論　文

Multifunctionality and Sustainability in Environmental Water Management: Insights Drawn from Japan's Water Environment Plans

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Abstract: Climate change has intensified global hydrological variability, creating urgent challenges for water security and freshwater sustainability. Environmental water management, integrating ecological, economic, and social dimensions, has become essential to sustainable development. This study compares Taiwan and Japan, focusing on institutional frameworks, governance structures, and case-based practices. Taiwan, despite abundant rainfall, faces uneven distribution, limited river storage, and legal gaps, as its Water Act does not explicitly recognize environmental water. Existing measures include ecological flow frameworks and wetland conservation. By contrast, Japan has developed a comprehensive and adaptive system, supported by national legislation, local ordinances, and strong community participation. Forty-seven regional cases highlight multifunctional practices such as water quality improvement, ecological restoration, recreational spaces, and cultural landscape revitalization. Comparative findings reveal four key dimensions—legal frameworks, community participation, governance flexibility, and multifunctionality—showing Japan's layered, adaptive approach versus Taiwan's institutional constraints. The study concludes that Taiwan could strengthen water governance by explicitly recognizing environmental water, improving institutional coordination, fostering participatory governance, and diversifying water sources. Such reforms would align Taiwan with global sustainability frameworks, including Integrated Water Resources Management and Doughnut Economics, providing a pathway toward resilient and sustainable water governance.

Keywords: environmental water, water resources management, water governance, sustainability

アブストラクト：本研究は、気候変動下での水資源不安定化を背景に、台湾と日本の環境用水管理を比較し、持続可能な水ガバナンスの方策を示すことを目的とする。研究方法は、台湾の法制度・政策資料と日本47地域の水環境計画事例を分析し、法制度・地域参加・ガバナンス柔軟性・多機能性の四軸で整理した。結果として、台湾は水利法に環境用水の明記がなく制度的空白が残るのに対し、日本は国法・地方条例・住民参加が連動し、多様な水源を活用する適応的システムを形成している。日本の事例は水質改善、生態修復、文化・教育の統合を通じ、多機能性を発揮している。台湾においては、法的明確化、部門連携、市民参加、地域間協働を強化することが求められる。両国比較を通じ、環境用水管理は生態・経済・社会を統合する枠組みであり、ドーナツ経済学の「安全で公正な空間」の実現、法と参加の重層化により持続可能でレジリエントな水ガバナンスを支える条件を明らかにした。

キーワード：環境用水、水資源管理、水ガバナンス、持続可能性

1. Introduction

Climate change has significantly affected the global hydrological cycle, exacerbating vulnerabilities in freshwater availability and water security (Intergovernmental Panel on Climate Change [IPCC], 2023). This is evident in the increasing variability of precipitation, prolonged droughts, and more frequent extreme weather events, which disproportionately affect water-stressed regions (IPCC, 2023). The Dublin Principles (1992) emphasize the foundational aspects of freshwater management, identifying four key principles: Ecological, Institutional, Gender, and Economic. The Global Water Partnership (2000) defines Integrated Water Resources Management (IWRM) as a process that promotes the coordinated development and management of water, land, and related resources to maximize economic and social welfare without compromising the sustainability of vital ecosystems. This framework aligns with the United Nations Sustainable Development Goal 6, which aims to ensure access to water and sanitation, integrating environmental, economic, and social dimensions in water resource management between 2020 and 2030 (United Nations, 2021).

The IPCC Sixth Assessment Report (2023) underscores water scarcity as a pressing global challenge, projecting that billions of individuals will experience heightened water stress unless adaptive measures are implemented. This situation necessitates the development of comprehensive water governance strategies that effectively balance ecological sustainability with societal and economic needs.

In addressing the interconnected social, environmental, and economic dimensions of sustainable development, Raworth (2017) introduced the concept of Doughnut Economics in her work Doughnut Economics: Seven Ways to Think Like a 21st-Century Economist. This framework proposes a "safe and just space" for economic development, between the social foundation supporting human well-being and the ecological ceiling safeguarding planetary boundaries. It emphasizes that human economic activities should operate within these boundaries to ensure social justice and environmental sustainability. Doughnut Economics provides a conceptual guide for envisioning a sustainable and equitable future for humanity, often called the "inhabitants of spaceship Earth." It integrates eco-evolutionary principles, novel ecosystems, and the dynamic interplay between social and ecological systems. The application of Doughnut Economics to water resource and environmental management highlights the imperative for resilient water governance strategies. These strategies must prioritize ecological security as a foundation for achieving sustainable water resources. Such an approach aligns with the broader goals of fostering ecosystem resilience and ensuring intergenerational equity in resource utilization.

