

INTERNATIONAL SMART WATER ACCOUNTING FOR SUSTAINABLE WATER SELF-SUFFICIENCY

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ABSTRACT

Water scarcity and inefficient water governance remain critical challenges for agricultural communities worldwide. This study aims to develop and analyze an International Smart Water Accounting framework to support sustainable water self-sufficiency through academic collaboration and community empowerment. The approach integrates water accounting principles, digital monitoring systems, and participatory governance to improve transparency, accountability, and efficiency in water resource management. Using a qualitative-descriptive and case-based approach, this study highlights how smart water accounting can be implemented as a scalable and replicable model across different agricultural contexts. The findings indicate that international academic collaboration enhances knowledge transfer, strengthens local capacity, and supports sustainable water governance aligned with global sustainability agendas. This study contributes to the advancement of water accounting practices and provides practical implications for policymakers, higher education institutions, and community-based water management initiatives.

Keywords: Smart Water Accounting, Sustainable Water Self-Sufficiency, International Collaboration, Water Governance, Agricultural Communities

1. INTRODUCTION

Water self-sufficiency has become a strategic priority for many countries as water scarcity, climate change, and agricultural demand continue to intensify. Agriculture remains the largest consumer of freshwater resources, yet water management practices in many regions are still characterized by limited transparency, weak accountability, and inefficient allocation mechanisms. These challenges highlight the urgent need for innovative and sustainable water governance models.

Water accounting has emerged as an important tool to support evidence-based decision-making by systematically measuring, recording, and reporting water inflows, outflows, and usage efficiency. However, conventional water accounting approaches often

lack real-time data integration and community participation, limiting their effectiveness in supporting sustainable water self-sufficiency.

The development of Smart Water Accounting, which integrates digital technologies, accounting frameworks, and participatory governance, offers a promising solution to these challenges. Moreover, international academic collaboration plays a crucial role in strengthening the capacity of higher education institutions to transfer knowledge, develop scalable models, and empower local communities through the three pillars of higher education: education, research, and community engagement.

This paper aims to explore how International Smart Water Accounting can support sustainable water self-sufficiency by combining accounting principles, smart systems, and international academic collaboration, particularly in agricultural communities.

2. LITERATURE REVIEW

2.1 Water Accounting and Sustainable Resource Management

Water accounting refers to a structured approach for identifying, quantifying, recording, and reporting water resources within a defined system or region. This approach applies fundamental accounting principles, including transparency, accountability, and traceability, to support sustainable water resource management. By providing reliable and systematic information, water accounting enables policymakers and stakeholders to make informed decisions based on empirical evidence.

Previous studies highlight that water accounting contributes to improved water allocation efficiency by revealing imbalances between water availability and consumption. Furthermore, it facilitates sustainability monitoring through indicators such as water productivity, irrigation efficiency, and environmental impacts associated with water use. These measurements serve as a critical foundation for designing and evaluating water management policies aimed at long-term sustainability.

In agricultural settings, water accounting plays a particularly important role, as agriculture represents the largest global consumer of freshwater resources. Through water accounting, water productivity can be assessed by comparing agricultural outputs with the volume of water utilized. This assessment supports the evaluation of irrigation practices, identifies potential inefficiencies, and promotes more sustainable and responsible water use in agricultural systems.

2.2 Smart Systems in Water Governance

Advances in digital technology have significantly transformed water governance through the adoption of smart systems. These systems include the use of sensors, Internet of Things (IoT) devices, digital dashboards, and decision support systems (DSS) that enable continuous, real-time monitoring of water resources. Such technologies enhance data accuracy and timeliness, thereby improving the quality of information available for decision-making.



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Smart water systems facilitate predictive analysis of water availability and consumption patterns, allowing early identification of risks such as water shortages, system losses, or inefficient irrigation. Digital dashboards further support effective communication by presenting complex datasets in accessible visual formats for diverse stakeholders, including water managers and community users.

When integrated with water accounting frameworks, smart systems strengthen the reliability, relevance, and usability of water-related information. Real-time data captured by sensors can be directly incorporated into water accounting reports, transforming water accounting from a retrospective reporting tool into a proactive mechanism that supports transparent, accountable, and evidence-based water governance.

2.3 International Academic Collaboration and Community Empowerment

International academic collaboration serves as a key mechanism for advancing knowledge, innovation, and capacity building through cross-border partnerships. Such collaboration enables the exchange of expertise, methodologies, and best practices across institutions, particularly in the fields of sustainable resource management and environmental accounting. As a result, higher education institutions can enhance both the quality and the global relevance of their academic and social contributions.

Within the context of sustainable development, international academic collaboration supports community empowerment by aligning global knowledge with local priorities and conditions. This process typically involves capacity-building activities such as training programs, technical assistance, and the co-development of context-specific solutions. Consequently, local communities are positioned not merely as beneficiaries, but as active participants in sustainable water management initiatives.

