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ANALYSIS OF THE IMPLEMENTATION OF WATER ENVIRONMENTAL SERVICES PAYMENT SCHEME IN THE CIMANUK WATERSHED

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Abstract

The degradation of the upstream area of the Cimanuk Watershed due to land conversion and deforestation has reduced the ecosystem's capacity to regulate water availability and quality. This phenomenon highlights the urgency of applying economic instruments in water resource management, particularly through the implementation of Payment for Environmental Services (PES). However, a fair and measurable mechanism for determining the economic value of water at the watershed scale remains absent, weakening incentives for upstream conservation actors. This study aims to formulate a scientifically grounded water pricing mechanism as a tool to address market failure in valuing ecosystem services and to promote sustainable watershed governance. The research applies a mixed-method approach using three valuation techniques: Contingent Valuation Method (CVM), Value of Marginal Product (VMP), and Full Cost Pricing. Findings reveal a significant disparity between the downstream community's willingness to pay (WTP) and the upstream community's willingness to accept compensation (WTA), emphasizing the need to internalize environmental externalities into water pricing. Policy recommendations include the adoption of full cost pricing for water, integration of PES into watershed planning frameworks, and the establishment of a transparent and participatory mechanism for allocating conservation funds.

Keywords: *water pricing, environmental services, Cimanuk watershed, economic valuation*

Abstrak

Degradasi wilayah hulu Daerah Aliran Sungai (DAS) Cimanuk akibat alih fungsi lahan dan deforestasi menyebabkan penurunan kapasitas ekosistem dalam mengatur ketersediaan dan kualitas air. Fenomena ini memperkuat urgensi penerapan pendekatan ekonomi dalam pengelolaan sumber daya air, khususnya melalui skema pembayaran jasa lingkungan (PES). Namun hingga kini belum tersedia mekanisme yang adil dan terukur dalam menetapkan nilai ekonomi air di tingkat DAS, sehingga insentif terhadap pelaku konservasi masih lemah. Penelitian ini bertujuan untuk merumuskan harga air berbasis pendekatan ilmiah sebagai instrumen insentif konservasi, sekaligus mengatasi kegagalan pasar dalam menilai jasa lingkungan. Metodologi yang digunakan adalah kombinasi pendekatan kualitatif dan kuantitatif dengan menggunakan tiga metode valuasi utama: Contingent Valuation Method (CVM), Value of Marginal Product (VMP), dan Full Cost Pricing. Hasil penelitian menunjukkan adanya kesenjangan signifikan antara kesediaan membayar (WTP) masyarakat hilir dan kesediaan menerima kompensasi (WTA) masyarakat hulu, serta pentingnya internalisasi eksternalitas lingkungan ke dalam struktur harga air. Rekomendasi kebijakan mencakup penetapan harga air berbasis full cost pricing, integrasi PES dalam perencanaan DAS, dan alokasi dana konservasi yang transparan dan partisipatif.

Kata Kunci: *harga air, jasa lingkungan, DAS Cimanuk, valuasi ekonomi*

I. INTRODUCTION

Watersheds (DAS) are crucial for hydrological regulation, encompassing discharge control, water distribution, and flood prevention (Euler et al., 2018; Bonell & Bruijnzeel, 2005). The stability of these functions is susceptible to interruption from the deterioration of upstream watershed areas, mostly caused by the unchecked expansion of agricultural land and urban developments (Euler et al., 2018; Kindu et al., 2017). Numerous international researches indicate that human activities in the upstream region directly affect the environmental carrying capacity and quality of watershed ecosystem services (Li et al., 2018). The ecological conditions of a watershed profoundly affect the quality and quantity of water flow (Pambudi & Kusumanto, 2023). Riparian vegetation and forest cover are essential for the absorption and storage of rainwater, as well as for erosion prevention via root systems. In developing nations, such as Indonesia, issues in watershed management are intensified by inadequate coordination among sectors and administrative regions (Atapattu & Kodituwakku, 2009). Moreover, insufficient community engagement in both upstream and downstream regions intensifies environmental deterioration, requiring a cohesive and cooperative strategy for watershed governance.

Numerous studies and experiences in watershed management reveal that the predominant challenges are not solely technical, but predominantly institutional, particularly concerning stakeholder coordination, active community engagement, and consensus on the utilization of watersheds for goods and services (Pambudi, 2022; Atapattu and Kodituwakku, 2009; Bonell and Bruijnzeel, 2005). In this context, stakeholders comprise individuals, community groups, official and informal organizations, along with governmental and private entities. In the context of sustainable development, it is essential to have access to information regarding environmental services to formulate more inclusive and adaptive development policies and planning (Chintantya & Maryono, 2017).

