

Policy analysis of water resources and irrigation management for strengthening food security in Indonesia

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Submitted 21 September 2025; Accepted 31 October 2025; Published 1 November 2025

ABSTRACT

Indonesia is still classified as a country with a relatively high population growth rate. Economic growth embodied in increased industrial, service, and urban activities requires support from various sectors, including raw water supply. Water resources for food security are related to irrigation's quantity, quality, and accessibility. Irrigation development can take the form of new infrastructure development, maintenance, and protection of the irrigation water source area. The strategic issue of irrigation as a follow-up from this, cannot be separated from the problem of competition in water allocation, the burden of irrigation service costs, and local political issues regarding water control at the site level. On a policy scale, water resource management for food security requires strengthening regulations, political will, land-use change management, coordination, and adequate funding from the central to regional levels according to their respective authorities. This paper attempts to analyze irrigation development policies in the context of water resources development which aims to provide input on food security policies in Indonesia. This study uses qualitative methods through literature studies on water resources management for food security in Indonesia. The literature review method is based on five principal regulations, ten papers, and government reports. The analysis result recommends food security in the irrigated agriculture sector with strategies to increase production capacity and expand services of irrigation networks. Problems with irrigation water availability can be anticipated by conserving upstream watersheds, optimizing and normalizing reservoirs, and building dam infrastructure as water reservoirs for supplies throughout the planting period. Policies related to water resources affect food security through increasing agricultural production, diversifying production (sufficient water availability supports non-rice farming), reducing the risk of dry seasons, increasing resilience to climate change, and reducing water conflicts. Ensuring sustainable food security demands immediate resolution of irrigation challenges through comprehensive water resource management strategies including upstream conservation, reservoir normalization, infrastructure development, improved governance, and community participation.

Keywords: *Food security, irrigation, policy, water*

INTRODUCTION

Water and food are interconnected, so poor water governance in a country will always be in the public spotlight. Water resources constitute a fundamental element underpinning human survival, ecosystem integrity, and economic development (Singh & Goyal, 2025). Indonesia has several water resource problems, such as water availability, drought, land use change, flooding, miscoordination, insufficient water reserves, and climate change. Successful management of water resources is one of the important keys to irrigation fulfillment and promoting better agriculture as a source of food production (Rachmawati et al., 2024; Sha et al., 2024). What is interesting in the case of Indonesia is that irrigation policies in this country have generally not considered sustainability aspects such as environmental protection, catchment damage, pollution, and mitigation of population growth (Pambudi, 2023a; Pambudi, 2023b).

The results of research by Umami et al. (2022) state that the issue of water resource development faces many challenges, especially in surface water policy. Surface water shortages have received a lot of public attention, marked by the unclear effectiveness of water governance towards sustainability, including in the agricultural sector. The availability of water resources affects the income of Indonesians associated with forestry, agriculture, and other occupations. The problems are caused by land cover and land use change, water pollution, reduced river water discharge, and overlapping policies that affect implementation. On the other hand, Suntana (2021) stated that not fulfilling people's water needs through various government policies is a form of state failure in carrying out the mandate of the basic law. Changes in watershed conditions due to non-optimal coordination between development actors trigger the importance of more comprehensive water resources policy recommendations (Sulistyaningsih et al., 2021).

In Indonesia, agricultural sector development supports food security as financial growth focuses. The authority's affection is dedicated to this sector, considering its function in growing excessive employment possibilities. Economic improvement that prioritizes the agricultural zone is a policy that has become acknowledged since the early 1960s. Historically, irrigation management in Indonesia has undergone several critical phases. During colonial rule and the early independence era, irrigation infrastructure development was primarily centralized, managed by the government, and characterized by minimal community involvement. During these periods, policy directions emphasized the expansion of agricultural areas (particularly for rice production) as a means to enhance national productivity. However, the centralized administrative framework underpinning these initiatives frequently gave rise to structural inefficiencies, constrained institutional openness, and a lack of robust accountability mechanisms (Tampubolon, 2023).

The economic crisis of 1998 further exacerbated these inefficiencies, causing substantial damage to irrigation networks due to inadequate operation and maintenance funding. Previously (within the 40s and 50s), agriculture became visible as a passive area in economic improvement and support for more active and dynamic sectors, which include the industrial (Pambudi & Kusumanto, 2023; Rozaki, 2021). Within the National Medium-time period development Plan 2020-2024 (RPJMN), one of the development priorities in Indonesia is achieving water, food, and energy security.

Indonesia is still classified as a country with a relatively high population growth rate. Economic growth embodied in expanded commerce, service, and urban activities requires support from various sectors, including raw water supply. Food and energy security is determined by water security. According to the Global Food Security Index (GFSI), Indonesia's food security in 2021 will decline compared to the previous year (The Economist Group, 2022). The GFSI in 2020 recorded that the food security index score reached 61.4 in Indonesia. However, in 2021 the index fell to 59.2. The problem of decreasing this index becomes interesting to analyze if it is associated with the causative factors from various aspects.

The food security associated with the development of water irrigation in Indonesia faces the challenge of increasing water demand, which is not matching with a constant supply, and even tends to decrease. It means the water resources rivalry is getting higher, while it cannot delay the water need (Euler & Heldt., 2018). The fulfillment of water needs must be fair to all parties, considering that delays in fulfilling water in one sector will impact a more complex multiplier effect. Food shortages in the future will be a problem of lack of availability of wild resources as a driving factor,

mismanagement, and sector egos related to many related parties in various regions. If this is not anticipated quickly, there can be a scarcity of agricultural food crops and harm to all parties (Tripathi & Singal, 2019).

The relationship between water resources management, irrigation, and food security in Indonesia thus demands urgent attention, both nationally and globally. Globally, climate change impacts, rapid population growth, and competing land-use pressures amplify the need for sustainable water resource management strategies (Priatna & Monk, 2023; Priatna & Khan 2024). Nationally, these pressures directly influence agricultural productivity, with irrigated agriculture serving as the backbone of Indonesia's food security. Approximately 6.7 million hectares of rice fields rely heavily on irrigation, contributing significantly to rice production that feeds 90% of the population (Tampubolon, 2023).

Sustainable water resource management emphasizes an integrated and holistic approach to managing water resources by balancing environmental, economic, and social considerations, ensuring long-term water availability and equitable access (Li & Wu, 2023). Effective water resources management necessitates the adoption of Integrated Water Resources Management (IWRM), a comprehensive approach that emphasizes coordination across sectors and scales. Central to IWRM is the inclusion of diverse stakeholders in decision-making processes, ensuring that various interests (ranging from government agencies to local communities) are adequately represented. It also incorporates ecosystem-based management principles to maintain ecological balance, while promoting adaptive governance that responds flexibly to environmental uncertainties and socio-economic changes. Moreover, IWRM prioritizes the fair and equitable distribution of water, recognizing it as both a public good and a vital resource for sustainable development across regions and populations. (Ijlil et al., 2025; Genjebo et al., 2023).

