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RESEARCH

Analysis of Surface Water Availability to Meet Agricultural Water Demands in Kediri Regency, Indonesia

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ABSTRACT This study aims to analyze the potential of surface water to meet agricultural water needs in Kediri Regency, Indonesia. Data from government agencies (i.e., Indonesian Bureau of Meteorology, Climatology, and Geophysics and Kediri Agriculture Office) and fieldwork were analyzed to achieve the research objectives. The data obtained consisted of rainfall, temperature, infiltration capacity, soil texture, root depth, and agricultural land area. The potential of surface water resources was calculated by using the Thornthwaite– Mather water balance method. The water balance results were compared with agricultural water demands, which were calculated on the basis of the area of agricultural land and type of crop, particularly paddy fields. Critical and noncritical conditions for surface water resources were classified on the basis of the ratio between the availability of surface water resources and the demand for agricultural water. Results showed that the total surface water potential widely varied by season. The water balance calculation indicated that all subwatersheds (SWs) experienced a water surplus in the rainy season, whereas almost all SWs were deficient in surface water in the dry season, Overall, the surface water in Kediri was critical in the rainy season and more severely critical in the dry season. The results of this study indicated that the high demand for agricultural water can affect the availability of water resources in the tropics. The results are expected to be considered in determining regional planning related to the use and need of water resources and supporting infrastructures.

1. INTRODUCTION

Water is one of the most important resources for human survival and life sustenance. Water resource availability is undeniably an absolute need to fulfill. However, in the last few decades, water resources have frequently reached an alarming tipping point (Ipcc 2022). With the decrease in global water resources in the future and increase population growth, the immediate and careful planning of strategies to meet future water needs through proper management is imperative (Kumalajati et al. 2017). Urgency also stems from the likelihood that insufficient water availability constrains development activities, which, to some extent, can affect the prosperity of dependent populations (Haddeland et al. 2014). The issues surrounding water availability are not only linked to the conditions of a body of water but also to land utilization and management (Gober et al. 2013).

Surface water is an example of a water resource that is withdrawn for various human activities, including agriculture. While agricultural water needs are proportional to the cropping area and intensity, surface water availability is determined by hydrological cycle components, especially those related to physiographic characteristics and dynamics in a region (Naylor et al. 2007; Sekaranom et al. 2021). Therefore, land-use change is a factor contributing to potential water availability. Kediri Regency, which is located in East Java–Indonesia, has five subwatersheds (SWs) that converge on the Brantas River. The fluvial landform divides the area into the east and west sides with different land characteristics (Setyorini et al. 2017). Geomorphologically, the east side of the river was formed by the volcanic activities of Mt. Kelud and Mt. Anjasmara and the west by those of Mt. Wilis (De Bélizal et al. 2012). These geomorphological conditions affect the amount of surface runoff flowing into the river, and the resulting surface water potential, which is inhomogenous on both sides of the river, affects the fulfillment of water needs.

In general, Kediri receives an average of 130–150 mm of rainfall every year with 6–15 rainy days (Regional Development Planning Agency of Jawa Timur Province 2013). The rainy season is from December to April, and the dry season is from May to November (Sekaranom et al. 2020). The season determines surface water availability, e.g., lower rainwater input tends to yield a smaller amount of available water in the dry season. Kediri relies on irrigation channels to supply water to agricultural areas, (Sari and Deswita 2019). Irrigation water is sourced from the surrounding rivers and springs. Accordingly, this study was conducted to analyze the ability of existing water resources to meet agricultural water needs by using the water balance based the calculated potential water availability and water demand in each of the 26 districts in the regency.

Previous studies related to water resources in the tropics generally show a high surplus of water resources (Nelson et al. 2009). However, several studies have reported that deficit conditions can occur due to various factors, for example, uneven rainfall pattern/season or overextraction by humans (Kagabu et al. 2013; Onodera et al. 2008; Widodo et al. 2021). In general, deficits particularly occur in urban areas with a high population. However, the impact of the agricultural sector on water resources is still rarely considered (Chaowiwat et al. 2016). In Indonesia, the agricultural sector, especially paddy field farming, is the most dominant sector (Naylor et al. 2007). Moreover, the high water demand of paddy fields shows the potential for extensive water resource extraction (Sari and Deswita 2019). This study aims to examine the influence of the agricultural sector on the availability of water resources. In further detail, this study aims to examine the criticality of surface water resources when compared with the water needs for agriculture.

