presentations was 'What did Uruguay learn from the 2019-2023 drought?', and participants were asked to share challenges and opportunities for improving drought risk management. Finally, 5 virtual meetings were held from April to September 2024 to jointly develop this paper.

## 2. Results and discussion

### 2.1. Analysis of the emergent problems arising from the drought 2019-2023

In accordance with the problems that have arisen regarding the availability of water in Uruguay, particularly for human consumption, this section describes and analyses the needs to be fulfilled regarding water management, identified as a priority by each institution.

The conformation of an integrated area of intersectoral participation, communication and specialized training (research focused on droughts) were needs expressed by most of the interviewees (**Table 3**).

**Table 3. Needs to be met by each institution in view of the experience gained during the 2020-2023 drought in Uruguay**

| Institution | Division | Integrated Scope | Commu nication | Training | Human Resour ces | Moni toring | Data bases | Protocol |
|---|---|---|---|---|---|---|---|---|
| INUMET[1] | | X | X | X | X | | X | |
| MA[2] | DINACC[2.1] | X | X | X | | | | X |
| | DINAGUA SP[2.2] | X | X | X | X | X | X | X |
| | DINAGUA AS[2.3] | X | X | X | X | X | X | X |
| MGAP[3] | OPYPA[3.1] | X | X | X | X | | | |
| | DR[3.2] | | X | | | | X | |
| SINAE[4] | | X | X | X | X | X | X | X |
| CTM-SG[5] | | | X | X | X | | | |
| ADME[6] | | X | X | X | | | | |
| INIA[7] | | X | | | | X | | |
| UDELAR[8] | FING[8.1] | | | X | X | X | | |
| | FAGRO[8.2] | X | | | | X | | |

[1]INUMET: Uruguayan Institute of Meteorology [2]MA: Ministry of the Environment [2.1]DINACC: National Directorate of Climate Change [2.2]DINAGUA SP: National Water Directorate, Situation and Forecast Room [2.3]DINAGUA AS: National Water Directorate, Groundwater [3]MGAP: Ministry of Livestock, Agriculture and Fisheries [3.1]OPYPA: Office of Agricultural Programming and Policy [3.2]DGDR: General Directorate of Rural Development [4]SINAE: National Emergency System [5] CTM-SG: Salto Grande Joint Technical Commission [6]ADME: Uruguayan Electricity Market Administration [7]INIA: Agricultural Research Institute [8]UDELAR: University of the Republic [8.1]FING: Faculty of Engineering [8.2]FAGRO: Faculty of Agronomy

The demand for an intersectoral sphere of participation and discussion points first to the need for immediate action, which requires knowing the scope of the actions to be taken, as well as the uncertainty associated with the length of time that these actions can be sustained. For example, since the government declared a water emergency in the metropolitan area of Uruguay on 19 June 2023, when there was only enough drinking water for 10 days, the availability of water from the 'Paso Severino' dam, which supplies the population of the metropolitan area with more than 1 million inhabitants, was reported daily. At this point, water quality had decreased substantially (Kruk *et al*., 2025), so the daily report also included recommendations regarding water consumption by vulnerable populations ('hypertensives', patients with kidney disease, pregnant women, etc.). The need for water at the urban level led to the use of wells with water of insufficient quality for use, for example in hospitals. At the rural level, in several places excavations for groundwater were carried out without the necessary authorizations to guarantee the supply, not only to those carrying out the new excavations, but also to those who already had wells as a water supply in the same area.

In this context, the demands on some institutions exceeded their capacity to respond to the situation (DINAGUA, SINAE). On the other hand, the need to involve actors, identify roles and know how to derive recommendations to inform the political system, both in the short and medium-long term, became visible (INUMET, DINACC, DINAGUA-AS, MGAP, SINAE, ADME, INIA, FAGRO; Box 3). The lack of a management plan at the inter-institutional level and a participatory environment to overcome contradictions was revealed (MGAP), as well as the need for an integrated institutional framework to manage drought risk (SINAE). The feasibility of generating climate service projects with a focus on droughts (DINACC) was raised, but given the strict responsibilities attributed to each institution, the initiatives and proposals should come from the other institutions, for example, INUMET, DINAGUA, MGAP or SINAE. In this framework, since the water emergency exceeded the capacities of most of the institutions taken separately, and there was the possibility of generating guidelines through projects with special funding (DINACC), it became clear that there was a need for a formal inter-institutional exchange that would enable medium and long-term actions.

