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A Policy Diagnosis of Urban Rainwater Management in the Mediterranean: Comparative Planning Frameworks in Turkey and Spain

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ABSTRACT

This study evaluates urban rainwater management policies in Turkey and Spain and their integration within spatial planning hierarchies amidst hydrological uncertainties driven by climate change. A comparative framework was applied to 20 key policy documents (10 from each country), encompassing national legislation, strategic action plans, technical guides, basin management plans, and local implementation documents. The methodology employs a mixed-method approach, utilizing qualitative content analysis to interpret policy discourse and scoring it against a quantitative rubric. Documents were evaluated on a scale of 0 to 3 across three primary criteria: bindingness, spatial integration, and circularity. Findings reveal that while Turkey possesses strong national legal mandates and parcel-based technical requirements, these strategic intentions fail to translate into local spatial plans due to a fragmented approach that separates flood and drought cycles. Conversely, Spain exhibits a robust policy hierarchy that effectively converts central policy into local urban design through standardized national guides and binding basin-level mandates. This diagnosis highlights the critical necessity of transforming rainwater management from a parcel-scale engineering detail into a legally integrated spatial asset within a multi-scalar planning hierarchy to ensure systemic urban resilience in Mediterranean geographies.

1. INTRODUCTION

Climate change has become a defining condition for urban systems, reshaping water cycles and exposing the limitations of conventional infrastructure and planning paradigms [1]. Rising temperatures, altered precipitation patterns, and increasingly frequent extremes place particular pressure on Mediterranean cities, which are recognized as climate-change hotspots due to their sensitivity to hydrological variability [2, 3].

Climate projections consistently indicate declining annual precipitation combined with increased rainfall intensity and irregularity. As a result, Mediterranean cities face dual and interconnected pressures: managing excess water during extreme rainfall events while simultaneously coping with prolonged drought and growing water scarcity [1, 4]. These conditions directly challenge the foundational assumptions of conventional rainwater management systems, which have historically been shaped by an engineering paradigm prioritizing rapid conveyance and removal [5]. While effective under relatively stable climatic conditions, such systems have proven increasingly inadequate in contexts characterized by greater uncertainty and variability [6].

In response to these limitations, alternative approaches such as Sustainable Urban Drainage Systems (SUDS) and nature-based solutions (NBS) have gained prominence in both research and practice. These approaches seek to retain, infiltrate, store, and reuse rainwater at or near its source, reducing runoff volumes while enhancing urban resilience [7]. However, an expanding body of literature emphasizes that the success of such approaches depends not only on their technical performance but also on their institutional embedding within planning systems, regulatory frameworks, and governance arrangements. Rainwater management is increasingly conceptualized as a socio-technical challenge shaped by planning cultures, scalar relationships, and decision-making processes [8-10]. Despite the growing recognition of the socio-technical nature of urban rainwater management, most studies evaluate these approaches primarily through their technical or hydrological performance. Comparatively less attention has been paid to how planning systems and institutional structures condition whether such measures can be implemented, coordinated across scales, and sustained over time. Consequently, the relationship between planning system structure and urban rainwater resilience remains insufficiently examined.

This study approaches rainwater management as a planning and governance problem rather than a purely technical one. It examines whether urban adaptive capacity emerges from the presence of specific technical measures or from the coherence of planning systems that organize them. To investigate this question, the research adopts a multi-scalar analytical framework tracing how rainwater policies are translated from basin-scale strategies to urban planning and infrastructure implementation. Turkey and Spain are selected not as exemplary or opposing cases, but as analytically comparable planning contexts operating under similar Mediterranean climatic pressures while differing in institutional organization and planning coordination. By analyzing national legislation, climate adaptation strategies, river basin management plans (Marmara and Tagus), and local planning documents in Istanbul and Madrid, the study evaluates how planning hierarchies structure the framing of rainwater as risk or resource, the bindingness of measures, and the existence of measurable targets.

The article tests the proposition that differences in urban rainwater resilience cannot be explained solely by technological capacity or climate exposure, but are associated with institutional characteristics of planning systems, particularly their degree of bindingness, cross-scale integration, and the translation of basin-level strategies into local spatial planning decisions. Accordingly, the paper conceptualizes urban resilience as a planning outcome and examines how planning frameworks shape the integration of rainwater into urban adaptation policies.

2. METHODOLOGY

The resilience of the urban rainwater cycle cannot be achieved through isolated technical interventions or building-scale solutions alone; it necessitates a robust integration within the overarching planning policy framework. To demonstrate this, this study employs a systematic content analysis methodology structured into two primary phases.

Table 1. Document inclusion and exclusion criteria for the selection process

Criterion Category	Inclusion Criteria	Exclusion Criteria
Scale & Hierarchy	Documents representing a multi-level governance framework, including national (laws/strategies), regional (basin-scale), and local (metropolitan) levels.	Policy documents that lack a clear jurisdictional or spatial link to the selected case study areas (Istanbul and Madrid).
Thematic Scope	Strategic documents and plans fundamentally centered on climate change adaptation and rainwater management.	General development plans that do not explicitly address climate-related hydrological risks or water governance.
Operational Status	Legislation currently in force, or the most recent and up-to-date versions of strategic plans and vision documents within their respective categories.	Superseded versions of laws or expired municipal plans that have been replaced by newer frameworks and no longer hold administrative weight.
Content Type	Documents providing governance frameworks, binding regulations, and spatial targets.	Purely technical manuals, material standards, or construction specifications without broader planning or policy implications.
Geographical Focus	Documents specifically covering the Mediterranean climate context or the administrative boundaries of the pilot basins and cities.	Basin plans for regions outside the study areas that do not offer comparative value to the Mediterranean urban rainwater cycle.

Table 2. Categorization of policy documents

Document Type	Turkey (Istanbul)	Spain (Madrid)	Total
Legislation (National)	2	1	3
Basin Management Plans (Regional)	3	3	6
Action Plans (National and local)	4	3	7
Urban Design Guidelines	0	2	2
Infrastructure Master Plans	1	1	2
Total	**10**	**10**	**20**

First, a rigorous selection process was established using predefined inclusion and exclusion criteria to ensure a balanced and relevant dataset (Table 1). The selection was governed by five strategic categories—scale and hierarchy, thematic scope, operational status, content type, and geographical focus—ensuring that only current, legally relevant, and spatially linked documents within the Mediterranean climate context were included while filtering out purely technical manuals or expired frameworks. Based on these criteria, a total of 20 strategic and operational documents were selected—10 from Turkey and 10 from Spain—representing a multi-scalar hierarchy of planning from national-level laws to regional basin strategies and local implementation guidelines (Table 2). The complete list and detailed characteristics of these primary policy and legal documents analyzed in the study are provided in Appendix A. Furthermore, the official climatological and water infrastructure datasets utilized for Turkey and Spain are detailed in Appendix B.