The research gap in this context is the absence of an equitable and quantifiable method for assessing the economic worth of water at the watershed level. Research in Indonesia infrequently combines three valuation methodologies (CVM, VMP, and full cost pricing) and associates them with the institutional framework of upstream-downstream PES. The research has emphasized upstream degradation and ecosystem services, although it has failed to reconcile the discrepancy between willingness to pay (WTP) downstream and willingness to accept (WTA) upstream within a functional pricing or incentive framework. The absence of data about social-environmental costs (MPC, MUC, MEC) and insufficient intersectoral coordination diminish the credibility of compensation. Urgency: Land degradation, variations in flow, floods and droughts, and reliance on irrigation result in economic losses, heighten the likelihood of conflict, and extend market failure. This paper presents an evidence-based water pricing model that incorporates externalities and establishes a transparent and participatory Payment for Ecosystem Services (PES) framework for decision-making in the Cimanuk watershed.

Conditions in Indonesia indicate that community participation in watershed and water resource management has not been supported by fair collaboration mechanisms, especially regarding the interactions among communities in the upstream, midstream, and downstream regions. A specific instance of this scenario is the administration of the Cimanuk River basin in West Java. The deterioration of the Cimanuk River Basin is marked by land conversion and upstream deforestation, undermining its water control capacity and hydrological equilibrium. Quantitative data reveals that roughly 10,450 hectares of vital land necessitate repair, with an estimated cost of IDR 177.1 billion. This degradation is projected to cause a water supply reduction of approximately 1,325.32 million m^3, derived from the ratio of critical land to total forest multiplied by the overall water availability of the irrigation network, indicating a decrease in the ecosystem's ability to sustainably provide water. These indices affirm considerable ecological constraints in the Cimanuk River Basin, posing hazards to water security, flooding, erosion, and socio-economic consequences for downstream regions.

Upstream communities possess considerable potential to sustain water supplies via conservation initiatives; however, there is an absence of an environmental services framework that equitably and systematically governs the reciprocal relationship between conservation stakeholders and downstream beneficiaries (Rustiana et al., 2017; Corn, 1993). Damage to river ecosystems may incite conflict stemming from water scarcity, heightening the possibility of social friction and competition for economic interests among sectors. This circumstance is bolstered by the prevailing societal belief that water is a public resource whose utilization cannot be restricted (Ratnaningsih, 2007).

The implementation of payment mechanisms for environmental services within watershed management remains uncommon in Indonesia, despite their potential as policy tools to identify the sources of environmental degradation and enhance collective awareness regarding the significance of conservation (Pattanayak, 2004; Ratnaningsih, 2007). The Cimanuk River basin traverses four administrative regions: Garut Regency, Sumedang Regency, Majalengka Regency, and Indramayu Regency. It extends 338 kilometers and has an annual water supply potential of 2.2 billion cubic meters, predominantly utilized for agricultural irrigation (Rustiana et al., 2017). Alterations in land cover and deforestation in the river's upstream region substantially impact the continuation of water control functions and hydrological equilibrium (Widiyanto & Hani, 2018).

In the context of sustainable development planning, water resource management must take into account ecological limits, the biosphere's carrying capacity, and the implementation of adaptive technologies (Pambudi, 2025). A strategic approach that has yet to be effectively executed is the calculation of water pricing at the watershed level. Analyzing water prices is essential for establishing a fair, transparent, and scientifically grounded incentive structure for environmental services. Nevertheless, comprehensive research on the economic valuation of water is currently lacking in the Cimanuk River basin, hence obstructing the formulation of incentive schemes that could serve as policy instruments to mitigate environmental degradation. Consequently, rigorous and scientifically grounded measures are essential for incorporating water valuation methodologies into watershed governance to guarantee the sustainability of ecosystem services and equitable community well-being.