2. MATERIALS AND METHODS

The data used in this study were classified into two categories, namely, data related to the balance of surface water and agricultural water needs. The data used for the analysis of surface water balance consisted of data on rainfall, temperature, infiltration capacity, soil texture, and root depth. Meanwhile, agricultural water needs were based on the area of irrigated agriculture and the intensity of agriculture. Rainfall and temperature data were obtained from eight meteorological stations from the Indonesian Bureau of Meteorology, Climatology, and Geophysics (BMKG) East Java Office. The spring discharge data were obtained from the Water Resources Division at the Office of Public Works and Housing for Kediri Regency. Data on infiltration capacity, soil texture, and root depth were acquired through field sampling by using the random sampling method. Irrigation area and cropping intensity were obtained from the Kediri Regency Agriculture Office.

At the preparation stage, data published by the local government and regional institutions in Kediri Regency were obtained. The data consisted of precipitation and temperature data from BMKG, as well as a map of the agricultural area and seasonal crop type from the Kediri Agriculture Office. The field data were obtained later during the survey stage conducted in June–August 2021. The collected data were infiltration rate, soil texture, and root depth. All of the data were used for the water balance analysis. The data acquired at the preparation and survey stages were further processed and analyzed on the basis of three major steps, namely, 1) surface water balance calculation, 2) irrigation water requirements, and 3) critical/noncritical classification.

Surface water indicates the total water availability from the runoff flowing through the area. It can be estimated from the amount of precipitation that is balanced by evapotranspiration and infiltration, which then becomes groundwater. The Thornthwaite–Mather water balance method was used to estimate the river discharge. The Thornwaite–Mather water balance model was utilized to determine the monthly surplus/deficit of water resources (Thornthwaite and Mather 1957) on the basis of rainfall and potential evapotranspiration (PET). PET was estimated on the basis of temperature data by using the following equations:

$$PET = 16 \times k \times (\frac{10 \times T_m}{I})^a \tag{1}$$

where

$$I = \sum_{n=1}^{12} i \tag{2}$$

where

$$i = (\frac{T_m}{5})^{1.514} \tag{3}$$

PET is the potential evapotranspiration (in mm), k is the adjustment factor based on latitude coordinates and the duration of solar irradiation, Tm is the monthly temperature (in Celsius), and I is the annual heat index calculated from the accumulated monthly heat index (i). The monthly heat index is determined by using the monthly temperature data. a is the coefficient calculated on the basis of the annual heat index and is shown in the equation below:

$$\begin{aligned} a = (675 \times 10^{-9} \times I^3) - (771 \times 10^{-2} \times I^2) \\ + (1792 \times 10^{-5} \times I) + 0.49239 \end{aligned} \tag{4}$$

If PET is greater than the rainfall (P), then the difference becomes the accumulated potential water loss (APWL). The APWL value is cumulative. Therefore, if the PET value is higher for several months, then the value in the previous month is accumulated until the last month. Conversely, if P >PET value, then the APWL value is 0. In the next step, the PET value is combined with the soil texture data and root depth data obtained from fieldwork to obtain available water capacity (AWC). By using the APWL and AWC data, soil moisture (ST) and the monthly difference in (ST) were calculated on the basis of the following formula:

$$\Delta ST_i = ST_i - ST_{i-1} \tag{5}$$

$$ST = AWCe\frac{APWL}{AWC} \tag{6}$$

The calculation of actual evapotranspiration (AE) is based on the condition wherein if P > PET, then AE is assumed to be the same as PET. Conversely, if the above conditions are not met, the value of AE is the difference between P and ΔST). The determination of the runoff value is based on the condition that surplus water becomes groundwater and appears as surface runoff in the following month. Assuming the runoff (R) is equal to 50% of the current month's surplus plus 50% of the previous month's runoff, the equation becomes as follows:

$$R_i = 50\% S_i + 50\% R_{i-1} \tag{7}$$

where

$$S_i = P_i - PET_i \tag{8}$$

The irrigation water requirement (in terms of the amount of water per unit area) was calculated in accordance with the Indonesian National Standard (SNI) number 19-6728.1-2002 (The Standard Council of Indonesia 2002). The SNI document regulates the calculation and publication of water balance and was used to calculate the agricultural water needs in Kediri. The SNI formula used to estimate agricultural water demand is as follows:

$$Q = L \times It \times a \tag{9}$$

where Q is the irrigation water demand (m^3/year), L is the irrigated area (Ha), It is the cropping intensity (percent of land utilization per year), and a denotes standard water use (equal to 1 L/s/ha for paddy field).