Environmental water management enhances ecosystem resilience while advancing sustainable development objectives (Arthington et al., 2018, Kosovac et al., 2023). Durán-Sánchez et al. (2018) emphasize the need for equitable water access and ecological preservation in sustainable management. Australia is renowned for having one of the most flexible water markets globally. Recognizing environmental water as a Commonwealth

asset, Australia has established a comprehensive regulatory framework for environmental water management. Moreover, the government allocates substantial funding to acquire environmental water through the water market, ensuring the sustainability and health of aquatic ecosystems (Wheeler, et al., 2023). Andrew, et al. (2020) pointed out, "Environmental water represents a key resource in managing freshwater ecosystems against pervasive." Mooij et al. (2019) further highlight the importance of social-ecological dynamics in aquatic ecosystem models, illustrating the need for comprehensive approaches to environmental management.

Jia et al. (2018) emphasize the role of water environmental carrying capacity in regional sustainable water management and development, demonstrating its fundamental importance in balancing ecological needs and human consumption. Ajami and Hornberger (2008) highlight that managing hydrological uncertainties is critical for ensuring water systems' sustainable and efficient operation, underscoring the need to prioritize environmental water management in policy and practice. These findings collectively highlight the pivotal role of environmental water management in mitigating the multifaceted risks posed by climate change, reinforcing its importance as a cornerstone of sustainable development. Chiueh (2021) suggests clearly defining and regulating environmental water rights to ensure water allocation does not damage ecosystems.

Environmental water management is pivotal in achieving sustainable water resources management, as it integrates ecological, economic, and social dimensions critical to maintaining water security and ecosystem health. Collectively, these perspectives affirm that environmental water management is indispensable in safeguarding the sustainability of water resources and meeting present needs while ensuring their availability for future generations. Kosovac et al. (2023) reviewed 538 peer-reviewed articles up to April 2021 and identified key themes related to environmental water, including the public, Indigenous communities, irrigators, and decision-makers. This underscores the intrinsic connection between environmental water, integrated water resources management (IWRM), and the interests of diverse stakeholders. This article analyzes environmental water management with a comparative focus on Taiwan and Japan, aiming to advance more sustainable approaches to water resources governance in both contexts. Comparing Taiwan and Japan is both relevant and justified. Taiwan faces geographical and legal constraints in environmental water governance, while Japan demonstrates a multi-layered system with strong community participation and diverse practices. Juxtaposing these contexts highlights how institutional and socio-cultural differences shape governance pathways, offering valuable insights for advancing sustainable water management in Asia and beyond.

2. Environmental Water Management in Taiwan

A subtropical island, Taiwan experiences abundant annual rainfall, yet its distribution is uneven. Approximately 70% of precipitation occurs during the summer typhoon and monsoon seasons, with steep terrain and short river systems allowing for the practical storage of only 20% of rainfall. These geographical and

climatic constraints, high population density, and intensive industrialization significantly challenge freshwater resource management. The impacts of climate change, such as increased variability in precipitation and extreme weather events, further underscore the urgency for effective environmental water management (Environmental Protection Administration [EPA], 2023; Water Resources Agency [WRA], 2022).

The legal and policy framework governing Taiwan's water management is based on the Water Act and the Basic Environmental Act, supplemented by laws such as the Water Pollution Control Act and the River Management Act. Recent efforts have embraced integrated water resources management (IWRM), emphasizing cross-sectoral and regional coordination. The Water Resources Agency oversees national water planning, while the Environmental Protection Administration (EPA) monitors water quality. These institutions collaborate to address both water quantity and quality issues, advancing a more holistic approach to water governance (EPA, 2023; WRA, 2022). However, Lin et al. (2020) note that watershed conservation efforts in Taiwan have delivered significant environmental benefits, particularly in regions with semi-arid challenges, showcasing the unique characteristics of island environments.

Despite the comprehensive framework, the Water Act lacks specific provisions for environmental water use as a distinct category. Article 18 of the Water Act prioritizes water rights in the following order: domestic and public use, agricultural use, hydropower generation, industrial use, navigation, and other designated purposes. Environmental or ecological water is not explicitly listed among these categories, highlighting a gap in recognizing environmental flows within the legal framework.