The evaluation was conducted by categorizing these documents into national, regional, and local levels. This multi-level approach demonstrates the step-by-step transition from broad policy goals to local-scale implementations and reveals the applicability levels of the criteria at each planning stage. In the second phase, the selected documents were evaluated against three core resilience pillars:

- Bindingness: Assesses the legal weight and enforcement capacity of the document, determining whether its provisions are mandatory requirements or mere recommendations.

- Integration: Examines the horizontal and vertical connectivity of the document, focusing on how effectively it provides technical and spatial inputs to sub-scale planning processes.

- Circularity: Evaluates the conceptual scope of the document in terms of holistic water management, specifically its capacity to treat rainwater as a resource by bridging the gap between flood mitigation and drought resilience.

To ensure a quantifiable and objective comparison, each document was scored on a scale of 0 to 3, with assessment levels specifically defined and coded for each criterion in Table 3. This systematic approach eliminates potential subjectivity by directly linking every assigned score to specific textual evidence, such as article numbers or section titles, identified during the content analysis. This evidence-based framework allows for a precise and replicable identification of "policy gaps" that hinder or facilitate urban water resilience in both Mediterranean contexts.

Table 3. Qualitative coding framework and scoring levels for policy evaluation

Score	Bindingness (Legal Force)	Integration (Spatial Standards & Input)	Circularity (Relational Risk & Potential)
0 (Ineffective)	The concepts (URWM, SUDS, Sponge City or water sensitive city) are not mentioned or referenced in the document.	There are no spatial standards or technical references for urban rainwater management in sub-scale plans.	Rainwater is managed only as a risk/waste (drainage-only); no potential use is identified.
1 (Low level)	A general vision exists, but lacks concrete tools, budgets, or specific targets.	There is conceptual guidance for sub-scales, but no defined concrete spatial standards exist.	Drought and flood risks are mentioned, but no relational link is established between these two extremes.
2 (Medium Level)	Spatial targets and indicators are defined, but enforcement or monitoring mechanisms are lacking.	Spatial standards are defined for sub-scales, but they are not identified as a mandatory threshold.	Rainwater is recognized as a potential resource (harvesting, etc.), but risk management remains fragmented.
3 (High Level)	Spatial targets are established alongside mandatory monitoring and legal enforcement mechanisms.	Spatial standards for sub-scales are identified as a mandatory threshold for plan approval and implementation.	Flood and drought management are fully integrated within a circular water cycle framework.

3. CLIMATE CHANGE IMPACTS ON THE MEDITERRANEAN URBAN RAINWATER CYCLE AND RESILIENCE APPROACHES

The Mediterranean basin is highly sensitive to climate change due to the deep interdependence between natural and human systems. According to the IPCC (2022), the cumulative impact of rising temperatures, prolonged droughts, and sea-level rise is exceeding the adaptive capacity of many cities, increasing urban vulnerability and disrupting the water cycle. Characterized as a “climate change hotspot,” the region faces significant declines in average precipitation and increasing variability [2]. While forecasts indicate a decrease in annual rainfall at the basin scale, future projections suggest shorter, more intense rainfall events that will increase runoff and flood risks, accompanied by longer dry periods [11]. Despite regional seasonal differences, future projections indicate shorter rainfall durations accompanied by higher intensities, resulting in increased surface runoff and flood risk (Figure 1). At the same time, longer dry periods are expected to exacerbate water stress.

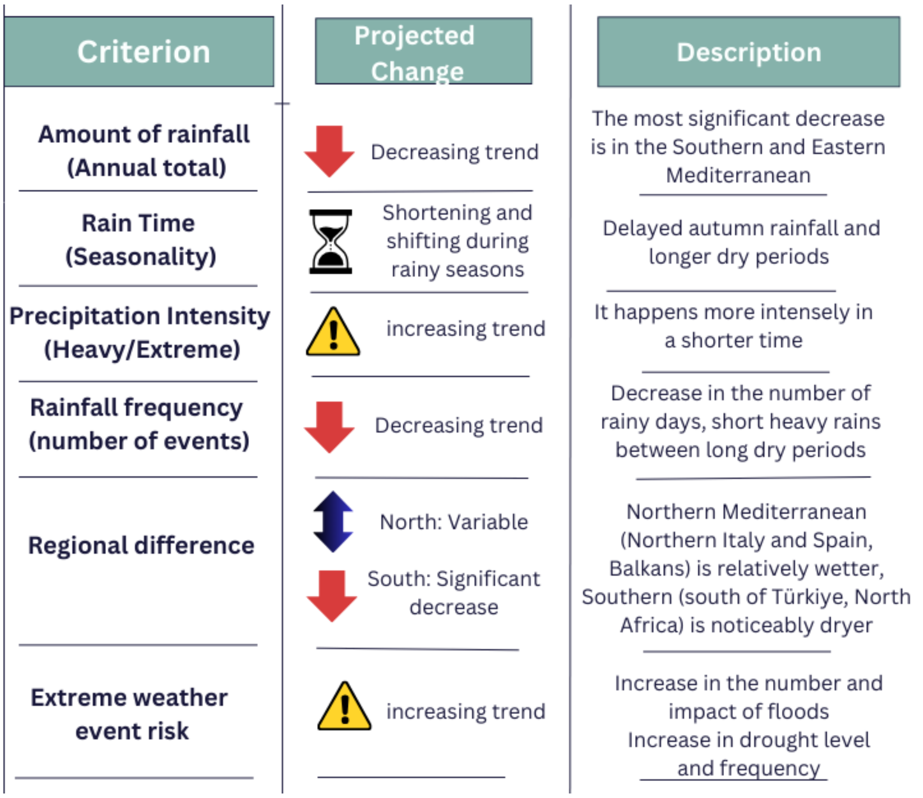

Figure 1. Precipitation regime change in the Mediterranean climate zone

Spatial differentiation of risk is becoming increasingly evident. Lazoglou et al. [12] identify the southeastern Mediterranean as a high-risk sub-region. Under the RCP8.5 scenario, total rainfall is expected to decrease by 30% to 40% in parts of the southern Mediterranean by the end of the century [4]. Importantly, increased rainfall intensity is not expected to compensate for overall declines, leading to the simultaneous occurrence of flooding and water scarcity. Urbanization trends further intensify these pressures. Rapid population growth and expanding urban areas – particularly along the eastern and southern coasts – increase water demand and amplify flood risks [13]. Rising temperatures accelerate evaporation and reduce the efficiency of large-scale storage systems such as dams, undermining the reliability of centralized water supplies [14].

