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Strengthening Türkiye's drought management: insights from international practices (Netherlands, UK and USA)

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This paper provides an examination of drought management strategies in three countries: the Netherlands, the United Kingdom (UK), and the United States of America (USA). Additionally, it includes an evaluation of Türkiye's approaches to water management and drought mitigation. Despite differing geographic, economic, and political conditions, these countries face similar challenges in drought management. Their approaches to dealing with drought have been examined from various perspectives, including institutional structures, legal frameworks, and operational strategies, with a focus on water allocation priorities, stakeholder collaboration, and the utilization of monitoring tools and data. The case studies revealed insights and experiences that can be used to evaluate and improve Türkiye's existing water management and drought mitigation strategies. By drawing on the experiences of top-performing nations in drought management, this paper provides insights for creating a strong and sustainable water management for Türkiye, effectively tackling the challenges posed by climate change and ensuring the long-term security of water resources.

KEYWORDS

best practices, climate, drought, policy, water management

1 Introduction

Water is a fundamental part of life in any society, vital for people's health and well-being, agriculture, businesses, and the environment. Water use patterns change daily, seasonally, and annually. Water resource levels and water use in different parts of any country can be affected by various factors, such as normal variations in rainfall that affect river flows used for abstraction, changes in reservoir and aquifer levels due to recharge or drawdown, and changes in the amount of irrigation needed for commercial crops or the maintenance of private and public gardens during periods of hot weather. Maintaining water needs for drinking, industrial, agricultural, and other usages are expected to be one of the most important challenges for societies, as is already apparent in some parts of the world (Bensoussan and Farhi, 2010). The intensification of the hydrological cycle due to human-induced climate change has a significant impact on water security, worsening existing vulnerabilities caused by various socioeconomic factors. This leads to increased risks of floods and droughts, and greater stress on water resources locally and regionally, even under low emission scenarios (Caretta et al., 2022).

Climate change puts established patterns of resource management and usage at risk because of long-run and often gradual trends in overall temperatures and rainfall patterns and changes in the frequency or intensity of extreme events such as flooding and drought (Sheridan and Allen, 2015). Managing these changes can be more difficult if other trends, such as those in population levels or demographics, need incorporation into planning. Public

health emergencies, like pandemics, may complicate matters even further. With increased vulnerability, changes in climate such as more intense and frequent storms, heatwaves, and sea-level rise could increase any stress on both society and the environment (Cissé et al., 2022). Climate change also alters the timing of water availability and makes some regions drier. Increases in evaporation with warmer temperatures reduce surface water and dry out soil and vegetation. In addition, warming in the winter months causes less rainfall than snow. Therefore, all these are linked and contribute to drought and put some places where droughts are expected to get more frequent, severe, and longer lasting at higher risk (Caretta et al., 2022).

Climate change and other global changes such as land-use changes, deforestation, urban sprawl, and impermeable surfaces have been linked to alterations in the hydrological cycle, atmospheric water content, and precipitation patterns. In Chapter 4 "Water" of IPCC AR6, it is stated that the intensification of the hydrological cycle due to human-induced climate change has a significant impact on water security, worsening existing vulnerabilities caused by various socioeconomic factors. This leads to increased risks of floods and droughts and greater stress on water resources locally and regionally, even under low-emission scenarios (Arnell, 1999; Bates et al., 2008; Delpla et al., 2009; Rockström et al., 2009; Allan, 2011; Giorgi et al., 2011; Watts et al., 2015; Caretta et al., 2022).

Considering Türkiye's location in the Mediterranean region, the report also highlights that "droughts have become more frequent and intense, especially in the north Mediterranean (high confidence)." This emphasis the urgency of addressing water resource challenges in Türkiye, as projected climate impacts are likely to exacerbate existing pressures.

1.1 A challenge: drought in Türkiye

Türkiye has a remarkable diversity of climate classifications, with four main categories (Tropical, Arid, Temperate, and Cold) and numerous sub-classifications, as shown in Figure 1. This climatic heterogeneity reflects the highly variable weather and climate characteristics across the country, even within its relatively limited geographic area. Coupled with an irregular spatial and temporal distribution of precipitation, these variations present significant challenges to water resource management and climate adaptation strategies. Moreover, projections indicate that the frequency and intensity of droughts are likely to increase across the Mediterranean region as a consequence of climate change (Ali et al., 2022). Given these projections, it appears increasingly probable that Türkiye's vulnerability to drought will escalate in the future, exacerbating risks to agriculture, water resources, and overall socio-economic stability.

Summer droughts in Türkiye occur annually in regions outside of the Black Sea, northern Marmara, and northeastern Anatolia as a result of the natural characteristics of the broad subtropical Mediterranean climate (Türkes, 2012; Türkeş and Altan, 2013). Meteorological, agricultural, and hydrological drought events can occur in any place and season. Since the early 1970s, droughts have been occurring more frequently and with greater severity. While not entirely exhaustive, there were significant instances of widespread droughts in the years 1928, 1973, 1989, 1990, 1993, 1999, 2000, 2008, 2013/14, and 2020/21/22. For instance, in 2008, Türkiye experienced its lowest recorded rainfall since 1974, with a total precipitation of 451.6 mm, and the 2008 drought in Ankara, the capital of Türkiye, resulted in a notable decrease in reservoir water levels to 3.8%,

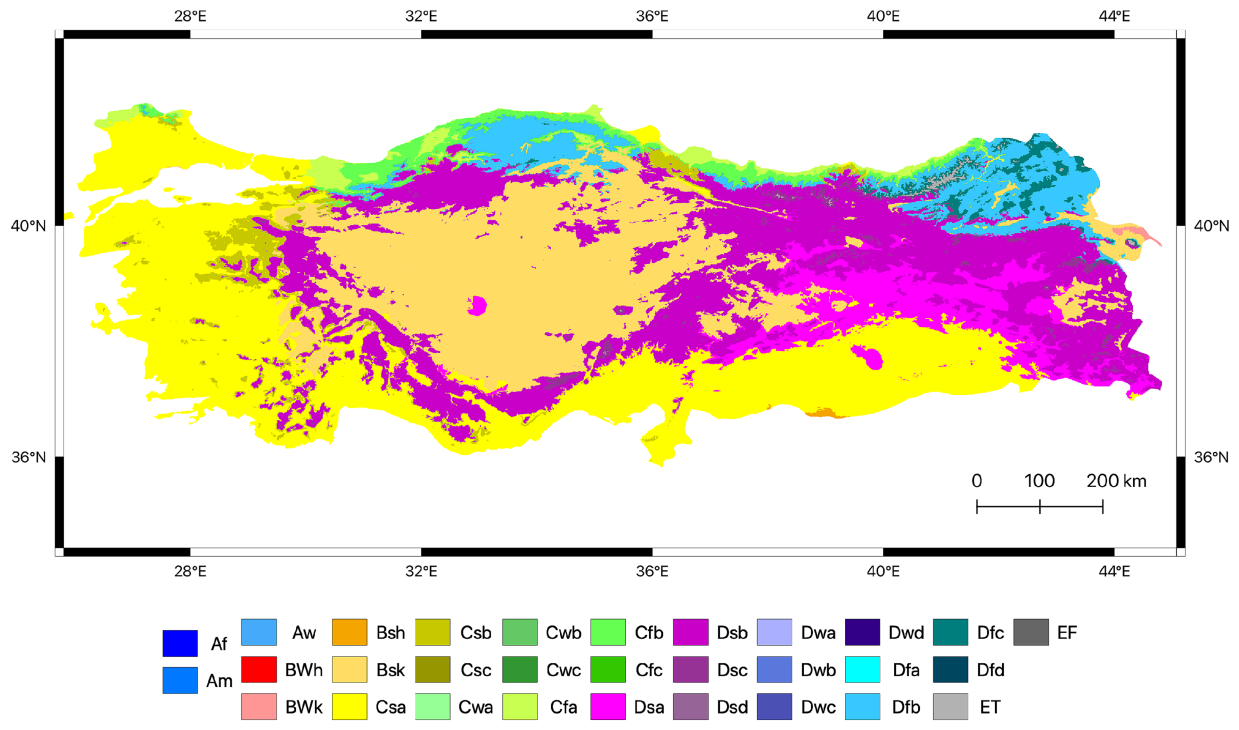

FIGURE 1
Köppen-Geiger classifications in Türkiye (adopted from Beck et al., 2018). The first capital letters of the colour scheme indicate five main climate groups: Tropical (A), Arid (B), Temperate (C), Cold (D), and Polar (E). The details of colour classification are given by Peel et al. (2007).

leading to a serious scarcity of drinking water (MoAF, 2017; TSMS, 2024a).

Regionally, the longest uninterrupted drought in Türkiye occurred between 1985 and 1994, lasting for 10 years in the Aegean and Southeastern Anatolia regions. In the Black Sea region, a drought period lasted 7 years from 1980 to 1986. The Central Anatolia region experienced a 6-year drought from 2003 to 2008, while the Mediterranean region faced a 6-year drought from 1989 to 1994. The Marmara region endured a 4-year drought from 1987 to 1990, and the Eastern Anatolia region saw a 3-year drought from 1972 to 1974. A nationwide drought affected Türkiye from 1989 to 1994, lasting 6 years (Simsek, 2010). According to Cebeci et al. (2019), considering the climate and geographical conditions, the very dry areas in Türkiye are particularly prominent in the Southeastern Anatolia region and large parts of the Aegean and Mediterranean regions. Since 2000, the spatial extent of drought in Türkiye has increased by 1.80%.