In river basin management, Taiwan has increasingly prioritized environmental water allocations. Major rivers, including the Zhuoshui and Tamsui, have adopted ecological flow frameworks to sustain aquatic ecosystems and mitigate the adverse impacts of over-extraction. These measures aim to balance resource use with the maintenance of environmental integrity, ensuring the functionality of aquatic habitats amidst growing anthropogenic pressures (WRA, 2022). Chiueh and Chen (2003) introduced the concept of a water bank, offering an effective tool for water resource allocation, particularly during periods of scarcity.

Agricultural water management also plays a critical role in environmental water governance. Paddy fields in Taiwan provide multifunctional environmental services (Chiueh & Chen, 2008), including microclimate regulation (Chiueh, Tan & Hsu, 2021). Economic considerations in water resource management are equally vital. Chiueh and Huang (2015) and Huang and Chiueh (2010) investigated the financial implications of transferring agricultural water to industrial sectors, focusing on price elasticity and willingness to pay during drought. These studies underscore the potential for market-based mechanisms to optimize scarce water resource distribution. Additionally, Jiang et al. (2023) applied a socio-hydrological approach to explore how water conservation initiatives enhance human well-being, providing a multidimensional perspective on sustainable water management.

Wetland conservation remains a cornerstone of Taiwan's environmental water management strategy.

Wetlands such as the Zengwen Estuary and the Cieding Wetland deliver crucial ecological services, including habitat provision, flood regulation, and water purification. Chiueh, Liao & Ou (2024) proposed nature-based water management methods to enhance Water Security.

Taiwan faces ongoing challenges in environmental water management, particularly in addressing the impacts of climate change. Wu, Chiueh & Hsu (2018) developed risk analysis models to address uncertainties in irrigation water availability, emphasizing adaptive strategies for agricultural resilience. (Chiueh, Tan & Hsu, 2021). Also, the cooling effects of paddy fields were quantified, demonstrating their importance in mitigating global warming impacts.

Future strategies should strengthen interdepartmental collaboration between water, environmental, and agricultural sectors, as it is essential to balance competing demands. Public education and participation must also be prioritized to elevate societal awareness and foster community-driven conservation efforts. Regional partnerships with neighboring countries, such as Japan and Southeast Asia, could facilitate the exchange of expertise and collaborative responses to shared water management challenges (EPA, 2023; WRA, 2022). By integrating scientific research, policy innovation, and public engagement, Taiwan can develop a more sustainable and resilient model of environmental water management, better equipped to navigate the complex challenges posed by climate change.

3. Sustainable Water Resource Management in Japan: Case Study Perspectives

To trace the origins and gain insights into Japan's water environment and the management of environmental water use, we referred to the "Water Circulation Plan Casebook (水循環計画事例集)" published in 2007 (Heisei 19) by the Water Environment Division, Water and Air Environment Bureau, Ministry of the Environment, Japan (Water Environment Division, Water and Air Environment Bureau, Ministry of the Environment, Japan, 2007). Based on this reference, we collected data on water environments and environmental water management in 47 regions across Japan, as shown in Appendix Table 1. The following sections analyze and reference specific cases from Appendix Table 1 and compare them with the findings from the "Model Project for Improvement of Water Environment in Asia," published by the Ministry of the Environment, Japan, in Reiwa 6 (2024) (Ministry of the Environment, Japan, 2024). This discussion examines the definition of environmental water, its legal framework, and the variations and distinctive characteristics observed across different regions.

3.1 Definition of Environmental Water

According to the 47 cases across Japan, environmental water is "used to improve water quality, maintain or create pleasant landscapes and water-friendly spaces, provide recreational areas, and protect habitats for

flora and fauna." This definition highlights the primary purpose of environmental water: achieving ecological conservation and improvement through the rational use of water resources.

3.2 Legal Basis of Environmental Water

From the 47 cases, the content suggests that the following regulations and policies guide its introduction and management:

3.2.1 Water Quality Regulations

Environmental water quality targets often reference the standards set by Japan's Ministry of the Environment, such as the Environmental Quality Standards for Water Pollution (水質汚濁に係る環境基準) and other relevant criteria, including standards for fisheries, agricultural use, and recreational waters. These standards ensure water quality suitable for specific purposes while safeguarding human health and ecosystems.

3.2.2 River Management Laws

Environmental water extraction and use must comply with Japan's river management laws. For instance, Table 1 shows that the abstraction of river water, including groundwater, requires approval from river administrators (Ministry of Land, Infrastructure, Transport and Tourism, prefectural governments, or municipalities), depending on the classification of the river (e.g., first-class, second-class, or independent systems). This demonstrates that environmental water usage is subject to administrative procedures.

