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Water Resources Assessment of Cirasea Sub-DAS, Bandung Regency

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Abstract: The phenomena that often occur in the Cirasea Sub-DAS are floods in the rainy season and droughts in the dry season. Climate change, land use changes, population growth and industrialization have put significant pressure on the availability of water resources in the Cirasea Sub-DAS. The purpose of this study is to gain a better understanding of water resources and their management in the area. The research method used in this study is descriptive with a quantitative approach. Water availability is calculated using the HEC-HMS simulation and water needs are calculated using the formula approach published by the Ministry of Environment, 2014. A comprehensive analysis of water availability and the risk of water scarcity is assessed using HEC-HMS. Calibration and validation are also carried out to determine the suitability between field discharge data (measured) and the calculation results using HEC-HMS (calculated). The calculation results of the mainstay discharge of the Upper Citarum River referring to SNI 6738-2015, obtained the mainstay discharge of the Upper Citarum River Q80 of 2.3 m3/second, Q90 of 1.52 m3/second and Q95 of 1.1 m3/second. This research can provide a significant contribution in optimizing the carrying capacity and management of water resources in the Cirasea Sub-DAS area. The results can also be used to help determine strategies and planning for future water resource management.

Keywords: Carrying capacity; Cirasea Sub-DAS; HEC-HMS; Water availability; Water needs

Introduction

Cirasea Sub-DAS is one of the Sub-DAS located in the Upper Citarum DAS, located in Bandung Regency, becoming a strategic area in providing raw water sources for the needs of the population and the agricultural sector. The Cirasea Sub-DAS River Area as part of the Upper Citarum DAS as explained in Bandung Regency Regional Regulation Number 27 of 2016 concerning the Bandung Regency Spatial Planning Plan for 2016-2036, especially in Article 23 letter (b) number (2). Based on the Decree of the Minister of Environment and Forestry No. SK.304/MENLHK/PDASHL/DAS.0/7/2018 oncerning the Determination of the River Basin Map, Cirasea Sub-DAS is geographically located at 107o 37′ 49″ BT - 107o 48′ 30″ BT and 6o 59′ 32″ LS - 7o 14′ 35″ LS and has an area of 38,594 hectares which is administratively located in 7 (seven) sub-districts in the Bandung Regency area, namely Kertasari Sub-district, Pacet Sub-district, Ibun Sub-district, Majalaya Sub-district, Ciparay Sub-district, Arjasari Sub-district, and Baleendah Sub-district. The existence of the Cirasea Sub-DAS which is located in the upstream part can greatly influence the hydrological function of the DAS as a whole (Somantri, 2024; McGrane, 2016; Almheiri et al., 2023).

The hydrological capacity of this area is a major focus (Yang et al., 2021; Guan et al., 2019; Remondi et al., 2016). The diverse landforms affect the ability of the

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Cirasea Sub-watershed to retain and store rainwater (Nepal et al., 2014; Stagl et al., 2014; Liu et al., 2024) . In the rainy season, the highlands and hills hold abundant water, providing abundant water sources for the rivers that flow downstream (Tesfai & Stroosnijder, 2001; Razali et al., 2018; French et al., 2017). However, in the dry season, this natural water capacity can be limited, causing a decrease in water availability felt by the local community and ecosystem (Cosgrove & Loucks, 2015; Ayanlade, 2024). In addition, water quality in the Cirasea Sub-watershed is also an important concern (Syamsiyah et al., 2025). Rapid population growth, expanding industrial activities, and intensive agricultural practices have increased pressure on water quality in the rivers and lakes in this area (Anh et al., 2023). Pollution by pesticides, excess nutrients, and industrial waste has caused significant declines in water quality, threatening the sustainability of aquatic ecosystems and the health of the people who depend on them (Hassaan & El Nemr, 2020; Rad et al., 2022; AbuQamar et al., 2024; Lin et al., 2022).

The use of the HEC-HMS program method can be an effective approach to conduct a comprehensive analysis of water availability and the risk of water scarcity (Odey & Cho, 2025). HEC-HMS is an integrated water planning tool that allows modeling of complex interactions between various aspects of water resource management, including water demand, water supply, land use patterns, and climate change impacts. The use of HEC-HMS can identify potential water scarcity, analyze the impacts of various water resource management scenarios, and formulate effective and sustainable water management strategies. With this background, this study aims to assess the threat of water scarcity and formulate an integrated water resource management strategy in the Cirasea Sub-watershed using the HEC-HMS program method. Through a deep understanding of water availability conditions and associated risks, it is hoped that this study can provide a significant contribution to the development of sustainable water resource management policies and practices in the Cirasea Sub-watershed area.

Method

The utilization of the Cirasea Sub-DAS rivers as explained in the Bandung Regency Regional Regulation Number 27 of 2016 concerning the Bandung Regency Spatial Planning Plan for 2016 - 2036, Article 24 paragraph (3), includes: Utilization of river water for households; Agriculture; Environmental sanitation; Industry; Tourism; Sports; Defense; Fisheries; Power generation; and Transportation. In the Cirasea Sub-DAS flow, there is utilization of river water other than for domestic activities of the community, namely in the form of intake of the Cikoneng Drinking Water Supply System (SPAM) and 13 Irrigation Areas (D.I.) with 2 D.I. (Wanir and Wangisagara) are the authority of the West Java Provincial Government and 11 other D.I. (Cirawa 1, Cirawa 2, Cienteng, Cienteng Lebak, Cijambu Raya, Rumbia, Bojong, Sawah Jeruk, Panganten, Ancol, and Linger) are irrigation areas under the authority of the Bandung Regency Government.