The most recent severe drought occurred in 2007, with the 2006–2007 agricultural year being the fifth driest period since 1970 (Çakmak and Gökalp, 2013; Akbaş, 2015). Severe drought conditions were particularly notable in the Central Anatolia, Aegean, and Marmara regions. During the 2006–2007 agricultural year, the most significant decrease in rainfall compared to the average was observed in the Aegean region at 44%. This was followed by decreases of 33% in Marmara, 22% in Central Anatolia, 14% in the Mediterranean, and 8% in Southeastern Anatolia.

To mitigate the damages caused by drought, the Turkish Agricultural Insurance Pool (TARSIM) has allocated substantial financial resources in recent years. Specifically, in 2021, TARSIM provided 222 million TL to address drought-related damages, and this amount increased to 366 million TL in 2022 (TARSIM, 2022). These financial commitments emphasize the significant economic challenges that drought conditions impose on the agricultural sector, necessitating considerable investments in damage control and mitigation efforts.

The review study by Soylu Pekpostalci et al. (2023) indicates that the majority of approaches used to analyze and predict drought occurrences in Türkiye focus on the assessment and forecasting of meteorological drought. A growing trend in the application of machine learning for short-term meteorological and hydrological drought forecasting has been noted. However, new remote sensing technologies and satellite-based indicators have been rarely used in Türkiye. The review emphasizes the necessity for additional research on the monitoring, forecasting, and pattern recognition of agricultural and hydrological droughts in Türkiye. Research indicates that drought occurrences of variable intensities emerge throughout diverse regions of Türkiye, and that drought poses an important risk to the nation's sustainable development. Recent studies on drought monitoring and forecasting have predominantly concentrated on meteorological drought, subsequently addressing hydrological drought. The Standardized Precipitation Index (SPI) received the greatest attention among other indices. This finding aligns with prior review studies, which demonstrate that SPI is the predominant index used by worldwide drought modelers. Although some research has focused on agricultural drought, no investigations of socioeconomic and ecological droughts have been identified in the last two decades. Consequently, it is emphasized that research should more thoroughly assess socioeconomic and ecological droughts throughout Türkiye.

1.2 Insights from international practices

All countries, except Iran, Eritrea, Libya, and Yemen, have differentiated but common responsibilities such as reducing emissions, publishing nationally determined contributions, financing and leading climate-related activities and projects, especially after adopting the Paris Agreement. Many economically and scientifically advanced countries are at the forefront of climate policies, especially in addressing water management issues. The Netherlands, the United Kingdom, and the United States are exemplary leaders in this regard, leveraging their industrial and technological expertise alongside their significant business and political influence globally. These countries were selected for their proven expertise and effectiveness in climate and drought management, serving as benchmarks for developing drought management strategies in Türkiye.

In the process of selecting countries for this study, the following steps were carefully followed. The methodology is structured in a stepwise process, as shown in Figure 2. The study begins with Case Country Selection, where candidate countries are evaluated based on criteria such as comprehensive climate policies, scientific expertise, data availability, effective tools, and comparable challenges to Türkiye. This is followed by an analysis of the nature and impacts of climate change in these countries, focusing on its effects on water resources. Subsequently, the research examines their policies and regulations related to water management, with a particular emphasis on drought management strategies. The study then identifies tools and technologies applicable to managing water resources under climate change, culminating in the development of a framework of tools and approaches for effective drought management. Finally, the findings are integrated into actionable recommendations for strengthening drought management in Türkiye, drawing on insights and best practices from the case countries.

All the aforementioned factors played a role in selecting these countries for this research, but the most current report from the United Kingdom's Climate Change Risk Assessment also analysed at reports from other countries to identify new methods and evaluate how they worked in national risk assessments, which focused on two countries (the United States and the Netherlands).

In the Netherlands, recent years have seen significant wet and dry weather. While the country generally focuses on flood prevention, the 2018–2020 and 2022 droughts have put pressure on its water management system, making it more vulnerable to drought. These droughts affected nature, agriculture, electricity, navigation, and water supply. In response to the drought effects, political actions have increased, and the Dutch government has developed a vision to encourage water and land to become a more dominant factor in spatial planning. Furthermore, a new policy titled "Water and soil leading in land use planning" has been announced. This policy aims to make the Netherlands more resilient to hydrological extremes. Overall, it is stated that the Netherlands needs significant changes in both water management and governance to cope with the impacts of climate change (Bartholomeus et al., 2023).

In the UK, Environment Agency has recently completed a review project titled "the review of the research and scientific understanding of drought." This review synthesizes the existing body of knowledge on drought and its impacts, offering an overview of our current understanding while identifying key gaps in the field. The review

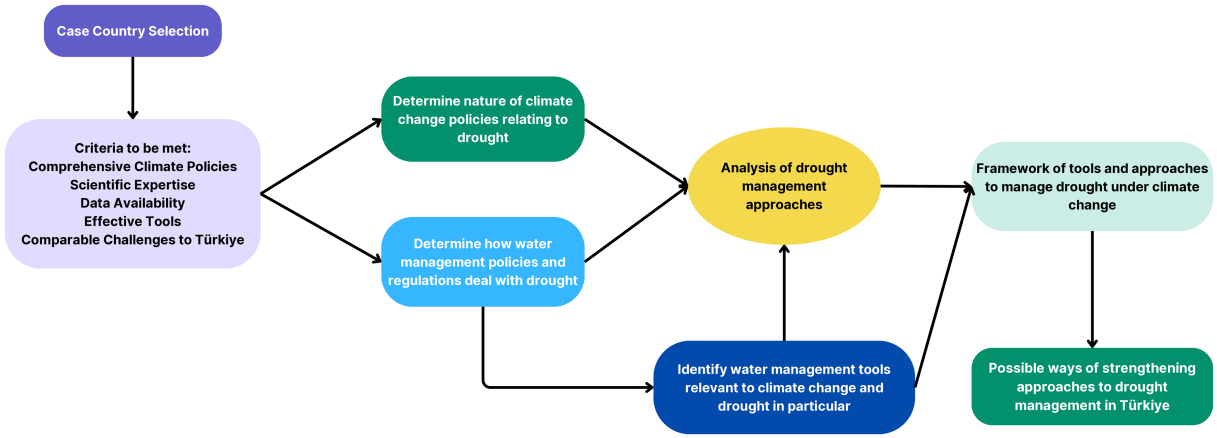

FIGURE 2
Methodological framework for strengthening Türkiye's drought management.

highlights several critical areas requiring further exploration, including the evolving nature of drought, advancements in modeling, monitoring, and data recovery, catchment processes and dynamics, as well as the development and conclusion of drought events. Additionally, it emphasizes the importance of viewing drought as a social construct, examining its impacts and interactions, and understanding the vulnerability and resilience of affected systems (Environment Agency, 2023).

In the USA, the onset speeds of current rapid droughts are comparable to or exceed those of the most rapidly evolving droughts of the past 70 years. These rapidly progressing drought occurrences challenge the conventional understanding of drought, and the strategies employed to address it. The emergence of rapidly progressing droughts has challenged forecasting and intervention skills. A trend toward an increase in the rate of rapid drought onset has been observed in a significant portion of the United States, particularly since 1985. Rapidly developing droughts may have unpredictable impacts, as drought affects various socio-environmental processes, and the progression from meteorological to hydrological, agricultural, socio-economic, and ecological drought is complex. Therefore, agricultural and water resource systems are particularly vulnerable to droughts, especially those with little to no early warning (Iglesias et al., 2022).

In the following sections, the policy mechanisms of the Netherlands, UK, USA, and Türkiye will be assessed, with a particular focus on how these countries address management for the impacts of drought.

2 National policies: water management and drought

2.1 Netherlands

Since the 2000s, the Netherlands has taken several concrete measures to combat climate change. The National Climate Adaptation Strategy (NAS) and the Delta Programme (DP) share common goals for climate adaptation. Adopted in 2012, the Delta Act ensures the Netherlands is safeguarded from flooding, well-prepared for extreme climate effects, and secures its freshwater resources. The Climate Plan, the National Energy and Climate Plan (NECP) and the National Climate Agreement contain the policies and measures to achieve climate goals. To deal with the impacts of climate change—in terms of mitigation, the Dutch government set targets (*Climate Act 253 – Article 2–1*) to *reduce the Netherlands' greenhouse gas emissions by 49% by 2030*, compared to 1990 levels, and *a 95% reduction by 2050* (The Netherlands, 2019, 2022).

2.1.1 Water management: drought

In the Netherlands, drought can be defined as *a lack of precipitation*, a decline in river flow, or both. In governmental reports (National Adaptation Strategy etc.), there is no specific explanation of drought as a natural hazard (except in some publications (van Lanen et al., 2018a, 2018b; Wolters et al., 2018; Mens et al., 2022) in which authors from ministries and Dutch universities) that simultaneously raises water demand and decreases water supply for humans, ecosystems, and economic sectors.

Due to not defining drought as a natural disaster and the Netherlands' history of drought, rather than being treated as a separate entity, drought management in the Netherlands is embedded within a larger, more complex water management regime that addresses both floods and droughts (ensuring freshwater supply and availability etc.). This more complex water management approach can be seen in the Delta Programme, National Water Plan, National Adaptation Strategy, and Climate Plan.

The UVW (2011) establishes specific agreements for the allocation of responsibilities for different aspects of water management. Netherlands' water is managed by the Rijkswaterstaat (the executive branch of the Ministry of Infrastructure and Water Management), responsible for the management of the major waters and district water boards, responsible for regional waters, such as canals and polder waterways. In addition, the central government, provinces, municipalities, and water boards are responsible for managing water issues, and it is seen that effective and better management relies heavily on collaboration among these entities (NWP, 2015).