The critical level of the surface water resources was determined as an index and classified in accordance with Hatmoko et al. (2012) and Hidayat et al. (2019). The critical level was determined by using an index and calculated on the basis of irrigation water demand and water availability. Given that surface water is the main source for irrigation in the study area, the water availability is determined only from the surface water. Therefore, the critical index is formulated as follows:

$$Critical\ level = \frac{Water\ demand}{Water\ avaibility} \times 100\% \tag{10}$$

On the basis of critical level, water resources are classified into four classes: 1) noncritical, 2) almost critical, 3) critical, and 4) extremely critical. If the index falls between 0%–50%, the water resource is classified as noncritical because the quantities of available water are larger than those of the demand (more than twice the demand). If the index falls between >50%–70%, the water resource is classified as almost critical because more than half of the available water resource has been utilized. The water resource is considered critical if the index is >70%–100% because most of the water resource (>70%) has been utilized to fulfill the water demand. Meanwhile, if the index exceeds 100%, the water resource is classified as extremely critical. The 100% threshold indicates that water demand has exceeded water availability.

3. RESULTS AND DISCUSSION

3.1 Precipitation pattern as the source of surface water potential

Rainfall acts as a primary source of surface water in an area. It partitions into infiltration and surface runoff that flows into ditches or rivers. Rainfall across Kediri was analyzed by creating an isohyet by using the data from eight climatological stations. Figure 1 shows the isohyet map derived from calculating the spatial distribution of rainfall. Regions receiving 1,800–2,100 mm/year of rainfall were evenly distributed, covering 72.15% of the entire study area. The highest rainfall interval of 3,300–3,600 mm/year was found only on the slopes of Mt. Wilis, covering approximately 3.19% of the area. As can be inferred from the rain distribution, surface water has enormous potential provided that appropriate and well-regulated extraction is implemented.

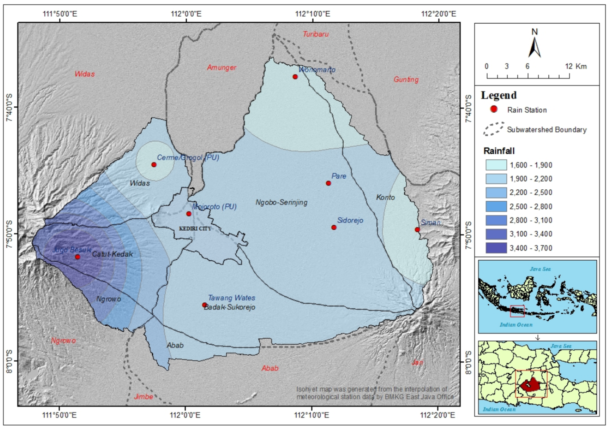

FIGURE 1. Isohyet map of the research area (interpolated by using the IDW method; rainfall data was obtained from BMKG East Java Office).

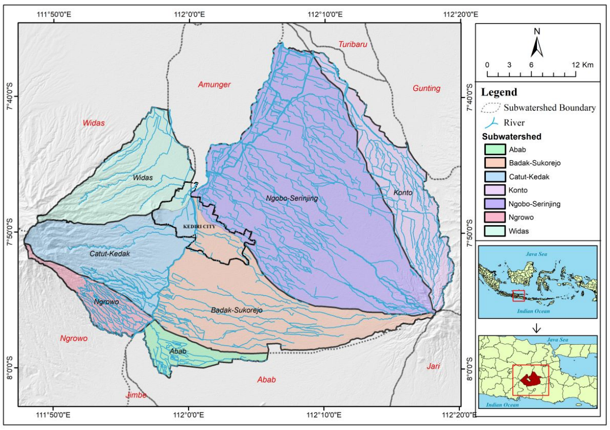

FIGURE 2. SWs in the research area.

3.2 Surface runoff estimation

Details on water discharge are fundamental for the calculation of surface water potential temporally (by season) and spatially (Hanif 2021). On the basis of natural resource management pattern in riverine areas, Kediri comprises seven SWs, all of which are part of the Brantas Tengah Watershed (Figure 2). However, not all SW segments are within the regency's administrative area, meaning that several SWs cover only a small part of the regency. Therefore, the unit of the analysis was determined only for the dominant SW that flows over the regency. The analysis identified seven SW flows to the Brantas River in the middle of the study area. The surface runoff potential was calculated for each SW. The result of the surface runoff estimation by using the Thronthwaite–Mather approach for each SW is shown in Table 1.