Recognizing water as an ecologically bounded, shared resource necessitates coordinated decision-making across sectors, communities, and administrative boundaries. This approach addresses challenges such as scarcity and pollution, enhances climate resilience, promotes conservation practices, and ensures equitable water access, integral to achieving food security and broader sustainable development. Increasingly, IWRM is recognized as foundational to sustainable water resource management, particularly for effective irrigation systems vital to food security. Recent studies highlight IWRM's effectiveness in sustainable governance, ecosystem integration, and stakeholder involvement. Adaptive IWRM practices mitigate drought impacts and enhance irrigation flexibility, crucial for agricultural productivity under climatic variability, thus significantly supporting national food security (Lyra & Loukas, 2023).

Policies related to water resources affect food security through increasing agricultural production, diversifying production (sufficient water availability supports non-rice farming), reducing the risk of dry seasons, increasing resilience to climate change, and reducing water conflicts (Liu et al., 2024). Indonesia has plentiful water. Nevertheless, ineffective water governance has exacerbated disparities in regional water distribution, undermined legal enforcement, contributed to escalating water pollution, and led to significant resource inefficiencies through excessive wastage (Tampubolon, 2023). Irrigation managed by the government has traditionally been a high-cost but inefficient public sector with transparency, accountability, and unprofessional management. We are aware that during the 1998 economic crisis, there was much increase in damage to irrigation networks due to the operation and maintenance performance not being handled optimally because the state did not focus on adequate rehabilitation funds support. The irrigation approach in the past, which was centralized, affected the small role of the community in the irrigation infrastructure management at that time, which resulted in increasing dependence on the government funds provision.

The reform of water resources management in Indonesia was initiated in 1997 through the implementation of the Water Sector Adjustment Program (WATSAP), marking a pivotal shift in the country's water governance paradigm. This program played a critical role in redefining national water policies by promoting integrated water resources management, institutional restructuring, and stakeholder participation. It also emphasized decentralization, sustainability, and improved service delivery. As a result, WATSAP profoundly influenced subsequent policy frameworks, encouraging a more holistic, equitable, and accountable approach to water governance that aligned with international standards and the evolving demands of environmental and socio-economic development (Tampubolon, 2023). In this case, what needs to be achieved includes 1) organizational framework and financing preparation for river basin management, 2) formulation of the policy framework for the water sources development, 3) arrangement for irrigation and institutional management, and 4) institutional arrangement and implementation of water quality management.

Along with the reform of decentralization of authority to the regions, the paradigm developed in sustainable development is shown by the environmental insight that does not ignore social and economic aspects. One crucial part of sustainable water resources management that attracts the government's attention is irrigation as a driver of achieving food security.

It must be recognized that irrigation which is traditionally managed by the government is the most

inefficient public sector with investment costs that are increasingly expensive and are characterized by transparency and public accountability that are less or nothing at all to their performance (Ma'Mun et al., 2021). Since the economic crisis, which reached its peak in 1998, damage to irrigation and irrigation networks has increased as a result of low operating and maintenance performance and inadequate rehabilitation funds. The approach to irrigation development in the past, which tended to be centralized and took over the role of the community in the management of irrigation infrastructure, led to increasing dependence on the provision of government funds and had an impact on decreasing community participation in the operation and maintenance of irrigation networks (Alaerts, 2020).

The development of food security and rural poverty reduction is 1 (one) of the main sectors of the 9 (nine) priorities of the national development agenda included in the Nawacita. Therefore, comprehensive, coordinated, and sustainable water resource management policies are necessary to mitigate these challenges effectively. Aligning water governance with agricultural productivity and food security policies, as emphasized in Indonesia's Medium-Term National Development Plan (RPJMN) 2020-2024 and the Nawacita agenda, is critical to achieving national development priorities. The policy direction of the Indonesian government to strengthen food security in the irrigated agriculture sector to improve food security is by increasing the capacity of production and the services of irrigation networks.

While extensive research has addressed the interconnections among water resource management, irrigation, and food security, previous literature predominantly analyzes these issues in isolation, focusing separately on technical irrigation aspects, climate change impacts, or specific policy challenges. Comprehensive analyses exploring the integral relationships among policy quality, regulatory frameworks governing water resource management, effectiveness of sustainable irrigation governance, and their collective influence on national food security in Indonesia remain relatively scarce. Specifically, critical assessments highlighting the inefficiencies of traditional government-led irrigation management, characterized by inadequate transparency, limited public accountability, and weak intersectoral coordination as principal causes of policy ineffectiveness and food insecurity, are limited. Thus, this research aims to address this literature gap by critically evaluating existing water resource and irrigation management policies, and proposing coherent, sustainable, and reform-oriented policy recommendations to effectively strengthen national food security. This paper attempts to analyze irrigation development policies in the context of water resources development which aims to provide input on food security policies in Indonesia.

METHODS

This paper examines policies on water resources, irrigation, and food security, also their issues are based on literature studies, particularly regarding the government policies implementation. Several variables of government policy issues, such as regulatory, funding, and technical aspects, reflect the condition of water resources management, including sustainable or only short-term oriented (Pambudi, 2025; Cao et al., 2020). This paper uses qualitative analysis through literature research about water resources management for Indonesia's food security. This study attempts to assess irrigation policies that are a part of sustainable water management and support Indonesia's food security.

The analysis begins by describing the general concept and condition of food security in Indonesia and the various regulations that form the basis of its policy. The next step is to describe the condition of water resources, their problems, and management, especially irrigation policies, as part of the state's efforts to achieve food security. Several journals were analyzed to serve as a reference in describing recommendations or general input from experts on the management of water resources that affect the development of food security. Several types of problems and case examples from various regions were also elaborated to strengthen the literature analysis needed to draw conclusions and provide recommendations.

Literature sources are five principal regulations, ten papers, and a minimum of four government reports. Gaps are empty gaps left by previous studies that are diverse and can appear at different levels. I see that there are many studies related to food security, irrigation, and water resources that inspired me to write this paper. The consideration for selecting 10 papers is that they most fully describe the condition of Indonesia, so I concluded to look for gaps, novelty, or findings and conclusions from my research that fill these empty gaps. The research results will offer recommendations based on existing regulations, scientific theory, budgets, and technical aspects to support Indonesian water and food security. There are five fundamental laws concerning water sources. Some of these regulations are 1) The 1945 Constitution of the Republic of Indonesia; 2) Law 17 of 2019 concerning Water Resources; 3) Law 23 of 2014 concerning Regional Government; 4) Law 18 of 2012 concerning Food; and 5) Government Regulation 37 of 2012 concerning Watershed Control. The government reports for the analysis are the National Medium-Time Development Plan documents, Regional Spatial Plans, Watershed Control Plans (RPDAS), Scheme for Water Resources Management, and others.

This paper employs a qualitative analytical method with a descriptive-comparative approach through an extensive literature review, conducted over a 16-week research period. The initial phase involves a preliminary

study to define the research scope and objectives. Data collection occurs between weeks three and six, encompassing scholarly journals, legal documents, government reports, and other academic publications sourced from databases such as Scopus and official national documents. Weeks seven and eight are dedicated to data selection and verification to ensure relevance and credibility. Analysis is conducted during weeks nine through twelve, focusing on evaluating water and irrigation policy frameworks in support of food security, including assessing sustainability dimensions such as regulatory, financial, and technical aspects. The thirteenth and fourteenth weeks are allocated for synthesizing findings and engaging in critical discussion. The final phase, occurring in weeks fifteen and sixteen, is devoted to formulating conclusions and evidence-based policy recommendations derived from the literature analysis.