Analyzing water pricing at the watershed (DAS) scale constitutes a strategic method for sustainable water resource management. Nonetheless, numerous impediments persist in constraining the research and execution of water pricing strategies at the watershed level. This table delineates six principal variables that serve as significant impediments. Firstly, **data constraints** present a primary obstacle. The absence of precise data regarding water availability, demand, and environmental variables hinders the execution of thorough water pricing analysis. Secondly, **insufficient knowledge** among local governments and stakeholders on the significance of water pricing information exacerbates the issue's low prioritization on the development agenda. Third, **financial limitations**, including insufficient funding, expertise, and monitoring apparatus, impede comprehensive research. Fourth, **technological limitations** encompass the intricacy of analytical methodologies and restricted access to pertinent technology and knowledge across different geographies. Fifth, **political factors** frequently exert considerable influence on water policy, complicating the pursuit of an impartial approach to water pricing. Ultimately, **societal and cultural limitations** in many areas continue to perceive water as a resource that should remain free, leading to significant opposition to the notion of water price. The six challenges illustrate that enhancing institutional capacity, improving public literacy, and supplying reliable data are vital requirements for advancing comprehensive and effective water pricing analysis in Indonesia. Addressing these hurdles can render payment for water environmental services schemes a fairer and more sustainable tool for watershed management (Mota et al., 2023; Adiansyah & Matrani, 2023; Marques et al., 2023; Angelia & Hakiki, 2021).

The Cimanuk River Basin (DAS) is a significant source of potable water and serves a crucial function for communities in West Java. Nonetheless, alterations in land cover within the upstream regions of the watershed have profoundly affected the ecological equilibrium, evidenced by variations in water discharge, heightened sediment transport, and the concentration of dissolved substances in the water flow. The interdependent interaction between upstream and downstream regions necessitates the implementation of an environmental services plan in sustainable watershed management. Water, as an essential component of the system, warrants recognition as an economically valued resource. Despite the technical and institutional challenges encountered in water pricing analysis at the watershed level, the endeavor of water economic valuation represents a vital advancement toward achieving equitable and sustainable management of water resources. This study seeks to: (1) assess water pricing using both qualitative and quantitative methodologies; and (2) ascertain the suitability of compensation from downstream communities to upstream conservation stakeholders within the context of a payment for environmental services framework. Forested regions in the upper sections of the watershed (DAS) are essential for preserving hydrological processes, mitigating erosion, and decreasing sedimentation (Asdak, 2010). Alterations in land use and forest degradation in the upper reaches of watersheds substantially affect both the quality and quantity of water flow, resulting in elevated sediment transport rates and increased dissolved material content (Azadi et al., 2018; Markandya & Richardson, 1992). Bonell and Bruijnzeel (2005) underscored that a watershed's water retention capacity is predominantly influenced by precipitation, the magnitude of infiltration zones, and the vegetation's capacity to manage surface runoff. The degradation of vegetation cover and escalating pressures on protected regions highlight the communities' role and social obligation in fostering ecosystem sustainability (Cumming, 2016; Watson et al., 2014).

From an environmental economic standpoint, each element of an ecological system, such as water flow within a watershed, possesses an inherent economic value that can be quantified using an ecosystem services framework. Ecosystem services refer to the direct and indirect advantages that humans obtain from ecosystem activities and processes (Costanza et al., 1997). Daily (1997) identifies four primary categories of ecosystem services: provisioning services, regulating services, sustaining services, and cultural services. A significant category of regulatory service is water environmental services, encompassing clean water provision, flood mitigation, and groundwater replenishment.

The "Water Ecosystem Services Theory" posits that water and freshwater ecosystems should be recognized as sources of multifaceted ecosystem services. The ecosystem services framework categorizes benefits into four distinct groups: provision (raw water, fisheries, biomass), regulation (natural filtration, flood control, erosion control), support (hydrologic cycle, soil formation, biodiversity habitat), and culture (recreational, spiritual, and local identity values). Consequently, freshwater is seen as an essential resource for domestic use, agriculture, and industry; rainforests, riparian forests, wetlands, rivers, and lakes function as "natural infrastructure" that provides water at minimal ecological expense when effectively managed. The flood and erosion control theory highlights the importance of riparian vegetation and land cover in mitigating peak discharges, retaining sediment, and stabilizing riverbanks. This strategy promotes investment in nature-based solutions—such as watershed restoration, mangrove rehabilitation, and floodplain restoration—which have demonstrated more adaptability and superior life-cycle cost efficiency compared to conventional gray infrastructure. The notion of water resource sustainability emphasizes intergenerational management as a fundamental principle: present consumption must not compromise the ecosystem's ability to fulfill future requirements. This necessitates cohesive watershed governance, equilibrium between upstream and downstream, effective water utilization, and incentive mechanisms such as payments for environmental services. The socio-economic aspect enhances the theoretical framework by assessing benefits and costs. Direct use values (such as drinking water and irrigation), indirect values (including regulatory services), and even existence and legacy values can be assessed through replacement cost, averted harm costs, willingness to pay, or cost-benefit analysis. The amalgamation of these theories directs policy towards three focal points: (1) incorporating the value of ecosystem services into planning and budgeting; (2) implementing evidence-based and participatory governance of land and water; and (3) formulating economic instruments and environmental standards that promote equity across regions and generations. Consequently, water is not simply a commodity; it is an ecological-economic cornerstone that necessitates preservation through a systematic, cross-sectoral, and sustainable methodology (Adiansyah & Matrani, 2023; Angelia & Hakiki, 2021; Yohana et al., 2017).