The aspects related to improvements in communication refer both to the in-house level of the institutions (INUMET, DINAGUA, MGAP, CTM-SG) and to the inter-institutional level (INUMET, DINACC, DINAGUA, SINAE, CTM-SG, ADME) (**Table 3**). At the internal level, the need for continuous updating of information was expressed, especially in emergency situations, although it is desirable that such updating be maintained over time (DINAGUA), which is also expressed as the need for a communication plan where those responsible are clearly identified (MGAP). The need to improve communication with users was also identified, for example with those who use water for irrigation (CTM-SG). On the one hand, irrigators need to know if water will be available, and on the other hand, from a water use planning policy, it is necessary to establish priorities, such as water for human consumption in a situation of scarcity, regulating what may or may not be destined for other uses. Regarding inter-agency communication, it was expressed that the dissemination of the information produced (INUMET) is not perceived as relevant by other institutions, since in several instances it was publicly stated that there was not enough information to take more timely measures or with more time, when the information had been opportunely communicated. In this sense, doubts were raised as to whether the current form of communication is efficient (INUMET), and the lack of channels to 'make visible' what is really the problem that could be helped to overcome (DINACC) was acknowledged.

In terms of research and training needs, general aspects related to droughts have been pointed out, such as education in risk and uncertainty management for the reduction of impacts and generation of resilience (DINACC, SINAE, ADME, FING, FAGRO) (**Table 3**). More specific aspects were also expressed, such as the need to deepen the knowledge of surface and groundwater systems in the region, as well as the importance of creating information to calibrate 'low water models' and obtain gauges for droughts (DINAGUA, CTM-SG, FING) (**Table 3**). Most institutions expressed the need to prioritise training in science and technology to find resilient systems that could adapt to current climate variability. These systems should be operational in each sector and be useful every year.

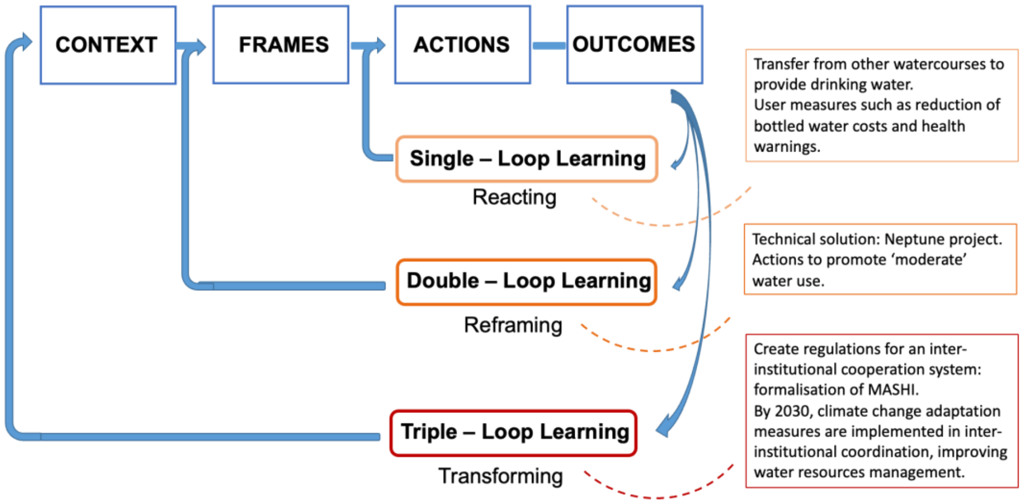
Strengthening the training of human resources, as well as increasing their number, was also repeatedly expressed (INUMET, DINAGUA-SP, DINAGUA-AS, MGAP, SINAE, CTM, FING), not only to face emergency situations (DINAGUA-SP, DINAGUA-AS, SINAE), but also for continuous work and updating (INUMET, DINAGUA-SP, DINAGUA-AS, MGAP, SINAE, CTM) to 'keep the issue alive' (FING). It was also mentioned that there is a need to give a hierarchy to the administrative career, providing opportunities for technical updating and improvements in salaries to ensure the permanence of qualified people in the institutions (DINAGUA-AS).