3.3 Surface runoff potential by season

Table 2 shows the surface water potential calculated by using the Thronthwaite–Mather approach and classified by season. Seasonal analysis was conducted given the large difference in rainfall between the dry and rainy seasons. The analysis indicated that a substantial decrease occurred in the dry season. The water availability in the dry season was only 14.90%–23.99% of that in the rainy season. The Widas SW had the largest seasonal difference in water availability in terms of percentage, whereas the Catut-Kedak SW had the smallest.

TABLE 1. Potential River Discharge of SWs in the Kediri Regency.

No	SW	Total SW area (m^2)	Surface runoff potential (m^3/month)
1	Abab	47,923,827	4,813,900
2	Badak-Sukorejo	265,795,934	25,149,350
3	Catut-Kedak	168,047,406	10,332,494
4	Konto	173,733,764	17,187,940
5	Ngobo-Serinjing	627,076,759	53,323,445
6	Ngrowo	56,142,179	4,760,648
7	Widas	157,229,978	15,294,699

Source: Calculation results 2021

3.4 Agricultural water demand

The agricultural area in Kediri consists of 47.10% nonrice fields, 42.80% technically irrigated rice fields, and 10.20% rainfed rice fields (Indonesian Bureau of Statistics, 2021). The irrigated fields require routine and careful maintenance to create sustainable food croplands and control their conversion into other land-use types. Irrigation is one of the main strategies for developing and improving the function of cultivated areas in Kediri to support the regional economy (Regional Development Planning Agency of Jawa Timur Province 2013). Table 3 indicates that the agricultural sector required a large amount of water: 91% for irrigation, 8.3% for croplands other than rice, and 0.7% for rainfed rice fields. The Ngobo-Serinjing SW had the largest agricultural water demand, particularly for irrigated paddy fields. Plemahan District had the highest demand. The Ngrowo SW required the least water for agriculture. Its low water demand is related to its abundance of nonrice fields (compared with the ratio of total agricultural lands) that require less water for agriculture.

3.5 Surface water balance

The balance of surface water resources was calculated to determine if parts of the study area are in a state of surplus or deficit (Table 4). In this analysis, the surface water availability was compared with the agricultural water demand. A surplus indicates that a watershed (SW in this study) is in good condition. A deficit indicates a shortage condition wherein the water demand is very high (Hidayat et al. 2019). In Kediri, surface water is over-extensively used in the agricultural sector, particularly in rice fields under irrigation and rainfed systems. The inability of surface water availability to meet water demand could lead to agricultural drought. Table 5 shows that three SWs experienced deficit, i.e., Ngrobo-Serinjing, Konto, and Adab. The rest of the SWs experienced water surplus, with the highest found in Badak-Sukorejo. The highest deficit was found at the Ngobo-Serinjing SW (more than −22 million cubic meters). The detailed analysis of the deficit based on the season is explained in the following paragraph.

Table 5 shows the water balance condition in all SWs during the dry and rainy seasons. In the rainy season, surface water availability was higher than water demand. The highest surface water surplus was found at the Badak-Sukorejo SW (almost 20 million cubic meters of water per month). However, in the dry season, all the SWs, except for the Ngrowo SW, experienced a water deficit (Table 6). In the Ngrowo SW, surface water availability was only slightly higher than the demand. In detail, the water deficit particularly can be linked to the vast irrigated agricultural area that spreads over Kediri. The Ngobo-Serinjing SW, which had the highest deficit annually, also experienced a water surplus in the rainy season. However, in the dry season, it experienced a large deficit due to high water demand for agricultural use. The deficit reached almost 50 million cubic meters per month.

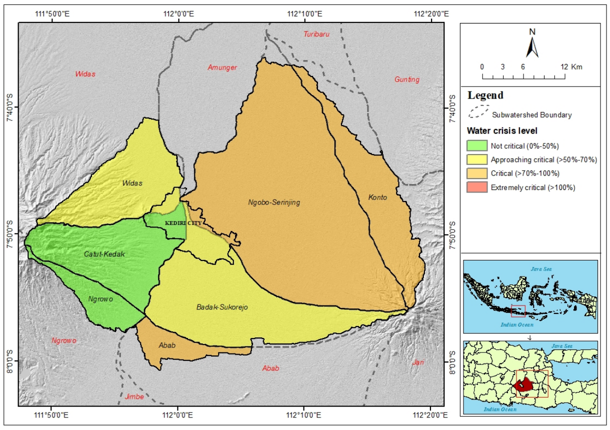

FIGURE 3. Critical indexes of the surface water in the study area during the rainy season (source: data processing, 2021).