Table 1. Utilization of Upper Citarum River Water

Name of Water User	Area (HA)
D.I. Cirawa 1	202.10
D.I. Cirawa 2	17.66
D.I. Cienteng	45.33
D.I. Cienteng Lebak	19.48
D.I. Cijambu Raya	43.99
D.I. Rumbia	8.28
SPAM Cikoneng	-
D.I. Bojong	35.90
D.I. Wanir	1.397.75
D.I. Sawah Jeruk	12.30
D.I. Panganten	16.90
D.I. Ancol	41
D.I. Linger	16.50
D.I. Wangisagara	1.428.78

Source: Bandung Regency Irrigation Commission, 2023; West Java Province DSDA, 2023

In this study, the research location was carried out in the Cirasea Sub-DAS which is included in the Upper Citarum DAS which administratively covers 7 (seven) sub-districts, namely Kertasari District, Pacet District, Ibun District, Majalaya District, Ciparay District, Arjasari District, and Baleendah District in Bandung Regency, West Java Province.

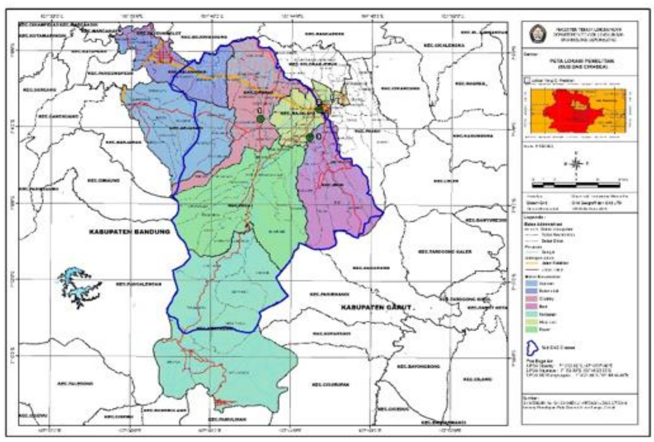

Figure 1. Map of research location (Cirasea Sub-DAS)

The data used for analysis are primary data and secondary data. The primary data used in this study are the results of field findings in the form of field documentation obtained through direct observation in the field and the results of in-depth interviews with water users. In-depth interviews are the process of obtaining information for research purposes by means of face-to-face questions and answers between the interviewer and the respondent or person being interviewed, with or without using an interview guide where the interviewer and informant are involved in a relatively long social life (Young et al., 2018; Read, 2018). In this study, the author used a probability sampling technique, namely disproportionate stratified random sampling. According to Mitani et al. (2021), disproportionate stratified random sampling is a technique used to determine the number of samples, if the population is stratified but less proportional. Due to limited time, funds, and manpower, in this study the author considered determining the sample. Determination of the number of samples was obtained based on the results of the relationship between respondents and the study, especially respondents at the research location. Therefore, the author did not determine the number of samples from each category of respondents. However, the author determined the classification of respondents as follows:

Table 2. Respondent Classification

Classification of Respondents	Number of People)	Information	Reason/Justification
Formal Leader	6	Village Apparatus, Related Services, Citarum Harum Task Force, Farmer Groups	This group has a significant role in decision-making and policy implementation related to water use and land use change. Formal leaders such as government officials and organizational leaders have authority and access to resources that allow them to influence the decision-making process.
Informal Leader	4	RT/RW	Involving this group will help in understanding the dynamics of policy and implementation at the local level.
Farmer (Owner / Cultivator)	13	-	Community or religious leaders, have strong influence in their communities even without
Livestock Farmer	7	-	formal positions. Involving this group will help in understanding the dynamics of policy and implementation at the local level. Farmers and ranchers are key stakeholders in land use change from agriculture to other uses. They will be directly impacted by this change, both economically and socially. Involving them in the research will provide valuable insights into the challenges they face and how they respond to this change.
Communities in the Area Experience Changes in Land Use from Agricultural Areas to Other Uses	5	1 representative of Cipeujeuh Village, Pacet District 1 representative of Maruyung Village, Pacet District 1 representative from Pakutandang Village, Ciparay District 1 representative of Biru Village, Majalaya District 1 representative from Sukamukti Village, Majalaya District	
	35		

Source: Primary data, 2023

Secondary data collection involves the use of data that has been collected by other parties for other purposes that may not be related to the research being conducted. The secondary data required include rainfall data, river flow discharge, river water utilization, demographics, land use, and others. The secondary data used in this study were obtained from: Literature and scientific publications; Official documents and government reports such as data sourced from the Citarum River Basin Center, West Java Provincial Water Resources Service, Bandung Regency Agriculture

Service, Bandung Regency Public Works and Spatial Planning Service and Bandung Regency Central Statistics Agency

Climatology data was obtained from the nearest station as shown in Figure 2. The locations of the climatology posts and the nearest identified rainfall posts are as follows: Bandung Geophysics Station; Ciparay Climatology Post; Ciherang Rain Post; Cileunca Rain Post; Cipanas Pangalengan Rain Post; Cisondari Pasir Jambu Rain Post; Hantap Rain Post; Kertamanah Rain Post. The calculation of river discharge uses data from the Ciparay Climatology Post with data correction from the Bandung Geophysics Station. Rain data processing was taken from Ciherang Post, Cileunca Post, Cisondari Pasir Jambu Post, Cipanas Pangalengan Post, and Kertamanah Post. Hantap Post was not used because the available data was very lacking. Hantap Post only provided 6 years of data from the 10-year data requirement.