Regarding the use of information, the need for more 'robust' databases was pointed out (INUMET) and for the computer system to allow automatic checking to generate responses that enable quick decisions, such as knowing who the beneficiaries of emergency policies (MGAP) are. In other institutions, the improvement in the databases is associated with the need to create/increase the monitoring of variables related to agronomic and hydrological drought (INIA, FAGRO, FING, DINAGUA-SP, DINAGUA-AS). In particular, and because of the improved coverage of measurements (monitoring) and their registration (databases), the creation of protocols for action and communication is demanded (DINAGUA-SP, DINAGUA-AS, DINACC).

### 2.2. Social learning and changes in the perception of the problem

The water emergency in Uruguay has shown different vulnerabilities and led to reflection on which aspects to prioritize. The needs identified in the previous item provide insight into the aspects that need to be improved within and among institutions for the 'system' to function in a more coordinated manner. In this section we propose to analyze, from the perspective of collective learning and in a broader way, the responses that have been given and those that are still needed to prevent similar problems in the future, as well as to create environmentally sustainable solutions that ensure resources for future generations. Pahl-Wostl (2009) argues that social or collective learning develops in looped learning cycles (**Figure 4**). Single-loop learning refers to an improvement of action strategies without questioning underlying assumptions. Double-loop learning refers to the revision of those assumptions (e.g. about cause-effect relationships) within a normative framework of values. In triple-loop learning, underlying values and beliefs, different ways of seeing the world and whether assumptions within one type of view no longer hold (**Figure 2**) are rethought.

**Figure 4. Sequences of social learning cycles and applications for integrated management of drinking water management in Uruguay**




Adapted from Pahl Wostl (2009), Lavell *et al*. (2012) and Cruz *et al*. (2018).

Measures related to the first loop consisted of transfers to reservoirs from other watercourses, measures such as lowering the cost of bottled water, health alerts due to water salinity, among other measures typically reactive to the emergency (**Figure 4**). There was also a demand for permanent consultation with INUMET related to short-term rainfall forecasts, although there had been a warning beforehand that the quarterly forecasts indicated a pluviometric deficit. As a result of this crisis, the state entity called Obras Sanitarias del Estado (OSE) began to share daily with DINAGUA the amount of water in the reservoirs ($m^3$) and its equivalence in days of supply to cover the demand for drinking water in the metropolitan area, information that should have been shared routinely before (Cantone *et al*., 2023).

On the other hand, the realization of a project for a new water infrastructure, known as the 'Neptune project', was proposed. In this context, underlying tensions about water privatization in Uruguay resurfaced (Dias *et al*., 2023). The solution proposed by the government appears to be insufficient in the eyes of technical teams from some institutions and civil society (press sources as examples: APU.uy, 2024; Redes, 2023). Firstly, because it does not comply with article 47 of the Constitution in two essential aspects: the absence of participation of users and civil society in the planning and decision-making bodies of the project, as well as the powers ceded in the operation to a private company when the supply of drinking water to the population should be provided exclusively and directly by state legal entities (Parliament of Uruguay, 2004). Secondly, because it was perceived as a solution from 'a past era', in which exclusively technical solutions were accepted as the answer to this kind of problem. It was also suggested from some sectors to learn from the experiences of other countries where moderate water use actions are promoted, as is the case of Chile, where long-standing actions have been taken in this sense.

At this point we are at the second level of social learning (reframing) (**Figure 4**), with longer-term solutions aimed at prevention. As desired solutions, we are approaching the third learning loop, which we are only just entering and where the proposals are related to water governance, with the perspective of achieving an integrated water resource management (**Figure 4**). The agreements must be guaranteed by representative bodies that include, at the very least, all relevant governmental levels.