During droughts, there is a hierarchy of water allocation depending on priority: four different water allocation categories with

national priority ranking in the Netherlands (Andreu et al., 2015). During times of drought, the highest priority (*Category 1*) is given to ensuring the safety of people and preventing permanent damage to infrastructure. The next priority (*Category 2*) is providing drinking water and generating electricity, ensuring adequate river water for cooling purposes. Agricultural, recreational, and fishing uses (*Category 3*) follow, with smaller-scale and higher-quality applications such as process water (*Category 4*) being the lowest priority. Every 2 weeks during a drought, the authorities responsible for the water system and its consumers come together to address any emerging issues and devise potential solutions. Drought management measures in the Netherlands has been widely accepted by water suppliers and customers (Wolters et al., 2018).

The Water Management Centrum Nederland (WMCN) has the responsibility to provide knowledge and information about the Dutch water system and operate the 'Helpdesk Water' service aiming to respond to questions from involved parties in water policy, water management, and water safety issues in the Netherlands. When extreme weather events hit the Netherlands, the Dutch government convened a national coordination committee to handle the situation. There are three national coordination committees: one each for flood, drought, and pollution. The Committee for Water Distribution (LCW) steps in when there is an excess demand for water due to conditions like extended drought and low river flows.

The Netherlands' future water strategy is detailed in the National Water Plan, which focuses on all water systems, including surface water, groundwater, and other water sources. This plan outlines the procedures necessary to ensure the future safety of the ducts' water system and the population (PBL, 2016). Several pieces of legislation, such as the Water Act, Water Management Act, and Surface Waters Pollution Act, deal with water-related matters in the Netherlands.

2.1.2 National Water Plan and Delta Programme

The Netherlands' water management plan consists of two main efforts: the National Water Plan and the Delta Programme. These initiatives are designed to address the country's water-related difficulties and ensure long-term sustainability and resilience.

2.1.2.1 National Water Plan

Based on the Dutch Water Act, a National Water Plan is adopted by the Minister of Infrastructure and Water Management (IenW), the Minister for Nature and Nitrogen Policy (NenS), and the Minister for Housing and Spatial Planning (VRO) every six-year cycle. For the same time frame, the federal government creates a plan for the management and development of national waters. These two initiatives have been combined into one programme called the National Water Programme 2022–2027 (NWP), published in 2022 (in Dutch). Adaptation to a changing climate, food risk management, freshwater and water distribution, water quality and nature, shipping, and specified uses of national waterways, including drinking water and water recreation, are major themes in the NWP. The main components of the National Water Plan (2016–2022) include flood risk management, freshwater, water quality, area-based assessment, water and environment, and financing.

Water management in the Netherlands is a shared responsibility among the central government, provinces, municipalities, and water boards. The central government is responsible for the main water system, outlines water management policies, and sets strategic objectives. The Management and Development Plan for the National Waters (Bprw) outlines the operational management procedures and necessary actions required to accomplish its strategic goals. However, a lack of coordination between the central government and local bodies needs to be considered for any type of disruptions in water management practices. The importance of cooperation in management was also highlighted in the evaluation of the NAS report published in 2023.

Protecting and managing freshwater resources are important parts of the Dutch economy and society, as 16% of the economy depends on an adequate freshwater supply. Due to climate change, salinization, and socio-economic developments (population growth and economic expansion), the demand for freshwater is increasing, and the risk of water scarcity is rising. In the National Water Plan, the freshwater section aims to secure supplies in areas from the main water system, which includes 'supply level' indicating the availability of freshwater and the probability of water shortages in a certain area under both normal and dry conditions. To address this, smart water management is essential, involving collaboration among water managers who utilize up-to-date, shared information. This approach improves the balance between supply and demand during water shortages. The report indicates that the present Delta Plan on Freshwater is sufficient to sustain the supply to regional systems, as determined by the freshwater stress test. However, it is important to consider the report's emphasis on the phrase "*Even now there is sometimes insufficient freshwater to meet demand*." In addition to this emphasis, the reaction paper to National Water Programme 2022–2027 highlights the importance of freshwater for the operation of the water system and its related uses, such as agriculture and nature. The availability of fresh water is no longer a given, as droughts during the summers of 2018 onwards have made some restrictions on water usage series in some areas. In the reaction paper, several organizations' users want the central government to pay attention to these issues and take further steps in specific areas to ensure a reliable freshwater supply.

The efficiency of the water management organizations, the adequacy of freshwater management strategies, the flexibility of area-based water management approaches, and the implementation ability of policies that strengthen the relationship between water and the environment are important parts of the success of NWP. This has also been reported in other detailed reports such as the Delta Programme and the National Water Programme, and efforts have been made to ensure more effective management.

2.1.2.2 Delta Programme

The Delta Programme is an initiative of the central government, provinces, municipalities, and district water boards of the Netherlands as a comprehensive plan to improve the water management policies of the Netherlands and to create a resilient system against climate change. Drought, one of the Programme's focus points, is critically important in terms of the sustainability of water resources and agricultural and ecological balances (Delta Programme, 2018).

The 2024 National Delta Programme published in September 2023 with the theme "Now for the Future" includes recommendations on spatial planning, public engagement, making more clear short-term choices, building bridges between partners, and regional implementations. The Programme includes various strategies for water management, including water conservation, increasing water storage capacity, and managing groundwater resources, and aims to

promote the efficient use of water and minimize water shortages during drought periods.

It encourages active participation of citizens in climate adaptation efforts. Since citizens directly experience the impacts of climate change, it is important for them to be informed about and involved in the measures being taken. By increasing public participation and resilience, the effectiveness and acceptability of the measures being implemented are enhanced.

The Programme recommends selecting clearer and more definitive short-term goals. This implies that while developing long-term solutions, short-term objectives should not be neglected. Especially in water management and spatial planning, making correct decisions in the short term can help prevent future problems. In this context, protecting groundwater, increasing water storage capacities, and promoting the efficient use of water are critical measures.

With the goal of making the Netherlands more liveable by 2050 and beyond, the Programme develops comprehensive strategies for combating climate change and managing water resources. While the Programme focuses on long-term planning, it also aims to provide actionable solutions in the short term. Key areas include spatial planning, economic use of water, and adjusting land use based on water availability.

While technology plays a significant role in water management and combating drought, it is not sufficient on its own. It is noted that public participation and awareness are crucial for the successful implementation of measures. Therefore, the Delta Programme is about to focus on concrete steps to change citizens' water usage habits and ensure the involvement of all segments of society in these processes, which is also mentioned in the letter to the Cabinet while presenting the report.

New data collection and cooperation with other countries are necessary for managing transboundary waters. This is crucial for the management of international river systems and the sustainable use of water resources. The Programme seeks to collaborate with neighbouring countries on the management of transboundary waters, aiming to protect water resources and establish resilient systems against climate change.

The Programme also mentioned the commitments and administrative structures and the fact that effective functioning of administrative structures at both national and local levels is necessary. The Programme plans to invest around 800 million euros in water management and drought mitigation. This investment will be used in areas such as increasing water storage capacities, promoting efficient water use, and spatial adaptation to ensure the sustainability of water resources.

The Programme also emphasizes the importance of increasing water supply while dealing with increased water demand and challenges by climate change—more frequent drought etc., and the importance of regional planning and different approaches. Since each region has unique characteristics and needs, regional differences should be considered in water management and climate adaptation efforts. The Programme also emphasizes integrated river management and discharge distribution. Integrated approaches are adopted for the effective management of river systems and the protection of water resources.

The Freshwater Delta Plan is a two-phase plan covering the periods 2015–2021 and 2022–2027. In the first phase, 51 measures were implemented, and the details of these measures are available in the Dutch version report of 'Freshwater Delta Plan phase 1' (Delta Programme, 2024). In the second phase, these measures are expected to increase for ensuring more effective and efficient water use. This includes the use of treated wastewater as an alternative, increasing the water retention capacity of sandy areas, and working on agriculture.

The Delta Programme offers comprehensive and integrated strategies for drought management. Significant steps are taken in setting clear short-term goals, involving citizens in adaptation efforts, and enhancing international cooperation. These strategies aim to ensure the sustainable use of water resources in the Netherlands and create a resilient system against climate change. Successful implementation of the Programme requires the participation and awareness of all segments of society.

2.1.3 Additional tools for water management

The Netherlands employs many specific instruments to improve its water management capabilities, in addition to detailed plans and policies. These tools offer essential data and insights, facilitating effective decision-making and proactive management of water resources. These tools can be listed as follows:

2.1.3.1 Drought Monitor and the Drought Portal

The Drought Monitor and the Drought Portal[1] is a product of the National Water Distribution Coordination Committee of the Water Management Centre Netherlands (WMCN-LCW) with contributions from other parties (such as the water boards, Rijkswaterstaat, the KNMI, and the provinces). It is only available in Dutch, but the portal contains the necessary information for drought management like precipitation, evaporation, groundwater, soil moisture, surface water, water quality, and long-term expectations (Rijkswaterstaat, 2022).

2.1.3.2 Climate Impact Atlas

Based on national data, the Climate Impact Atlas gives an overview of the (future) flood, waterlogging, drought, and heat risks in your region and indicates the order of magnitude of the potential impact. The Climate Damage Atlas predicts the damage that will be caused by flooding, extreme heat, and drought in the Netherlands between 2018 and 2050. Damages from heat-related hospitalizations and structural damage from flooding are only two examples of what this programme might predict for city residents in general. The programme also shows the residual risk of flooding in the principal water system.

2.1.3.3 NAS Adaptation Tool

The effects of climate change are illustrated in four different types of diagrams in the NAS (2016). The NAS conceptual diagrams (conceptual maps) provide a visual synthesis of the current scientific understanding of the direct and indirect implications of rising temperatures, precipitation, drought, and sea levels.

