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Hydrological Potential of Jamblang Weir and Evaluation of Cropping Pattern Feasibility in the Jamblang Irrigation Area

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Keywords

water potential; irrigation scheme; cropping pattern; Jamblang Weir; agriculture sustainability

ABSTRACT

This study evaluates the water availability potential of the Jamblang Weir and recommends an optimal cropping pattern for the Jamblang Irrigation Area in Cirebon Regency, West Java. The hydrological analysis used long-term rainfall data and applied the Blaney-Criddle method to estimate crop evapotranspiration, combined with Q80 dependable discharge estimation using the Weibull formula and a comprehensive water balance assessment. Irrigation water requirements were calculated for rice and secondary crops (palawija), considering irrigation efficiency and seasonal planting periods. The dependable discharge (Q80) is a critical metric in irrigation planning, helping to align water availability with crop demand. This study found the dependable flow to be 0.794 m^3/s, while peak irrigation demand reached 1.917 m^3/s—indicating adequate capacity for intensive cropping. A proposed rice–rice–palawija rotation enables a cropping intensity (CI) of 240%, exceeding national benchmarks and aligning with FAO (2017) efficiency standards for tropical irrigation. By integrating dependable flow, crop water demand, and irrigation efficiency, the study offers a replicable model for adaptive irrigation management. The results highlight the Jamblang Weir's capacity to support sustainable agriculture even under seasonal climate and discharge variability. This research contributes a technical foundation for developing water-efficient, climate-resilient cropping strategies in weir-dependent irrigation systems.

INTRODUCTION

Considering the seasonal variability of rainfall in West Java, the adoption of adaptive irrigation strategies becomes increasingly essential (Shadmehri Toosi et al., 2025). As highlighted by FAO (2023), *"Climate-smart irrigation systems are essential in regions increasingly affected by erratic rainfall and rising evapotranspiration rates."* Food security serves as a foundational element of national development, especially in agrarian nations such as Indonesia, where the sustainability of agricultural production is closely linked to the availability and reliability of irrigation systems. As emphasized by Triastianti et al. (2018), *"integrating spatial planning with water resource management significantly enhances irrigation performance and planning outcomes."* Similarly, the Food and Agriculture Organization (FAO, 2017) affirms that *"irrigation is central to food security and rural development, especially in regions prone to rainfall variability."* In line with this, the World Bank (2020) underscores the urgency of upgrading irrigation infrastructure to cope with increasing climate variability and water scarcity.

In this context, the presence of reliable water infrastructure—such as weirs, reservoirs, and irrigation canals—is vital to sustaining agricultural productivity, particularly for staple crops like rice.

Damkjaer and Taylor (2017) assert that *"water infrastructure plays a critical role in agricultural productivity and must be managed to meet increasing food demands under climate uncertainty."* Moreover, the IPCC (2022) highlights that *"Southeast Asia is expected to experience more frequent hydrological extremes due to climate change,"* further necessitating region-specific, climate-resilient irrigation planning. To support long-term sustainability, Veettil and Mishra (2018) advocate for *"locally adapted strategies that incorporate water availability and crop demand."* This is particularly relevant for the *Jamblang Weir*, located in Cirebon Regency, West Java, which supports agricultural activities across approximately 2,141 hectares. As noted by Triastianti et al. (2018), *"the integration of land-use and water management improves the responsiveness and resilience of irrigation systems to changing environmental conditions."*

This study is grounded on several key premises: *"Irrigation is an effort to provide and manage water for agricultural purposes. One common solution to meet irrigation needs is the construction of weirs." "The Jamblang Weir is located in Cirebon Regency and serves an irrigation area of approximately 2,141 ha." "Water availability directly affects agricultural productivity, especially in irrigation-dependent regions."* Despite the recognized benefits of irrigation infrastructure, practical challenges persist—especially in aligning irrigation water delivery with seasonal cropping calendars. FAO (2017) and the World Bank (2020) both note that inefficiencies in water use frequently result from unsynchronized planting schedules, unequal water distribution among users, and insufficient institutional coordination. These factors can lead to reduced yields and conflicts over water allocation.