The assessment of aquatic ecosystem services is becoming vital for the development of conservation strategies and payment for ecosystem services (PES) methods. Marques et al. (2023) underscored that a precise economic valuation method can aid policymakers in prioritizing the conservation of vital regions within watersheds. Mota et al. (2023) and Bushron et al. (2022) asserted that ecosystem services are dynamic, with their value shaped by intricate interactions among biotic and abiotic components.

In this context, it is essential to comprehend the theory of water environmental services in order to develop participatory, sustainable, and inclusive water resource management strategies. Adiansyah and Matrani (2023) underscore the importance of community participation in PES schemes for the ecological and social sustainability of watershed management.

Several countries, particularly those in Southeast Asia, have successfully implemented environmental services. The following are successful/promising examples of the implementation of **environmental services (PES) in the water sector** in Southeast Asia.

Table 1. Examples of Environmental Services in the Water Sector in Several Countries in Southeast Asia

Country	Scheme and Location	Buyer/Financing Party	Core Mechanism	Results/ Success (summarized)	Source
Vietnam	National PFES (started from Lâm Đồng pilot; now national)	Hydroelectric power plants and drinking water companies pay per hectare of upstream area	Contribution per hectare/ year for watershed protection; funds are managed by provincial environmental funds	>99% of PFES revenue comes from watershed protection for hydropower; tariff ~VND 350,000/ha/year; scheme provides a stable source of conservation funding.	MARD/ CIFOR-ICRAF; Science Direct
Thailand	Mae Sa Watershed, Chiang Mai	Local authorities/ PDAM and tourism actors as benefit payers	Economic assessment of water and water quality → basis for forest conservation PES contracts	Water benefit valuation provides financial justification for service payments; it is used by local authorities as policy evidence.	CMU Journal (2020); ASEAN Haze Portal
Phillipines	Various watersheds : Bakun, Maasin, Sibuyan, Baticulan	Water district/local hydropower plant & LGU	Upstream reforestation/ protection agreements with communities; activity/results-based payments	Case studies show PES strengthens watershed conservation & supply reliability, although governance/coordination remains a challenge.	Review PIDS; CBD case studies
Malaysia	Babagon Catchment , Sabah (Kinabalu City)	Water utilities & local government; NGO support	Pilot PES scheme for upstream restoration and protection (±3,000 ha) which supplies ~57% of KK water	The pilot prepares a sustainable financing model for water security for approximately 500,000 beneficiaries; tests community readiness and funding options.	LEAP; Sabah govt./consulting notes

Note: Success is typically assessed by the durability of conservation funds, the fortification of upstream-downstream institutions, and the demonstration of economically feasible benefits (water quality/quantity), as indicated in the aforementioned sources.

Ecosystem services do not require market transactions to assess their worth in rupiah. A metric is required to quantify the extent of monetary purchasing power individuals are prepared to forfeit to acquire environmental services. This approach is predominantly employed to assess the economic value of ecosystem services. Concurrently, ecosystem value quantifies the significance of ecosystem services to human existence. Economists assess the value of ecosystem services to humans by assessing the monetary amount individuals are prepared to pay for their preservation or enhancement (Mota et al., 2023; Bushron et al., 2022). The value of ecosystem services can enhance comprehension of the advantages an environment offers to human well-being. Establishing a suitable price for ecosystem services will enhance appreciation, awareness, and care for these services.

II. METHOD

Integrating upstream and downstream functions sustainably is essential for managing a watershed that is fair and sustainable, emphasizing the equilibrium among economic, social, and environmental factors (Rogers et al. 2008; Asdak 2010). The continuity of water quality and quantity in the Cimanuk watershed is determined by diverse restoration initiatives, forest and land conservation, and effective land use planning. The issue of water supply may serve as a rectification for the environmental services market if the policy strategy implemented is associated with the price of water itself (Common & Stagl, 2005; Panayotou, 1998). Optimal water regulation will occur if funding from environmental services is allocated to address the fundamental causes of watershed degradation, specifically in the upstream region of the Cimanuk watershed.