In response to growing pressure on urban infrastructure, alternative approaches emphasizing the retention, infiltration, storage, and reuse of rainwater have gained prominence. NBS, adopted by the European Commission in 2008, are defined as nature-inspired and nature-supported systems that are cost-effective, enhance resilience, and provide environmental, social, and economic benefits through locally adapted and resource-efficient interventions [7]. In Mediterranean European countries such as Spain and Italy, these approaches are increasingly operationalized through SUDS, which aim to align the urban water cycle with natural hydrological processes through flexible, site-specific designs at multiple scales.

SUDS are compatible with key European policy frameworks, including the European Green Deal, the 2030 EU Biodiversity Strategy, the Water Framework Directive, and the Floods Directive. Empirical studies demonstrate that SUDS provide an effective framework for implementing NBS in urban rainwater management and for strengthening the resilience of the urban water cycle [15, 16]. Southern European countries within the Mediterranean climate zone, particularly Spain and Italy, have made notable progress in SUDS implementation [17, 18]. However, the effectiveness of such approaches ultimately depends on how rainwater is conceptualized within planning systems, regulatory frameworks, and planning structures, rather than on their technical performance alone.

4. RAINFALL PROJECTIONS AND URBAN RAINWATER CYCLE CHALLENGES OF TURKEY

Recent studies align Turkey's climate projections with Mediterranean patterns, showing a long-term increase in rainfall-related disasters from the 1940s to 2024, with a significant surge after the 2000s. Between 2010 and 2024, storms and heavy rainfall became the most frequent disasters [19]. Concurrently, rising temperatures since 2005 have intensified the severity and frequency of droughts [20]. National climate scenarios project a long-term decrease in precipitation alongside increased irregularities. These trends, combined with persistent drought risks and infrastructure unable to accommodate such extremes, have led to a rise in urban flooding across the country.

Recent changes in Turkey's rainfall regime and amounts corroborate projections of future climate conditions. In 2025, annual precipitation decreased by 26.3% relative to the 1991–2020 average and by 29.2% compared with 2024, marking the lowest precipitation in the past 65 years. Summer precipitation in 2025 fell by 53% compared with the climatological norm and by 49% relative to the previous year. Regional assessments indicate below-average annual precipitation in all regions, with the largest declines in Marmara and Southeastern Anatolia: 34.4% below normal in Marmara, Turkey's most densely populated region, and 53% below normal in Southeastern Anatolia [21]. The problems related to Turkey's urban rainwater cycle can be listed as follows:

•Turkey lies in the eastern and southern Mediterranean climate zone, where sub-regions are highly vulnerable to drought and precipitation variability under projected climate scenarios. Combined with existing urban infrastructure deficiencies, these factors heighten the fragility of the urban rainwater cycle.

•Rapid urbanization and rising water demand coincide with declining annual precipitation and increased evaporation from dams. Major metropolitan areas, particularly Istanbul, rely on inter-basin water transfers that disrupt the natural balance of donor basins and create long-term socio-economic risks.

•In the Marmara region, which hosts Turkey's highest and most concentrated urban population, dam water levels have reached critical thresholds in recent years. As of December 28, 2025, the average occupancy rate across all of Istanbul's supply reservoirs had plummeted to 18%. This data represents the lowest recorded value for the month of December over the past decade, underscoring the escalating hydrological stress in the metropolitan area [22]. These data indicate that a dam-dependent urban water supply lacking alternative sources produces a low-resilience system when combined with rainfall irregularity, population pressure, and climate change.

Since 2021, Turkey has initiated legal and strategic efforts to promote rainwater use, supported by small-scale, fragmented implementations. However, a comprehensive institutional and legal framework that addresses urban water infrastructure in an integrated, cyclical manner is still lacking. As a result, conventional gray engineering solutions for urban rainwater management are expected to be insufficient for adapting to growing extremes in the urban water cycle.

5. FINDINGS: COMPARISON OF THE LOCATION OF SUSTAINABLE URBAN DRAINAGE SYSTEMS IN THE TURKISH-SPANISH PLANNING SYSTEM

5.1 National legislation

Among the Mediterranean countries, Spain's studies and publications on SUDS are particularly noteworthy [23]. Since 1998, SUDS have been implemented incrementally in new Spanish urban projects, often independently of regional legal frameworks. From 2005, various regional regulations and guidelines tailored to specific climatic conditions emerged [24]. Following the formal inclusion of SUDS in national regulations and strategies in 2016, multi-criteria decision-making tools were developed at the urban scale. A national framework now enables regional and local authorities to establish their own mandatory, incentive or advisory instruments, supported by systematic evaluation methods [16, 25]. The most recent advancement, Real Decreto 665/2023, amends Hydraulic Public Domain regulations to strongly incentivize SUDS. This reform mandates that local governments develop rainwater management strategies and integrate SUDS into monitoring and reporting procedures, building on the 2016 prioritization of SUDS in new urban developments.

The 2023 regulation establishes binding, nationwide standards, requiring integrated SUDS plans (PIGSS—Plan Integral de Gestión del Sistema de Saneamiento) for settlements with populations exceeding 50,000. These plans must be guided by capacity management principles, precipitation scenarios, and multifaceted risk assessments related to drought and flooding. Furthermore, the regulation mandates digital monitoring and recording systems to support evidence-based decision-making in water-cycle management (Appendix A, Doc 1). By positioning SUDS at the core of national water management, rather than treating it as an isolated tool within housing or urban planning, this initiative promotes a comprehensive, whole-water-cycle approach. This approach effectively integrates drainage, groundwater protection, water resources, and pollution control, emphasizing the interrelationships within the urban water cycle.