RESULTS AND DISCUSSION

The governance of Indonesia's water sources pursuits to fulfill the primary needs of a developing population however is limited by the ecosystem's carrying capacity. Water governance in sustainable development relates to laws, regulations and policy cannibalism, and complex silos in water management. Through the years, water resource management has responded to food, water, and power needs. On the other hand, natural resources have portability limits and should have considered carefully. The water problem is an ecological balance issue related to environmental sustainability (Pambudi, 2025; Shackleton et al., 2019). Ecology is associated with ecosystems, where there are biotic and abiotic additives. Ecology relates to people and includes a balance of financial and environmental elements.

For decades, food security development become Indonesia's national development priority (Shah et al., 2023). Most areas of food security are included in action plans and regulations of the government, even though there is still overlap. A study was conducted on Indonesian water and food security regulations in Indonesia to identify recommendations for this research.

Food security is the basic needs fulfillment related to adequate, secure, diverse, and affordable (in quantity and quality) food (Arif et al., 2020). The "food security" definition in Law 18 of 2012 concerning Food includes "individuals" and "appropriate spiritual beliefs" and also the nation's "culture". It could be considered as an "enrichment scope" from the preceding explanation in Law 7 of 1996 concerning Food. It states that the explanation of "food security" in Law 18 of 2012 concerning Food is considerably suitable with the definition from the FAO or Food and Agriculture Organization, where "food security occurs when everyone, at any time, has physical and economic access to food that is safe and nutritious enough to meet their

dietary needs and food preferences for an active and healthy life.”

Several studies have found that the environment can have a significant effect when human activities do not apply conservation principles. More extensively, the coordination and integration problem among fields and areas in watershed control is likewise a difficult obstacle to environmental troubles (Pambudi, 2025). In addition, if development goals are to be more sustainable, it is necessary to pay attention to the contribution and role of the community. For Indonesia, the problem of watershed control significantly influences the overall condition of water sources, which are spreading across almost all major islands. Demand for raw water for industrial activities, the service sector, and urban needs is estimated to increase 2 to 3 times the need. The issue of water security has become a national development agenda for five years and is even planned for 2045. Table 1 shows the data and projections of Indonesia's surface water availability from 2000 to 2045. This table specifically describes the condition of water resources in Indonesia, emphasizing the need for special attention to certain regions in Indonesia that face water availability vulnerabilities. This vulnerability affects irrigation security, which is feared to impact food production.

In general, in the baseline situation, the domestic water supply at the national level can still fulfill the public water demand. The supply availability (supply/demand ratio) is at the level of 342% to 223% of water demand in 2000-2050. However, spatially, water availability at the regional (island) level shows scarcity in certain areas. Special attention needs to be given to water reserves on the island of Java, which has entered a scarce status, and

Table 1. Data and projection of Indonesia's surface water availability in 2024 – 2045 (m³/capita/year).

Year	Sumatra	Java	Bali	Kalimantan	Sulawesi	Maluku	Papua
2024	8,675.48	595.08	1,835.57	43,854.74	9,760.36	29,646.92	170,430.09
2030	7,950.12	546.52	1,713.35	40,305.76	8,956.95	27,451.80	157,197.03
2035	7,393.86	509.97	1,616.98	37,595.86	8,364.889	25,715.61	146,992.25
2040	6,875.53	476.62	1,526.69	35,079.64	7,808.14	24,079.94	137,474.19
2045	6,392.18	445.82	1,443.74	32,741.38	7,293.24	22,550.18	128,568.884

Source: Bappenas (2023).

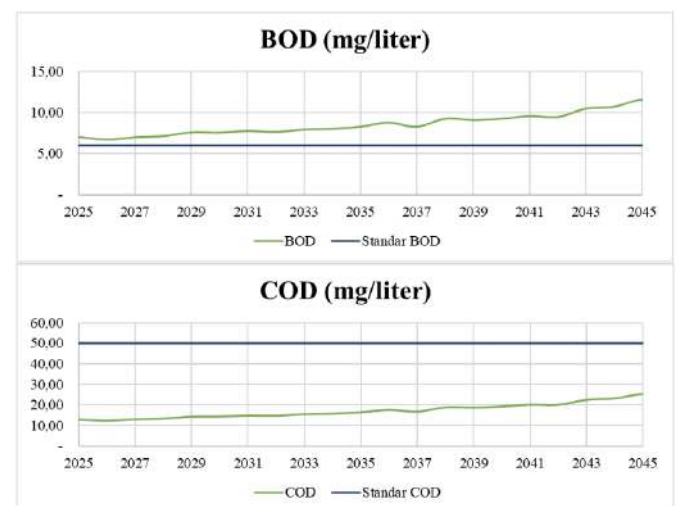
in the Bali-Nusa Tenggara region, which has a confined status.

Improvements also need to be made to water quality, which has declined since 2015 (Pambudi, 2025; Bappenas, 2019). Major water resources policies focus on water conservation, utilisation, and water quality. Emphasis is put on the conservation of water resources because of its vital role in achieving sustainable development (Pambudi & Kusumanto, 2023).

Water resources issues are not only related to quantity, but also quality. In baseline conditions, national water quality tends to deteriorate with continuous BOD and COD values increment every year (Bappenas, 2019; Razali et al., 2018). Figure 1 shows that the standard

values of BOD and COD in Indonesia used as water quality standards are based on Government Regulation 82 of 2001 with class III water quality that can be used for freshwater fish farming, animal husbandry, water for irrigating crops, and other uses that require water quality of the same quality, meaning that the quality is already below the quality of drinking water. Several policies listed in the RPJMN have in fact not been able to overcome the declining ability of water resources as water providers and water quality continue to deteriorate, and the implementation of policy scenarios is only able to inhibit the rate of decline.

Figure 1 shows that the BOD value at the national level will even exceed the BOD standard limit in 2030 (BOD Class III standard in Government Regulation Number 82 of 2011). The COD value at the national level still has not exceeded the COD Class III standard in Government Regulation Number 82 of 2011 but shows values that continue to increase every year. Implementing sustainable agricultural management can suppress the BOD value and pass the BOD standard in



Source: Bappenas (2023).

Figure 1. Data, and projections of water (a) BOD and (b) COD value in Indonesia 2025-2045.

2038. It also repressed the COD value, although it still showed increasing values.

Generally, there are three main issues of water resources: conservation, usage (utilization), and control of the destructive force of water. Conservation of water resources is crucial, considering that this policy is vital in the sustainable development concept to support other sectors (Pambudi, 2025). Water resource conservation policies cannot be separated from the watershed locus, and its ecosystem, which is land and hydrologically, has a vital position in supporting urban and rural socio-economic activities. Generally, water resource conservation policies consist of water resource protection and preservation, water conservation, and water quality management and control. These three policies are

spread across many sectors: forestry, environment, public works/infrastructure, fisheries, agriculture, plantations, mining (groundwater), and others. This policy should have a significant impact on the watershed.