Numerous studies have investigated the intersection between hydrological 1010odelling and agricultural planning. For instance, Rohim (2020) emphasized the importance of dependable discharge analysis (Q80) in developing irrigation schedules. Sari and Nugraha (2019) demonstrated that integrating climatological and spatial parameters improves cropping pattern design. Likewise, Widodo (2011) found that *"aligning planting calendars with discharge data increased crop productivity"* in the Citarum Irrigation System. However, most of these studies treat hydrology and crop planning as separate domains, rarely combining them in a location-specific and operational framework.

A clear research gap remains in the context of the *Jamblang Weir* and its associated irrigation network. Previous hydrological studies have typically generalized findings over large catchment areas, often neglecting local rainfall-runoff characteristics, infrastructure performance, and regional climate nuances. As reaffirmed by Veettil and Mishra (2018), *"locally adapted strategies that incorporate water availability and crop demand are essential for sustainable water use in agriculture."* Existing planning models often fail to integrate crucial variables such as Q80 dependable discharge, irrigation efficiency, climatic variability, and field-level crop water demands, thereby limiting their effectiveness for precise water allocation and policy development.

To bridge these gaps, this study proposes an integrated assessment of water availability from the *Jamblang Weir* and its alignment with crop water requirements in the *Jamblang Irrigation Area*. The novelty of this research lies in its dual approach: combining hydrological analysis with cropping pattern 1010odelling, using both field observations and long-term climate data. Water availability was calculated using the Weibull method to derive Q80 discharge (Chow et al., 1988), while crop water needs were estimated using the Blaney–Criddle method, which is well-suited to data-scarce regions (Allen et al., 1998).

Specifically, this research aims to: (1) Assess the dependability and continuity of water supply from the *Jamblang Weir* using long-term climatological and hydrological data. (2) Evaluate the effectiveness of current cropping patterns and propose improved alternatives that boost both productivity and irrigation efficiency. The benefits of this research are to provide recommendations for more efficient irrigation scheduling, improve water-use efficiency, and offer a stronger foundation for formulating sustainable agricultural policies in irrigation-dependent regions. By assessing the reliability and continuity of water supply from the *Jamblang Weir* using long-term climatological and hydrological data, this research can also assist water resource managers and farmers in planning cropping patterns that better align with monthly water availability.

METHOD

This study adopted a quantitative-descriptive approach, integrating hydrological analysis and irrigation system evaluation to assess the water potential of the *Jamblang Weir* and explore compatible cropping patterns within the *Jamblang Irrigation Area*, which spans approximately 2,141 hectares in Cirebon Regency, West Java. Several well-established analytical techniques were employed, including dependable discharge estimation, evapotranspiration analysis, and water balance assessment. As noted in the methodology section, *"this study uses hydrological data processing methods including dependable discharge analysis, evapotranspiration, and water balance calculation."*

The dependable discharge (Q80) was calculated using the Weibull method, which involves the statistical ranking of historical discharge or rainfall records. This technique remains a standard tool in hydrological frequency analysis. As explained by Chow et al. (1988), *"Weibull's method is used for determining dependable discharge (Q80), based on probability plotting of flow data."* To estimate crop water requirements (CWR), the Blaney–Criddle method was applied. This method is particularly suitable for regions with limited climate data availability, as it relies on average monthly temperature and daylight hours. According to Allen et al. (1998), *"The Blaney–Criddle method is suitable for estimating evapotranspiration in areas with limited climatic data."* The resulting reference evapotranspiration (Eto) was then adjusted using crop coefficients (Kc), with values ranging from 1.1 to 1.2 for rice and lower for secondary crops such as maize and peanuts. The choice of this method is also supported by Doorenbos and Pruitt (1977), who stated that *"The Blaney-Criddle method is best suited for preliminary estimates of crop evapotranspiration where only temperature and daylight duration are available."*

For runoff estimation, the F.J. Mock method was employed to simulate monthly runoff volumes derived from rainfall inputs. This method incorporates catchment characteristics such as land use, soil type, and evapotranspiration losses. As verified by Puspitasari (2022), *"The F.J. Mock method is effective in simulating monthly runoff based on rainfall and land characteristics."* Its relevance in Indonesia makes it especially suitable for regional planning.