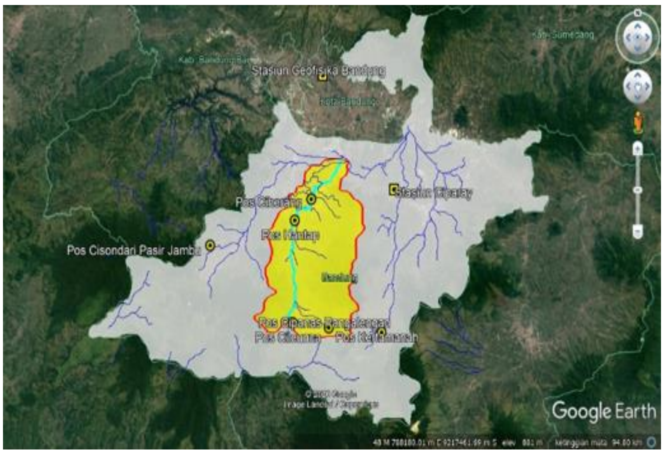

Figure 2. Data source stations around Bandung regency

Method of Analysis of Water User Community Perception

The data analysis technique related to the perception of water user community is carried out descriptively qualitatively. According to Bazen et al. (2021), the qualitative descriptive analysis method is to analyze, describe, and summarize various conditions, situations from various data collected in the form of interview results or observations regarding the problems studied that occur in the field.

Water Needs Analysis Method

The calculation of water needs in this study is calculated using the formula (KLH, 2014):

$$D_A = N \ x \ KHL_A \quad (1)$$

Where:
DA = Total water requirement (m^3/year)
N = Population (people)
KHLA = Water requirement for decent living

Water Availability Analysis Method

Analysis of water availability data is carried out on rainfall data to test data consistency, climatology data to obtain potential evapotranspiration. In the data analysis, the HEC HMS simulation process is also carried out, water availability analysis and comparing the discharge from the HEC HMS simulation results with the observed discharge.

Water Balance Analysis Method

The water balance is expressed in various ways, including the Surplus and Deficit Balance which is calculated using the following equation:

$$Balance \ Sheet = Q_{Availability} - Q_{Ne} \quad (2)$$

Where:
Balance: Water Balance
QNeed: Water Need (m3)
QAvailability: Water Availability (m^3)

The surplus deficit balance is called a "surplus" if the equation result is positive and is called a "deficit" if the equation result is negative.

HEC-HMS Modeling Method

The use of the HEC-HMS program in this study is to assist researchers in modeling water flow, evaluating policy scenarios and predicting the impact of water use on water availability in the Cirasea Sub-DAS.

Table 3. WEAP Modeling Scenarios

Scenario	Description
1	Existing condition/ without additional water utilization
2	Additional water utilization in the form of a dam intake owned by BBWS Citarum

Water Resources Carrying Capacity Analysis Method and Water Criticality Level

The calculation of water carrying capacity in this study refers to the Regulation of the Minister of Environment No. 17 of 2009 concerning Guidelines for Determining Environmental Carrying Capacity in Regional Spatial Planning. The method for calculating water carrying capacity in an area uses the approach of availability and need for water resources for the population in a healthy and proper manner. Determination of Water Carrying Capacity Status: The water carrying capacity status is obtained from a comparison between water availability (SA) and water needs (DA); If SA > DA, the water carrying capacity is declared a surplus; If SA < DA, the water carrying capacity is declared a deficit or exceeded; In addition to determining the water resource carrying capacity, the data on water availability and needs will also be calculated for their criticality level. The criticality level of water is expressed by the Water Criticality Index (IKA) which is calculated using the following equation:

$$IKA = \frac{W_n}{W_s} x100\% \quad (3)$$

Where:
IKA: Water Criticality Index (%)
Wn: Amount of Water Needs (m^3)
Ws: Amount of Water Availability (m^3)

The percentage of water criticality index is then compared with the water criticality criteria referred to by Martopo (1991) in Hamdani et al. (2017) as presented in the following table:

Table 4. Water Criticality Criteria (Martopo, 1991)

Criticality Index (%)	Classification
0 – 50	Not Critical
50 – 75	Somewhat Critical
75 – 100	Critical
> 100	Very Critical

Calibration and Validation

The calibration and validation process in HEC-HMS modeling is carried out to test the reliability of the model in representing the hydrological response of the Cirasea Sub-watershed based on available rainfall and river discharge data. Calibration aims to adjust model parameters such as initial abstraction, curve number (CN), lag time, and baseflow, so that the results of the discharge simulation are close to the observed discharge data. In this study, the calibration period was carried out for the period 2010 to 2016, while the validation period used data from 2017 to 2022. The calibration process was carried out iteratively by considering land-specific hydrological parameters and climatological conditions of the Cirasea Sub-watershed area. Validation was carried out by comparing the average discharge value of the simulation results to the observed discharge. The difference between the two shows a deviation of <10%, which is still within the tolerance limit for watershed-scale modeling. With these results, the model can be said to be quite representative and suitable for use for further hydrological analysis in the Cirasea Sub-DAS.

Result and Discussion

Water User Perception

The survey results generally show that the amount of water available for agricultural land, especially agricultural land under the D.I. Wanir, is insufficient to meet agricultural needs. This is indicated by the irrigation schedule regulated by the Citarum Regional PSDA UPTD, located in Cipeujeuh Village, Pacet District, Bandung Regency. As information provided by one of the Farmer Group Leaders in Cipeujeuh Village, this scheduling was implemented after the construction of the PDAM intake (SPAM Cikoneng) in the Maruyung Village area, Pacet District and the decline in environmental conditions upstream, especially changes in land use in the Gunung Wayang area. He stated that the fulfillment of water needs was the subject of the biggest conflict that had occurred several years ago. According to the Cipeujeuh Village apparatus and the Head of RW 05 Cipeujeuh Hamlet, from 2016 to 2019 there was a conflict in the water gate area in Cipeujeuh Village.