The SINAE, which was created by law (SINAE, 2009), enables risk management in a broad sense. The experience carried out since 2016 intermittently by this body, where information is shared in the so-called Water Situation Analysis Table (MASHÍ for its Spanish acronym), implies in practice a system of inter-institutional cooperation that did not previously exist. At present, only the ‘Water Situation Monitoring Group’ operates within the MASHÍ, which has met monthly since 2022 and produces a report on the subject, a technical effort that is not usually taken as a reference for high-level political decisions. This inter-institutional coordination effort has been carried out without any specific regulation. In turn, the Minister of Livestock (MGAP) has the power established by law to declare an agricultural emergency based on the advice of an Agricultural Emergency Commission (created by Article 4 of Decree Nº 829/008). To this end, a specific fund (Agricultural Emergency Fund, FAE for its Spanish acronym) (IMPO, 2008) has been created to deal with agricultural emergencies, including those related to water deficit events (an agricultural emergency is defined as one arising from extreme climatic, sanitary or phytosanitary events that decisively affect the viability of producers in a region or sector).

In this context, it is deemed necessary to make the regulatory framework, attributions, resources and responsibilities compatible in terms of integrated drought risk management, given that SINAE has the mandate of a comprehensive approach to articulate resources, capacities and synergies of the State as a whole. Overlapping functions, ambiguities in legislation, lack of political support and inadequate stakeholder participation are key barriers to integrated water resource management (Ray *et al*.; 2022). As Smith and Stirling (2010) argue, learning in this case would only lead to transformation if linked to formal policy processes.

As adaptation measures after the 2019-2023 drought and at the moment in process, DINACC together with other institutions such as DINAGUA have proposed several options for 2030 within the framework of international agreements on water resources, which would also be placed in the third social learning loop (**Figure 2**). The aim is to visualize adaptation needs, challenges and priorities, both to recognize national progress and to put potential projects or studies on the agenda. These measures consist of the implementation of six integrated watershed management plans; implementation of water safety plans in 15 drinking water systems and at least two sanitation safety plans in two localities in the hinterland; and the availability of technologies and procedures to prevent, detect and reduce the effects of algal blooms in priority areas. Other, more cross-cutting measures, for example, the generation and implementation of climate services through co-production processes (Cantone *et al*., 2023; Hidalgo & Natenzon, 2014) are important for the integration of knowledge and the development of innovative approaches.

Another important aspect related to learning is the change in perceptions of the problem and, consequently, the actions to be taken, which generally include the provision/use of climate services (Muller *et al*., 2024; van Valkengoed *et al*., 2022; Cruz *et al*., 2021).

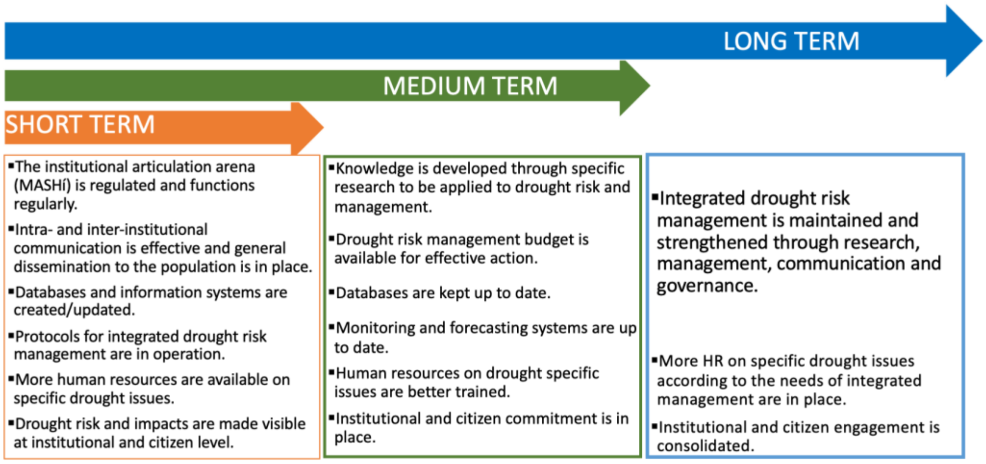
According to Muller *et al*. (2024), most of the literature on climate services reports that climate services provide behavioural responses, i.e. based on the implementation or development of plans, policies or programs. So far, perceptions and attitudes have been considered mostly unconnected to climate services, although an individual's response has an impact not only on him/herself (internal impact), but also on other individuals and their environment (external impact). **Figure 4** illustrates different responses according to learning loops. These 'operational' responses reflect changes in perception, creating feedback that influence climate service design and decision-making. The way users respond to drought situations may affect drought hazard, vulnerability and impacts, as evidenced through questioning of the Neptune project in Uruguay (**Figure 4**). Human activities, together with climate variability, affect various hydrological processes and, in turn, the spread of droughts (IPCC, 2021). As the predominant form of climate services are forecasts, early warnings and tailored sectoral tools and information, it is envisioned that further development of climate services would require moving from the provision of climate data to the provision of information on how climate or weather information relates to users' decision spaces (Muller *et al*., 2024). This shift in improving climate services implies that in addition to providing timely, science based and tailored information on climate, weather, or water issues, training is provided on how to use both data and tools, enhancing at the same time the understanding of how they are used and how (if so) they change users' perceptions, behaviour and actions.