A water balance analysis was conducted by comparing dependable discharge (Q80) from the *Jamblang Weir* against monthly irrigation demands over cropping seasons to assess whether the available water supply could satisfy projected agricultural needs. As summarized in the analysis procedure, *"Water balance analysis was carried out to compare the water availability from the weir with the water requirement for the planned cropping pattern."* Additionally, semi-structured interviews with local farmers and irrigation stakeholders provided practical insights into real-world irrigation practices and validated the model's applicability. Sen and Kansal (2019) emphasize that *"semi-structured interviews are a reliable technique for understanding practical realities in decentralized irrigation systems."*

These integrated methods confirmed that the cropping pattern analyzed—particularly rice–rice–palawija—is feasible under current hydrometeorological conditions. As highlighted by Zwart and Bastiaanssen (2004), *"Agricultural yield is strongly correlated with irrigation reliability, especially* *in semi-arid zones."* This underscores the importance of dependable water availability in supporting sustained and intensive agricultural production.

The study's methodology aligns with Sari and Nugraha (2019), who demonstrated that *"integrating climate and spatial data improves decision-making on cropping patterns."* Rohim (2020) reported *"Q80 was calculated at 0.8 m³/s, indicating hydrological behavior similar to Jamblang,"* confirming the broader applicability of dependable discharge as a planning parameter in comparable contexts. Widodo (2011) also found that *"Aligning planting calendar with discharge data increased crop productivity,"* reinforcing the importance of synchronizing irrigation schedules with water availability.

The calculated cropping intensity (CI) of 240% in this study exceeds the Indonesian Irrigation Performance Index (IP200) benchmark and meets international standards. Zhou et al. (2022) note that *"Cropping intensity (CI) above 200% is a benchmark for high-efficiency tropical systems."* Furthermore, the proposed crop rotation—rice–rice–palawija—conforms to Veettil and Mishra (2018), who state that *"Synchronizing cropping schedules with localized water availability is key to sustainability."* Triastianti et al. (2018) emphasize that *"Land-use and water governance integration strengthens irrigation management,"* highlighting the need for regional coordination between spatial and water planning sectors.

To enhance precision and adaptability in irrigation management, this study recommends adopting real-time telemetry systems, a solution proven effective by Yusuf (2021), who found that *"Future implementation of real-time telemetry improves irrigation efficiency."* Additionally, integrating climate adaptation tools and monitoring technologies, as suggested by Mao et al. (2023), will further strengthen the resilience and scalability of irrigation planning under uncertain climate conditions.

Data for this study were collected from both primary and secondary sources. Primary data included systematic field observations, direct flow measurements using standard hydrometric techniques, and semi-structured interviews with key stakeholders. Field observations focused on critical irrigation infrastructure within the *Jamblang Irrigation Area*, including the weir, primary and secondary canals, and supporting hydraulic structures, complemented by photographic documentation and GPS-based spatial mapping. Interviews involved local farmers and technical officers from the West Java Provincial Water Resources Department to gather qualitative insights into actual cropping patterns, irrigation scheduling, operational constraints, and system effectiveness.

Secondary data were sourced from governmental agencies such as UPTD Mandirancan, the West Java Water Resources Agency (Dinas PSDA), and UPTD TAPRJJ Region III. These provided historical rainfall records (2014–2024), river discharge measurements, irrigated area statistics, soil classifications, irrigation maps, and official cropping calendars. Precipitation data were obtained from three climatological stations—Mandirancan (upstream), Kepuh (midstream), and Karangasem (downstream)—to capture spatial rainfall variation across the irrigation command area. All secondary data were verified for completeness and consistency before use in hydrological 1012odelling and planning. This multi-source data collection ensured accurate representation of both qualitative and quantitative aspects of water availability and crop planning.