This research technique employed a straightforward qualitative and quantitative literature review to analyze issues and assess the cost of water in the Cimanuk Watershed utilizing the idea of Payment for Environmental Services (PES). A qualitative research was conducted to examine the idea of environmental services in the Cimanuk Watershed. A quantitative analysis was performed through valuation utilizing various methodologies, specifically the Contingent Valuation Method, Value of Marginal Product of Water, and Full Cost Pricing (Ratnaningsih, 2007; Soesastro & Atje, 2005; Chandler & Suyanto, 2004; Pattanayak, 2004; Panayotou, 1998; Ratnaningsih, 1996; Markandya & Richardson, 1992).

Contingent Valuation Method

Environmental services can be valued in two ways: firstly, by directly querying people both upstream and downstream of a watershed regarding their perceived value or price of water for a certain environmental service. This approach is commonly known as the Contingent Valuation Method (CVM). This approach equates environmental services with market commodities and services. Secondly, assessing the willingness to pay (WTP) and the willingness to accept (WTA) helps ascertain the differences in compensation anticipated by communities located upstream and downstream of a watershed.

Value of Marginal Product of water

The manufacturing of goods and services necessitates many inputs to create a product. Water is a commonly utilized input in the production process; nevertheless, it is not accounted for as a cost element in the same manner as other inputs. The calculation of the Value of Marginal Product (VMP) of water serves to ascertain its value as an input factor in a production process. To determine the price of water, it is essential to first compute the elasticity coefficient for water (□) utilized in the industrial process. The fundamental premise of this concept is that each company endeavors to maximize its profit, implying that the price of the input factor (water price) is equivalent to the value of the marginal product of water (VMPWater), which can be articulated as follows (Ratnaningsih, 1996):

$$H_A = VMP_A \text{ ....} (1)$$

or because $VMP_A = MP_A \times P_Q$, then

$$H_A = MP_A \cdot P_Q \text{ ....} (2)$$

$$MP_A = \tau \cdot \frac{Q}{A} = \left(\frac{\Delta Q}{\Delta A} \cdot \frac{A}{Q} \right) \frac{Q}{A} \quad (3)$$

which is:

VMP_A = Value of Marginal Product of water

MP_A = Marginal Product of water or the increase in production due to the addition of 1 unit (m3) of water.

τ = regression coefficient of water variable or water elasticity

Q = rice production level (tons)

A = water usage rate (m3)

P_Q = price of rice (Rp)

H_A = water price (Rp/m3)

To derive an estimate of water prices in the agricultural sector, the MPA should be multiplied by the average production price of rice (PQ).

Full Cost Pricing

The basis for determining full cost pricing can be seen in Figure 2 (Panayotou, 1998), which explains that market failure in assessing external costs causes the marginal environmental cost (MEC) to be equal to zero, thus shifting point A to point B because the social costs of environmental damage are not taken into account. Institutional failure, especially in regulating ownership rights, causes the use of water as a public good to be unlimited. This results in a lack of public desire to conserve water resources, where water use currently has a tendency to be exploitative. The opportunity cost (Marginal User Cost, MUC) of forest resources as a water system is not taken into account, so the cost of depletion is equal to zero and will shift point B to point C. Water price subsidies provided by the government due to the social functions and public goods inherent in water have caused water price distortion. This causes the marginal production cost (MPC) to be lower than the social opportunity cost (Social Opportunity Cost = SOC), resulting in excessive use and shifting point C to point D.

The above understanding can be formulated in the following equation:

$$P = MSOC \text{ ....} (4)$$

which MSCO = MPC + MUC + MEC ......(5)

thus P = MPC + MUC + MEC .... (6)

Figure 1 depicts the demand curve (D), which represents the marginal social benefit (MSB) associated with different amounts of water use (output). A governmental price subsidy results in elevated water consumption when the price is P0 and usage reaches Q0. The adoption of a pricing policy via a full cost pricing strategy diminishes water use from Q0 to Q* and elevates the price of water from P0 to P*. The full cost pricing approach to economic valuation effectively integrates previously overlooked social and environmental costs, offering reliable insights into water resource scarcity, as evidenced by elevated prices during periods of scarcity and reduced prices during times of surplus.