### 2.3. Steps for integrated drought risk management

As mentioned in the Introduction, in the case of Uruguay, the energy sector can be considered an example from which to learn, since the changes made in recent decades have made it possible to reduce the impacts of the last water crisis.

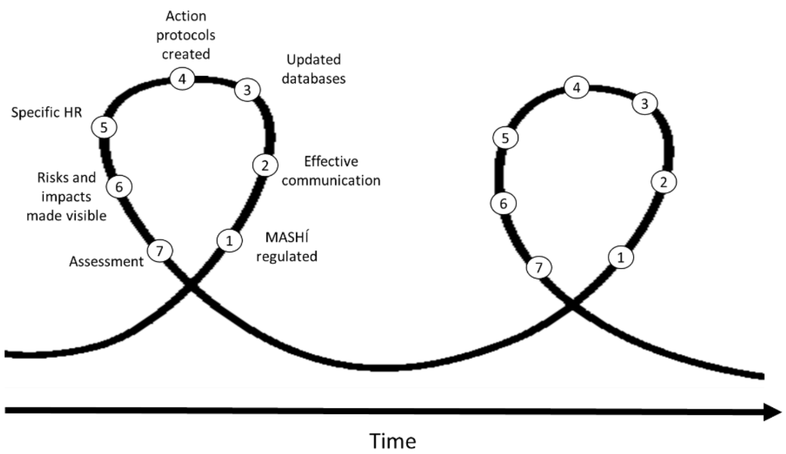
The Uruguayan energy sector has successfully adapted to droughts by incorporating wind and solar energy sources into the energy matrix, mostly hydroelectric. At the same time, a new management figure (ADME) was created by law in 1997 and subsequently regulated (IMPO, 2000). This process, which took several years, allowed for an adjusted energy risk management, in which updated information on prices, rainfall, availability of wind sources and algorithms specifically designed to reduce uncertainty are used to forecast sufficiently in advance the availability of energy supply for the population. The creation of this management figure also made it possible to overcome the difficulties in obtaining updated information from the National Administration of Power Plants and Electric Transmissions (UTE, for its Spanish acronym), a state entity with similar characteristics to OSE for the case of water. During the last drought, it was still possible to export energy to Argentina and Brazil, in contrast to what happened in the urban-rural drought of 1988-1989. However, the current water issue presents a greater challenge, since being water treated as a human resource enshrined in the Uruguayan Constitution, the cost of improvements in the water supply system it cannot be passed on to the consumer, like in the case of energy.