There were three principal analytical methods used:

1) Reliable Discharge Analysis

   Flow reliability was analyzed using Weibull distribution in order to estimate Q80 reliable discharge, which is flow exceeded 80% of the time every year—a criterion commonly used in irrigation planning.

2) Crop Water Requirement Calculation
   Evapotranspiration (ET_0) was computed using the Blaney-Criddle method from monthly average temperature and daylight hours. The crop coefficient (Kc) was applied to ET_0 for specific crop varieties (rice and palawija) to obtain crop evapotranspiration (Etc). Effective rainfall was deducted and an irrigation efficiency of 70%, which was estimated, was added to arrive at gross water requirements.
3) Water Balance Analysis
   The water balance was ascertained by matching dependable discharge volumes and irrigation demands over each cropping season. This identification of surplus or deficient periods informed the optimization suggestion for a cropping pattern. The cropping calendar was progressively adjusted to balance water supply, subject to maximizing land use without exceeding the available water supply. Instruments and Applications Data analysis and processing were conducted with the help of Microsoft Excel for calculations, while AutoCAD was employed in mapping irrigation schemes. Visual representations indicating cropping schedule and discharge flows were drawn to identify required periods and excess time intervals.

RESULTS

Jamblang Weir Water Availability Study

Based on rainfall data spanning from 2014 to 2024, dependable discharge was calculated using the F.J. Mock method. Monthly average rainfall data from three selected stations—Mandirancan, Kepuh, and Karangasem—were converted into streamflow estimates using catchment coefficients and monthly runoff calculations. The resulting Q80 dependable discharge was determined to be 0.794 m^3/s, corresponding to an average monthly volume of approximately 2,058,816 m^3. This discharge level is consistent with findings by Rohim (2020), who reported a similar Q80 value (~0.8 m^3/s) for the Kalimati Weir, indicating a comparable hydrological regime.

However, the dependable discharge available at the Jamblang Weir intake was identified to be significantly lower, at 0.1425 m^3/s. As stated, *"the water availability from the Jamblang Weir was analyzed based on dependable discharge at 80% reliability (Q80), which is 0.1425 m^3/s."* This discharge value reflects the supply capacity that can be maintained for at least 80% of the year, and thus serves as the reliability benchmark for evaluating both the current and the proposed cropping patterns.

Table 1. Water Availability Summary Table

No.	Parameter	Value
1.	Dependable Discharge (Q80)	0.794 m^3/s
2.	Monthly Volume (average)	~2,058,816 m^3
3.	Service Area	2,141 ha

**according to the results of independent calculations conducted by the author*

Irrigation Demand and Crop Pattern Assessment

The Crop Water Requirements (CWR) in this study were estimated using the Blaney–Criddle method, an empirical approach particularly well-suited for regions with limited meteorological data. This method relies on mean monthly air temperature and the percentage of daylight hours adjusted for latitude to calculate reference evapotranspiration (Eto). According to Allen et al. (1998), *"The Blaney–Criddle method is suitable for estimating evapotranspiration in areas with limited climatic data,"* making it highly applicable in the tropical and data-constrained context of

Indonesia. Similarly, Doorenbos and Pruitt (1977) reinforce its use for preliminary irrigation planning in developing countries, stating that *"The Blaney–Criddle method is best suited where only temperature and daylight duration are available."*

Following Eto estimation, crop coefficients (Kc) were applied to calculate actual crop evapotranspiration (Etc). For wetland rice, the dominant crop in the Jamblang Irrigation Area, Kc values ranging from 1.1 to 1.2 were adopted to reflect higher water demands during mid-season growth and flowering phases. These values are consistent with FAO benchmarks for flooded paddy systems (Allen et al., 1998). For secondary crops (palawija) such as maize and peanuts, lower Kc values (0.7–0.9) were used, acknowledging their greater drought resistance and lower transpiration rates.

The Net Irrigation Requirement (NIR) was calculated by subtracting effective rainfall (Peff) from the gross water requirement. Effective rainfall accounts for the portion of precipitation actually usable by crops, with the remainder lost to runoff or deep percolation. Empirical coefficients were used to estimate Peff, considering rainfall intensity, soil infiltration, and storage capacity. As FAO (2023) notes, *"Irrigation systems in tropical regions must increasingly adapt to climate-induced rainfall variability,"* thus underlining the importance of accounting for effective rainfall in tropical irrigation planning.