3.2.3 Sewage Laws

When treated sewage is used as environmental water, it must adhere to sewage law standards and reuse guidelines, such as those outlined in the *Technical Guidelines for Sewage Reuse* (*下水処理水循環利用技術指針*). For example, Oita City's Castle Park moat (Case 25) uses highly treated sewage water, meeting landscaping water quality standards.

3.2.4 Local Government Ordinances

Many cases show that local governments enact ordinances tailored to regional needs to promote the introduction and management of environmental water. For instance, Koura Town, Shiga Prefecture, enacted the *Koura Town Community Development Ordinance* to encourage resident participation in projects like the Seseragi Park (Case 8). These ordinances reflect the local governments' emphasis on environmental conservation and community development.

3.3 Variations in Definition Across Cases

Environmental water management in Japan demonstrates diverse applications and definitions, tailored to address unique regional needs and objectives. These projects reflect the country's commitment to leveraging water resources for ecological preservation, quality improvement, and community engagement. By analyzing selected case studies, this paper explores the multifaceted strategies employed in environmental water management, emphasizing their adaptability and impact.

3.3.1 Addressing Water Quality Improvement

Improving water quality remains a priority in many Japanese cases, particularly in response to pollution caused by domestic and industrial wastewater. For instance, the Jonai River in Kitakyushu, Fukuoka Prefecture (Case 2), implemented measures to combat water quality deterioration and eliminate unpleasant odors. This intervention highlights the need for targeted strategies to restore polluted water bodies in urban settings. In contrast, the Agricultural Waterway in Misato, Akita Prefecture (Case 43), exemplifies a focus on ecosystem preservation. This project targeted protecting endangered species such as Ibaratomiyo (Pungitius pungitius), integrating biodiversity conservation into agricultural water management. These cases underscore the dual objectives of improving water quality and safeguarding ecological systems.

3.3.2 Creating Water-Friendly Spaces

Environmental water management in Japan often extends beyond functional objectives, aiming to create water-friendly spaces that enhance community life. The Daisawa Seseragi Greenway in Setagaya, Tokyo (Case 21), transformed a polluted drainage channel into an urban oasis using treated wastewater. This project demonstrated how reclaimed water can advance environmental protection and urban livability by integrating ecological and aesthetic improvements.

Similarly, the Adachi Waterway in Tokyo (Case 12) repurposed urban waterways into recreational spaces, supporting community engagement and relaxation. Meanwhile, the Rokugo and Shichigo Irrigation Canals in Sendai, Miyagi Prefecture (Case 6) illustrate the multifunctionality of water resources. Initially serving irrigation purposes, these canals were adapted to host concerts and environmental education programs for children, merging cultural and educational engagement with resource management. These initiatives highlight the role of water environments in fostering social connections and enhancing community identity.

3.3.3 Restoring Historical and Ecological Features

Restoration projects in Japan often focus on preserving or revitalizing historically and ecologically significant water features. In Mitaka, Tokyo, the Sengen River (Maruike Park) project (Case 16) restored the dried-up Maruike Pond using groundwater, involving residents in the planning process. This initiative revived a

historical water feature and created a water-friendly space with cultural significance, emphasizing the integration of social and environmental objectives.

In Hiratsuka, Kanagawa Prefecture, the Kawauchi River (Case 4) addressed water flow issues during non-irrigation periods by introducing river water to sustain flow. This project improved water quality while supporting agricultural and ecological needs, highlighting the importance of ensuring consistent water availability for multifunctional purposes.

3.3.4 Considerations for Water Source Selection

The choice of water sources is a critical consideration in environmental water management, influenced by regional resource availability. In areas with limited natural water resources, treated sewage often serves as environmental water, as seen in the Castle Park Moat in Oita City (Case 25). Conversely, regions with abundant natural resources, such as the Dobo River Park in Sagamihara, Kanagawa Prefecture (Case 14), rely on groundwater or springs to meet their environmental water needs. Some projects further integrate resource recycling by repurposing industrial or agricultural water, as demonstrated by the Uchikawa Water System in Sakai, Osaka Prefecture (Case 30). These examples illustrate the adaptability of environmental water management strategies to diverse resource contexts.

3.3.5 The Multifunctionality and Sustainability of Environmental Water Management in Japan

The case studies analyzed here showcase the versatility and adaptability of environmental water management across Japan. Whether addressing water quality improvement, creating recreational spaces, restoring historical features, or selecting appropriate water sources, these projects reflect a nuanced understanding of regional needs and priorities. By integrating ecological, social, and cultural objectives, Japanese environmental water management demonstrates a holistic approach that serves as a model for sustainable water resource utilization. These initiatives underscore the potential of environmental water to contribute to broader environmental protection, community development, and biodiversity conservation goals.