**Figure 5. Expected results in the short, medium and long term to prevent negative impacts of droughts in Uruguay**




The formalization of the MASHÍ, identified as the only area of intersectoral participation in practice, is included as the first expected result for the short term (1 to 2 years) (**Figure 5**). The need to have and strengthen a regularly functioning intersectoral dialogue space (Wilhite, 1996) was the need expressed almost unanimously by the institutions involved (**Table 3**), visualized in turn within the third learning loop (**Figure 4**). Although Motsumi *et al*. (2023) claim that cross-sectoral collaboration platforms alone are not enough, since other aspects (capacity support, individual interests and leadership) need to be covered, the formalization of MASHÍ is considered a fundamental step for integrated drought risk management in Uruguay. From that space, it will subsequently be possible to move towards new forms of governance that effectively involve local stakeholders in decision-making with a systemic perspective (Hagenlocher *et al*., 2023). The MASHÍ can promote the generation of dialogues that make it possible to learn about sources of funding, prioritize the collaborative use of these funds and coordinate the relevant actions, in addition to keeping all institutions updated on the status of water resources. Also from this area, agreed guidelines can be drawn for effective communication (Wilhite, 1996), both at the institutional level and directed towards a general audience, as well as identifying the places where the incorporation of human resources is urgent (**Figure 5**) in response to needs that have been repeatedly expressed (**Table 3**). In addition, it is underlined the importance to cover the needs related to monitoring, the creation of protocols and the elaboration/maintenance of databases (**Figure 5**), although these aspects have been specifically requested by the Ministries of Environment and Agriculture and by the research institutes (INIA and UDELAR) (**Table 3**). **Figure 6** shows the evolution of these aspects as processes, including an evaluation stage as a form of feedback for continuous improvement.

**Figure 6. Steps required to achieve short-term results to prevent negative impacts of droughts in Uruguay**




In the medium term (5 years), it is understood that the actions previously undertaken in the short term will be maintained and actions will have been taken to incorporate new improvements to the management system (Wilhite, 1996), such as the provision of funds and the creation of specific knowledge to be applied to drought risk management (**Figure 5**). It is also understood that the iterativity of the science-politics dialogue is maintained (Carbajal & Hidalgo, 2022; Lemos & Morehouse, 2005). Within this timeframe, and perhaps optimistically, changes in problem perception, communication and knowledge creation (research) will have taken place, all of which were important for improvements in the energy sector. It is also likely that changes in water governance will deepen, depending on the evaluation of the processes so far (this evolution can be depicted as in **Figure 6** but noting the specific steps for the medium and long term). As indicated above, the MASHÍ will be a platform from which new arrangements can be identified to strengthen an integrated water management system (Motsumi *et al.*, 2023).

According to Hagenlocher *et al*. (2023), drought risk assessment is still in its infancy compared to that of other weather and climate hazards, mainly due to the complexity of drought, the high level of uncertainties in its analysis and the lack of community agreement to address the problem. In this regard, it is considered that to realize an effective management system for these risks in practice, sectoral interdependencies, feedback and potential networked risks need to be understood. For this reason, it is suggested that it will take longer to strengthen the system (long term, tentatively set at 10 years) and will require the incorporation/updating of technology and human resources to enable continuous improvement of the management system (Wilhite, 1996), as well as maintaining institutional and citizen commitment (**Figure 5**).

## Conclusions

Through a process of co-production of knowledge, this article analyses the case of Uruguay in relation to the drinking water issue in the context of the drought that affected the southern region of South America in the period 2019-2023. It is concluded that there are currently no sufficient mechanisms in place to deal with future droughts such as the one experienced in that period. Strategies aimed at comprehensive drought risk management are outlined below.

Improvements in governance, starting with the formalization of an integrated arena for intersectoral participation, as well as in communication and targeted research in water resources to find resilient systems that could adapt to current climate variability, were identified as the most important needs to be covered, according to the questions to be answered in this article. The development of climate services to avoid new crises in the supply of drinking water to the population is considered urgent. The social learning approach is seen as an appropriate approach to do this in an interinstitutional agreed manner, as well as to coordinate preventive actions. At the same time, the actions to be taken and the development of climate services should incorporate into the political system the recognition of changed perceptions of the problem on the part of civil society, to reconcile possible solutions. Taking advantage of the work of science-policy co-production, sustaining it over time, and involving civil society in its demands, would be key to generating political commitments for a structural change in regulatory frameworks and management practices around water.

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