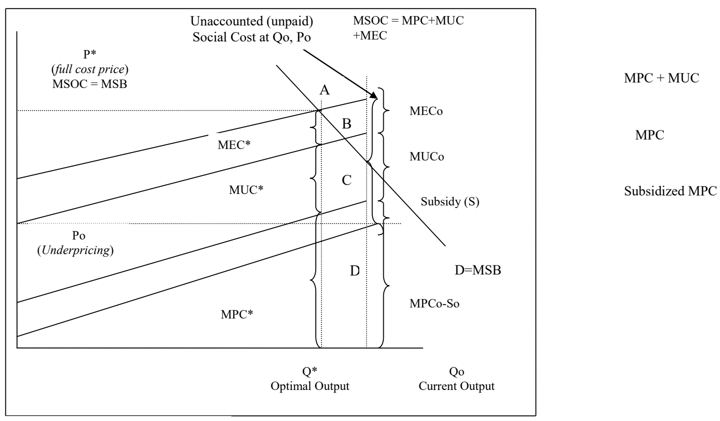

Figure 1. Full Cost Pricing Method

Source: Panayotou, 1998

III. RESULT AND DISCUSSION

The payment for environmental services (PES) approach, which entails establishing water prices that mirror the economic value of forest environmental services, is a viable strategy to mitigate funding limitations for forest and land rehabilitation and conservation efforts in upstream watersheds. This method relies on market-oriented economic instruments designed to include the negative externalities of land use activities into the price mechanism. This mechanism redefines water from a freely accessible public resource to a commodity of significant economic worth, owing to its essential ecosystem functions. This market mechanism is anticipated to foster a paradigm change in societal attitudes toward the environment, transitioning from an exploitative approach to one that prioritizes sustainability.

Watersheds, as cohesive hydrological systems, are essential for the allocation of water for diverse human requirements, including household, agricultural, industrial, and environmental sustainability. Under optimal conditions, watersheds can efficiently collect rainwater, facilitate its infiltration into the soil, and provide water reserves during arid periods. Nonetheless, in some areas in Indonesia, land conversion and the degradation of upstream forests have compromised this role. Disparities in land utilization and vegetation deterioration have diminished water infiltration, resulting in heightened surface runoff of rains, which escalates the risk of flooding and drought while harming the entire ecosystem. This signifies that the natural capacity of watersheds to absorb and retain water is diminishing over time.

Historically, Indonesia's environment has frequently been seen as a common property resource, presumed to be plentiful and devoid of quantifiable commercial worth. As a result, there are no regulatory measures established to curtail the overexploitation of this resource. In this context, pricing water as a surrogate for environmental services is an essential measure in illustrating that natural resources are finite. An economic evaluation of water is essential to provide a framework of incentives and disincentives that promotes sustainable and efficient management.

This research employs multiple quantitative methods to assess the value of water concerning environmental services in the Cimanuk Watershed. One approach is the full cost pricing method, which accounts for all explicit and implicit costs associated with water purchase, including environmental expenses. Additionally, the marginal product value method is employed to evaluate the incremental contribution of water as a production input. This approach is enhanced by the contingent value method utilizing two primary indicators: willingness to accept and willingness to pay. The willingness to accept denotes the compensation level anticipated by the community for tolerating environmental alterations or harm, whereas the willingness to pay signifies the community's readiness to invest in the preservation or enhancement of environmental quality. The juxtaposition of these two values elucidates the perceived disparity between beneficiaries and suppliers of environmental services, serving as a crucial foundation for devising an equitable and sustainable payment framework for such services.

The selection of Lohbener District (downstream), Purwajaya Village (middle technical irrigation), and Karangmulya Village (upstream/agroforestry/simple irrigation) was intended to represent the upstream–middle–downstream gradient of the Cimanuk Watershed and the variations in network typology (technical, semi-technical, simple). All three regions are characterized by lowland rice farming and possess accessible data on output prices, irrigation discharge, and agricultural practices, facilitating the consistent estimation of MPAir/VMP, WTP–WTA, and a comprehensive cost pricing methodology. Lohbener signifies downstream users with financial capability; Purwajaya denotes land transition and flood danger; and Karangmulya embodies upstream conservation stakeholders and opportunity costs. This amalgamation offers spatial, economic, and institutional representation to develop an equitable and relevant PES framework, beneficial for policy sensitivity analysis and confirmation of empirical results.

Willingness to Accept (WTA) of Rice Farmers in the Cimanuk Watershed Downstream

A study of the payment for environmental services (PES) scheme in the Cimanuk Watershed evaluated both the willingness to pay (WTP) of downstream farmers and the willingness to accept compensation (WTA) of 20 upstream farmers transitioning from forest use to agroforestry. The findings indicated an average compensation demand of IDR 878,804 per month or IDR 555 per m³ of water, roughly 13% greater than their existing monthly income. Conversely, downstream farmers were prepared to pay IDR 265,217 each harvest or IDR 530,434 year. The considerable disparity between WTA and WTP illustrates variations in perception and economic capability among locations. Willingness to Pay (WTP) is constrained by financial capacity, but Willingness to Accept (WTA) denotes the minimal anticipated income compensation without an upper threshold. This disparity highlights the difficulties in establishing an equitable and sustainable compensation framework, as well as the necessity for policy interventions such as subsidies or cross-incentives to reconcile the value gap between users and providers of water environmental services conservation in the watershed.