Table 4. Comparative assessment of policy documents at the national legislation

	Turkey		Spain
	Regulation on rainwater collection, storage and discharge systems (2017)	Regulation on amendments to the Planned Areas Zoning Regulation (2021) + revision (2025)	Real Decreto 665/2023
Bindingness (Legal Force)	2	2	3
Integration (Spatial Standards & Input)	0	0	3
Circularity (Relational Risk & Potential)	2	2	3

Table 5. Comparative assessment of policy documents at the national climate change action plans

	Turkey		Spain
	Climate Change Adaptation Strategy and Action Plan (2024-2030)	Water Efficiency Strategy Document and Action Plan (2023-2033)	National Plan for Adaptation to Climate Change (PNACC) (2021-2030)
Bindingness (Legal Force)	2	1	1
Integration (Spatial Standards & Input)	0	0	0
Circularity (Relational Risk & Potential)	2	1	3

Two regulations in Turkey explicitly address SUDS: the 2017 Rainwater Collection, Storage and Discharge Systems Regulation and the amendments on rainwater storage in the Planned Areas Zoning Regulation (2021, with an additional amendment in 2025). As summarized in Table 4, this framework diverges from the Real Decreto paradigm by treating rainwater primarily as an infrastructure input rather than as a flow requiring integrated management. The 2017 regulation focuses on technical design and implementation, emphasizing engineering components such as pipe systems, storage structures, filtration units, and discharge points (see Section 4) It neither mandates rainwater systems nor directly link them to planning instruments, instead defining technical conditions applicable when such systems are installed. While it contributes to establishing a common terminology for rainwater management in Turkey, the regulation addresses the rainwater cycle and basin-scale management in a fragmented manner (Appendix A, Doc 2).

The 2021 Planned Areas Zoning Regulation amendment introduces limitations related to scale selection and integration with planning. Under Article 5, it mandates roof-surface rainwater storage for parcels larger than 2,000 m², while implementation for smaller parcels is left to the discretion of local authorities (Appendix A, Doc 3). This approach reduces rainwater management to building-scale technical measures rather than adopting a holistic hydrological perspective. The 2,000 m² threshold is not linked to rainfall patterns or basin characteristics, effectively excluding smaller parcels and most urban open spaces, thereby weakening network coherence. The 2025 amendment, within Article 6, strengthens provisions on rainwater use in terms of scope and technical detail but continues to operate primarily at the parcel scale. Numerical thresholds for roof area and storage volume are introduced, and compliance with technical standards becomes an integral part of the permitting process (Appendix A, Doc 4).

As presented in the evaluation results in Table 5, while the national legislation in Turkey treats rainwater as a 'technical detail to be managed at the parcel scale,' the Spanish framework conceptualizes it as a 'strategic resource and an integral component of spatial planning.' The high performance of the Spanish legislation across all three criteria is explicitly grounded in Article 259 of Real Decreto 665/2023, which mandates the integration of drainage strategies into broader urban systems while enforcing binding standards for water circularity. In contrast, the score of 0 received by Turkey in the Integration criterion—despite the parcel-based requirements in the Planned Areas Zoning Regulation—serves as the most concrete evidence of the systemic disconnect between national infrastructure regulations and urban planning processes.

The evaluation of national-scale action plans reveals that while Turkey exhibits a higher institutional commitment at the strategic level than Spain, there are fundamental conceptual differences in how the water cycle is addressed. Turkey's Climate Change Adaptation Strategy and Action Plan (2024-2030) outperforms its Spanish counterpart in the bindingness criterion with a score of 2. This score is justified by the administrative obligations and implementation responsibilities defined under "Strategy Implementation, Article 9" (page 117). The document's Circularity performance (2 points) is verified by the integrated perspective on water recovery and rainwater harvesting developed under "Strategic Goal 3" (page 77) (Appendix A, Doc 5).

The second critical Turkish document at this scale, the

Water Efficiency Strategy Document and Action Plan (2023-2033), receives 1 point for Bindingness due to the administrative framework provided under "Goal 1" on page 73. For Circularity, it scores 1 point as it addresses the technical potential for water reuse (page 22). However, the "0" score for Spatial Integration in both Turkish documents confirms that these strategic goals lack concrete spatial standards or design criteria required to provide direct input for sub-scale planning processes (Appendix A, Doc 6).

On the Spanish side, PNACC (2021-2030) scores 1 point for bindingness, as it remains largely advisory. However, it reaches the maximum threshold with a score of 3 in the Circularity criterion. This high performance is justified in "Section 7.3: Water Resources," where the document defines water resources as a relational cycle between drought and flood risks and adopts a holistic approach to water conservation. Similar to the Turkish examples, this Spanish strategic document scores "0" in the Integration criterion as it does not function as a direct spatial implementation tool (Appendix A, Doc 7).

While the action plans of both countries acknowledge the importance of rainwater use and SUDS, their underlying planning logics differ markedly. Turkey's plans prioritize technically specified actions and discrete interventions, focusing on what should be implemented. Spain's PNACC, in contrast, emphasizes organizational coherence, and the integration of adaptation objectives across planning scales, focusing on how adaptation should be structured within the planning system. Despite growing institutional awareness in Turkey, rainwater-related measures remain fragmented, insufficiently linked to basin-scale objectives, and highly dependent on local implementation capacity. In Spain, rainwater management is embedded within the broader urbanization-basin-climate nexus, functioning as a core instrument on climate change adaptation rather than a supplementary technical measure.

5.2 National level guides

Turkey currently lacks a national-level guideline on urban drainage systems, representing a significant systemic divergence from the Spanish model. Spain has established a comprehensive framework titled Guías de Adaptación al Riesgo de Inundación: Sistemas Urbanos de Drenaje Sostenible, which serves as a critical technical bridge missing in the Turkish planning hierarchy. Although not strictly binding, this guide scores 2 for Bindingness and 2 for Spatial Integration by providing adaptable technical solutions and infrastructure typologies tailored to Spain's diverse climatic conditions (Appendix A, Doc 8).

In the Spanish context, the guide mandates that SUDS typologies be scaled across three distinct zones: infiltration and deceleration for the wet-temperate north; storage-oriented micro-rain gardens for the Mediterranean region; and bio-filters with drought-tolerant vegetation for semi-arid areas. By establishing these specific technical standards and runoff coefficients, the guide achieves a maximum score of 3 for Circularity. It transforms rainwater from a waste product into a site-specific resource, ensuring that strategic circularity goals are translated into mandatory, place-specific design requirements.

Consequently, while Spain's guide formally embeds sustainable drainage within national climate policy through a uniform nationwide terminology, the Turkish framework remains fragmented. In Turkey, although separate action plans address climate change and water efficiency, the absence of a national design manual results in a '0' score across all criteria at this scale. Without standardized parameters for SUDS design, site selection, and volume calculation, sustainable drainage in Turkey tends to remain at a conceptual level, forcing local authorities to rely on traditional gray-infrastructure solutions instead of operationalizing resilient, spatial interventions.