NAS Adaptation Tool was released in 2018 to let users create their own conceptual diagrams to better understand the potential benefits and threats that climate change poses to their specific challenges or areas of expertise (The Knowledge Portal, 2022). In addition, there are

1 https://droogteportaal.nl

other tools developed by the government and other parties available in the Knowledge Portal, helping the Netherlands become more climate- and water-resilient.

2.2 United Kingdom

The United Kingdom is the first country having a legally binding long-term framework to cut carbon emissions with the series of climate risk assessments for the current conditions and over the long term by 2100 (Brisley et al., 2012). Reducing greenhouse gas emissions by at least 80% lower than the 1990 baseline by 2050 was introduced in the Climate Change Act 2008; however, with the amendment of the target for 2050 (in 2019), the UK set the targets for *achieving net-zero emissions by 2050* (2008 c.27/1(1)).

2.2.1 Water management: drought

According to the UK Environment Agency (2017), a drought occurs when "*a period of low rainfall leads to a water scarcity*" and is defined as follows (Environment Agency, 2017):

- Drought is a *natural weather event.*
- Drought is a *natural hazard* for people, water companies and the government.
- A drought is a *natural event that we cannot prevent*.

The United Kingdom has a well-established framework for long-term drought and water resource management. There are other additional governance systems in place, and there are numerous crucial actors and procedures engaged in the management of drought (Hannaford et al., 2019). The European Environment Agency classifies the United Kingdom as a water-stressed nation as its sensitivity to drought hazard has exceeded the alert threshold (20%) on the Water Exploitation Index (water abstraction as a proportion of the freshwater resource) (Visser-Quinn et al., 2021).

During the second cycle of CCRA, drought risks (including water supply etc.) were identified as follows (Kovats and Osborn, 2016): PB14: Risk of household water supply interruptions—Climate change may create conditions that favour the development of droughts. Temporary use bans may become more common. There are large uncertainties related to the future incidence of droughts and the capacity of water companies to address them.

In the latest report (CCRA3), it is identified that global warming is expected to enhance the intensity of weather extremes, and meteorological, agricultural, and hydrological droughts are expected to become more severe with the impacts on water resource management. Drought in the UK has been analysed by using Drought Severity Index (DSI) and is a potential threat as the UK heats, especially with hotter and drier summers (Slingo, 2021).

To mitigate the negative effects of drought on ecosystems and human populations, *the Environment Agency* provides guidance on monitoring, reporting, and advising, and acts as needed. It is the responsibility of *water companies* to ensure that their customers have a steady supply of water while also reducing the company's impact on the environment. Water resources policy is within the responsibility of *the government*.

Occasionally, the links between the functions of each agency and department listed above are unclear (even trying to define their responsibilities). According to the 2004 Civil Contingencies Act, no one department has legal responsibility for drought or heatwave risk management. The public's awareness of who is accountable for which duty has decreased as the responsibilities of various organisations have shifted. Similarly, the varying interpretations of obligation have resulted in a reluctance to incur expenses in the lack of defined funding mechanisms. This has had a certain influence on the management and control of drought adaptation (Zaidi and Pelling, 2014).

As lots of responsibilities are shared among different organizations, the National Drought Group (NDG) was established by the Secretary of State (Defra) in 2012 so as to manage and coordinate responsibilities during drought times. The National Drought Group (NDG) is to bring together the government and the major sectors to plan and oversee strategic drought initiatives. The National Drought Group is responsible to manage and coordinate planning and responses on the economic, social, and environmental impacts, the development and communication of consistent messages, updates, advice, and guidance, contingency planning and action in relation to water conservation issues, and resource sharing in the short and medium term, and scenario planning for drought escalation.

The National drought team consists of various stakeholders in order to comply with the requirements of managing and coordinating drought impacts and actions. It is notable that neither the UK Centre for Ecology & Hydrology (UKCEH) and the British Geological Survey (BGS) are members of NDG. The chair of the NDG is environment Agency, and includes central government bodies, water companies and other water related groups and stakeholders (Environment Agency, 2017).

With the Water Act 1989, former water agencies were privatised under the national idea, and the Water Industry Act 1991 outlined the primary powers and responsibilities of water and sewerage undertakers, the water quality and aims, as well as the responsibilities of the National Rivers Authority (now the Environment Agency). Some of the subsequent legislations in the UK are the Competition and Service (Utilities) Act 1992, the Environment Act 1995, the Water Act 2003 and 2014, and the Flood and Water Management Act 2010 (Ofwat, 2018).

2.2.2 'Drought response: our framework for England' and drought plan

The UK's water management plan consists of two main efforts: 'Drought response: our framework for England' and Drought Plan. These initiatives are designed to address the country's water-related difficulties and ensure long-term sustainability and resilience.

2.2.2.1 'Drought response: our framework for England'

'Drought response: our framework for England' developed by the Environment Agency aims to minimize the impacts of drought situations across the country and ensure the sustainable management of water resources. The Environment Agency coordinates drought management and ensures the protection of water resources by collaborating with the government, water companies, local authorities, and other stakeholders. Communication and information strategies are implemented to meet and protect the water needs of the public, businesses, and the environment during drought situations. This framework also includes monitoring the recovery process after droughts and learning from the experiences, aiming for a more

effective response to future drought situations. It aims to ensure consistency in coordinating drought management, and sets out: the drought impacts, the responsibilities and coordination, actions for managing drought, monitoring drought, advising the government for possible actions, and reporting and communication with others.

In Chapter 3: Drought impacts and actions, it focuses the impacts on different sectors and what can be done in terms of measures before and during a drought. Drought has diverse consequences, including public water supply, agriculture, gardening, environmental concerns, and industry. Water companies are required to provide sufficient water resources to fulfil the demands of the population, but drought has impacts on water supply by reducing groundwater levels and reservoir storage. To address this situation, water companies implement a range of steps including investing in new water sources, protecting reservoir tanks, implementing water-saving initiatives, minimising leaks, and implementing temporary usage restrictions. Water companies can put temporary use restrictions to reduce water consumption and promote conservation, which is among the first steps taken to limit water usage. Drought permits and orders, on the other hand, are legal instruments that provide for greater flexibility in managing water supplies. During droughts, water companies can apply to the Environment Agency for additional water from specific sources or to change current abstraction licences.

Drought reduces crop yield and negatively affects livestock. Farmers can increase their resilience through measures such as increasing irrigation efficiency, extending winter water withdrawal periods, and preparing emergency plans for animal water supply—as highlighted in the report.

In drought situations, water companies have an obligation to provide limited potable water for domestic properties if water supplies dry up. It is recommended to review and improve resistance to drought and contact local councils and the Drinking Water Inspectorate.

In addition, drought negatively affects ecosystems. Healthy ecosystems are generally drought tolerant and can recover quickly. The Environment Agency works to protect animals and habitats at risk by collaborating with environmental NGOs and local conservation group, taking protection, and supporting fish migration.

Drought affects navigation by reducing water levels and flows. Navigation authorities cooperate with the Environment Agency to manage water resources and inform mariners. Additionally, extreme heat and drying soil can affect infrastructure such as roads and rail networks. South-east England is regularly affected due to soil shrinkage. These can be handled by cooperating with navigation authorities, operating structures such as locks and dams, monitoring soil shrinkage effects on infrastructure, and taking measures to maintain railway geometry.

In industry, drought affects water use. Even though the energy sector is generally more resilient, many manufacturing and food processing facilities can be affected. It is recommended to provide up-to-date information on drought impacts by collaborating with sectors, promoting emergency plans, and enforcing drought orders to prioritize water use for basic needs.

In Chapter 4: Our drought teams and actions, the Environment Agency has established specific drought stages and reaction plans to control droughts and coordinate responses to their effects. Droughts are classed into five levels, ranging from normal (green) to severe (red). At each stage, precise meteorological, hydrological, and environmental variables are monitored, and necessary responses are performed. These actions include launching internal drought plans and teams, imposing voluntary or mandatory water withdrawal restrictions, implementing environmental protection measures, and processing drought licences and orders for public water delivery.

Drought can have varying degrees of severity. During a drought, the primary actions conducted are to cope with environmental incidents, increase water supplies, and to protect the environment. Dry weather can cause lowering water levels in rivers, lakes, and ponds, resulting in overpopulation and exposure to disease and predators. Furthermore, warmer weather increases the likelihood of algal blooms, which can cause lower oxygen levels in the water and fish fatalities. The Environment Agency strives to respond rapidly to complaints of dead or distressed fish in rivers, streams, and lakes, and may undertake emergency fish rescue operations in some situations.

Water businesses can get a drought permit from the Environment Agency during severe drought. Each drought permit application site has a specialised crew to offer feedback. The water business must show further water saving measures before applying which might involve public notification campaigns, temporary use limitations, leak management, and main pressure reduction. The Environment Agency informs the Secretary of State of drought orders but does not approve greater water withdrawals without demand management measures.

With numerous indicators—some of them is given in the next section, drought is regularly monitored with meteorological, hydrological, and environmental factors. Drought monitoring includes river flows, groundwater levels, reservoir fill rates, and water quality, in which the Environment Agency uses them to assist local and national teams analyse drought and identify actions. Monitoring includes taking present and predicted weather into consideration and acting.

In Chapter 5: How we communicate with others, the role of the Environment Agency in water corporations, government, external partners, and the public to plan and act is identified. When extended dry weather is identified, formal reporting begins; informal reporting may occur during regular dry weather. The Agency notify the government, media, abstraction permission holders, and the public about extended dry weather, its effects, and safeguards. Some of the communications during drought as listed below:

- Establishing strong connections with water companies to guarantee drought strategies and public water supply are implemented.
- Informing the government water resource conditions and suggest measures.
- Helping water companies promote water efficiency to consumers, businesses, and industries, and notify key sectors about drought and its effects.
- Support water extraction permit holders for improve water efficiency and drought mitigation.
- Coordinating national and regional drought management communications.