People who use Citarum River water from the lower areas, such as people from Biru Village and Sukamukti Village, Majalaya District, came to the Citarum Regional PSDA UPTD office in Cipeujeuh Village with sharp weapons and this has caused unrest for the people in Cipeujeuh Village, Pacet District. "Currently, the condition of fulfilling water needs from the Citarum River is still lacking, even in the past people from the lower areas came here (to the PSDA UPTD office) carrying sharp weapons because the water was not flowing, and there was almost a big riot. That's why during the socialization, the Village conveyed the conditions that had occurred, and asked if something like that happened again who would be responsible, because even now when the Citarum River water rotation schedule is being carried out, it is not uncommon for many people outside Cipeujeuh Village to come carrying sharp weapons to maintain the flow of river water to their respective areas. " (Head of Hamlet RW 05 Cipeujeuh, interview February 6, 2023).

Figure 3. Interview with Cipeujeuh Village Apparatus, Pacet District, Bandung Regency

In addition, the farmers interviewed explained that to ensure the flow of water from the Citarum Water Resources Management Unit (UPTD PSDA) water gate in Cipeujeuh Village to agricultural land, water collection is always carried out, also known as "di anir". To carry out this water collection, it is not uncommon for groups of people using Citarum river water to use sharp weapons and sometimes cause unrest in the community. Farmers in Manggungharja Village, Majalaya District also said that so far, to meet their agricultural water needs, especially during the dry season, farmer groups have used water pumps to help the flow of water from the D.I. Wanir channel to their agricultural land. Another water shortage conflict occurred in Sukamukti Village, Majalaya District where according to the Sukamukti Village farmers, the flow of irrigation water must be shared with industrial activities. Two farmers in Kampung Mekar Asih RT 03/ RW 13 Sukamukti Village, Majalaya District complained about the current drought in their rice fields, so that some of their rice fields are used for secondary crops or dry fields, especially during the dry season.

Figure 4. Interviews with farmers in Majalaya and Ciparay Districts

The conflict generally occurred from the Citarum Water Supply Unit (UPTD PSDA) Water Gate area downstream, while for the upstream area (Maruyung Village) which is located before D.I. Wanir, there was no problem of water shortage. This was confirmed by the Head of Maruyung Village who said that agricultural land in Maruyung Village had never experienced a water shortage from the Citarum River. He said that agricultural land that uses the flow of the Citarum River has never experienced a water shortage even during the dry season. "So far, the availability of water for agricultural land in the Maruyung area has been sufficient. There has been no conflict or problem in the Maruyung Village area related to meeting water needs for agriculture. This happens because the location of agricultural land that uses the flow of the Citarum River is not that large/many." (Head of Maruyung Village, interview February 6, 2023). One of the members of the Citarum Harum Task Force also said the same thing, where he explained that during his time working in Sector 3 Citarum Harum, no community members had submitted complaints about the decrease in the water discharge of the Citarum River.

Figure 5. Interviews with (a) Maruyung Village Apparatus, Pacet District, Bandung Regency; and (b) Citarum Harum Task Force

In terms of information on planting patterns, one hundred percent of respondents said that extension workers from the Bandung Regency Agriculture Service always provide extension to carry out planting pattern procedures in accordance with recommendations from related agencies, namely the rice-rice-secondary crops planting pattern. However, the majority of farmers do not follow the directions or recommendations for the planting pattern, and continue to carry out the rice farming pattern as usual. For most farmers, rice planting in the dry season is carried out as usual, with the same planting area. This condition occurs because the farming community in the study area believes that the transition from rice fields (rice) to secondary crops requires more costs and is twice as much as planting rice.

As a result, most farmers in the area continue to plant rice in the dry season, even though the harvest is not as optimal as the rainy season. According to the Pacet District Agriculture UPT, the planting patterns in Ciparay and Pacet Districts are different. In the upstream area of the Citarum River (Pacet District) there can be 3 planting seasons (rice - rice - rice) in one year, while in the downstream area of the Citarum River

(Ciparay District and Majalaya District) there can only be 2 planting seasons (rice - rice or rice - sticky rice). In terms of changes in land use that occurred in the study area, respondents stated that most of the changes were made by land owners for economic reasons and not because of water availability problems. The majority of changes in rice field land use were replaced by residential or housing areas.

Water Needs Analysis

Water use in the Cirasea Sub-DAS is dominated by irrigation needs. As presented in Table 1, there are thirteen irrigation areas and one PDAM intake in the Cirasea Sub-DAS flow with estimated water needs presented in the table 5.

Based on data obtained from the West Java Province Water Resources Service in the 2023 Global Cropping Plan and Water Balance, the largest water requirement for the Wanir irrigation area is 2,936.7 liters/second which occurs in November II, while the largest water requirement in the Wangisagara irrigation area is 2.656.5 liters/second which occurs in December I. The other five irrigation areas (Bojong, Sawah Jeruk, Panganten, Ancol and Linger) have free intake buildings, so there is no information on recording irrigation discharge and the calculation of irrigation discharge is carried out using assumptions. The use of water in the Cirasea Sub-DAS for domestic and non-domestic use, the existing conditions were obtained from PDAM Tirta Raharja data which were then projected until 2040. The existing conditions of clean water use in Bandung Regency have increased every year. The need for clean water in Bandung Regency until 2021 is 256 liters/second, with the existing raw water supply from PDAM Tirta Rahajra being 217 liters/second, it is estimated that from the existing supply debit there is a water deficit of 39 liters/second in 2021 until it is estimated that there will be a water deficit of 387 liters/second in 2040.