In Presidential Regulation Number 2 of 2015, the Medium-Term National Development Plan (RPJMN) 2015-2019 launched a water resource conservation program supported by a balance of 3 aspects: infrastructure, ecosystem, and social institutions. It continues in Presidential Regulation 18 of 2020 concerning the RPJMN 2020-2024, where conservation of water resources in the infrastructure aspect carry out in the form of water reservoirs revitalization, such as ponds; basins; and reservoirs. The ecosystem aspect is carried out by improving watershed ecosystems, forests, land rehabilitation, and spatial planning to accommodate community activities, fisheries, agriculture, and industry and ensure water availability and quality. Social and institutional aspects carry out in the form of strengthening community involvement in watershed management, strengthening coordination between sectors, and encouraging the implementation of action plans contained in several documents such as Regional Spatial Plans (RTRW), Scheme for Water Sources Management, Watershed Management Plans (RPDAS), and others. The lack of active community participation is caused by the unavailability of legal instruments, utilization systems and management, and institutional regulations that support the realization of community participation in water resource conservation. To reduce the gap, providing a fair share of the involvement of community participation is needed in the planning, implementation, and monitoring of water resource conservation at the site level.

The policy on water conservation and irrigation as outlined in *Presidential Regulation No. 12 of 2025 on the National Medium-Term Development Plan (RPJMN) 2025–2029* underscores the state's commitment to ensuring the sustainability of water resources as a fundamental pillar of national food security. Within the medium-term development framework, water conservation is positioned not merely as an ecological imperative but as a core component of inclusive and sustainable economic development strategies. The RPJMN 2025–2029 explicitly advocates for the enhancement of irrigation systems through network rehabilitation, improved water use efficiency, and the adoption of modern irrigation technologies leveraging digital and geospatial innovations.

This approach is designed to address critical challenges posed by climate change, watershed degradation, and disparities in water distribution across regions and sectors. The government is committed to advancing integrated water management infrastructure based on eco-regional principles, taking into account environmental carrying capacity and resilience

thresholds. Furthermore, the integration of water conservation efforts with capacity-building for farmers and irrigation management institutions constitutes a central axis for fostering a resilient, adaptive, and sovereign food system. Accordingly, this policy transcends technical dimensions, anchoring itself in a broader agenda of socio-ecological resilience in pursuit of Indonesia's Vision 2045.

Vegetative water resource conservation is embodied in land and woodland rehabilitation regulations to restore critical lands in watersheds and forest control units. Those efforts still face challenges regarding the status and rights of the crucial land to be planted. Besides, there are different situations with the non-optimum land tenure in the watershed. However, there has been a decrease in the deforestation rate within forest areas. Also, there has been a significant reduction in forest and burnt land area with optimal countermeasures. The current watershed tends to have excess damage and decreased quality. It can be measured from indicators of increased sedimentation and erosion rates because of land-use changes in the upstream regions, from forests to plantations, agriculture, and settlements. Another indicator is hydrology, with exceptionally high fluctuations in river discharge during the dry and rainy periods and a decrease in the quality of water (Razali et al., 2018; Rachmawati, 2024).

The non-optimal achievements of water resources policies need further review. The aspects of ecology, hydrology, economics, and other scientific branches in various studies cannot be separated from the dynamic nature of water resources, which impacts the fragmented handling efforts in several Ministries/Institutions (Li et al., 2018). The handling by each sector is based on sectoral regulations and tasks so that in a particular time process, a sectoral egoism will be formed, which focuses more on each other interests. It impacts the occurrence of overlapping or even a “gap” (vacancy) of the institution's responsibilities and authorities that plan and formulates regulations. Furthermore, existing regulations increase policy overlap, even activity cannibalism.

The synthesis of regulations as the basis for policies and budget allocations is an exciting discussion topic. As is well known, almost all life aspects and policies in Indonesia are based on many formal regulations, which may overlap. It could be visible while the present regulations state in various water resources conservation policies, found “program/activity cannibalism” so that the targeted outputs and outcome are also not accomplished. Sectoral ego in governance starts from the sectoral ego in the regulations made. Despite laws, water resources policies are also interesting to review as the impact of these regulations.

The water resources problem in the watershed is associated with the quantity, quality, continuity, and accessibility of water. Several regions where watershed

conditions are still in good condition generally also experience several issues in the quantity and quality of water resources, which include Kalimantan and Papua. At the policy level, social and institutional aspects are carried out in the form of strengthening community involvement in watershed management, strengthening coordination between sectors, and encouraging the implementation of action plans in several documents such as Regional Spatial Plans, Schemes Management of Water Resources, Watershed Control Plans (RPDAS), and others. The lack of active community participation is caused by the unavailability of legal instruments, utilization and management systems, and institutional regulations that support community participation in water resource conservation. In reducing the gap, it is necessary to involve the community in planning, implementing, and monitoring water resource conservation at the site level.

The difficulty for farming communities to obtain irrigation water hinders the government from achieving the goal of food security. This situation is no longer ideal for achieving a balanced water balance condition and worsens by the dependence on the food sector (especially rice)(Yuswandi et al., 2024), which dominates by the product from the island of Java. In its policy, the government targets three plantings in a season to meet domestic food needs, especially rice, but this is not easy to achieve. The government also intends to reduce rice imports, but it is also challenging to achieve. Adequate irrigation water may be accomplished if the water resource problem in the upstream area is handled correctly and supported by routine maintenance of irrigation facilities. The quality of upstream watershed management can affect the water storage capacity (amount) in existing reservoirs/dams, including sedimentation, and the significance of building new dams/reservoirs to accommodate other large quantities of water.

Irrigation services are essential for an agrarian country like Indonesia. Excellent irrigation services can improve the farmer group's welfare and elevate the status of an independent state. What is happening now is that

irrigation services are not yet optimal, as evidenced by water availability to meet cropping needs on agricultural land. Water availability is the main problem in irrigation that occurs annually, especially during the dry season. Lack of irrigation water supply usually occurs during Planting Duration II (dry season) until entering the wet season. The severity of water scarcity in each region can vary, even to the point of drying up completely. This problem occurs in every observation region. The diminishing water availability limits the water supply that may be stored and distributed for agricultural irrigation.

The sustainability of water development remains an academic concept unless it is linked to clear objectives that must be attained in given territories and to the management processes needed to achieve this. Management of the natural resources within a watershed or river basin territory area is a valuable option for guiding and coordinating management processes for development in light of environmental variables. To turn environmental policies into concrete actions is necessary to have suitable management bodies, which usually are very complex. Establishing such bodies means generating a mixed public and private system that should be financially independent, socially oriented, and sensitive to environmental aspects and must also act in a democratic and participative manner. The problem of managing water resources, especially related to irrigation and food security in Indonesia, can be summarized from various scientific literature that several researchers have written. The essence of this boils down to policy and governance issues. Water resource management policies to support food security exist due to various factors such as the availability of raw water, infrastructure and governance problems, conflicts of interest, and land conversion problems for different interests other than food security. The author conducted a review of various literature related to the linkage of water resources management, irrigation, and food security in Indonesia as part of the gap analysis to obtain the views of previous experts as well as look for gaps for future strengthening (Table 2).

Table 2. Literature review on water resources management.