Higher education institutions play a strategic bridging role by linking scientific research, public policy, and community-level implementation. Through the integration of education, research, and community engagement, universities translate international collaboration outcomes into practical interventions that strengthen local capacities and promote sustainable water governance.

2.4 Sustainable Water Self-Sufficiency

Sustainable water self-sufficiency refers to the capacity of a community or region to meet its water needs independently without compromising ecological balance or diminishing water availability for future generations. This concept emphasizes the integration of economic viability, social equity, and environmental protection in water resource management. Achieving water self-sufficiency therefore requires attention not only to water quantity, but also to water quality, usage efficiency, and inclusive governance structures.

The concept aligns closely with global sustainability frameworks, particularly Sustainable Development Goal (SDG) 6, which emphasizes universal access to clean water and sanitation, as well as the implementation of transparent, inclusive, and accountable water governance systems. Sustainable water self-sufficiency depends on

governance mechanisms that are data-driven, participatory, and responsive to local conditions.

In practice, sustainable water self-sufficiency can be achieved through the integration of water accounting, smart water systems, and community empowerment strategies. This integrated approach enables communities to better understand water usage patterns, improve efficiency, and make informed decisions that support long-term sustainability. As such, water self-sufficiency represents not only a technical objective, but also an ongoing social and institutional process.

2.5 Conceptual Framework of the Study

This study develops a conceptual framework that integrates key theoretical components discussed in the previous subsections, namely water accounting, smart water systems, international academic collaboration and community empowerment, and sustainable water self-sufficiency. The framework is designed to explain how these interrelated elements collectively contribute to sustainable water governance, particularly within agricultural contexts.

At the foundation of the framework lies water accounting, which serves as a core mechanism for ensuring transparency, accountability, and systematic measurement of water resources. By applying accounting principles to water resource management, water accounting provides structured information on water availability, consumption, efficiency, and sustainability performance. This information forms the essential baseline for evidence-based decision-making and policy formulation.

Building upon this foundation, smart water systems function as an enabling mechanism that enhances the effectiveness of water accounting. The integration of sensors, digital monitoring tools, and decision support systems enables real-time data collection and analysis. As a result, water accounting evolves from a retrospective reporting approach into a proactive management tool capable of supporting predictive analysis, risk assessment, and adaptive governance. The combination of water accounting and smart systems significantly improves the reliability, timeliness, and relevance of water-related information.

The framework further incorporates international academic collaboration and community empowerment as a catalytic dimension that facilitates knowledge transfer, capacity building, and contextual adaptation. Through cross-border academic partnerships, global best practices in water governance and sustainability accounting can be translated into locally appropriate solutions. Community empowerment plays a critical role in ensuring the effective implementation and long-term sustainability of the framework by fostering stakeholder participation, ownership, and institutional learning.

Based on the synthesis of previous studies on water accounting, smart water systems, international academic collaboration, and sustainable water governance, this study proposes a conceptual framework as illustrated in Figure 1.

International Smart Water Accounting for Sustainable Water Self-Sufficiency

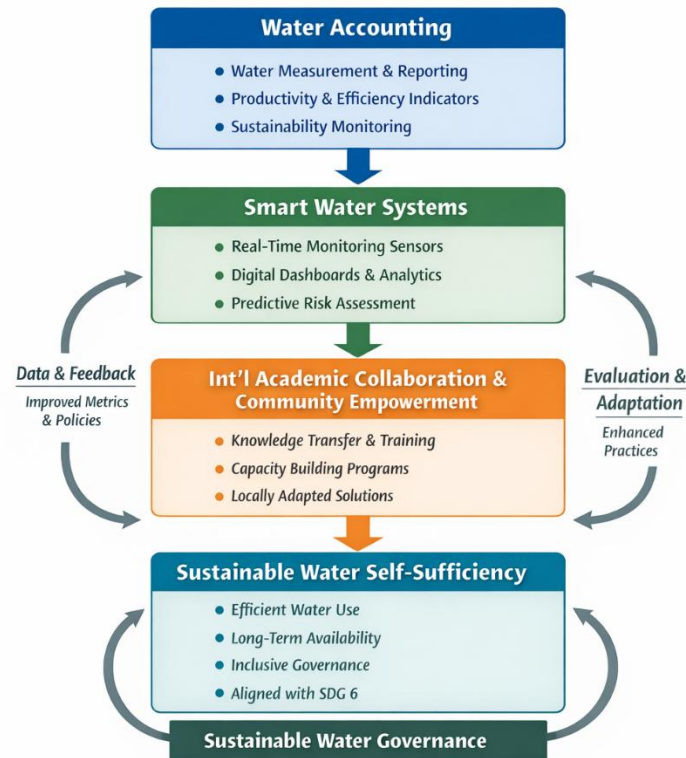


Figure 1. Conceptual Framework of International Smart Water Accounting

The final outcome of the conceptual framework is sustainable water self-sufficiency, defined as the ability of communities to meet their water needs efficiently and equitably without compromising environmental integrity or future water availability. This outcome reflects not only technical improvements in water management, but also strengthened governance structures that align with global sustainability agendas, particularly Sustainable Development Goal (SDG) 6.