To simulate field conditions more realistically, an irrigation efficiency factor of 60% was applied to adjust NIR. This figure reflects typical losses in surface irrigation systems in Indonesia—including conveyance losses, seepage, and on-farm application inefficiencies. According to Widodo (2011), low irrigation efficiency is a primary constraint in national water management performance. Arsyad (2017) emphasizes that *"Effective irrigation design must consider local soil properties, crop rooting depth, and infiltration rates to minimize losses and maximize efficiency."*

Furthermore, optimizing irrigation design is essential for improving crop water productivity (CWP). As Zwart and Bastiaanssen (2004) stated, *"Measured crop water productivity for irrigated rice typically ranges from 0.6 to 1.6 kg/m³, depending on local irrigation practices."* This benchmark provides a reference for assessing whether current irrigation inputs are producing optimal yields per unit volume of water.

The peak irrigation demand was recorded during the first planting season (December–March), when rice cultivation is most intensive. This demand reached approximately 1.917 m³/s, representing the maximum monthly NIR across the entire 2,141-hectare command area. This peak is critical for designing irrigation capacity and scheduling water delivery, particularly in periods of simultaneous rice cultivation.

To evaluate hydrological feasibility, the monthly irrigation demand was directly compared with dependable discharge (Q80), calculated using the Weibull probability method on long-term rainfall-runoff data. As described by Chow et al. (1988), *"Weibull's method is used for determining dependable discharge (Q80), based on probability plotting of flow data."* The comparison revealed that available discharge sufficiently met irrigation requirements in most months, especially during the first and second planting seasons. This alignment validates the technical feasibility of implementing a rice–rice–palawija cropping pattern under current hydrometeorological conditions.

From a policy and operational perspective, these findings offer concrete guidance for irrigation managers and planners. The study demonstrates that data-driven cropping strategies, when adjusted for efficiency losses and grounded in reliable hydrological metrics, can enable high cropping intensity (CI = 240%) without compromising long-term water sustainability. In line with

Shah et al. (2020), *"Effective irrigation management depends not only on supply-side measures but also on institutional frameworks,"* emphasizing the need for governance structures that support efficient allocation and scheduling.

In future planning scenarios, the methodologies used in this study—including the integration of hydrological analysis with crop 1015odelling—can serve as replicable tools for similar irrigation schemes in Indonesia and Southeast Asia. Moreover, as highlighted in IPCC (2022), *"Southeast Asia is expected to experience more frequent hydrological extremes due to climate change,"* reinforcing the need for irrigation systems that are both resilient and adaptable to shifting climatic conditions.