Willingness to Pay (WTP) of Farmers in the Cimanuk Watershed Upstream

In the context of evaluating the payment for environmental services (PES) scheme in the Cimanuk Watershed, this study not only highlights the willingness to pay (WTP) of downstream farmers but also examines the willingness to accept (WTA) of upstream farmers. Twenty upstream respondents were asked to consider a scenario of reforesting the land they manage, with a shift in economic activity toward an agroforestry system. Two main responses reflected the farmers' economic and social considerations. The average compensation expected by upstream farmers in Garut Regency was IDR 878,804 per month, equivalent to IDR 555 per m³ of water used, representing an increase of approximately 13% compared to their current monthly income of IDR 778,370. On the other hand, downstream farmers were only willing to pay IDR 265,217 per harvest, or approximately IDR 530,434 per year. This significant gap between WTP and WTA indicates a value asymmetry rooted in the limited purchasing power of downstream communities, while upstream compensation expectations are based on minimum projections of actual income replacement without any upper limit on demand. This disparity poses a crucial challenge in designing equitable and sustainable PES schemes.

a) Value of Marginal Product of water

The calculation results using data from 3 sample locations, namely Lohbener District, Purwajaya Village, and Karangmulya Village obtained a Marginal Product value of water of 0.253 for downstream rice and 0.291 for upstream rice. To obtain an estimate of the water price, MPAir must be multiplied by the average output price, namely the price of rice (PQ) where in this study it was found that the average price of rice downstream in 2007 was Rp 2,245 per kg, then the price of water is:

$MP_{Air} \times P_Q = P_{Air}$

0,253 x Rp 2.245,- = ***Rp 653,29 per m³***
(Rounding Rp 653,-)

To determine the water value for upstream rice plants, MPAir must be multiplied by the output price of rice (PQ). This study found that the average price of rice upstream was IDR 1,980 per kg; so, the water price is:

$MP_{Air} \times P_Q = MC_{Air}$

0,2196 x Rp 1.980,- = ***Rp 434,84 per m³***
(Rounding Rp 435,-)

b) Full Cost Pricing Method

The full cost pricing method employs a comprehensive methodology to assess the value of water procurement, encompassing the physical infrastructure of water channels along with the social and environmental costs associated with water production. To determine the value or price of water using this method, a minimum of three financial components must be identified:

i. Marginal Production Cost (MPC)

The physical value of water procurement can be determined by aggregating all expenses associated with investment, operation and maintenance, water channel rehabilitation, and water management into a single cost component. The expenses utilized to determine this total production cost are confined to financial or explicit charges, specifically those that are really disbursed. Additionally, economic or implicit costs have been overlooked, including the opportunity costs for farmers unable to cultivate their land due to the construction of irrigation facilities, as well as the loss of employment prospects resulting from the ongoing development of these infrastructures. Consequently, the aggregate physical expenditure for water acquisition utilized in this study is as follows:

Table 1. Physical Costs of Water Procurement in 2018

Information	Costs (Rp/ha)
New Investment	35.000.000,-
Operation and maintenance	190.000,-
Channel Rehabilitation	8.100.000,-
Sub Total	43.290.000,-
Management fee (10% from total)	4.329.000,-
Total	47.619.000,-

Sumber: Hasil Analisis, 2023

Given that the expenses enumerated in Table 1 pertain to 2018, whereas the irrigation channel data for the Cimanuk Watershed originates from 2015, it is imperative to use a discount factor to accurately adjust the physical costs of water procurement to the 2015 timeframe. The discount factor applied is 7%, reflecting the average yearly inflation rate (Soesastro & Atje, 2005) over a three-year duration. Consequently, the physical expense of water acquisition per hectare for technical channels in 2015 is:

$P_o = P_t /(1 + r)^t$ ....(7)

$P_o = \frac{47.619.000}{(1 + 0,07)^3}$ = **Rp 38.872.653,-**

Table 2. MPC Value of Water Procurement in the Cimanuk Watershed in 2015

Waterways type	Water amount (Mil. m^3)	Irrigation Area (ha)	Total Water Cost (Rp. Juta)	Water MPC (Rp/m^3)
Technical	1.824,80	96.002	3.731.597,7	2.044,93
½ Technical	558,87	29.402	715.350,66	1.279,99
Simple	737,53	38.801	541.273,95	733,90