4. Comparative Analysis of Environmental Water Management in Taiwan and Japan

Drawing on research and case studies from both Taiwan and Japan, this study finds that Taiwan's environmental water governance is shaped by abundant yet unevenly distributed rainfall, legal gaps in recognizing environmental flows, and mounting pressures from industrialization and climate change (EPA, 2023; WRA, 2022; Wu, Chiueh & Hsu, 2018; Chiueh, 2021). A major issue in Taiwan's environmental water management is the absence of explicit provisions in the Water Act recognizing "environmental water" as an independent category and the lack of a designated authority responsible for its management. Japan, in contrast,

has developed a more comprehensive and flexible system, supported by national legislation, local ordinances, and active community participation, with 47 regional cases exemplifying multifunctional applications (Water Environment Division, 2007; Ministry of the Environment, 2024). Table 4-1 compares environmental water management in Taiwan and Japan, highlighting differences in geographical and climatic conditions, significant

Table 4-1 Institutional and Case-Based Comparison of Environmental Water Management in Taiwan and Japan

Dimension	Taiwan	Japan
Geographical and Climatic Conditions	Abundant annual rainfall but uneven distribution; 70% of precipitation occurs during summer typhoon and monsoon seasons, with only about 20% effectively stored due to steep terrain and short rivers (EPA, 2023; WRA, 2022).	47 regional cases demonstrate diverse approaches to water source utilization (Water Environment Division, 2007; Ministry of the Environment, 2024).
Major Challenges	High population density, rapid industrialization, and climate change impacts (Wu, Chiueh & Hsu, 2018). Lack of explicit legal recognition of environmental water (Chiueh, 2021).	Pollution from domestic and industrial wastewater, water shortages during non-irrigation periods, and dried-up historical water bodies, addressed through community participation and restoration projects (Water Environment Division, 2007).
Legal and Policy Frameworks	Governed by the Water Act, the Basic Environmental Act, and related legislation; however, Article 18 of the Water Act does not explicitly list environmental water (WRA, 2022).	Guided by Environmental Quality Standards for Water Pollution, river management laws, sewage reuse guidelines, and local ordinances (Water Environment Division, 2007).
Governance	The Water Resources Agency is responsible for water quantity, while the Environmental Protection Administration oversees water quality; gradually advancing Integrated Water Resources Management (IWRM) (EPA, 2023; WRA, 2022).	Dual support of national laws and local ordinances, with strong community participation (Water Environment Division, 2007).
Management Strategies and Tools	- Legal Regulation: Ecological flow frameworks (WRA, 2022). - Academic Initiative: Water bank (Chiueh & Chen, 2003). - Academic Initiative: Multifunctional services of paddy fields (Chiueh & Chen, 2008; Chiueh, Tan & Hsu, 2021).	- Practical Case: Water quality improvement (Jonai River, Case 2). - Practical Case: Wastewater reuse (Castle Park moat in Oita City, Case 25). - Practical Case: Restoration of historical water bodies (Maruike Pond in Mitaka, Case 16; Kawauchi River, Case 4) (Water Environment Division, 2007).
Economic Aspects	Studies on price elasticity and willingness to pay for reallocating agricultural water to industrial sectors during droughts (Huang & Chiueh, 2010; Chiueh & Huang, 2015).	Primarily supported by institutional guarantees, with less focus on market-based mechanisms (Water Environment Division, 2007).
Ecological and Social Values	Wetland conservation (e.g., Zengwen Estuary and Cieding Wetland) (Chiueh, Liao & Ou, 2024).	Community-based water-friendly spaces (Adachi Waterway, Case 12; Daisawa Seseragi Greenway, Case 21) (Water Environment Division, 2007).
Future Directions	Strengthening interdepartmental collaboration, promoting public education and participation, and fostering regional cooperation (EPA, 2023; WRA, 2022).	Continued enhancement of community participation and multi-level governance, serving as an international model (Ministry of the Environment, 2024).

challenges, legal and policy frameworks, governance structures, management strategies and tools, economic considerations, and ecological and social values. The comparison underscores how institutional design and practical applications shape distinct pathways for sustainable water governance in both contexts.