In terms of communicating with targeted people, the Environment Agency uses many ways to inform the public about water shortage, its effects, and how to prepare. A drought communication strategy guides and ensures consistency with national and local initiatives. Common communications methods target critical areas and reinforce messages.

Media releases, drought maps, and briefings send the correct words to the right audience. GOV.UK provides current and general information. Alerts and information are updated on social media. Significant rainfall during droughts can create local or widespread flooding, prompting flood warnings.

In Chapter 6: Recovering from drought, the partner assistance, water abstractors, environmental monitoring, and priority measures to restore to normal functioning are all elements of drought recovery are listed. It is highlighted that environmental monitoring should continue after the drought to assess site recovery and detect long-term environmental impact. The healing phase lets fish move upstream and return to their original area. Restocking may be needed, and certain rivers may take years to recover due to upstream movement barriers.

2.2.2.2 Drought Plan: South East Water Drought Plan 2022 to 2027

Section 39B of the Water Industry Act of 1991 as amended by the Water Act 2003—*"It shall be the duty of each water undertaker to prepare, publish, and maintain a drought plan."*—mandates that water companies must develop drought plans which are intended to indicate how a water company intends to monitor and manage future drought-related events, reduce water demand, and mobilise additional resources while minimising the need of drought orders and permits and guaranteeing supply security. Water companies are expected to include the following list of components when drafting a drought strategy (Environment Agency, 2021): Drought Triggers, Demand Management, Supply Management, Extreme Drought Actions, Communication, Environmental Assessment, and End of Drought.

The most recent drought plan cycle goes hand in hand with UK CCRA report cycle, and many companies (such as Thames Water, Affinity Water, and Anglian Water) published their drought management plan in 2022 (in line with requirements of Water company drought plan update which came onto force in January 2020). This update was required to consider of experiences identified from the prolonged dry weather and drought between 2017 and 2019, and other new knowledge, information, and experiences.

The South East Water Drought Plan 2022 to 2027 provides a comprehensive analysis of various measures to be considered during periods of both increased and decreased drought severity. It covers a range of management, operational, and communication strategies that should be considered. It is emphasized that working together with customers and stakeholders is crucial for the success of the plan, as it allows for the creation of the best possible result.

The company monitors various indicators related to drought risk, specifically focusing on groundwater, surface water, groundwater recharge, demand, and triggers such as bulk supplies and transfers. These indicators help assess the overall drought level in the relevant region. The level of drought determines the necessary actions to be taken if a drought occurs and eventually subsides.

With the lessons learned from the demand peaks observed in 2018 and 2020, the monitoring and evaluation of demand-driven droughts includes the comparison of summer demand peaks with trigger levels. As part of Water Resources Management Plan 2024, it is highlighted that it is important to enhance resilience to future peak events by developing additional scenarios.

The company implemented the adoption of the colour-coded 'traffic light' system (green, yellow, amber, and red) to incorporate the Environment Agency's national drought framework. This system effectively communicates the severity of droughts and provides clear guidance on the necessary actions to be taken.

After a drought has ended, the company enter a phase known as the "post drought" period. During this time, actions and gather valuable insights to better prepare for future droughts is reflected. Following is the five components of the drought plan.

2.2.2.2.1 Drought management actions

The report highlights the implementation of demand saving and optimisation actions in drought management actions. South East Water's approach to drought management emphasises the importance of being responsive, flexible, and able to adapt rapidly. Agility is at the core of South East Water's vision and commitments. Given the varying factors that can affect droughts, it is crucial to remain flexible to effectively address and respond to their unique characteristics and potential impacts.

2.2.2.2.2 Extreme drought management actions

In the event of a severe drought, the reports details what to do. To postpone the need to activate the backup plan related Level 4, these measures are put in place right after Level 3 'red' limitations (non-essential use drought bans) to prevent the water from running out of tanks or standpipes.

It is stated that the alternatives presented were designed after consulting with experienced operational and engineering managers and after perusing case studies on a national and international scale. The recommendations state that these measures can be put into place during times of severe drought, are practical from a technological standpoint, and usually will not have any long-term effects.

2.2.2.2.3 Customer communications

The report highlights the company's commitment to water conservation efforts. Recognition is given to individuals who made significant contributions in conserving water, with the active participation of retailers and representatives from new appointments and variations (NAV) in the planning phase. Keeping customers well-informed is a top priority.

2.2.2.2.4 Environmental assessment

The report highlighted a decrease in the availability of drought permit options due to the environmental assessment process. Furthermore, it is noted that extensive evaluations were conducted on Strategic Environmental Assessments and Habitat Regulations Assessments. The assessment also considers the potential impacts on protected areas. By updating the environmental baseline data, the company made sure that the most current information was accessible. It has been highlighted that a solid foundation of data is crucial for comprehending the restoration of ecosystems following a period of drought. This has provided valuable insights for making informed decisions to mitigate the potential long-term environmental impacts of actions during drought.

2.2.2.2.5 End of a drought

The report mentions that the same indicators will be utilised to determine the conclusion of drought events. As the severity of the drought decreases, the Drought Management Team will assess which measures are no longer required and will cease implementing them. Restrictions on usage, including temporary bans, drought orders, and

permits, will continue to be enforced until the drought subsides and conditions return to normal.

The company continues to monitor the resources, particularly groundwater recharge, during the winter period. Whether the drought has come to an end is determined by the validity of the following statements over a period of 1 month:

- all areas at normal overall drought severity level
- the recharge triggers at level 0 or level 1 for each site
- the reservoir trigger at level 0
- returned all drought permits/orders.

2.2.3 Additional tools for water management

Although drought plans prepared by the water undertakers to cover the five-year plan for water management (in general), separate weekly and monthly reports are issued by Environment Agency. These additional reports provide the same idea about the development of water-related difficulties over the weeks and months, and useful in the fight against drought (especially by supplying early warning).

2.2.3.1 Hydrological summary

Monthly Hydrological Summary is published via the National Hydrological Monitoring Programme (NHMP), and discusses the hydrological conditions of the previous month, focusing on rainfall, river flows, groundwater levels, reservoir stocks in historical perspective, regional precipitation data—both recent and, if substantial, longer-term accumulations. In addition, maps and representative hydrographs showing river flow and groundwater levels, as well as summary statistics and current stock information for a selection of key reservoirs, are included.

2.2.3.2 Water situation report and rainfall and river flow summary

In water situation reports, data comes from the Environment Agency, the Met Office, and water undertakers' measuring and monitoring: the amount of precipitation, how dry the soils are and how much precipitation they can absorb, the amount of water flowing through rivers, and the quantity of water contained in aquifers and reservoirs. In addition, a weekly summary of rainfall and river flow is provided for a better understanding and monitoring of the present situation in the UK.

2.2.3.3 The UK Water Resources Portal

The UK Water Resources Portal is a dynamic platform for (near) real-time hydrological monitoring across many geographical scales in the United Kingdom. The site demonstrates the usage of real-time river flow data from the Environment Agency and the Scottish Environmental Protection Agency and COSMOS-UK soil moisture data by compiling it all in one location.

2.3 United States of America

Over the years, the United States Congress has not approved any specific climate act (except some legislation aiming to achieve climate change goals), and; therefore, climate policy at the federal level in the United States largely depends on pre-existing legislation and international agreements, which includes the Clean Air Act (1963), the Clean Water Act (1972), the Comprehensive Environmental Response Compensation and Liability Act (1980), and recently the Infrastructure Investment and Jobs Act (2021) funding clean energy technologies. These legislative powers play a significant role in fighting climate change and helping the US reach its climate goals. In the Long-Term Strategy of the United States (submitted to UNFCC in accordance with Article 4, paragraph 19, of the Paris Agreement in November 2021), the United States has committed to *reducing net GHG emissions by 50–52% below 2005 levels in 2030*, and it has set the targets of *achieving net-zero emissions by 2050* latest, officially (State Department, 2021).

2.3.1 Water management: drought

In the USA, drought can be defined as abnormally dry conditions, a lack of precipitation resulting in a water shortage, and/or a period of abnormally dry weather long enough to cause a serious hydrological imbalance, and a deficiency of precipitation over an extended period of time (usually a season or more), (Wehner et al., 2017; NIDIS, 2022). According to the US Environment Protection Agency (EPA), and the Disaster Assistance Improvement Program (DAIP), drought is defined as follows (DAIP, 2022; US EPA, 2022);

- "Droughts are one of the costliest *natural disasters* that can affect the U.S"
- "We usually *do not think of droughts in the same way as other natural disasters*, such as floods or hurricanes"

In 1998, the National Drought Policy Act was established by Congress and stated for preparedness and mitigation to reduce the need for emergency relief. After that, National Drought Policy Commission (NDPC) was created to advise Congress. In order to enhance monitoring, prediction, and information for drought information, the National Integrated Drought Information System (NIDIS) within the NOAA was authorised (Folger et al., 2013).

In NCA5, "Water," covers drought management in detail as well as related issues in Chapter 4. The achievements of water management and the challenges they have in adjusting to climate change are emphasized. It has been specifically mentioned that institutions responsible for allocating water and infrastructure requirements are insufficient to adjust to the changing environment. Techniques include basin management, nature-based solutions, planned displacement, flood plain management, and water conservation and reuse were explored among the management and planning techniques. However, it is noted that the rate at which precipitation is changing is failing to keep along with changes in regulations, and the lack of current indicators makes it challenging to implement the necessary measures to protect communities.

As there are several parties involved in water management, no single entity is ultimately accountable for the mix of land and water usage consequences that have led to the widespread deterioration of the nation's waters. In the USA, safe drinking water, restoration and maintaining oceans, watersheds, aquatic systems, and protection human health are ensured by the Office of Water (EPA, 2020; USGS, 2020).