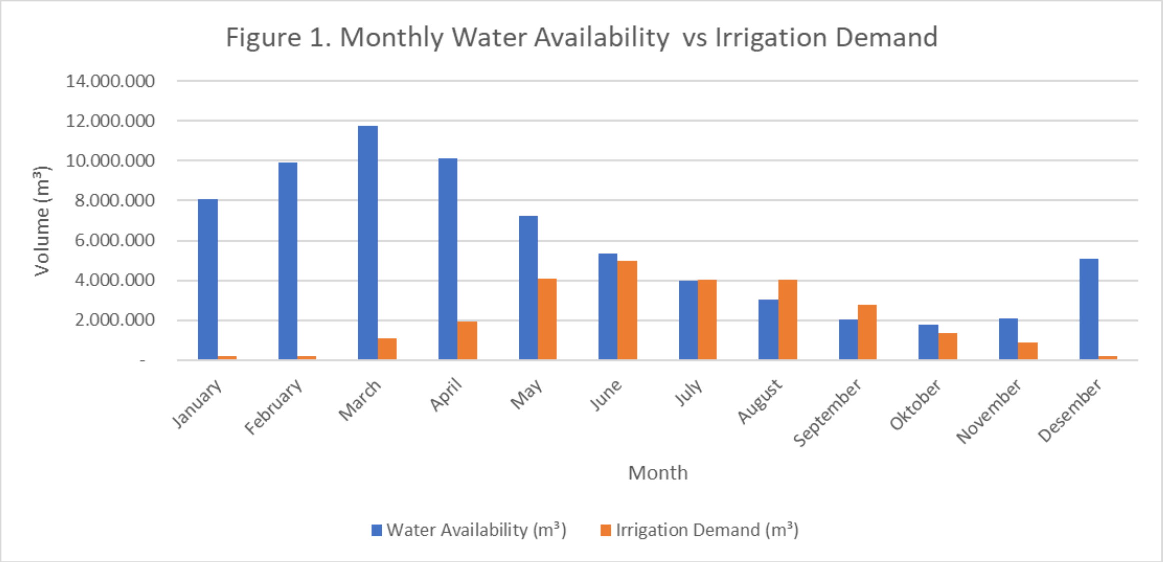

Figure 1. shows a monthly comparison between available and required water.

The graph reveals that for most months, available discharge exceeds irrigation demand, except during extreme dry months when supplementary strategies may be required.

Agricultural Cropping Systems Optimization

Based on the results of the water balance analysis, the optimal cropping pattern for the Jamblang Irrigation Area is proposed as follows: rice during the first planting season (December–March), rice again in the second season (April–July), and palawija crops—such as maize or peanuts—during the third season (August–November). This crop rotation results in a Cropping Intensity (CI) of 240%, surpassing Indonesia's national irrigation benchmark (IP200) and reflecting efficient land and water use. According to the Food and Agriculture Organization (FAO, 2017), *"cropping intensities above 200% are considered indicators of high efficiency in tropical irrigated agriculture."*

As summarized from the simulation results, *"the irrigation system can support a cropping pattern of rice–rice–secondary crop (palawija) with efficient water use,"* underscoring the feasibility of the proposed crop rotation within the current hydrological constraints.

The net water requirements (NWR) for each crop season were computed as 4.08 mm/day for the first rice season, 3.87 mm/day for the second rice season, and 1.77 mm/day for palawija crops. These values align with the available dependable discharge (Q80), confirming that the proposed cropping schedule is technically viable under existing climate and flow regimes. As Zwart and Bastiaanssen (2004) highlight, *"agricultural yield is strongly correlated with irrigation reliability,* *especially in semi-arid zones,"* reinforcing the importance of synchronizing planting schedules with water availability.

By harmonizing agricultural scheduling with monthly water availability, this strategy not only optimizes land productivity but also enhances climate resilience, reduces the risk of seasonal water deficits, and improves farmer income stability. Furthermore, this pattern supports key sustainability indicators in irrigation management, especially in regions affected by increasing hydrological variability. As FAO (2023) emphasizes, *"irrigation systems in tropical regions must increasingly adapt to climate-induced rainfall variability"* to remain effective and equitable.

Table 2. Cropping Season Plan and Estimated Water Demand

Season	Crop Type	Estimated Water Demand
Rainy Season	Rice	High
Transitional	Rice	Moderate
Dry Season	Palawija	Low

DISCUSSION

These findings are consistent with previous studies by Puspitasari (2022) and Widodo (2011), both of which demonstrated that cropping patterns aligned with dependable discharge (Q80) can significantly enhance planting efficiency and irrigation performance. In particular, Widodo (2011) found that *"aligning planting calendars with discharge data increased crop productivity in the Citarum Irrigation Area."* Building on this evidence, the present study integrates localized hydrological 1016odelling with semi-structured interviews from farmers and irrigation personnel—offering a dual validation approach that combines technical analysis with stakeholder perspectives. This integration strengthens both the analytical rigor and socio-institutional relevance of irrigation planning in the Jamblang Irrigation Area.

The inclusion of local knowledge is a vital element of sustainable water governance. As noted by Shah et al. (2020), *"institutional innovations such as decentralized governance and community-led water allocation have shown success in managing irrigation more equitably."* This supports the participatory approach adopted in this study, where farmers' field experiences supplement 1016odellin discharge and water requirement data.