Table 5. Water Use for Irrigation Needs and PDAM Intake

Name Of Water User	Water Needs (LT/DTK)
D.I. Cirawa 1	202.10
D.I. Cirawa 2	17.66
D.I. Cienteng	45.33
D.I. Cienteng Lebak	19.48
D.I. Cijambu Raya	43.99
D.I. Rumbia	8.28
SPAM Cikoneng	450
D.I. Bojong	37.50
D.I. Wanir	2.936.70
D.I. Sawah Jeruk	12.08
D.I. Panganten	19.17
D.I. Ancol	44.17
D.I. Linger	18.75
D.I. Wangisagara	2.656.50

Source: PDAM Tirta Raharja, 2023; Bandung Regency Irrigation Commission, 2023; West Java Province DSDA, 2023

Table 6. Water Use for Domestic and Non-Domestic Needs in Bandung Regency

Use Of Clean Water		Year								
	Unit	2017	2018	2019	2020	2021	2025	2030	2035	2040
Consumption										
- Domestic	lt/dtk	123	148	157	146	159	209	271	334	396
- Non-Domestic	lt/dtk	28	11	12	11	12	16	21	25	30
- Total Consumption	lt/dtk	151	159	169	157	171	225	292	359	426
Non-Revenue Water (NRW)	%	27.98	27.26	27.01	26.78	26.56	25.65	24.52	23.39	22.26
Water Needs										
- Average (Qavg)	lt/dtk	209	219	231	215	232	302	387	469	549
- Maximum (Qmax)	lt/dtk	230	241	254	236	256	332	426	516	604
Existing Supply	lt/dtk	217	217	217	217	217	217	217	217	217
Water Balance (Existing Supply to Qmax)	lt/dtk	-13	-24	-37	-19	-39	-115	-209	-299	-387

Source: Analysis results, 2023

Water Availability Analysis

The analysis of the water availability discharge of the Upper Citarum River (Cirasea Sub-DAS) also considers other water users, especially the existing intake (Cikoneng SPAM) and irrigation areas. Especially the Wanir and Wangisagara Irrigation Areas, during the current year there have been changes in the area of irrigation areas, where for the Wanir Irrigation Area which originally had an area of 1,880 Ha, from the results of the spatial analysis until the time this study was compiled, its area has changed to 1.397.75 Ha, while the area of the Wangisagara Irrigation Area which originally had an area of 1,687 Ha is now 1.428.78 Ha. Changes in the area of the irrigation area will certainly have implications for the amount of irrigation water needed. The flow scheme of the Cirasea Sub-DAS and the water needs of each activity are presented in full in the following figure.

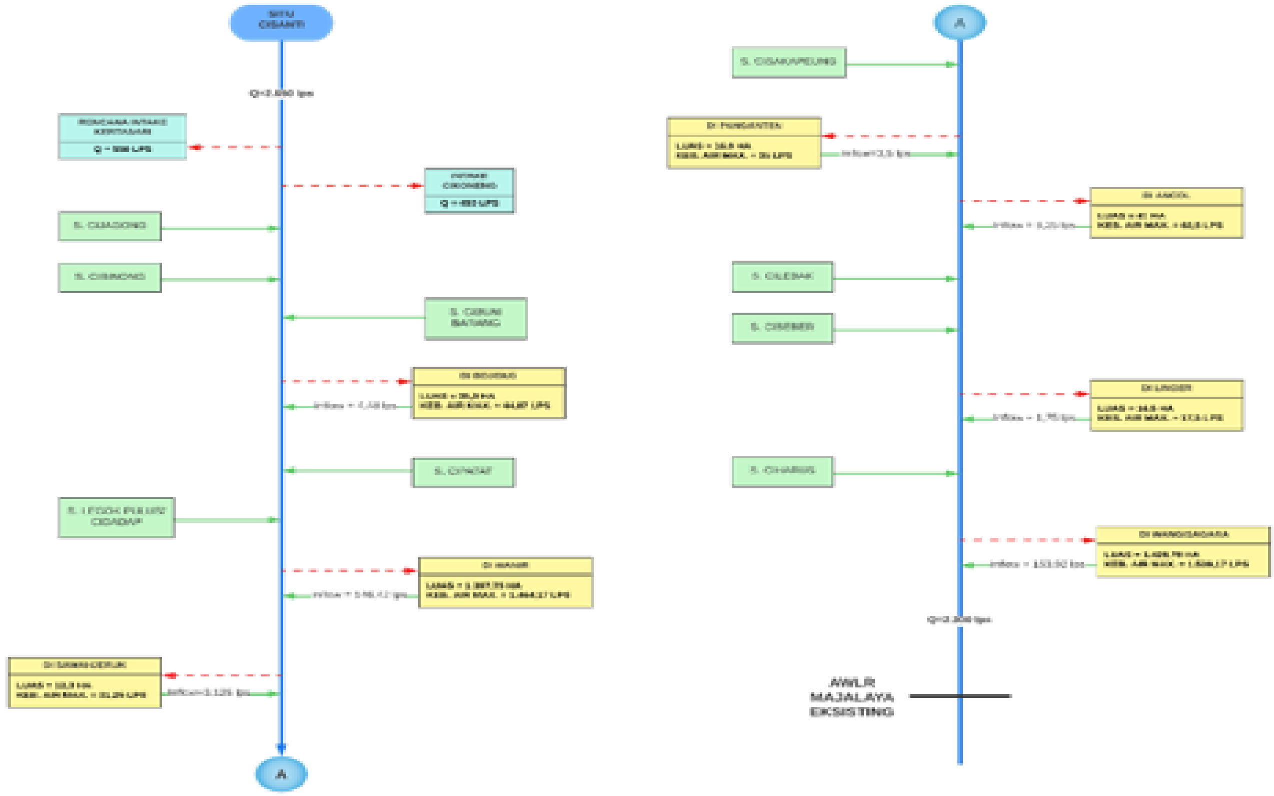

Figure 6. Cirasea Sub-DAS flow scheme

Based on HEC HMS modeling, information was obtained that the flow discharge of the upstream Citarum River to the mainstay discharge in the Wangisagara Irrigation Area is as follows.