The Clean Water Act (CWA) and the Safe Drinking Water Act (SDWA) are two of the nation's laws regulating water quality, with primary oversight falling on the Environmental Protection Agency (EPA). The Food and Drug Administration is in charge of ensuring

the safety of bottled water shipped across state lines, while NOAA and NASA are crucial in water monitoring and observation during times of extreme weather.

The Office of Water is in charge of enforcing the Clean Water Act and the Safe Drinking Water Act. It also manages parts of the Coastal Zone Act Reauthorization Amendments of 1990, the Resource Conservation and Recovery Act, the Ocean Dumping Ban Act, the Marine Protection, Research, and Sanctuaries Act, the Shore Protection Act, the Marine Plastics Pollution Research and Control Act, the London Dumping Convention, the International Convention for the Prevention of Pollution from Ships, among other statutes (EPA, 2020).

The governor of a state or a tribal authority may apply to the President of the United States for a disaster declaration when the disaster calls for a response that exceeds the capacity of the state, municipal, or tribal government. An official disaster declaration may only be made by the President. A presidential disaster declaration can either be an emergency disaster (emergency services to protect lives, property, public health and safety, or to mitigate or avert the threat of a catastrophe) or a major disaster (hurricanes, tornadoes, storms, high water, wind-driven water, tidal waves, tsunamis, earthquakes, volcanic eruptions, landslides, mudslides, snowstorms, *droughts*, fires, and explosions) declaration. In addition to the Presidential declaration, drought can also be declared at the state level by following a certain process, which differs from state to state. Apart from federal and state-level drought declarations, regional water authorities and water suppliers can declare drought emergencies/decelerations to immediately reduce the consumption of all imported water sources and urge responsible water use and water conservation at the state level.

2.3.2 California Water Plan 2023

Updated every 5 years, the California Water Plan (DWR, 2023) is the state's strategic plan for equitable and sustainable development, management, and management of water resources. This plan outlines the current and projected state of California's water-dependent natural resources, water supplies, and water needs in agriculture, urban areas, and the environment under different future scenarios. The first "State Water Plan" was created in 1931 and described the statewide use of water resources.

The 2023 update emphasises the significance of watershed-specific measures for climate adaption. It emphasises the need for investments in multi-sector collaborations and solutions at the watershed and regional scales, in addition to providing incentives and support for thorough analysis and adaptation strategies tailored to the unique climate vulnerability of each watershed. These actions are essential because California's present rate of adaptation is not keeping up with the effects of climate change.

Leading collaborative open data projects, technical research, and planning activities with local, regional, tribal, and federal partners are the Department of Water Resources (DWR) and other state agencies. Among the common objectives are:

- enhancing access, reporting, and monitoring of water data.
- updating methods for forecasting and observation.
- creating models, decision-support tools, and accounting systems for water.
- enhancing the coordination of DWR, state agencies, and regional water programmes' use of open data and analytical tools.
- improving state-wide awareness of climate risks and vulnerabilities.
- determining the best adaption techniques.

Update 2023 promotes a larger role for watershed- and regional-scale projects, especially those that support establishing networks of non-profits, local government agencies, tribal governments, and community leaders. These programmes aim to:

- Promote more equitable outcomes for water management by utilising participatory regional governance and decision-making processes.
- Encourage the use of the best available knowledge and analytical techniques to standardise the production of scientifically driven studies of climate vulnerability.
- Encourage regional planning by using watershed hydrology as a guiding principle to establish the planning area's size, scope, and quantifiable results.
- Include a strong and reliable method for monitoring results at the watershed scale using resilience measurements and indicators.

The intricate governance of California's water management system is typified by the overlap and interdependence of local, regional, state, federal, and tribal entities. Because of this complexity as well as the wide range of local water allocation, rate assessments, and risk mitigation strategies, frontline communities find it difficult to engage with governance structures and make decisions.

The California Water Plan Update 2023 outlines seven key objectives designed to enhance the state's water resilience in the face of climate change, improve infrastructure, and promote equitable and inclusive water management practices. These can be listed as:

- Support Watershed Resilience Planning and Implementation to enhance watershed resilience to mitigate the impacts of climate change.
- Improve Resiliency of "Backbone" State, Federal, and Regional Built Water Infrastructure to improve existing infrastructure and adapt operations for climate change.
- Improve Resiliency of Natural "Backbone" Infrastructure to accelerate ecosystem restoration and identify critical ecosystem hubs.
- Advance Equitable Outcomes in Water Management to improve community engagement and access to state assistance programs.
- Support and Learn from Tribal Water and Resource Management Practices to support and learn from Tribal water management practices.
- Increase Flexibility of Regulatory Systems to support regulatory programs and ensure they are adaptable to future challenges.
- Provide Guidance and Support Resources for Implementation of Actions toward Water Resilience to align resources with the needs of California water management.

2.3.3 Additional tools for water management

In terms of early warning and drought management, the United States has a well-established framework on both the federal and state levels. There are lots of available tools, maps, and reports

for drought such as US Drought Monitor, Drought Impacts in the USA, State Drought Management Plans, and the U.S. Drought Portal.

2.3.3.1 The U.S. Drought Portal

The U.S. Drought Portal (www.drought.gov) was launched in 2008 and is regarded as the main government website for drought information. The website delivers drought-related data, decision-support tools, resources, and information, including monitoring and forecasting, planning & preparedness, and applied research. The U.S. Drought Portal is operated jointly by NOAA's National Integrated Drought Information System (NIDIS) and NOAA's National Centres for Environmental Information (NCEI).

2.3.3.2 U.S. Drought Monitor (USDM)

The U.S. Drought Monitor (USDM) is the current standard approach for operational drought monitoring in the United States. It produces a composite drought index that is widely utilized by policymakers. Each week, the US Drought Monitor publishes a map showing which areas of the country are under drought and the extent of those droughts (NDMC, 2023). The National Drought Mitigation Centre (NDMC) produces a monthly report titled "Drought Impacts in the United States" to supplement the Drought Monitor map.

2.3.3.3 State drought management plans

In addition to national assessments and reports, each state has its own drought management plan in a separate report, annexe, or section of state water plans. The main aim is to discuss initiatives that assist in mitigating the possible implications of drought on business, the water supply, and public health and safety. While the most recent drought plan was published by North Carolina, the oldest and not updated plan belongs to Iowa (however, currently is in the process of updating). As noted, many of these plans are very old (NDMC, 2024).

2.4 Türkiye

In April 2016, Türkiye signed the Paris Agreement mentioned in its National Declaration as a developing country and ratified the Agreement on 7 October 2021 (deposited with the UN Secretariat on 11 October 2021) by completing the domestic law approval process. It is also declared that Türkiye approved a goal to *reach net-zero emissions by 2053*. An amended version of Türkiye's Nationally Determined Contribution (NDC) presented at COP27, the Minister of Environment, Urbanization, and Climate Change declared *the peaking of GHG emissions by 2038* and a *new reduction target of 41% by 2030* (up from 21%).

2.4.1 Water management: drought

According to the Ministry of Agriculture and Forestry, drought is "*a natural phenomenon* that negatively affects land, water resources, production systems and causes serious hydrological imbalances as a result of rainfall falling significantly below normal recorded levels." In the Strategic Plan 2019–2023 by the Disaster and Emergency Management Presidency (AFAD in Turkish), drought is anticipated to be considered within *the definition of a disaster*. In various governmental documents (MoAF, 2017; GDAR, 2022; AFAD, 2024; GDWM, 2024a; TSMS, 2024b), it is defined as:

- "Drought is an *enigmatic natural disaster*."
- "It is considered the most devastating of all *natural disasters*."
- "Drought is *a natural disaster*."

The structure of water management in Türkiye is centralised. At the national level, strategic decisions and plans are made centrally and then carried out by the provincial units of the relevant ministries and local administrations. Within this administrative structure, numerous institutions and organisations are involved in water management, playing various roles and operating at different levels. These institutions and organisations can be classified into three administrative levels: national, regional, and provincial.

Within the management structure, Provincial Water Management Coordination Boards present the basin-scale management plans implementation tracking table to the Basin Management Committees. Basin Management Committees evaluate the work carried out by Provincial Water Management Coordination Boards and relevant institutions or organizations and submit the meeting minutes and reports they prepare to the Basin Management Central Board. The Basin Management Central Board also addresses the agenda issues created according to the delegation reports from the basins and presents them to the Water Management Coordination Board.

During the 1st Water Council organised by the Ministry of Agriculture and Forestry in 2021, water efficiency, basin-scale water management, water law and policy, water security and wastewater services, protection and monitoring of water resources, and the effects of climate change on water resources and adaptation were discussed. The 1st Water Council Final Declaration, which includes 28 articles outlining the decisions made at the conclusion of the council, has been published (MoAF, 2021). One of the main aims of the Water Council was to develop a comprehensive Water Act. However, since the initial drafts were published in 2011, there has been little progress in finalizing this legislation, and still under review.

The Ministry of Agriculture and Forestry, General Directorate of Water Management has recently published a document titled "Water Efficiency Strategy Document and Action Plan (2023–2033) within the Framework of Adaptation to the Changing Climate." In addition, the implementation of the measures outlined in the policy document is also incorporated in the 12th Development Plan.

The National Water Plan (2019–2023) prepared by the Ministry of Agriculture and Forestry highlights several challenges in water resources management (GDWM, 2019). These include weaknesses in water legislation, conflicts of authority between institutions, lack of coordination and institutional capacity, imbalances between water demand and availability in certain basins/regions, high water losses in agriculture irrigation, and significant water loss in drinking water networks and distribution systems (currently standing at a 32%). Several challenges have also been identified, including the impact of drought, excessive water withdrawals, and the pressures of water pollution on ecosystems. Furthermore, there are issues with the protection of water resources and water pollution, as well as the necessity to prevent pollution in dam basins and river basins, particularly those that supply drinking water.