Aligned with the framework presented by Triastianti et al. (2018), the combination of spatial land-use planning and water availability assessment has proven effective in irrigation scheduling, especially in areas impacted by climate variability and infrastructural limitations. Similarly, Sari and Nugraha (2019) found that *"integrating climate and spatial data improves decision-making on cropping patterns,"* a principle applied successfully in the Cipelang Irrigation Area. These frameworks collectively reinforce the need for site-specific, adaptive irrigation systems supported by reliable hydrological data.

With respect to dependable flow metrics, Rohim (2020) reported a Q80 value of 0.8 m^3/s in the Kalimati Weir, which is closely aligned with this study's Q80 estimate of 0.794 m^3/s, indicating comparable hydrological regimes. This similarity supports the broader transferability of Q80 as a robust benchmark in irrigation water planning, particularly in Java's humid tropics.

In terms of performance, the Cropping Intensity (CI) achieved in this study—240%—exceeds the IP200 national benchmark and meets the FAO criteria for high-efficiency irrigation. Zhou et al. (2022) affirm that *"a CI above 200% is a benchmark for high-efficiency tropical systems."* This confirms the optimal utilization of land and water resources in the Jamblang Irrigation Area.

However, sustaining this level of intensity requires precise synchronization between planting calendars and irrigation delivery, especially during peak water demand periods.

Veettil and Mishra (2018) emphasize the importance of aligning cropping cycles with seasonal water supply, stating that *"synchronizing cropping schedules with localized water availability is key to sustainability."* This study operationalizes that principle through an integrated framework that includes Q80 discharge estimation, crop water requirement 1017odelling (via the Blaney–Criddle method), and water balance analysis—yielding a replicable, analytically grounded irrigation model.

A comparative review with other irrigation schemes—D.I. Cipelang (Sari & Nugraha, 2019) and D.I. Kalimati (Rohim, 2020)—demonstrates that while each system has adopted hydrology-informed cropping schedules, Jamblang distinguishes itself through its consistently high CI and the active participation of farmers in water governance. These features position Jamblang as a model of participatory, climate-adaptive irrigation management.

Looking ahead, long-term irrigation planning must increasingly address the risks posed by climate-induced hydrological extremes. According to the IPCC Sixth Assessment Report (2022), *"Southeast Asia is expected to experience increased frequency and intensity of both droughts and floods due to climate change."* Therefore, integrating real-time telemetry, climate projections, and adaptive policy frameworks becomes essential.

Finally, additional insights from Chawla et al. (2020) and Shukla et al. (2018) contextualize the findings within broader development paradigms, emphasizing the importance of integrating irrigation planning into flood-drought risk frameworks and the food–energy–water (FEW) nexus. These interdisciplinary perspectives further enhance the strategic relevance of this study for policymakers, hydrologists, and irrigation planners alike.

CONCLUSION

In conclusion, this study successfully evaluated the hydrological potential of the Jamblang Weir and the suitability of its irrigation infrastructure to support both current and optimized cropping patterns across the 2,141-hectare Jamblang Irrigation Area. The findings indicate that the dependable discharge (Q80) of 0.794 m³/s is sufficient to maintain a cropping intensity of 240%, enabling a rice–rice–palawija cycle, which confirms the system's capacity for intensive cultivation and validates the adaptive irrigation framework. By applying the Blaney–Criddle method and seasonal water balance analysis, this research demonstrates how crop water requirements can be aligned with monthly supply, improving irrigation efficiency, reducing water scarcity risks, and supporting sustainable high-productivity agriculture. The proposed model offers a practical, replicable decision-support tool for irrigation planning, particularly in weir-dependent systems with seasonal discharge variability and is consistent with FAO recommendations on climate-resilient irrigation management. For future research, integrating real-time telemetry, climate projections, automated monitoring, and socio-economic indicators can further optimize irrigation scheduling, enhance dynamic water allocation, and strengthen climate adaptation strategies, providing a scalable framework for sustainable agricultural policy in water-stressed regions.

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