No	Author	Title	Summary
1	Ijlil et al. (2025)	Building bridges to achieve SDG 6 and integrated water resources management: an assessment of stakeholder integration in the Saïss region, Morocco.	This article assess stakeholder integration in the Saïss region, Morocco, emphasizing that effective IWRM hinges on inclusive, multi-level collaboration. Their SWOT-informed evaluation highlights strength in local engagement but weaknesses in institutional coordination. The study advocates for enhanced stakeholder linkage, continuous participation, and cross-sectoral dialogue to bolster agricultural irrigation resilience, water governance, and SDG 6 attainment.
2	Singh & Goyal (2025)	A review of India's water policy and implementation toward a sustainable future.	This article critically analyze India's water policy evolution, identifying policy implementation gaps and emphasizing decentralization through Practical IWRM. They demonstrate how integrating AI-driven smart water systems markedly enhances irrigation: enabling real-time loss detection,

			optimized distribution, purification, and conservation. These insights affirm that embracing technology and locally tailored governance is crucial for achieving sustainable water and agricultural irrigation
3	Pambudi (2025)	Policy and Regulatory Implementation in Water Resources Conservation Development in Indonesia: A Critical Analysis	This article finds that Indonesia’s water conservation efforts are hampered not by regulatory gaps or funding shortages, but by fragmented, overlapping frameworks that undermine coherence. He identifies “programmatic cannibalism,” where conflicting policies actively compete and dilute impact. The study underscores the necessity for regulatory harmonization, institutional integration, and watershed-aligned governance to improve agricultural irrigation and safeguard water
4	Sha et al., (2024)	Agricultural subsidies on common prosperity: Evidence from the Chinese social survey	This paper demonstrate that agricultural subsidies significantly uplift rural incomes, promote equitable prosperity, and stimulate farmland transfers. Their robust analysis reveals subsidies particularly catalyze irrigation-related productivity gains and curtail land abandonment, underscoring their potential to reinforce sustainable agricultural water use and food system resilience.
5	Li, P., & Wu, J. (2023)	Water resources and sustainable development	This article find that achieving sustainable agricultural irrigation hinges on a comprehensive understanding of water quality dynamics, the mitigation of anthropogenic impacts, and the implementation of integrated watershed management, supported by digital innovations to enhance efficiency and ensure ecological and food system resilience.
6	Tampubolon, J. (2023)	Food and agricultural sector in Indonesia’s economic growth during COVID-19 pandemic: an ARDL approach	This article reveals that despite the COVID-19 pandemic, Indonesia’s agricultural and food processing sectors demonstrated remarkable resilience, exhibiting a long-term bidirectional relationship with economic growth. The ARDL analysis confirms their pivotal role in sustaining macroeconomic stability during periods of external shock.
7	Umami et al., (2022)	A review on water management issues: potential and challenges in Indonesia	This article reviews the water resources issue regarding potential challenges, health impacts, and government decisions in Indonesia. Furthermore, it is linked to existing problems to obtain the actual conditions overview of water management problems in Indonesia.
8	Suntana (2021)	The Controversy of Water Resources Legislation in Indonesia: An Islamic Constitutional Law Approach	The Indonesian Government considers that existing water regulations, both laws and government regulations, are insufficient to regulate water resources issues. Laws related to water resources in Indonesia sparked controversy in society, so many parties opposed the law because it was considered inconsistent with Article 33 Paragraph (3) of the Constitution 1945 concerning people's welfare.
9	Sulistyaningsih et al., (2021)	Public Policy Analysis on Watershed Governance in Indonesia	This paper focuses on evaluating watershed policies and institutional control and objectives to observe government policies on watershed governance in Indonesia. A qualitative technique of content analysis is used to inform and formulate government policies concerning planning, coordination, implementation, monitoring, evaluation, and accountability of the central and regional governments in managing watersheds.
10	Cao et al., (2020)	Evaluation of natural support capacity of water resources using principal component analysis method: a case study of Fuyang district, China	This paper evaluate the natural support capacity (NSC) of water resources in Fuyang District, China, using principal component analysis. Their study reveals that the most significant drivers include availability of surface and groundwater, permissible water withdrawal, and chemical oxygen demand levels. After 2000, NSC declined due to rising pollution, underscoring the importance of safeguarding water quality to sustain agricultural irrigation and resource resilience

Source: Analysis result (2025).

Based on the table above, the author analyzes that tater resource management policies to support food security are caused by various factors such as the availability of raw water, infrastructure, and governance problems, conflicts of interest, and the problem of land conversion for different interests other than food security.

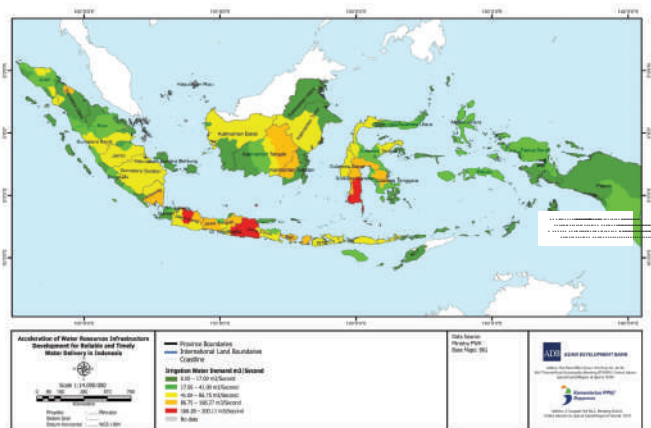
Raw Water Availability Problems

Food is a fundamental human need, and its fulfillment is a human right assured by the Indonesian Law of 1945 as a fundamental component in improving the quality of human resources. Indonesian agriculture requires proper irrigation with adequate water availability. The primary problem associated with water availability for irrigation is water resources (Pambudi, 2019). Water resources are

containers or places of natural or artificial water located on, above, or below the soil's surface. Environmental damage in the upstream area reduces the water supply. Several business that harm the environment impact a reduction in the environment's carrying capacity for water sources preservation: environmental damage, specifically forest reduction. Vegetative water resource conservation is manifested in land and forest rehabilitation policies to restore critical lands in watersheds and forest management units.

Those efforts will also meet challenges associated with the status and rights of the land to be planted. Besides, there are different challenges with the non-optimum land use management in the watershed. However, there has been a reduction in the deforestation rate within forest areas. Also, there has been a significant reduction in forest and burnt land area through effective countermeasures. The current watershed is experiencing a lot of degradation and quality decrement. It may be measured from the indicators of increased erosion and sedimentation rates because of land-use changes in the upstream regions, from forests to plantations, agriculture, and settlements. Another indicator is hydrology, exceptionally high river discharge fluctuations in the dry and rainy seasons, and decreased water quality (Razali et al., 2018).

The need for water for irrigation was studied by Idris et al. (2021). In increasing food sovereignty, the Indonesian Government's policy directives in strengthening food security in the irrigated agriculture sector are through a strategy to increase production capacity and improve irrigation network services. The conditions shown in Figure 2 indicate that food security policies related to water resources and their management cannot be separated from the condition or portrait of irrigation water demand in Indonesia. Based on field data, some activities are identified as causing environmental damage to water resources, such as logging or woodland conversion and mining activities of class C (Azadi et al., 2018).



Source: ADB (2025).

Figure 2. Irrigation Water Demand in Indonesia.