The mission of the Strategic Plan 2019–2023 by AFAD is defined as "carrying out necessary work for the effective management of processes related to disasters and emergencies, ensuring coordination among relevant institutions and organizations, and producing policies in this field" (AFAD, 2019). However, the mission does not

specifically include a strategy for responding to drought. Instead, the plan highlights Türkiye's support to over 50 countries affected by various disasters, including earthquakes, floods, droughts, and famines.

In 2014, AFAD published the Road Map Document for Climate Change and Related Disasters (2014–2023) to coordinate institutions and organizations and ensure effective management of climate change and related disasters (AFAD, 2014). In terms of drought management, the document outlines the roles and responsibilities of authorized institutions, stating that the primary institution responsible for drought management in Türkiye is the Ministry of Agriculture and Forestry.

In the second Climate Change Adaptation Strategy and Action Plan (2024–2030), 14 different adaptation measures have been identified for water resources management (MoEUCC, 2024), and these can be listed as follows:

- Preparation of basin-scale management plans
- Development of monitoring and information systems for water and wastewater management
- Improvement of legislation
- Determination of the effects of climate change on water resources
- Follow-up of the Water Efficiency Strategy Document and Action Plan (2023–2033) within the Framework of Adaptation to Changing Climate
- Protection of basins that provide drinking and utility water
- Updating standards to protect water quality and increasing reuse to 15%
- Monitoring the quality and levels of aquatic ecosystems and preparing water budgets
- Establishment of legal structures for rainwater
- Reduction of water loss rates and reuse of rainwater and greywater
- Increasing efficiency in agricultural irrigation
- Protection of groundwater resources
- Efficient use of water in the industrial sector
- The implementation of early warning systems for drought

2.4.2 A short interview with the directorate general of water management

As a part of doctoral study funded by Turkish government, a discussion with the Head of the Drought Department in the Directorate General of Water Management provided significant insights into the preparation process of basin-based drought management plans.

During the discussion, the question was raised whether the drought management plans prepared on a basin basis were based on any guidelines—like in the UK and had any legal foundation. The Head of the Drought Department stated that these plans were not based on any specific guidelines and were prepared using information obtained from the General Directorate of Water Management officials and academics involved in the tender process. Additionally, it was noted that these plans were considered as the preparation phase.

It was also conveyed that the National Drought Management Strategy Document and Action Plan (2017–2023) were drafted based on the opinions gathered from meetings held at different times with the Drought Management Strategy Document and Action Plan Working Group, consisting of stakeholders, institutions, organizations, and academics.

Regarding drought monitoring, it was mentioned that meteorological drought analyses were conducted by the General Directorate of Meteorology (MGM) and that agricultural drought maps were produced by the Ministry of Agriculture and Forestry (MoAF). However, the lack of coordination and issues in information exchange between institutions were also highlighted. During the discussion, it was emphasized that suggestions for ensuring coordination in the national development plan and climate change adaptation plan were proposed.

When asked about which institution, organization, or group was responsible for conducting the current drought analysis and implementing measures, it was learned that there was no such established structure and that institutions took measures on their own initiative.

Additionally, it was mentioned that the Drought Management Plans were more about analysing the current situation rather than being a comprehensive plan. The more details about drought management plans will be given in the following section.

2.4.3 National Drought Management Strategic Document and Action Plan (2017–2023) and River Basin Drought Plan

There are two important documents that play a crucial role in managing drought in Türkiye: the National Drought Management Strategic Document and Action Plan (2017–2023), which is currently undergoing updates (MoAF, 2017), and the River Basin Drought Management Plan. Unfortunately, there is no specific guideline or policy document available for drought management plans as also mentioned in a brief interview; therefore, the Marmara Drought Management Plan (GDWM, 2023) is detailed below.

2.4.3.1 National Drought Management Strategic Document and Action Plan (2017–2023)

This report is a strategic plan developed to address the drought in Türkiye, with the objective of establishing a drought management policy that is sustainable, results-oriented, and based on concrete objectives. The second section includes a comprehensive list of drought management legislation, laws, and regulations. There is mention of certain studies conducted on drought, particularly agricultural drought, in the section on studies conducted within the framework of drought management in Türkiye. However, no information is provided regarding these studies. Furthermore, the significance of measures such as the development of early warning systems appears to be underestimated in contrast to the studies conducted in this section.

Measures implemented prior to, during, and following drought are discussed in detail. Prior to drought, it is necessary to conduct research that includes the establishment of drought indicators and indexes, the development of drought prediction and early warning systems, and the development of drought management plans. Implementation of drought emergency action plans and the operation of water supply and storage facilities in accordance with the drought situation are appropriate measures to take during a drought. In the aftermath of the drought, it is imperative to assess the extent of the damage and offer the requisite assistance to the affected sectors. Listed below are the weaknesses determined in the drought management:

- Difficulties in accessing data,
- Difficulties in coordination,
- Poor legislation,
- Inadequacies in the policies and strategies related to basin management, and a lack of coordination between the sectoral investment policies,
- Issues with ensuring stakeholder and public participation,
- Insufficient data information system,
- Inadequacies in criteria and methods for prioritising basin projects and activities,
- Lack of plans at higher levels serving as a guide to basin studies,
- Limited information regarding the impacts of previous droughts, and
- Lack of drought-related units in many organisations.

The report concludes with a brief description of the current state of Türkiye, specifically the central management system.

2.4.3.2 Marmara Drought Management Plan

This report, similar in structure to other basin drought reports, aims to reduce the adverse impacts of drought and water scarcity on production resources and socio-economic well-being through a basin management approach. It considers the water budget of the Marmara Basin and its vulnerability to drought.

The first four sections highlight the crucial role of water in sustaining life and the detrimental impact of drought on various sectors including drinking water, agriculture, and industry. The geographical, topographic, and socio-economic characteristics of the Marmara Basin are investigated along with the methodologies employed in drought analysis and the water budget of the basin. This section can be described as a background information of the present circumstances.

The fifth section of the plan included the examination of the impacts of drought on various sectors within the Marmara Basin, as well as the assessment of their susceptibility to such conditions. The methods employed in sectoral vulnerability analyses were thoroughly explained, and calculations were conducted for the exposure index, water use index (WEI), and water use index+ (WEI+). Through extensive analyses, the impacts of drought on various sectors such as agriculture, industry, tourism, drinking water, and ecosystems were thoroughly examined. The study also assessed the vulnerability of each sector to drought. In addition, various strategies and techniques have been suggested to mitigate the impacts of drought on different sectors. These strategies involve implementing various methods to improve water efficiency, decrease loss-leakage rates, and minimise water consumption.

The sixth section provides a detailed analysis of the objectives of the Marmara Basin Drought Management Plan and the recommended measures to achieve these objectives. The primary objective of the plan is to effectively and sustainably manage water resources in the Marmara Basin, while also promoting the rational use of water during periods of drought and water scarcity. In this context, a comprehensive plan was developed and proposed some measures.

These measures encompass various aspects such as water conservation, efficient water management, protocols for handling drought situations, and sustainable long-term strategies. Efforts to minimise the impact of drought, particularly in the Marmara Basin, involve enhancing water efficiency, reducing water loss rates, and reducing water consumption. Furthermore, it is recommended to implement more efficient approaches in agriculture, industry, and drinking water consumption.

- ensuring efficient water use for irrigation
- reducing water losses in water systems
- using recycled water in industrial zones
- development of a network for measurement and monitoring
- reducing drought-related environmental damage
- protecting wetlands
- raising awareness of the drought

It is stated that the Emergency Action Plan should be monitored, evaluated, and regularly updated to ensure the effectiveness of the Drought Management Plan. This section provides an overview of the drought management cycle, the institutions and organisations involved in its implementation, and their respective duties and responsibilities.

2.4.4 Additional tools for water management

As noted in previous sections, there is a lack of coordination and willingness to share data openly and freely, resulting in limited tools for monitoring the water environment. The most popular and freely accessible tool is the drought maps published by TSMS. Another more complex tool, currently in its third phase of development, is the National Water Information System (USBS).

2.4.4.1 Drought analyses—TSMS

The Turkish State Meteorological Service (TSMS) is responsible for meteorological activities in Türkiye, including the analysis and monitoring of drought conditions (TSMS, 2024a), and provides information on drought through its extensive network of observation stations that collect data on temperature, precipitation, humidity, wind, and other climatic variables. These data can be requested through the MEVBIS platform, which requires a registered account and the payment of a fee (TSMS, 2024c). TSMS publishes both annual and monthly drought analyses, which include meteorological drought maps featuring key indicators such as the Standardized Precipitation Index (SPI) and the Percent of Normal Index (PNI). The monthly maps provide a visual representation of drought conditions across Türkiye, highlighting areas experiencing different levels of drought severity.

2.4.4.2 National Water Information System (USBS)

The National Water Information System (USBS in Turkish) is an information system established by the General Directorate of Water Management to ensure the effective and efficient management of water resources in Türkiye. This system provides an integrated platform for collecting, monitoring, evaluating, and sharing data on water resources (GDWM, 2024b).

Visitors can log in to see how data is presented across Türkiye. However, while the system aims to publish water data, it is not possible to freely download the data sets. To download, upload, or delete data, one must log in as an authorized user with the necessary permissions, which typically requires employment at the General Directorate. Even as an authorized user, it is prohibited to use the data in any study without obtaining permission from the data owner.