With respect to legal frameworks, Taiwan's Water Act continues to lack explicit recognition of environmental water and a designated authority, in contrast to Japan's multi-layered system that integrates national standards with enabling local ordinances (WRA, 2022; Chiueh, 2021; Water Environment Division, 2007; Ministry of the Environment, 2024). Regarding community participation, Taiwan's wetland initiatives reveal meaningful local engagement, whereas Japanese cases more systematically institutionalize resident involvement, thereby linking governance with education, culture, and stewardship (Chiueh, Liao & Ou, 2024; Water Environment Division, 2007). In terms of flexibility, Taiwan is making progress toward IWRM and interdepartmental coordination but remains constrained by hydro-geographic realities and legal gaps; Japan, by contrast, employs diversified water sources through dual national–local governance to achieve adaptive, place-specific management (EPA, 2023; WRA, 2022; Water Environment Division, 2007). Finally, with respect to multifunctionality, Taiwan's paddy fields and wetlands provide verified ecological and climatic benefits, while Japanese cases more explicitly integrate ecological restoration with recreation, heritage, and environmental education (Chiueh & Chen, 2008; Chiueh, Tan & Hsu, 2021; Water Environment Division, 2007).

Taken together, these correspondences substantiate the study's conclusion that strengthening Taiwan's legal recognition and dedicated governance of environmental water—while expanding participatory, multi-source, and multifunctional practices—offers a concrete pathway toward resilient and sustainable water management. As summarized in Table 4-2, the synthesis of comparative findings from Taiwan and Japan highlights four key dimensions—legal frameworks, community participation, governance flexibility, and multifunctionality—demonstrating how institutional gaps and contextual constraints in Taiwan contrast with Japan's layered, community-based, and multifunctional approach. This alignment provides a solid foundation for policy recommendations aimed at advancing resilient and sustainable water governance in Taiwan.

As climate change continues to impact the global hydrological cycle, the critical importance of environmental water management cannot be overstated. Environmental water management is a multidimensional issue that spans ecological, economic, and social domains. Through an analysis of Japan's cases in water environment management and environmental water conservation, this study highlights Japan's multifunctional and adaptive approaches that successfully balance environmental protection, community needs, and economic development. Guided by a clear legal framework and the active role of local governments, Japan provides valuable insights for Taiwan and other nations in the following areas:

1. **Multilevel Regulatory Support**: The integration of national-level environmental standards with region-specific ordinances ensures the effectiveness of environmental water management.
2. **Emphasis on Community Participation**: Many cases illustrate how active involvement of local residents

Table 4-2 Alignment of Comparative Findings with Core Conclusions on Environmental Water Management

Comparative Findings	Taiwan	Japan	References
Legal frameworks	The Water Act (Art. 18) does not explicitly recognize environmental/ ecological water; no dedicated authority; ecological flow frameworks are used in basin management, but the legal basis remains partial.	National environmental quality standards, river management laws, and sewage-reuse guidelines, reinforced by local ordinances, provide a layered legal–institutional foundation.	WRA (2022); Chiueh (2021); Water Environment Division (2007); Ministry of the Environment (2024)
Community participation	Wetland conservation and local initiatives (e.g., Zengwen Estuary, Cieding Wetland) indicate community roles, though institutionalized participation can be strengthened.	Numerous cases embed resident co-production (e.g., Adachi Waterway, Daisawa Seseragi Greenway, Kōra Town Seseragi Park), linking education, culture, and stewardship.	Chiueh, Liao & Ou (2024); Water Environment Division (2007)
Flexibility in governance and resource use	IWRM and interdepartmental coordination are advancing, but flexibility is constrained by uneven rainfall, steep topography, and legal gaps.	Adaptive portfolios draw on groundwater, springs, reclaimed wastewater, and reuse of agricultural/industrial water; dual national–local governance enables place-based tailoring.	EPA (2023); WRA (2022); Cases 14, 25, 30 (Water Environment Division, 2007)
Multifunctionality	Paddy fields provide multiple ecosystem services, including microclimate regulation; wetlands offer habitat, flood regulation, and purification.	Cases simultaneously pursue water-quality recovery, ecological restoration, recreation, heritage landscapes, and environmental education (e.g., Jonai River, Maruike Pond, Rokugo/Shichigo canals).	Chiueh & Chen (2008); Chiueh, Tan & Hsu (2021); Cases 2, 6, 16, 21 (Water Environment Division, 2007)

in planning and implementation strengthens the sense of ownership and responsibility for shared resources.