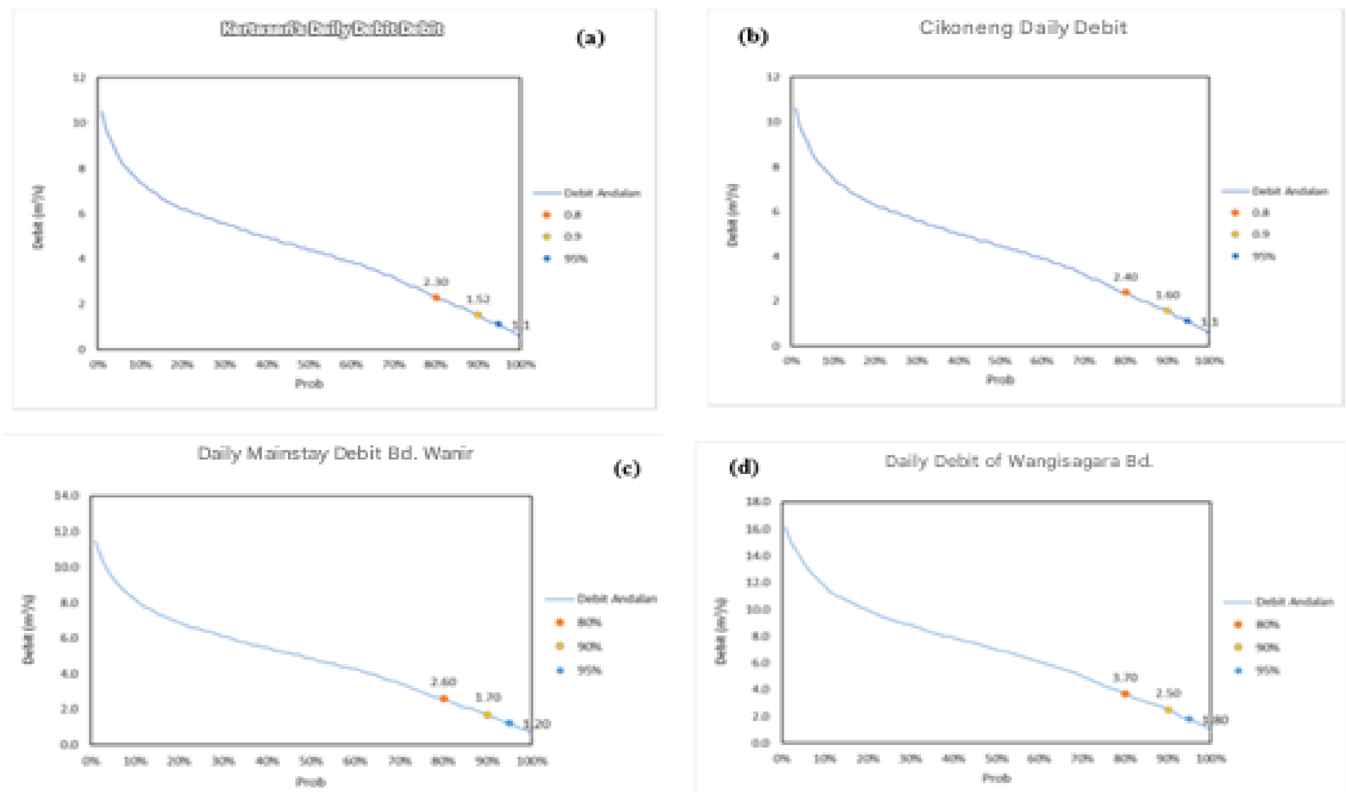

Figure 7. FDC curve of main discharge (a) Situ cisanti; (b) Cikoneng intake (PDAM Tirta Raharja); (c) Wanir dam; and (d) Wangisagara dam

Water Balance Analysis

From the calculation results of the main discharge, an analysis can be made regarding the existing water balance conditions at the dam and existing irrigation areas, where from the results of the water balance analysis it can be seen that the quantity of water in the upstream Citarum River (Cirasea Sub-DAS) in existing conditions has a supply reliability of 100% to meet the needs of the Cikoneng intake owned by PDAM Tirta Raharja, while in meeting the Wanir and Wangisagara Irrigation Areas, the quantity of water in the upstream Citarum River in existing conditions has a supply reliability of > 97%. There is a water deficit in the Wanir irrigation area in October II - November I, and in July II, October II to November II in the Wangisagara irrigation area.