Governance and Infrastructure Problems

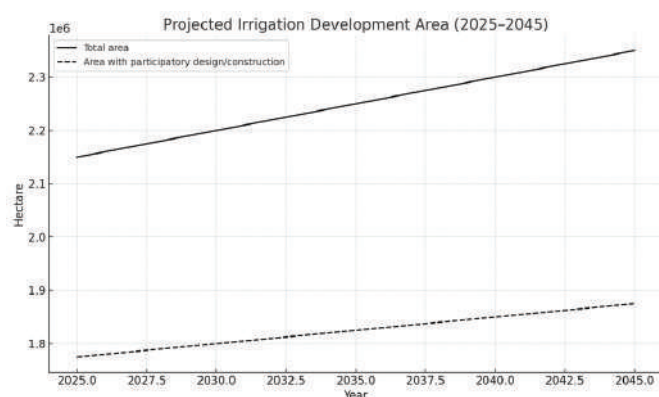
Availability of irrigation water and management of weirs and water collection/intake containers are the problems related to governance and infrastructure. Several things that need to be considered include dams and reservoirs in proper condition tend to decline while the demand will increase. Some potential regions for agriculture do not have sufficient raw water resources, so they need water resources from reservoirs. Indramayu District, the most extensive rice-producing area in West Java Province, is one of the prominent examples of agricultural areas that do not have adequate water reserves. The Cipancuh Reservoir, covering 700 ha areas, may only function in the planting period (wet season) because of no water supply apart from rainwater and severe siltation in the reservoir. If this reservoir is optimized, it could best irrigate 6,314 ha of paddy fields. Meantime, the planned construction of the Cipanas Reservoir has not been realized. Currently, the government is focusing on building new reservoirs. The government constructed 13 dams in 2015, specifically Raknamo and Rotiklod Reservoirs in East Nusa Tenggara, Tanju, Mila, and Bintang Bano Reservoir in West Nusa Tenggara, Lolak Reservoir in North Sulawesi, Passeloreng Reservoir in South Sulawesi, Tapin Reservoir in South Kalimantan, Telaga Waja Reservoir in Bali, Logung Reservoir in Central Java Karian Reservoir in Banten, Seigong Reservoir in Riau Islands, and Keureto Reservoir in Aceh. However, the revitalization of existing reservoirs also needs to be done to provide enough advantages, which includes the Cipancuh Reservoir in Indramayu Regency.

The new era of irrigation policy in Indonesia with participatory design and construction practices will involve more participation from various parties, such as farmers, local communities, local governments, technical experts, and non-governmental organizations. The aim of this approach is to create irrigation systems that are more efficient, sustainable, and appropriate to local needs and conditions. Total irrigated area in Indonesia where the application of the new irrigation policy is documented, and total irrigated area with the recorded practice of participatory design/construction. Figure 3 below shows, in general terms, the total area irrigated with participatory design and construction practices recorded in the period 2025–2045.

The management of dam and reservoir infrastructure in several places has not been running well due to sedimentation problems caused by human activity factors and overlapping policies/regulations between the central and regional governments as well as between sectors. The issue of ego-sectoral governance and regional ego focusing on their respective goals causes the decline in the age of reservoir utilization as planned.

It should remember that Law 17 of 2019 states that Water Resources Conservation is to preserve the

continuity of the existence, function, and carrying capacity of Water Resources. Water Resources Conservation regarding the Water Resources Management Plan through the following activities: a) water resources protection and preservation; b) water conservation; c) water quality management; and d) water pollution control. Protection and preservation of water resources aim to protect and preserve water resources and their environment against damage or disturbance caused by natural resources and human actions.



Source: Bappenas (2023).

Figure 3. Total irrigated area in Indonesia where the application of the new irrigation policy is documented, and total irrigated area with the recorded practice of participatory design/construction.

Interference with Other Parties Problem

It is undeniable that there are conflicts of interest in some areas of Indonesia between water use for irrigation

and other benefits. Considering that this is one of the main problems in the non-smooth supply of water to irrigate rice fields to produce food, it needs to be a concern. One case study that can be used as an example is water use in the Lekopancing Dam, monopolized by the Makassar City PDAM (Regional Drinking Water Company), while agricultural irrigation is only the second option after fulfilling the PDAM's needs first.

Based on this case, it is known that the allocation of water in Indonesia is very multi-interested; with water management mechanisms that have involved many parties, it is not easy to synergize for a just and sustainable interest. Thus far, the Government has developed a pattern of management cooperation among the Central, Regional Governments and business entities. Ideally, the development of such collaboration should uphold the principle that partnership should not interfere, override, or negate the people's right to water in a participatory and responsible manner.

Land-use Change Issues

The water allocation problem dominates the water resources challenges in the future among irrigation, industry, and domestic/household needs and involves difficult decisions to balance policy for food, nature, and society (Niu et al., 2023). It will change the roles of development planners, regional planners, and water resource managers that need to include land use activities that result in surface runoff and groundwater recharge (Wang et al., 2024). Unbalanced land conversion with adequate conservation impacts the land's carrying capacity for environmental resilience.

Table 3. Summarize findings of water and irrigation issues related to food security.

No	Key Issues	Dimensions of the Problem	Implications for Food Security
1	Raw Water Availability	Watershed degradation, deforestation, land conversion, extractive activities	Decline in ecosystem carrying capacity and water shortages for irrigation, especially in dry seasons
2	Governance and Infrastructure	Sedimentation of reservoirs, inadequate maintenance funding, institutional overlaps	Reduced lifespan of hydraulic infrastructure and insufficient irrigation water distribution
3	Sectoral Water Use Conflicts	Monopoly of water usage by domestic/industrial sectors over agriculture	Allocation conflicts and diminished prioritization of irrigation needs
4	Land Use Change	Agricultural land conversion due to urban and economic pressures	Permanent loss of productive farmland and reduced food production potential
5	Deteriorating Water Quality	Increasing BOD and COD levels, limited pollution control mechanisms	Decline in irrigation function and reduced agricultural yield quality
6	Weak Community Participation	Absence of enabling legal and institutional frameworks for participatory governance	Limited local oversight and engagement in conservation and water management
7	Sectoral Ego and Regulatory Fragmentation	Policy overlaps, siloed institutional mandates, uncoordinated programs	Obstacles to integrated implementation and policy coherence

The increasing population needs and the demand for better life quality influences land use changes. In a land like rice fields, changes to other uses significantly impact the disruption of local food security. In general, rice fields conversion to other usage creates more destructive problems than the effects of various factors, including droughts, floods, and pest/disease outbreaks (Idris, 2021). During dry, floods, and pest/disease attacks, the resulting food problems are temporal, which means it only happens when the incident occurs. Meanwhile, if there is a land use change, the food production problem is permanent (will continue for a long time), although land use changes do not occur anymore.

Local authority policies affect forest rehabilitation attempts through Forest Management Units (KPH) due to changes in land use. Local government regulations significantly change forest management processes, including institutional management (human resources, organization, allocation, infrastructure) and regulatory authorities in forest management. Vegetative water resource conservation is included in land and forest rehabilitation policies for critical land restoration in watersheds and Forest Management Units (Roengtam et al., 2023).

Availability of irrigation water and management of weirs and water collection/intake containers are the problems related to governance and infrastructure. The summarize findings of water and irrigation issues related to food security shown by Table 3.