3. DISCUSSION

The implementation of International Smart Water Accounting represents a comprehensive and integrative strategy for advancing sustainable water self-sufficiency. By combining accounting frameworks, smart technologies, and international academic collaboration, this approach addresses not only technical challenges but also governance and institutional dimensions of water management.

From an accounting perspective, the application of water accounting principles enhances transparency, consistency, and accountability in water resource utilization. Structured measurement and reporting systems allow stakeholders to evaluate water efficiency, monitor sustainability indicators, and assess long-term resource availability. This accounting-based approach transforms water management from an ad hoc

operational activity into a systematic governance process grounded in measurable performance outcomes.

The incorporation of smart technologies further strengthens this framework by enabling real-time monitoring, data integration, and predictive analysis. Digital sensors, dashboards, and decision support systems improve the accuracy and timeliness of water-related information, allowing stakeholders to respond more effectively to water scarcity, climate variability, and operational risks. As a result, smart water accounting supports adaptive decision-making and enhances resilience within agricultural water systems.

A critical dimension of this model is the role of international academic collaboration, which facilitates methodological innovation, comparative research, and capacity development. Through cross-border partnerships, higher education institutions contribute scientific expertise, technological transfer, and best practices in sustainability accounting and water governance. Collaborative research initiatives and training programs enhance local competencies, ensuring that advanced water accounting models are appropriately adapted to local socio-economic and environmental contexts.

Moreover, the integration of community empowerment within the smart water accounting framework reinforces stakeholder participation and institutional sustainability. The participatory nature of data collection, monitoring, and evaluation fosters a sense of ownership and shared responsibility among community members. This social engagement not only improves compliance and operational effectiveness but also strengthens local institutions and collective decision-making processes.

Importantly, the findings of this study emphasize that smart water accounting should not be viewed solely as a technical or informational tool. Instead, it functions as a governance mechanism that aligns accounting systems, digital innovation, and community empowerment within an international collaborative framework. This alignment supports sustainable water self-sufficiency by integrating global knowledge with local action, thereby contributing to broader sustainability agendas, particularly Sustainable Development Goal 6 (Clean Water and Sanitation).

Overall, the discussion demonstrates that International Smart Water Accounting offers a scalable and adaptable model for sustainable water governance, capable of addressing complex water challenges through interdisciplinary collaboration, technological integration, and participatory implementation.

Table 1. Outcomes and Impact Indicators of International Smart Water Accounting

Dimension	Indicator Category	Specific Indicators	Regional Relevance (West Java)
Governance Outcomes	Transparency & Accountability	- Availability of standardized water accounting reports - Increased transparency in irrigation water allocation	Supports provincial water governance reforms and irrigation management accountability

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Dimension	Indicator Category	Specific Indicators	Regional Relevance (West Java)
		- Improved compliance with water governance regulations	
Technological & Operational Outcomes	Smart Water Management	- Real-time water monitoring data availability - Improved accuracy of irrigation scheduling - Reduction in water losses and inefficiencies	Relevant to irrigation systems in agricultural areas of West Java
Capacity Building Outcomes	Human Resource Development	- Increased technical skills of local water managers and farmer groups - Improved data literacy and decision-making capacity	Strengthens local institutional capacity in rural and agricultural communities
Community Empowerment Outcomes	Participation & Ownership	- Active involvement of communities in water monitoring and reporting - Strengthened sense of ownership over water resources	Enhances social cohesion and participatory governance at village and farmer-group levels
Environmental Impacts	Sustainability & Resilience	- Improved water-use efficiency in agriculture - Reduced risk of water overextraction - Enhanced resilience to climate variability	Supports sustainable water availability for West Java's agricultural sector
Socio-Economic Impacts	Livelihood & Productivity	- Increased agricultural productivity - Improved income stability for farming communities - Reduced conflicts over water resources	Contributes to rural economic resilience and food security
Policy & Institutional Impacts	Policy Mainstreaming	- Integration of smart water accounting into regional policies - Evidence-based water planning and budgeting	Aligns with provincial and national water resource management strategies

Dimension	Indicator Category	Specific Indicators	Regional Relevance (West Java)
Academic & Global Impacts	Internationalization & Collaboration	- Joint publications and international research outputs - Knowledge transfer and best-practice adoption	Positions West Java as a model for international smart water governance

4. CONCLUSION

This study demonstrates that International Smart Water Accounting is a viable and strategic approach to supporting sustainable water self-sufficiency, particularly in agricultural communities. By integrating accounting frameworks, smart technologies, and international academic collaboration, this model enhances transparency, accountability, and community capacity in water governance.

The findings suggest that higher education institutions play a critical role in advancing sustainable water management through the internationalization of education, research, and community engagement. Future studies are encouraged to apply this framework in diverse geographical contexts and incorporate quantitative performance indicators to further validate its effectiveness.

Overall, International Smart Water Accounting provides a scalable and replicable model that contributes to global efforts toward sustainable water governance and community empowerment.

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