Source: Analysis Result, 2023

ii. Marginal User Cost (MUC)

To determine the entire value of water procurement, one must consider both the physical costs (Marginal Private Cost/MPC) and the Marginal User Cost (MUC), representing the value of environmental advantages forfeited owing to the current use of natural resources. Within the Cimanuk Watershed, the MUC strategy employs critical land area as an indicator of forest degradation that jeopardizes future ecosystem functionality. Land conversion and logging activities have diminished water management capacity, consequently decreasing sustainable water availability. The MUC estimate was based on the restoration expenses for 10,450 hectares of important land, totaling IDR 177.1 billion. The primary assumption is that this soil deterioration directly affects the irrigation water supply. The value is derived by calculating the ratio of critical land to total forest, multiplied by the volume of water present in the irrigation system.

(L. Critical land ÷ L Forest Land) x Total Water = Amount of Water Lost

(131.348 ha ÷ 308.503 ha) x 3.119,89 Mil. m^3 = 1.325,32 Mil. m^3

By dividing the cost of critical land rehabilitation by the amount of water lost, the water MUC value is obtained, namely:

Rp 177.107,86 mil. ÷ 1.325,32 mil. m^3 = **Rp 134 per m^3** (rounding).

iii. Marginal Environmental Cost (MEC)

The Marginal External Cost (MEC) signifies the ecological value of trees in delivering water-related environmental services. The MEC value was derived by a benefit transfer methodology, utilizing valuation outcomes from prior research. A Scottish Government study indicated that forest degradation considerably adds to heightened flood and erosion hazards in the watershed area. The ecological impact value was utilized to determine the externality costs in the agricultural sector of the Cimanuk watershed by converting the US dollar value to rupiah (US$1 = Rp14,000) and compensating for purchasing power disparities with a PPP adjustment factor of 9.6% (Ratnaningsih, 2007).

Table 3. Calculation of the Cost of the Impact of Forest Damage on Flooding and Erosion in the Cimanuk Watershed

Criteria	Costs (Rp/Ha)
Losses in the agricultural sector	555.448
Damage due to erosion	4.936.378
Cleaning fees	16.908.998
Household Losses	115.154
Loss of income	160.877
Total	22.676.855

Source: Analysis Result, 2023

The total cost of these losses is divided by the total water availability in the irrigation channel to produce the MEC value, specifically:

Rp 22.676.855,- ÷ 19.008 m^3 = **Rp 1.193,- per m^3**

By thoroughly defining the cost components of MPC, MUC, and MEC, water prices can be precisely established using a full cost pricing methodology, which reflects the complete economic cost of water acquisition. The estimations are systematically given in Table 4 below.

Table 4. Water Price Based on Full Cost Pricing Calculation (Rp/m3)

Irigation	MPC	MUC	MEC	Total
Technical	2.045	134	1.193	3.372
½ Technical	1.280	134	1.193	2.607
Simple	734	134	1.193	2.061

Source: Analysis Result, 2023

IV. CONCLUSION

A study on the execution of a water price-based payment for environmental services (PES) plan in the Cimanuk Watershed indicates that an economic value approach to water may serve as a successful tool for advancing sustainable environmental protection. This study underscores the divergence in perceptions of water value between upstream and downstream communities and presents a systematic framework for establishing equitable and scientifically grounded water pricing. A notable discovery is the substantial disparity between the willingness to pay (WTP) of downstream communities and the willingness to accept (WTA) of upstream communities, indicating an imbalance in perception and economic capacity regarding the valuation of water environmental services. The full cost pricing methodology yields water price estimates that more accurately represent the ecological, social, and physical costs neglected by traditional approaches. Moreover, the water price instrument has demonstrated efficacy as a market correction mechanism that internalizes the adverse effects of watershed degradation while concurrently offering incentives for conservation stakeholders in upstream regions. These findings necessitate the implementation of policies to address the value disparity, fortify institutions, and secure sustainable funding. The government is urged to implement water pricing based on full cost recovery, taking into account cross-subsidy mechanisms or fiscal incentives to bridge the disparity between willingness to pay (WTP) and willingness to accept (WTA). The incorporation of PES programs into watershed-focused regional development planning necessitates clear and participatory legislation. PES monies must be administered with accountability and allocated only for conservation, land restoration, and the empowerment of upstream communities.

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