3. **Flexible Water Source Utilization**: Tailoring water sources to regional resource conditions maximizes the sustainable use of available water resources.
4. **Multifunctionality**: Combining water quality improvement, ecological conservation, and societal needs demonstrates a comprehensive approach to water resource management.

In contrast, Taiwan faces severe geographical and climatic challenges in environmental water management, particularly due to uneven rainfall distribution and limited river storage capacity. High population density and rapid industrialization further exacerbate pressures on water resources. While Taiwan has made progress in adopting integrated water resources management (IWRM), including the restructuring of agricultural water management under the Irrigation Agency, environmental water remains underrepresented in the legal framework. Moving forward, Taiwan's strategies should focus on:

1. **Revising Legal Frameworks**: Explicitly incorporating environmental water into the priority hierarchy within the *Water Act* and establishing clear environmental flow requirements.

2. **Enhancing Cross-Sector Collaboration**: Strengthening cooperation among water, environmental, and agricultural agencies to facilitate effective resource management.
3. **Increasing Public Engagement**: Promoting education and outreach to raise societal awareness of the significance of environmental water management.
4. **Fostering Regional Collaboration**: Establishing partnerships with Japan and other Asian nations to share and adopt successful environmental water management practices.

Resilient water governance not only secures the long-term sustainability of water resources but also fosters the realization of the "safe and just space" envisioned by Doughnut Economics. Amidst the global challenges of climate change and water scarcity, the experiences of Japan and Taiwan in water environment management and environmental water conservation offer guidance for policy formulation and implementation in other regions. Only through comprehensive management strategies and international cooperation can we ensure the long-term sustainability of water resources.

5. Conclusion

In conclusion, this comparative study of Taiwan and Japan underscores the academic significance and practical value of examining diverse governance contexts in environmental water management. Taiwan demonstrates the difficulties posed by uneven rainfall, limited storage capacity, and gaps in legal recognition, while Japan illustrates how multi-level legal frameworks, strong community participation, diversified water sources, and multifunctional practices can enhance resilience and sustainability.

By juxtaposing these two cases, the analysis validates the relevance of cross-national comparison and offers transferable lessons. Japan's experience reveals the value of an integrated and adaptive system—anchored by national standards, reinforced by local ordinances, and supported by citizen participation—that successfully balances ecological protection, social needs, and economic development. For Taiwan, adopting these lessons by strengthening legal recognition of environmental water, improving institutional coordination, expanding participatory governance, and diversifying strategies provides a concrete pathway toward resilient water governance.

As climate change reshapes the global hydrological cycle, the urgency of environmental water management cannot be overstated. It is inherently multidimensional, integrating ecological, economic, and social domains. Strengthening Taiwan's governance framework while drawing on Japan's adaptive practices would not only secure long-term water sustainability but also align with global frameworks such as Integrated Water Resources Management and Doughnut Economics. Ultimately, resilient water governance safeguards ecosystems and ensures intergenerational equity, sustaining both ecological integrity and human well-being under mounting climate challenges.

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Appendix

Appendix Table 1 Water circulation plan case (水循環計画事例) in Japan

No.	Region	Case Description
1	Setagaya, Tokyo	Jidaifu Park utilizes a pump to draw water from a river, purify it, and reintroduce it, improving water quality.
2	Kitakyushu, Fukuoka	The Jonai River case focuses on improving urban river water quality and landscapes, turning it into a tourism resource.
3	Takaoka, Toyama	The Takaoka Castle Park moats case aims to improve water quality and landscapes through water diversion.
4	Hiratsuka, Kanagawa	The Kawauchi River case addresses water shortage during non-irrigation periods and improves water quality.
5	Kitami, Hokkaido	The Horikan River case showcases creating a water-friendly urban space using natural flow and rainwater.
6	Sendai, Miyagi	The Rokugo and Shichigo irrigation canal case transforms historic agricultural waterways into spaces for tourism and leisure.
7	Hino, Tokyo	The local waterway case uses the "Water Steward System" to encourage community participation in waterway maintenance and management.
8	Koura, Shiga	The Seseragi Park case demonstrates creating a water park with recreational and educational value through community participation.