5.3 Regional level basin management plans

In this section, at the regional level, plans for the Marmara Basin and the Tagus River Basin encompassing Istanbul and Madrid respectively are examined. The evaluation at this scale is based on a total of six documents, covering the general management plan, flood risk management plan, and drought management plan for each basin (Table 6).

Table 6. Comparative assessment of policy documents at the regional level basin management plans

	Turkey			Spain		
	Marmara Basin Management Plan	Marmara Basin Flood Management Plan	Marmara Basin Drought Management Plan	Tagus Basin Management Plan	Tagus Basin Flood Management Plan	Tagus Basin Drought Management Plan
Bindingness (Legal Force)	2	1	1	3	3	3
Integration (Spatial Standards & Input)	1	2	0	3	3	2
Circularity (Relational Risk & Potential)	2	1	2	3	3	3

The Tagus basin plans are founded on safeguarding and regulating the basin's natural dynamics by maintaining ecosystem and hydro morphological integrity within the water cycle. SUDS term is not typically used as a heading or explicit category, since basin management plans are framed around the broader hydrological cycle rather than urban infrastructure terminology. Instead, they embed core SUDS principles, including the protection of natural flow regimes, the joint management of floods and droughts, and the reduction of urbanization pressures on the water system (Appendix A, Doc 9, 10, 11). Spain's basin plans follow a standardized structure common to other EU river basins: their methodology, mandatory contents, and section order are defined by the Floods Directive and the Water Framework Directive, and each plan is revised on a six-year cycle [26].

In Marmara, flood and drought are handled through separate two plans, the Marmara Flood Management Plan and the Marmara Drought Management Plan, whereas in the Tagus Basin they are administratively distinct but managed within a holistic framework with shared performance targets that complement the urban water cycle. The Marmara Flood Management Plan prioritizes stream improvement (e.g., bed cleaning and channel arrangement) without explicit links to urban infrastructure (Appendix A, Doc 12). The Drought Management Plan mentions green infrastructure for rainwater management only in recommendations and does not integrate these measures into scenarios, water budgets, supply–demand projections, or drought severity models (Appendix A, Doc 13, 14, 15).

The evaluation of the Regional Basin Management Plans reveals a fragmented structure within the Turkish planning hierarchy, where strategic goals at the basin scale struggle to find a binding pathway to local implementation. In the Marmara Basin Management Plan, the bindingness criterion receives a score of 2, supported by the mandatory "Program of Measures" defined in Section 7. This section outlines the administrative responsibilities and requirements for basin-level water protection. Regarding spatial integration, the plan scores 1 based on the environmental objectives detailed in Section 5, which provide a conceptual framework but lack the specific spatial indicators needed for direct sub-scale planning input. However, the plan demonstrates a stronger performance in circularity (Score: 2); within Section 2, the baseline characteristics of the basin are defined by acknowledging both flood and drought risks relationally, explicitly identifying rainwater as a potential resource for the region.

Conversely, the thematic management plans—the Marmara Basin Flood Management Plan and the Drought Management Plan—exhibit a more disconnected and advisory nature. Both documents receive a low score of 1 for bindingness, as their provisions for urban rainwater systems remain largely conceptual. In the Flood Management Plan (Section 7) and the Drought Management Plan (Sections 5 and 6), rainwater interventions are mentioned as strategic necessities but lack the legal force required to mandate specific local-level implementations. This fragmentation is most evident in the Integration scores; while the Flood Management Plan scores 2 due to its specific risk mapping, the Drought Management Plan scores 0, confirming that it fails to provide any concrete spatial standards or technical inputs for urban planning at the lower scales.

The maximum score of 3 for Bindingness in the Tagus Basin Management Plan is justified by the mandatory monitoring and legal enforcement mechanisms detailed in Section 16: El Programa de Medidas. Furthermore, the plan achieves a score of 3 for Integration as Section 17: La Normativa explicitly defines the necessary spatial inputs and standards for sub-scale planning frameworks. Regarding Circularity, the plan is evaluated with a score of 3 because Section 16 conceptualizes extreme weather events—both drought and flood—as part of a relational cycle, thereby establishing a holistic management mechanism for the entire basin.

Similarly, the Tagus Flood Management Plan secures its scores through comprehensive legal and technical frameworks. The score of 3 for Bindingness is supported by Sections 1 and 2, which outline rigorous legal obligations, monitoring programs, and implementation mechanisms. The plan also achieves a score of 3 for Circularity; Section 3.1.3 emphasizes the improvement of infiltration and water storage conditions within urban basins, addressing flood risk and water conservation simultaneously. This integrated approach is further reinforced in Section 2.1.4.7, which promotes SuDS (Sustainable Drainage Systems) applications. By focusing on the retention, conveyance, and storage functions of urban water infrastructure to manage urban runoff, the plan treats the water cycle as a holistic system within the built environment and urban texture.

While the Tagus Basin Management Plan and the Flood Management Plan receive full marks in the Integration category by imposing direct structural constraints and zoning boundaries on the urban texture, the Drought Management Plan is assigned a score of 2. Although the latter defines spatial standards—such as xeriscaping and local storage requirements—it leaves the implementation of these standards to the discretion of local authorities and fails to mandate direct land-use obligations within sub-scale planning frameworks.

5.4 Local scale: Climate action plans, infrastructure master plans, and design guides

The confluence of dense urbanization and climate change generates complex pressures and vulnerabilities for sustainable infrastructure management and water resources planning. This is particularly pronounced in the Mediterranean climate zone, where changing precipitation patterns threaten the urban water supplies through heightened flood and drought risks. The discussion proceeds with a comparative analysis of how Istanbul and Madrid, both characterized by high urbanization rates and concentration of population and production in the Mediterranean climate zone, incorporate the rainwater cycle and SUDS into their planning processes.

Climatically, Madrid exhibits a Mediterranean continental regime, attributable to its distance from the sea and high elevation (approximately 650–700 m). The city experiences prolonged, very hot summers with low annual precipitation but is nonetheless highly exposed to flood risk from intense, sudden rainfall events. By contrast, Istanbul has a more temperate climate, moderated by marine humidity from both the Black Sea and the Sea of Marmara. The average annual precipitation in Istanbul (1950–2024) is 660.8 mm, compared with 421 mm in Madrid (1981–2010) (Appendix B, Doc 1 and 2). Approximately 90% of Madrid's municipal water supply is drawn from dams and river basins, with the remaining 10% from groundwater wells. In Istanbul, about 99% of potable water is supplied from surface water sources, regulators and dams, while only 1% of groundwater is used in industrial or rural areas (Appendix B, Doc 3). These data indicate that both cities are strongly dependent on centralized surface water resources, with a particularly high reliance in Istanbul, underscoring their vulnerability to precipitation variability characteristic of Mediterranean climates. In this context, evaluating urban vulnerabilities requires shifting the focus from localized infrastructure toward a broader river-basin scale, which directly conditions the evolutionary hierarchy of settlements under global climate change pressures [27].