Figure 8. Upper intake cikoneng water balance (PDAM Tirta Raharja) existing condition

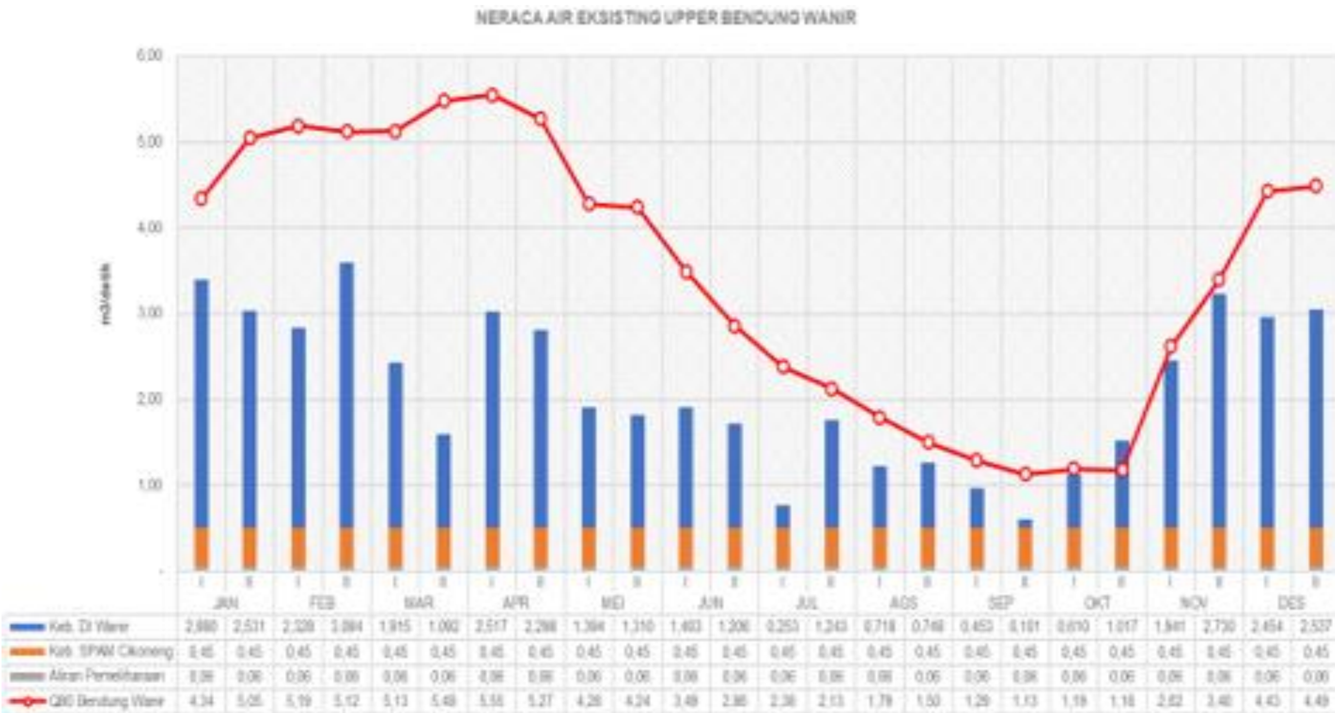

Figure 9. Existing condition of wanir dam water balance

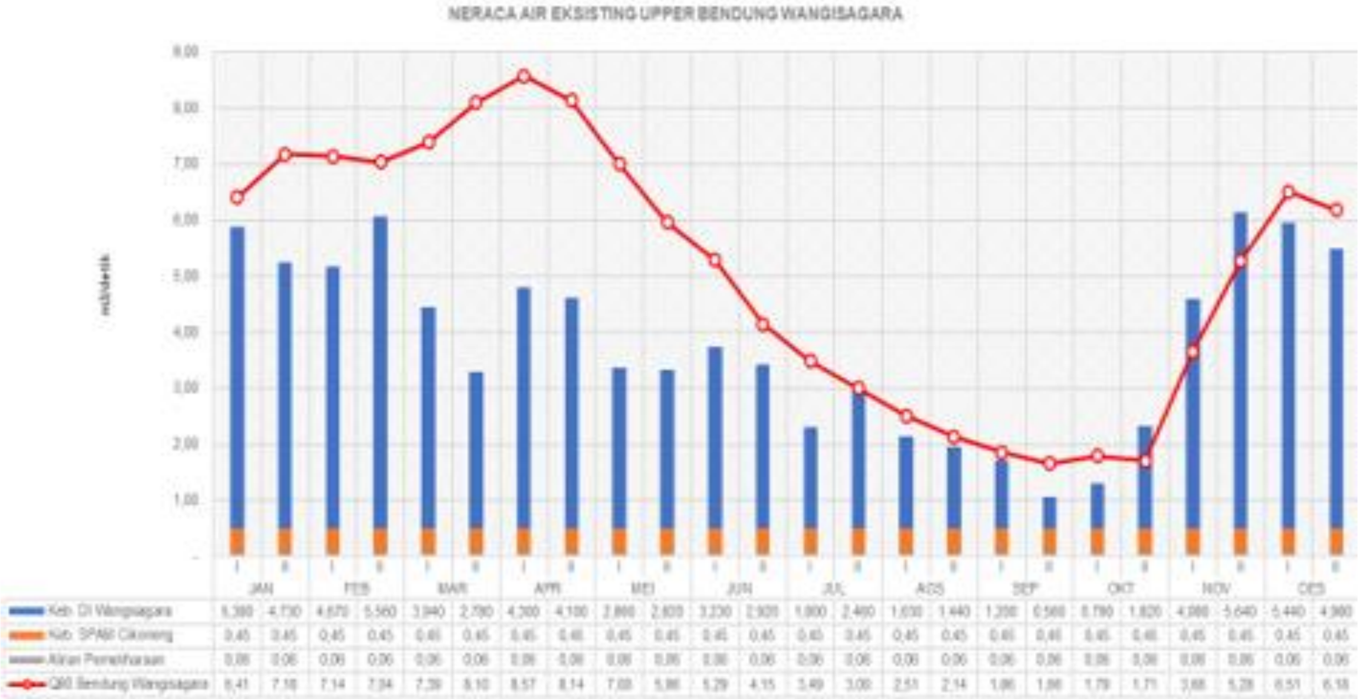

Figure 10. Existing condition of wangisagara dam water balance

Although the water balance analysis shows high supply reliability for Cikoneng SPAM (>97%) and Wanir and Wangisagara Irrigation Areas, findings in the field indicate a water deficit in certain periods, especially in D.I. Wanir in October II - November I, and in D.I. Wangisagara in July II, October II to November II. This is reinforced by the perception of water users, especially farmers in D.I. Wanir, who stated that the amount of water available was insufficient for their agricultural needs, as evidenced by the irrigation scheduling. Conflicts related to water shortages also occurred in Cipeujeuh Village, where people from downstream areas even came with sharp weapons to ensure that water flowed to their area. In addition, farmers in Manggungharja Village were forced to use water pumps during the dry season to channel water from D.I. Wanir. Another conflict also emerged in Sukamukti Village, where irrigation flows had to be shared with industrial activities, causing drought in farmers' rice fields and forcing them to switch to secondary crops or dry fields during the dry season (Arifah et al., 2022; Tahasin et al., 2024). The disparity between the results of the water balance analysis and field conditions is likely caused by several factors. First, changes in land use in the upstream area, especially on Mount Wayang, have caused a decline in environmental conditions that have an impact on water availability (Herrera-Pantoja & Hiscock, 2015).

Second, despite instructions for a rice-rice-secondary cropping pattern, the majority of farmers continue to plant rice conventionally, even in the dry season, because of the perception that switching to secondary crops requires greater costs (Sánchez et al., 2022; Nyang'au et al., 2021; Schaub et al., 2023). This cropping pattern that is not in accordance with water availability conditions directly increases the demand for irrigation water, especially during the dry season, exacerbating the deficit (Ingrao et al., 2023; Feng et al., 2024; Zingaro et al., 2017). Third, the existence of "water collection" by groups of people using Citarum river water, sometimes with violence, indicates inefficiency and potential injustice in water distribution. Meanwhile, upstream areas such as Maruyung Village do not experience water shortages because the area of agricultural land that utilizes the flow of the Citarum River is not too large. This indicates an imbalance in water distribution between upstream and downstream, as well as between various water use sectors. The projection of domestic and non-domestic water needs in Bandung Regency shows a significant increasing trend (Sugiyono & Dewancker, 2020; Rustiadi et al., 2021), with an estimated clean water deficit reaching 387 liters/second in 2040. Although this data covers Bandung Regency as a whole and not just the Cirasea Sub-DAS, the increase in clean water needs regionally will put additional pressure on water resources, including those sourced from the Cirasea Sub-DAS.

Water Resource Carrying Capacity and Water Criticality Level