The table encapsulates a synthesized evaluation of multifaceted issues identified in the results and discussion section of the paper. The analysis reveals that challenges in irrigation and water resource governance stem from a complex interplay of environmental degradation, institutional fragmentation, weak regulatory enforcement, and insufficient community engagement. Despite the existence of national policies and development programs, their effectiveness is often undermined by overlapping mandates, sectoral egoism, and uncoordinated implementation. Water scarcity, both in quantity and quality, is exacerbated by upstream degradation and weak infrastructure management. Furthermore, land-use change and intersectoral conflicts in water allocation contribute to the systemic risks threatening food security. Therefore, a holistic, ecosystem-based, and participatory governance model is crucial to bridge the gap between policy formulation and on-ground realities, ensuring sustainable irrigation and long-term national food resilience.

Food security will be inadequate when it cannot answer the water challenges for food security in the future. Irrigated agriculture is, in fact, almost always supported by pervasive rain. A key strategy for improving rainfed agriculture involves investing in additional irrigation to get through the dry season. The two types of crop production, in other words, involve green water and

blue water to meet crop water needs, although in different proportions. As the government's goal is to achieve food security, the issues of irrigation water availability should be immediately resolved by upstream conservation, maximizing reservoir capacity with normalization, and building dams to store water that can accommodate all planting seasons throughout the year. Water and irrigation issues for food security are generally related to surface water availability, governance, policies, regulations, sector egos, regional egos, and land-use changes due to the pressure of needs resulting from population growth with various interests, which are increasingly varied.

Based on the analysis, several recommendations can be given, such as: a) Conduct environmental conservation in upper watershed by upstream normalization and increasing its carrying capacity by conservation; b) Dams normalization by regularly cleaning and dredging of sediments to achieve their maximum capability in storing water to distribute to irrigation canals in the existing agricultural areas; c) Build technological media to monitor dams/reservoirs condition and predict irrigation water needs immediately; d) Implementing law enforcement against damaging of protected irrigation water resources; e) Accelerate the provision of adequate, secure, and affordable water from resource to paddy or another field; f) Developing modern distribution network for irrigation community and public participation in policy planning; g) Formulating innovative management/business scheme for local water provision (regional authorities); h) Institutional arrangement and policy for irrigation management; i) Increasing public awareness and involvement in water-saving behavior.

CONCLUSION

This study finds that the critical barriers to sustainable food security in Indonesia stem primarily from unresolved challenges in water and irrigation governance. Despite the abundance of water resources, issues such as upstream watershed degradation, ineffective infrastructure maintenance, policy fragmentation, sectoral competition, and uncontrolled land-use changes continue to undermine the efficiency and resilience of irrigation systems. The alignment between water availability and agricultural demand, particularly in rice-producing regions, remains weak, threatening the country's capacity to ensure long-term food resilience. Addressing these challenges requires a paradigm shift toward integrated water governance that emphasizes upstream conservation, institutional coordination, legal enforcement, and the active involvement of local communities in irrigation planning and management.

However, this study is limited by its reliance on secondary data derived from literature reviews, which

restricts the ability to capture real-time field complexities and region-specific policy dynamics. It does not encompass direct stakeholder engagement or empirical validation of policy impacts on irrigation performance. Future research should explore in-depth case studies to assess local governance capacities, the effectiveness of participatory irrigation schemes, and the application of digital technologies in monitoring and decision-making. Additionally, comparative studies across regions or countries could illuminate successful models of institutional reform and integrated policy frameworks that support water-secure and food-resilient development.

ACKNOWLEDGEMENTS

My deepest gratitude to the Directorate of Monitoring, Evaluation, and Control of Regional Development Bappenas for providing knowledge, opportunity, and facility support. Many thanks are due to my current director Agustin Arry Yanna, SS, MA; my counselor Dr. Ir. Medrilzam, M.Prof. Econ; my former director Ir. Basah Hernowo, MA and Ir. Wahyuningsih Darajati, M.Sc.; Devy Paramitha Agnelia, S.T., M.PWK; and all staff of the Directorate of Monitoring, Evaluation, and Control of Regional Development Bappenas for helpful suggestions to the paper.

REFERENCES

- ADB. (2025). 43220-014: Integrated Participatory Development and Management of Irrigation Program. Asian Development Bank. Retrieved from <https://www.adb.org/projects/43220-014/main>
- Alaerts, G. J. (2020). Adaptive policy implementation: Process and impact of Indonesia's national irrigation reform 1999–2018. *World Development*, 129, 104880. <https://doi.org/10.1016/j.worlddev.2020.104880>
- Arif, S., Isdijoso, W., Fatah A.R., & Tamyis, A.R. (2020). Strategic Review of Food Security and Nutrition in Indonesia: 2019–2020 Update. Jakarta, Indonesia: The SMERU Research Institute.
- Azadi, H., Keramati, P., Taheri, F., Rafiaani, P., Teklemariam, D., Gebrehiwot, K., & Witlox, F. (2018). Agricultural land conversion: Reviewing drought impacts and coping strategies. *International Journal of Disaster Risk Reduction*, 31, 184–195. <https://doi.org/10.1016/j.ijdrr.2018.05.003>
- Bappenas. (2023). Dokumen Kajian Lingkungan Hidup Strategis Rencana Pembangunan Jangka Panjang Nasional (KLHS RPJPN) 2025–2045 (Strategic Environmental Assessment Document of the National Long-Term Development Plan (KLHS RPJMN) 2025–2029). Jakarta: Badan Perencanaan Pembangunan Nasional. Retrieved from [chrome-extension://efaidnbmnnnibpcajpcgclefindmkaj/http s://lcdi-indonesia.id/wp-content/uploads/2024/01/Laporan-KLHS-RPJPN-Tahun-2025-2045.pdf](https://lcdi-indonesia.id/wp-content/uploads/2024/01/Laporan-KLHS-RPJPN-Tahun-2025-2045.pdf)
- Cao, F., Lu, Y., Dong, & Li, X. (2020). Evaluation of natural support capacity of water resources using principal component analysis method: a case study of Fuyang district, China. *Appl Water Sci*, 10(192). <https://doi.org/10.1007/s13201-020-1174-7>
- Euler, J., & Heldt, S. (2018). From information to participation and self-organization: Visions for European river basin management. *Science of The Total Environment*, 621, 905–914. <https://doi.org/10.1016/j.scitotenv.2017.11.072>
- Genjebo, M. G., Kemal, A., & Nannawo, A. S. (2023). Assessment of surface water resource and allocation optimization for diverse demands in Ethiopia's upper Bilate Watershed. *Heliyon*, 9(10). <https://doi.org/10.1016/j.heliyon.2023.e20298>
- Idris, A. M. S. (2021). Country Reports Indonesia. Irrigation and Drainage. <https://doi.org/10.1002/ird.2589>
- Ijlil, S., Essahlaoui, A., Essahlaoui, N., Skrimizea, E., Parra, C., Mili, E. M., & Van Rompaey, A. (2025). Building bridges to achieve SDG 6 and integrated water resources management: an assessment of stakeholder integration in the Saiss region, Morocco. *Water International*, 1–22. <https://doi.org/10.1080/02508060.2025.2458967>
- Li, P., & Wu, J. (2023). Water resources and sustainable development. *Water*, 16(1), 134. <https://doi.org/10.3390/w16010134>
- Li, R., Zheng, H., Lv, S., Liao, W., & Lu, F. (2018). Development and evaluation of a new index to assess hydrologic regulating service at the sub-watershed scale. *Ecological Indicators*, 86, 9–17. <https://doi.org/10.1016/j.ecolind.2017.12.023>
- Liu, F., Shahzad, M. A., Feng, Z., Wang, L., & He, J. (2024). An analysis of the effect of agriculture subsidies on technical efficiency: Evidence from rapeseed production in China. *Heliyon*, 10(13), e33819. <https://doi.org/10.1016/j.heliyon.2024.e33819>
- Lyra, A., & Loukas, A. (2023). Simulation and evaluation of water resources management scenarios under climate change for adaptive management of coastal agricultural watersheds. *Water Resources Management*, 37(6), 2625–2642. <https://doi.org/10.1007/s11269-022-03392-x>
- Ma'Mun, S. R., Loch, A., & Young, M. D. (2021). Sustainable irrigation in Indonesia: A case study of Southeast Sulawesi Province. *Land use policy*, 111, 105707. <https://doi.org/10.1016/j.landusepol.2021.105707>
- Niu, C., Wang, X., Chang, J., Wang, Y., Guo, A., Ye, X., Wang, Q., & Li, Z. (2023). Integrated model for optimal scheduling and allocation of water resources considering fairness and efficiency: A case study of the Yellow River Basin. *Journal of Hydrology*, 626, 130236. <https://doi.org/10.1016/j.jhydrol.2023.130236>