At the level of upper-scale plans, the use of Madrid's urban rainwater infrastructure is not mandated as a direct requirement; rather, it is guided by a holistic water management framework with measurable outcome indicators. The specification of monitorable targets for water quality, flood risk, and system performance, alongside the plans' qualitative principles, plays a key role in reinforcing this indirect binding effect. In Istanbul, by contrast, basin plans do not perform this coordinating function. As a result, rainwater infrastructure is implemented mainly through fragmented, project-based interventions tied to parcel-size standards (2021 Planned Areas Zoning Regulation Amendment) and is largely left to the discretion of local administrative authorities.

The plans and the design guide analyzed for Madrid and Istanbul have been scored as presented in Table 7, and the evaluations for each are detailed as follows:

•PIGSS is a technical plan that enables the collaborative management of urban wastewater and rainwater systems, focusing on analyzing the behavior of water during precipitation. It is a mandatory requirement for settlements with a population of 50,000 and above, in accordance with Real Decreto 665/2023 (Appendix A, Doc 1). While a final public report has not yet been prepared for Madrid, it is known that tenders for technical support and plan preparation have been opened [28]. The Plan Integral de Gestión del Sistema de Saneamiento (PIGSS) achieves a maximum score of 3 across all criteria, reflecting its role as a high-performance operational framework for local water management. Regarding bindingness, the plan's legal force is derived directly from Real Decreto 665/2023, which transforms it from a strategic vision into a mandatory requirement for large urban settlements. Its Integration score of 3 is justified by the plan's intrinsic nature; as a technical instrument that analyzes hydraulic behavior during precipitation, it inherently provides the precise spatial standards and structural inputs necessary for the built environment. Finally, the plan secures a 3 in Circularity by enabling the collaborative management of wastewater and rainwater systems. By treating these components as an integrated cycle rather than separate disposal issues, PIGSS functions as a self-sustaining monitoring and management mechanism that ensures systemic resilience within the urban texture.

•The Madrid Climate Adaptation Action Plan (2025) functions as a strategic policy brief that identifies key urban climate risks and establishes a framework for resilience. Regarding Bindingness and Integration, the plan is evaluated with a score of 1 for both criteria; while it articulates overarching visions, it treats rainwater management as a conceptual adaptation area without defining quantitative targets or mandatory spatial standards, as these technical details and implementation mandates are primarily relegated to basin plans and other specialized instruments. However, the document achieves a score of 3 in Circularity, as it successfully integrates rainwater management within a holistic climate adaptation cycle, framing it not merely as a drainage issue but as a fundamental component of the city's long-term systemic resilience and relational risk management (Appendix A, Doc 14).

•The Canal de Isabel II 2025-2030 Strategic Plan is a regional business plan and vision document prepared by Canal de Isabel II, the institution that oversees Madrid's water cycle, covering corporate strategy, including financing, digitalization and investments, as well as measurable targets for the urban drainage system of not only the city center but also the entire Autonomous Community of Madrid [29]. The document achieves a maximum score of 3 across all criteria due to its role as a mandatory investment roadmap that secures bindingness through allocated financing and legislative commitment. It also excels in integration and circularity by translating high-level strategy into measurable spatial targets and managing the entire water cycle as a holistic, digitalized, and integrated system.

•"Madrid's Basic Design Guide for Sustainable Rainwater Management Systems in Green Areas and Other Open Spaces" (2018) provides comprehensive guidance for implementing SUDS for source control in Madrid. It defines numerical standards and evaluates infrastructure typologies based on topography, hydrology, rainfall and vegetation. This document establishes selection criteria to optimize sustainable drainage within the city's specific urban context (Appendix A, Doc 15). The guide is assigned a score of 2 for both Bindingness and Integration because, while it provides essential spatial standards for urban settlements, it functions as a technical manual rather than a strictly mandatory legislative act or a direct planning instrument. However, it earns a score of 3 in Circularity for its ability to spatialize infrastructure typologies that simultaneously manage storage and conveyance, effectively addressing dual climate risks within a holistic water management framework.

Table 7. Comparative assessment of policy documents at the local scale

	Turkey			Spain			
	IMM Sustainable Energy and Climate Action Plan (2023-2030)	IMM Climate Change Action Plan (2021-2030)	The ISKI Drinking Water and Sewage Master Plan (2023-2053)	Madrid Climate Adaptation Action Plan (2025)	PIGSS (Plan Integral de Gestion del Sistema de Saneamiento)	The Canal de Isabel II 2025-2030 Strategic Plan	Madrid's Basic Design Guide for Sustainable Stormwater Management Systems in Green Areas and Other Open Spaces (2018)
Bindingness (Legal Force)	0	2	1	1	3	3	2
Integration (Spatial Standards & Input)	1	2	0	1	3	3	2
Circularity (Relational Risk & Potential)	0	2	1	3	3	3	3

Istanbul has formulated a series of strategies aimed at addressing climate change and managing rainwater at the urban level. The following section will delineate these strategies in different plans.

•The Istanbul Metropolitan Municipality (IMM) Sustainable Energy and Climate Action Plan, set forth by the IMM encompasses the years 2023 to 2030. In the context of Istanbul's rainwater management, a comparative analysis was conducted of the flood vulnerabilities of the districts (based on flow retention index, flow retention amount, and flood volume) with a focus on highlighting the urban flood risk. Although SUDS and the sponge city concept against urban floods were introduced as part of adaptation actions, measurable targets were not established for this (Appendix A, Doc 16). The plan mentions the sponge city concept merely as a vision (Section 3.4.2: Adaptation actions regarding vulnerabilities), without providing a concrete implementation framework (bindingness score: 1). Although flood-related analyses are included, there are no spatial standards directly transferred to lower-scale planning (integration score: 0). Furthermore, despite referencing the sponge city approach, the plan treats rainwater as a risk and a waste product to be discharged rather than a potential resource; its primary focus remains on securing water supply through conventional dams and regulators (circularity score: 0).