Based on the Regulation of the Minister of Environment No. 17 of 2009, water carrying capacity is assessed from the comparison of water availability (SA) and water needs (DA). If SA> DA, water carrying capacity is declared a surplus, while if SA <DA, it is declared a deficit or exceeded. The results of the water balance analysis show that although in general the water supply of the Upper Citarum River has high reliability, there is a deficit in certain periods in D.I. Wanir and Wangisagara indicate that at these times, the water carrying capacity in these locations is exceeded or is in a deficit condition. The calculation of the Water Criticality Index (IKA) will provide a more detailed picture of the level of pressure on water resources. By using the equation IKA = (Wn/Ws)*100%, where Wn is the amount of water demand and Ws is the amount of water availability, and comparing it with the water criticality criteria (Nahib et al., 2022; Jayanti et al., 2023; Zhang et al., 2020; Wang et al., 2024), it can be determined whether the Cirasea Sub-DAS is in a non-critical, slightly critical, critical, or very critical condition. The deficit conditions identified in the Wanir and Wangisagara D.I. during certain periods indicate that the IKA in the area at these times is likely to show a "slightly critical" or even "critical" classification (IKA> 50%), depending on the magnitude of the deficit.

Conclusion

Although the water balance analysis shows high supply reliability for the Cikoneng SPAM and the Wanir and Wangisagara Irrigation Areas in general, field findings indicate a water deficit during certain periods in the Wanir Irrigation Areas (October II – November I) and Wangisagara (July II, October II – November II). The perception of water users confirms the scarcity of water for agriculture in the downstream area of the Cirasea Sub-watershed, which triggers conflicts between water users. Changes in land use in the upstream and non-compliance with recommendations for planting patterns, where farmers tend to continue planting rice even in the dry season due to cost considerations, directly contribute to increasing water needs and worsen the deficit conditions. Domestic and non-domestic water demand in Bandung Regency is also projected to continue to increase, adding pressure on water resources in the future. This study shows that although overall water availability may seem sufficient, the main problem lies in the distribution, management, and unsustainable patterns of water use, especially in downstream areas and during the dry season. The results of this study can provide significant contributions in formulating an adaptive and sustainable integrated water resource management strategy in the Cirasea Sub-watershed, taking into account future water demand projections and the social and economic dynamics of local communities. The strategy needs to focus on optimizing water distribution, promoting adaptive cropping patterns, enforcing land use regulations, and increasing community awareness and participation in water resource management.

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The author declares that there is no conflict of interest related to this research. This research was conducted independently and was not influenced by personal interests, professional relationships, or financial affiliations. All decisions made during the research and writing process were made objectively and with scientific integrity.

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