- Pambudi, A. S. (2023a). Evaluation of government funding support for national priority development related to the environmental sector in regions. *Indonesian Journal of Applied Environmental Studies*, 4(1), 10-21.
- Pambudi, A. S. (2023b). Environmental land use conflicts and ecosystem services: paper review. *Indonesian Journal of Applied Environmental Studies*, 4(2), 58-63.
- Pambudi, A.S. (2025). Policy and Regulatory Implementation in Water Resources Conservation Development in Indonesia: A Critical Analysis. *Protection: Journal Of Land And Environmental Law*, 3(3), 103-130. <https://doi.org/10.38142/pjlel.v3i3>
- Pambudi, A.S., & Kusumanto, T. (2023). *Water Resources Governance in Indonesia Towards Environmental Sustainability Along with Social and Economic Development*. In: Triyanti, A., Indrawan, M., Nurhidayah, L., Marfai, M.A. (eds). *Environmental Governance in Indonesia*. Environment & Policy, Vol 61. Springer, Chambridge. https://doi.org/10.1007/978-3-031-15904-6_16
- Priatna, D., & Khan, S. M. (2024). The importance of education and role of educational institutions in climate change mitigation and achieving UN SDG 13 "Climate Action". *Indonesian Journal of Applied Environmental Studies*, 5(1), 1-5.
- Priatna, D., & Monk, K. A. (2023). Progress, Challenges, and the Nexus of Research and Impact - the importance of technology in biodiversity conservation in Indonesia. *Indonesian Journal of Applied Environmental Studies*, 4(1), 3-9.
- Rachmawati, A., Priatna, D., & Rosadi. (2024). Evaluation of the Ciplabuan River's water quality and measures for reducing water pollution in the Sukabumi Regency. *Indonesian Journal of Applied Environmental Studies*, 5(1), 20-24.
- Razali, A., Syed Ismail, S. N., Awang, S., Praveena, S. M., & Zainal Abidin, E. (2018). Land-use change in the highland area and its impact on river water quality: a review of case studies in Malaysia. *Ecological Processes*, 7(1). <https://doi.org/10.1186/s13717-018-0126-8>
- Roengtam, S., Agustiyara, A., & Nurmandi, A. (2023). Making Network Governance Work in Forest Land-Use Policy in the Local Government. *SAGE Open*, 13(3), 1-17. <https://doi.org/10.1177/21582440231194491>
- Rozaki, Z. (2021). Food security challenges and opportunities in Indonesia post COVID-19. *Advances in Food Security and Sustainability*, 6, 119-168. <https://doi.org/10.1016/bs.af2s.2021.07.002>
- Shackleton, R. T., Larson, B. M. H., Novoa, A., Richardson, D. M., & Kull, C. A. (2019). The human and social dimensions of invasion science and management. *Journal of Environmental Management*, 229, 1-9. <https://doi.org/10.1016/j.jenvman.2018.08.041>
- Sha, Z., Ren, D., Li, C., & Wang, Z. (2024). Agricultural subsidies on common prosperity: Evidence from the Chinese social survey. *International Review of Economics and Finance*, 91, 1-18. <https://doi.org/10.1016/j.iref.2023.12.006>
- Shah, M. I., AbdulKareem, H. K. K., Ishola, B. D., & Abbas, S. (2023). The roles of energy, natural resources, agriculture and regional integration on CO2 emissions in selected countries of ASEAN: does political constraint matter? *Environmental Science and Pollution Research*, 30(10), 26063-26077. <https://doi.org/10.1007/S11356-022-23871-3/METRICS>
- Singh, S., & Goyal, M. K. (2025). A review of India's water policy and implementation toward a sustainable future. *Journal of Water and Climate Change*, 16(2), 493-510. <https://doi.org/10.2166/wcc.2025.560>
- Sulistyaningsih, T., Nurmandi, A., Salahudin, S., Roziqin, A., Kamil, M., Sihidi, I. T., ... Loilatu, M. J. (2021). Public Policy Analysis on Watershed Governance in Indonesia. *Sustainability*, 13(12), 6615. <https://doi.org/10.3390/su13126615>
- Suntana, I. (2021). The Controversy of Water Resources Legislation in Indonesia: an Islamic Constitutional Law Approach. *Jurnal Hukum Islam*, 19(2), 193-212. <https://doi.org/10.28918/jhi.v19i2.4421>
- Tampubolon, J. (2023). Food and agricultural sector in Indonesia's economic growth during COVID-19 pandemic: an ARDL approach. *Agricultural and Resource Economics. International Scientific E-Journal*, 9(2), 223-244. <https://doi.org/10.22004/AG.ECON.337442>
- The Economist Group. (2022). *Global Food Security Index (GFSI) 2022*. Retrieved <https://impact.economist.com/sustainability/project/food-security-index/download-the-index>
- Tripathi, M., & Singal, S.K. (2019). Use of principal component analysis for parameter selection for development of a novel water quality index: a case study of river Ganga India. *Ecol Indic*, 96, 430-436. <https://doi.org/10.1016/j.ecolind.2018.09.025>
- Umami, A., Sukmana, H., Wikurendra, E.A. & Paulik, E. (2022). A review on water management issues: potential and challenges in Indonesia. *Sustain. Water Resour. Manag.* 8, 63 (2022). <https://doi.org/10.1007/s40899-022-00648-7>
- Wang, S., Chang, J., Xue, J., Sun, H., Zeng, F., Liu, L., Liu, X., & Li, X. (2024). Coupling behavioral economics and water management policies for agricultural land-use planning in basin irrigation districts: Agent-based socio-hydrological modeling and application. *Agricultural Water Management*, 298, 108845. <https://doi.org/10.1016/J.AGWAT.2024.108845>
- Yuswandi, Y., Priatna, D., & Rosadi, R. (2024). Cimandiri Watershed, Sukabumi District: A dynamic model for optimizing water resources. *Indonesian Journal of Applied Environmental Studies*, 5(2), 84-91.