3 Discussion and conclusion

In this paper, the overview of climate change and detailed drought management strategies of the Netherlands, United Kingdom, United States, and Türkiye have been compared. Despite differing geographic, economic, and political conditions, these countries face similar challenges in drought management. Their approaches to dealing with drought have been examined from various perspectives, including laws and regulations, targets, main climate assessments, and drought definitions. The comparison of countries' approaches is given in Table 1.

The Netherlands integrates drought management within its broader, more complex water management regime that addresses both floods and droughts. Drought is not treated as a separate natural disaster but is embedded in general water management strategies. The Delta Programme, National Water Plan, and tools like the Drought Monitor and Drought Portal are essential components in monitoring and managing water resources during drought periods. The UK has a well-established framework for long-term drought and water resource management. The Environment Agency coordinates drought management and ensures the protection of water resources by collaborating with the government, water companies, local authorities, and other stakeholders. The National Drought Group (NDG) oversees strategic drought initiatives, and water companies are required to prepare and implement drought plans. In the USA, drought management is addressed through the National Drought Policy Act 1998, emphasizing preparedness and mitigation strategies. The National Integrated Drought Information System (NIDIS) provides crucial drought monitoring and information. The U.S. Drought Portal is one of the good examples as it includes monitoring, early warning, sector specific impacts and research. Drought various federal and state agencies, such as the Environmental Protection Agency (EPA) and the National Oceanic and Atmospheric Administration (NOAA), play significant roles in managing water quality and monitoring during droughts.

Türkiye manages drought through strategic plans such as the National Drought Management Strategy Document and drought management plans based on river basins. Drought management involves coordination at both local and national levels, including water-saving measures, public awareness campaigns, and emergency plans. This coordination at national and local levels comes from Türkiye's governmental structure, where high-level decisions are made by ministries and then implemented by local authorities. While Türkiye is still finalizing climate and water-related laws, these policy documents guide the country's approach to drought management. By adopting more integrated and coordinated approaches from these countries, Türkiye can improve its water management strategies and ensure sustainable management of water resources. These four countries, despite implementing different methods and policies in drought management and climate change mitigation, each strive to develop the most suitable strategies according to their conditions. Common components such as early warning systems, water-saving measures, and public communication are critical in drought management. However, the definitions and approaches to drought management vary across countries.

Overall, the integrated water management model of the Netherlands, the centralized authority coordination of the United Kingdom, and the early warning and information dissemination systems of the United States provide valuable examples for strengthening Türkiye's water management policies. The insights gained from these countries can guide necessary adjustments to make Türkiye's water management strategies more effective and sustainable.

Türkiye can develop a more effective and sustainable drought management approach by drawing on the Netherlands' integrated water management model, the United Kingdom's centralised authority coordination (and detailed drought management plans), and the United States' early warning and information sharing systems.

The drought management guidelines for Türkiye should be established since management plans now rely significantly on official and academic perspectives at various stages, which will cause inconsistency in different plans, and the Environment Agency's guidelines in the United Kingdom can serve as a model. Then, municipalities in Türkiye responsible for water supply should develop their own drought management plans that complement existing basin management plans which can draw inspiration from the Netherlands' integrated water management system. This integrated approach emphasises the need for collaboration among multiple stakeholders, including as municipalities, regional water authorities, and national agencies, to achieve cohesive and successful water management policies. Comprehensive communication tactics, such as educating the public and stakeholders about droughts, launching water conservation programmes, and declaring emergency measures, should be implemented. Specific indicators, such as rainfall, river flow, groundwater levels, and reservoir storage, should be defined to decide when interventions are required. Furthermore, steps to reduce water demand should be implemented, such as fixing leaks, encouraging water efficiency, and implementing temporary usage limits. To guarantee sustainable water supply management, the plans should include environmental evaluations to understand the consequences on ecosystems and minimise long-term damage. Once a drought has subsided, efforts should be made to monitor recovery, eliminate limitations, and evaluate performance in order to better plan for future droughts.

Furthermore, Türkiye can learn from the United States, where the Drought Portal (drought.gov) serves as a platform for early warning and information access. Türkiye's National Water Information System (USBS) is a valuable source of water-related data; however, it lacks broad data access and the transmission of critical data to decision-makers. The U.S. Drought Portal provides real-time monitoring, forecasting, and decision-support capabilities that are critical for proactive drought management. Setting up a similar portal in Türkiye would improve early warning capabilities and enable simple access to critical data for all parties involved in water management. This would also address Türkiye's current limitations in terms of data access, which impedes efficient coordination and prompt response to drought conditions.

Moreover, Türkiye would benefit from implementing the various drought monitoring and reporting systems employed in these nations. For example, the General Directorate of State Hydraulic Works, which is in charge of water-related matters in Türkiye, should publish or make available open-access data, and prepares reports like the Hydrological Summary, River Flow Summary, and Water Situation Reports in the UK. Similarly, tools like the Drought Portal, Drought Monitor, Climate Impact Atlas, Climate Damage Atlas, National Climate Adaptation Strategy, Delta Programme, Climate Plan, and National Water Plan in the Netherlands, as well as the U.S. Drought Monitor (USDM), State Drought Management Plans, and State Climate Action Plans in the United States, could serve as models for Türkiye. Implementing these technologies would considerably improve the country's ability to manage its water supplies and respond effectively to drought.

TABLE 1 Countries' approaches.

Countries/key components	Netherlands	United Kingdom	United States of America	Türkiye
Climate act	The Climate Act (253) was adopted in 2019. It aims to reduce greenhouse gas emissions and prepare a climate plan.	The Climate Change Act 2008 established a long-term and legal framework.	No specific climate law, existing regulations aim to achieve climate change goals.	No specific climate law yet, in draft stage.
Mitigation targets	Reduce greenhouse gas emissions by 49% by 2030 compared to 1990 levels, 95% reduction by 2050.	Net-zero emissions by 2050.	50–52% reduction in net GHG emissions by 2030 compared to 2005 levels, net-zero emissions by 2050.	Peak GHG emissions by 2038, and net zero emissions by 2053
Main climate assessment	National Climate Adaptation Strategy (NAS) focuses on raising awareness and promoting deliberate action.	Climate Change Risk Assessment (CCRA) and National Adaptation Programme (NAP3).	National Climate Assessment (NCA) informs public and private decision-making, does not make policy suggestions.	National Climate Change Mitigation and Adaptation Action Plans
Drought definition	As a lack of precipitation, a decline in river flow, or both. No specific explanation as a natural hazard.	As natural events, natural hazard, and natural event that we cannot prevent.	The costliest natural disasters, not thinking in the same way as other natural disasters.	An enigmatic natural disaster.
Drought declaration	Committee for Water Distribution (LCW) steps in when excess demand for water due to conditions like extended drought and low river flows.	The National Drought Group (NDG) bringing together the government and the major sectors to plan and oversee strategic drought initiatives.	Presidential declaration for a major disaster at federal level, state level deceleration by the Governor, and the declaration by regional water authorities and suppliers	No specific drought declaration process
Responsibilities	The Water Management Centrum Nederland (WMCN) responsibility to provide knowledge and information about the Dutch water system	The Environment Agency for better guidance on monitoring, reporting, and advising, and acts as needed, Water Companies ensuring to have a steady supply, and reducing impact on the environment, and the Government for water resources policy.	Safe drinking water, restoration and maintaining oceans, watersheds, aquatic systems, and protection human health are ensured by the Office of Water and the Environmental Protection Agency (EPA)	Mainly the Directorate General of Water Management, but centralized water management and can be classified into three administrative levels: national, regional, and provincial.
Drought approach	The broader and more complex water management regime, not treated as a separate natural disaster but is embedded in general water management strategies. Coordination between water authorities is essential. Rijkswaterstaat (executive arm of the Ministry of Infrastructure and Water Management) is responsible for managing major water bodies, while regional water boards manage local water sources such as canals and polder waterways	A well-established framework for long-term drought and water resource management. The Environment Agency coordinates drought management and ensures the protection of water resources by collaborating with the government, water companies, local authorities, and other stakeholders. The National Drought Group (NDG) oversees strategic drought initiatives, and water companies are required to prepare and implement drought plans.	Addressed through the National Drought Policy Act 1998, emphasizing preparedness and mitigation strategies, relying on early warning at federal and state levels. The National Integrated Drought Information System (NIDIS) Various federal and state agencies, such as the Environmental Protection Agency (EPA) and the National Oceanic and Atmospheric Administration (NOAA) provides crucial drought monitoring and information dissemination.	Manages drought through strategic plans and action plans, such as the National Drought Management Strategy Document. Drought management involves coordination at both local and national levels, including water-saving measures, public awareness campaigns, and emergency plans.
Drought monitoring and additional reporting	The Drought Portal, the Drought Monitor, the Climate Impact Atlas, the Climate Damage Atlas, National Climate Adaptation Strategy, Delta Programme, Climate Plan, and National Water Plan.	The UK Water Resources Portal, Hydrological Summary, River Flow Summary, and Water Situation Reports.	The U.S. Drought Portal, the U.S. Drought Monitor (USDM) State Drought Management Plans, and State Climate Action Plans	Drought Analyses, National Water Information System, National Drought Management Strategy Document and Action Plan, and River Basin Drought Management Plans

In addition, Türkiye currently lacks a proper drought declaration process, and implementing systems comparable to those in these nations would be beneficial. For example, in the Netherlands, the Committee for Water Distribution (LCW) intervenes when there is an excess of water demand owing to prolonged drought and low river flows. In the United Kingdom, the National Drought Group (NDG) brings together the government and major industries to plan and monitor strategic drought efforts. Drought declarations in the United States can be issued by the President at the federal level, the Governor at the state level, and regional water authorities and suppliers. Establishing a similar governance structure in Türkiye, with a dedicated committee that can declare drought conditions and coordinate response measures, would improve drought management effectiveness, which include government bodies, municipalities, water suppliers, and regional authorities.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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