•The IMM Climate Change Action Plan (2021-2030) recognizes the increasing pressure on water resources driven by urban expansion, population growth, and climate change. Although it is situated within a comprehensive adaptation agenda addressing droughts and floods, views rainwater as a potential resource, and provides guidance for lower-scale planning, the plan lacks direct enforcement mechanisms, spatial thresholds, or specific standards for these lower-tier plans. Consequently, the plan did not reach the highest performance level in the evaluation, receiving a score of 2 for each respective criterion (Appendix A, Doc 17).

•The ISKI Drinking Water and Sewage Master Plan (2023-2053) serves as the primary technical framework for Istanbul's water infrastructure. Based on the preparatory draft report of the plan, rainwater continues to be treated primarily as a risk to be controlled rather than a strategic resource. Although sustainable urban drainage and water-sensitive city concepts are referenced, the proposed measures focus on large-scale, project-based interventions and remain weakly integrated into lower-scale spatial planning, largely overlooking urban surface runoff management at the implementation level (Appendix A, Doc 18). Consequently, the evaluation of the draft report yielded a bindingness score of 1, as it lacks a final enforcement framework; an integration score of 0, due to the disconnect with local spatial planning tools; and a circularity score of 1, reflecting a conceptual mention of resource potential that is not yet supported by systemic reuse strategies.

6. DISCUSSION

The comparative analysis of urban rainwater management policies in Turkey and Spain reveals a fundamental structural divergence that transcends mere technical capacity. While both Mediterranean nations face similar climatic pressures, the research identifies two distinct governance trajectories: a centralized-mandate model in Turkey and a multi-scalar integrated hierarchy in Spain. Evaluating these trajectories across the administrative scales allows for a precise identification of the policy gaps that facilitate or hinder urban water resilience.

At the highest level of governance, the findings challenge the initial assumption of a fragmented Turkish framework. In fact, the cumulative scores for National Legislation—8 for Turkey and 6 for Spain (see Table 8)—suggest that Turkey has established a more proactive central mandate. The 2017 and 2021/2025 revisions to the Planned Areas Zoning Regulation impose significant legal force, making rainwater harvesting and storage mandatory for larger parcels. However, this national strength is also its primary weakness. The Turkish framework treats rainwater as a technical detail to be managed at the parcel scale rather than a strategic resource integrated within spatial planning. While Spain's Real Decreto 665/2023 scores lower in raw mandatory volume at the parcel level, it achieves maximum performance in integration by mandating drainage strategies as a non-negotiable part of the broader urban system in Turkey. The legislation remains restricted to a technical engineering perspective; while it specifies storage requirements, it lacks the spatial standards necessary to integrate water into urban settlements. This confirms a systemic disconnect where national laws do not communicate effectively with the spatial planning hierarchy, leaving the implementation to be handled as a building-scale obligation rather than a city-scale resilience strategy.

Table 8. Overall comparison of policy scores for Turkey and Spain

	Turkey	Spain
National legislation	8	6
National action plans	6	4
National guides	0	7
Regional level basin management plans	12	26
Local action plans, master plans and guides	9	30
Total	**35**	**73**

A similar pattern of centralized intent is observed in the National Action Plans, where Turkey scores 6 against Spain's 4. Documents such as the Climate Change Adaptation Strategy and Action Plan (2024–2030) display a higher level of administrative commitment and bindingness than Spain's equivalent national adaptation plan. This indicates that the Turkish state formally recognizes climate resilience as a core administrative responsibility. Yet, the core issue lies in the conceptualization of the water cycle. The Turkish plans tend to handle flood mitigation and drought resilience as separate sectoral issues. This lack of circularity—the failure to treat drought and flood as a single, relational cycle—prevents the transition to a holistic resource management logic. In contrast, Spanish strategic documents exhibit a deeper conceptual understanding of the relational risks, even if they carry less direct legal force at this specific scale. The Spanish approach treats the water cycle as a dual-facing reality where flood prevention and water scarcity are managed through the same integrated tools, a perspective that is currently absent in the more reactive Turkish strategic documents.

The most critical failure in the Turkish policy chain is identified at the National Guides scale, where Spain scores 7 and Turkey scores 0 (Table 8). The absence of a national design manual in Turkey creates a catastrophic spatial instruction gap. Without standardized guidelines, local municipalities are left to interpret national mandates without a unified technical or spatial language. Spain's National Design Guide for Sustainable Rainwater (2018) serves as the essential transmission belt that translates high-level policy into site-specific interventions. It ensures that circularity—such as utilizing green spaces for infiltration and local reuse—is a standardized design requirement. In Turkey, the lack of such a guide forces local practitioners to rely on traditional, gray-infrastructure solutions. This institutional void effectively blocks the development of place-specific, nature-based circular solutions, as there are no standardized spatial indicators to guide designers and planners in creating site-appropriate drainage systems.

The transition to the Regional Level through basin management plans represents the only scale where the Turkish system begins to overcome its spatial silence. The Marmara Basin Flood Management Plan achieving a score of 2 in Integration is a pivotal counter-example to the national-scale disconnect. It suggests that regional-scale documents are beginning to provide the spatial inputs that national laws lack, acknowledging the necessity of managing water at the hydrological boundary. However, the comparison with Spain's Tagus (Tajo) Basin Plans, which score 26 (as documented in Table 8), highlights the maturity of the Spanish hydraulic hierarchy. Spain's basin plans act as a statutory filter through which all local urban growth must pass, ensuring that water capacity directly dictates spatial development. In Turkey, while basin plans have improved conceptually—especially in circularity regarding drought management—they still function largely as advisory frameworks with a bindingness score of 1. This highlights a specific institutional exception: Turkey is successful in conceptualizing drought as a resource issue at the basin scale, yet it remains hindered by an asymmetric legal structure that prevents these plans from having a mandatory impact on local zoning.

The culmination of these scalar dynamics is most evident at the Local Action Plans and implementation scale, where Spain reaches a score of 30 and Turkey remains at 9 (Table 8). In Madrid, local implementation documents like the PIGSS and the Canal de Isabel II Strategic Plan achieve maximum scores because they are supported by the integrated national and regional hierarchy. These are not merely advisory visions; they are operational frameworks that possess direct spatial mandates. In Istanbul, the local performance is bifurcated. The IMM Climate Change Action Plan stands out as a successful exception, scoring a consistent 2 across all criteria and proving that local strategic will is high. However, this progress is undermined by sectoral documents such as the ISKI Drinking Water and Sewage Master Plan, which maintains a traditional engineering focus and scores 0 in integration. This confirms that without a national bridge in the form of technical guides, local water management in Istanbul remains a utility service handled by a sectoral authority rather than a spatial planning pillar shared by urban planners.