No.	Region	Case Description
9	Niigata City, Niigata	The Toyanogata case involves restoring multifunctionality to agricultural drainage through workshops and community engagement.
10	Ina, Nagano	The Nakasei case focuses on converting old agricultural waterways into more natural water channels, creating habitats for biodiversity.
11	Nerima, Tokyo	The Fujimi Pond case explores improving pond water quality in an urban park.
12	Adachi, Tokyo	The Adachi Waterway and Storage Channel case creates a water-friendly space and provides flood control using rainwater and new waterways.
13	Mitaka, Tokyo	The Sengen River (Nogawa Yukibashi) case restores urban river flow and ecology through water diversion.
14	Sagamihara, Kanagawa	The Dobo River Park case creates a natural water environment in the park using groundwater and springs.
15	Kiyose, Tokyo	The Kiyose Seseragi Park case uses a groundwater circulation system to create a water-friendly space and ecological habitats.
16	Mitaka, Tokyo	The Sengen River (Maruike Park) case restores a historic pond using existing well water.
17	Itami, Hyogo	The Konya Pond case improves pond water quality through a new water diversion system.
18	Tochigi City, Tochigi	The Marunuma Nagatoro Park case combines spring water and groundwater to create a water park.
19	Kitakyushu, Fukuoka	The Teraizugawa case uses tunnel spring water to stabilize river flow and create firefly habitats.
20	Yokohama, Kanagawa	The Imai River case involves community participation to transform an urban river into a recreational space for residents.
21	Setagaya, Tokyo	The Daisawa Seseragi Greenway case creates urban green spaces and water environments using treated wastewater.
22	Kawasaki, Kanagawa	The Egawa Seseragi Promenade case creates a water-friendly walkway using treated wastewater.
23	Daito, Osaka	The Goryo Irrigation Canal case upgrades the sewage system to achieve water resource recycling.
24	Kawagoe, Saitama, and others	The Furo River case emphasizes community participation in improving river water quality through water diversion.
25	Oita City, Oita	The Castle Park Moat case improves historic castle moat water quality using water circulation technology.
26	Yokohama, Kanagawa	The Egawa Seseragi Greenway case creates water-friendly spaces using treated wastewater.
27	Kamihayashi, Niigata	The Oike case maintains pond water levels using agricultural irrigation canals in the absence of natural water sources.
28	Tago, Aomori	The Seseragi Waterway case creates scenic waterways using agricultural drainage.
29	Eniwa, Hokkaido	The Eniwa New Town "Megumino" case creates water-friendly environments in a new town using agricultural irrigation canals.
30	Sakai, Osaka	The Uchikawa Water System case improves river water quality using groundwater from industrial and agricultural reservoirs.

No.	Region	Case Description
31	Mishima, Shizuoka	The Genbe River case creates a water-friendly community space using factory cooling water in collaboration with local businesses.
32	Soka, Saitama	The Yagota Irrigation Canal case repurposes underutilized agricultural water for environmental purposes.
33	Soka, Saitama	The Kasai Irrigation Canal case also focuses on repurposing agricultural water for environmental purposes.
34	Koriyama, Fukushima	The Rainwater Mainstream Promenade case creates a water-friendly walkway using rainwater purification systems.
35	Koganei, Tokyo	The Biotope Waterway case purifies water naturally to enhance biodiversity.
36	Ota, Tokyo, and Kawasaki, Kanagawa	The Tenmizu Garden and Senzoku Gakuen School cases create ecological ponds using rainwater collection systems.
37	Mitaka, Tokyo	The Sengen River (Akebono Park) case creates a natural park using rainwater storage facilities.
38	Kamihayashi, Niigata	The Ariake Community Freshwater Park case creates an ecological park using existing water sources and new facilities.
39	Musashino, Tokyo	The Sengen River (Green Space) case increases river flow using water treatment plant backwash water, improving accessibility.
40	Yokohama, Kanagawa	The Shimo-Tanamoto Seseragi Greenway case uses existing sewage pipelines to create a green belt with ponds.
41	Kami, Miyagi	The Miyazaki Eastern Community Agricultural Drainage case creates eco-friendly and recreational drainage channels through community participation.
42	Nasushiobara, Tochigi	The Nasu Plain Irrigation Canal case balances agricultural water use with ecological protection and community involvement.
43	Misato, Akita	The Agricultural Waterway case protects endangered species and their habitats using eco-engineering.
44	Machida, Tokyo	The Tsurumi River Source case protects spring water at the river source through community efforts.
45	Konan, Kochi	The Kamii River case transforms historic agricultural waterways into spaces with tourism and educational significance.
46	Taketa, Oita	The Hirata Agricultural Waterway case creates biodiversity-rich environments through eco-engineering methods.
47	Shibata, Niigata	The Agricultural Waterway case protects endemic fish habitats through waterway remodeling.

Source: Water Environment Division, Water and Air Environment Bureau, Ministry of the Environment, Japan. (2007)