The synthesis of these documents reveals a significant structural contrast in policy distribution. Table 8 highlights that Turkey's performance is concentrated at the highest administrative levels, where its scores for National Legislation (8) and National Action Plans (6) meet or even exceed Spain's (6 and 4, respectively). This indicates a strong central mandate and a proactive state recognition of climate resilience. However, the overall performance gap—35 for Turkey versus 73 for Spain—stems from the 'scalar transmission' of these policies. While Turkey's resilience strategy remains largely confined to top-level mandates and parcel-scale requirements, Spain's strength lies in its National Guides (7) and Local Implementation (30). This suggests that the primary challenge for the Turkish system is not a lack of policy intent, but the absence of bridging documents and spatial standards needed to translate national goals into site-specific, circular urban designs.

7. CONCLUSION

This comparative content analysis demonstrates that urban rainwater management is not merely a technical infrastructure issue, but a challenge of multi-scalar planning hierarchy and legal integration. Despite facing similar climatic risks, the cases of Spain and Turkey exhibit fundamental differences in how resilience is institutionalized. While Turkey stands out with a strong legal will at the national level and mandatory parcel-based applications, it is observed that this success is not effectively transferred to the local scale within the spatial planning hierarchy, as the system is fragmented by boundaries between institutional and technical jurisdictions. In contrast, the Spanish case offers an integrated "policy delivery mechanism" that translates national policy into local spatial practices through national design guides and binding basin plans.

The most striking finding of the analysis is the approach within the Turkish system that treats flood and drought as independent problems rather than a single cycle. This constitutes the primary barrier preventing the circular use of water as a "resource" and the localization of NBS. The lack of spatial indicators and national technical guides causes high-level strategic intentions to dissolve before they can be transformed into concrete urban design standards at the local level.

In conclusion, resilience in the urban rainwater cycle is possible not only by increasing parcel-based storage capacity but by establishing water management as an inseparable pillar of spatial planning. It is a critical necessity for Turkey to transition from its current "parcel-oriented technical mandate" model to a legally integrated hierarchy supported by spatial standards, extending from the basin scale to the neighborhood scale, as seen in Spain. Future planning policies should conceptualize water not as "waste" but as a strategic "spatial asset," making climate adaptation a founding principle of urban design.

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NOMENCLATURE

NBS	Nature-based Solutions
SUDS	Sustainable Urban Drainage System
URWM	Urban Rainwater Management
IPCC	Intergovernmental Panel on Climate Change
PIGSS	Plan Integral de Gestión del Sistema de Saneamiento
IMM	Istanbul Metropolitan Municipality

ISKI	Istanbul Water and Sewerage Administration (Istanbul Su ve Kanalizasyon İdaresi)	PNACC	National Climate Change Adaptation Plan (Plan Nacional de Adaptación al Cambio Climático)

APPENDIX

Appendix A. List of primary policy documents analyzed

No.	Document Title	Type	Issuing Body/ Country	Year
1	Real Decreto 665/2023	Royal Decree / Regulation	BOE (Official State Gazette) / Spain	2023
2	Regulation on rainwater collection, storage, and discharge systems	National Regulation	Official Gazette (T.R. Official Gazette) / Turkey	2017
3	Regulation on amendments to the zoning regulations for planned areas	National Regulation	Official Gazette (T.R. Official Gazette) / Turkey	2021
4	Regulation on amendments to the zoning regulations for planned areas	National Regulation	Official Gazette (T.R. Official Gazette) / Turkey	2025
5	Climate Change Adaptation Strategy and Action Plan (2024-2030)	National Strategy & Action Plan	Ministry of Environment, Urbanisation and Climate Change / Turkey	2023
6	Water Efficiency Strategy Document and Action Plan within the Framework of Adaptation to a Changing Climate (2023-2033)	National Strategy & Action Plan	Ministry of Environment, Urbanisation and Climate Change / Turkey	2022
7	National Climate Change Adaptation Plan (PNACC) (2021-2030)	National Adaptation Plan	Ministry for the Ecological Transition and the Demographic Challenge (MITECO) / Spain	2020
8	Flood Risk Adaptation Guidelines: Sustainable Urban Drainage Systems	Technical Design Guide	Ministry for the Ecological Transition (MITECO) / Spain	2019
9	Tagus Special Drought Plan	River Basin Management Plan	Tagus Hydrographic Confederation (CHT) / Spain	2018
10	Flood Risk Management Plan for the Spanish Part of the Tagus River Basin District (2022–2027): Annex 2	River Basin Flood Management Plan	Tagus Hydrographic Confederation (CHT) / Spain	2022
11	Informational document on the Tagus River Basin Management Plan	River Basin Hydrological Plan	Tagus Hydrographic Confederation (CHT) / Spain	2023
12	Marmara Basin Flood Management Plan	River Basin Flood Management Plan	Ministry of Agriculture and Forestry / Turkey	2023
13	Marmara Basin Drought Management Plan Final Report Volume 1, 2, 3	River Basin Drought Plan	Ministry of Agriculture and Forestry / Turkey	2023
14	Climate adaptation action plan of the City of Madrid	Local Climate Action Plan	Madrid City Council / Spain	2025
15	Basic Guide to Designing Sustainable Stormwater Management Systems	Municipal Technical Guide	Madrid City Council / Spain	2018
16	Istanbul Sustainable Energy and Climate Action Plan	Municipal Climate Action Plan	Istanbul Metropolitan Municipality (IBB) / Turkey	2023
17	Istanbul Climate Change Action Plan (2021-2030)	Municipal Climate Action Plan	Istanbul Metropolitan Municipality (IBB) / Turkey	2021
18	Istanbul Drinking Water and Sewerage Master Plan Scoping Report	Infrastructure Master Plan	ISKI / Turkey	2021

Appendix B. Data sources and climatological datasets

No.	Data Provider/ Publisher	Dataset Title	Description & Scope	Year
1	Turkish State Meteorological Service (MGM)	Official Climate Statistics for Istanbul	Official historical meteorological and precipitation data for Istanbul	2025
2	State Meteorological Agency of Spain (AEMET)	Standard Climate Values: Madrid, Retiro	Official historical climatological records and norms for Madrid (Retiro station)	2025
3	Istanbul Water and Sewerage Administration (ISKI)	ISKI Annual Activity Report 2024	Operational water management and infrastructure activity report for Istanbul	2024