3.6 Critical level of surface water availability

Water availability and demand were further analyzed to identify the critical level. The critical index was calculated on the basis of the ratio of water availability to water demand (Esterlita and Suprayogi 2019), which, in this study, was calculated for agricultural water needs in the dry and rainy seasons. The result showed various ranges of criticality, from noncritical to critical (Table 7). Three SWs were identified as critical, namely Adab, Konto, and Ngobo-Serinjing. Two SWs were classified as almost critical, namely, Badak-Sukorejo and Widas. The rest (Catut-Kedak and Ngrowo) were classified as noncritical. These results indicated that although all SWs had a surplus in the rainy season, some had limited surface water availability due to high agricultural demand.

Table 8 also shows that the critical level was generally lower during the rainy season than during the dry season mainly because a substantial amount of rainwater transformed into runoff, increasing surface water availability. Despite the increase in precipitation, some SWs in Mt. Kelud in the east side were classified as severely critical (Figure 3) because of the high water demand of the agricultural sector due to the strategic planning of the Kediri Regency at those locations as the main area for agricultural products.

In the dry season, the surface water balance in most of the SWs exhibited a severe critical level, which is attributable to the low rainwater input and high agricultural water demands (Table 8). Ngobo-Serinjing, which had the highest values, was the area with the largest agricultural area. Extensive land utilization for agriculture is also inseparable from geomorphological conditions, i.e., a combination of alluvial material and flat terrain, that are suitable for farming practices (Figure 4). The Ngrowo SW had the lowest critical index but was still classified as critical in the dry season. This condition was also influenced by the higher percentage of dry-land farming than that of paddy field farming.

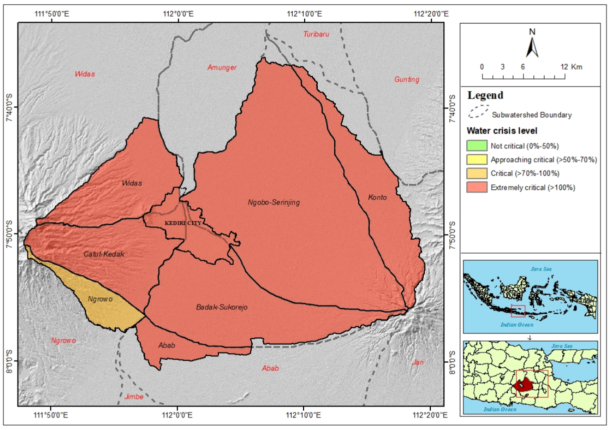

FIGURE 4. Critical index of the surface water in the study area during the dry season (source: data processing, 2021).

In the tropics, high rainfall is often associated with high water availability. However, this association is not always true because of the high water demand in some locations. For example, the dominance of agricultural land in Kediri can result in high food production (Sari and Deswita 2019). This situation is supported by agricultural land suitability, which is supported by fertile volcanic soils (De Bélizal et al. 2012). Nevertheless, water resource availability must be considered to meet water demands. In the future, urban areas are predicted to compete with agriculture for water resources (Flörke et al. 2018) under the influence of the increase in population and climate change, which causes uneven rainfall distribution in terms of space and time (Naylor et al. 2007). The above condition is in line with the surface water resource crisis in Kediri that mainly occurs in the dry season and causes high water resource susceptibility (Widodo et al. 2021). In addition to Kediri, drought conditions in the dry season have increased in several areas in Indonesia and have affected agricultural productivity (Sekaranom et al. 2021). In Central Java, surface water deficit due to agricultural demands mainly occurs in the upstream part of the watershed (Andriyani et al. 2017). Surface water availability is higher in the downstream area. Meanwhile, some areas often become urbanized and experience water resource overextraction (Onodera et al. 2008). The results of this analysis can provide an overview that is regionally related to the increasing demand for water resources in the future that needs to be anticipated.

4. CONCLUSIONS

The results of the study on the availability of surface water resources and the need for agricultural water in Kediri showed that the agriculture sector can significantly influence the availability of water resources. In general, the availability of surface water resources presents a contrast between the dry and rainy seasons. Surface water reserves in the dry season are only approximately 20% of those in the rainy season. Meanwhile, the need for agricultural water resources in Kediri is very high as indicated by the critical and very critical levels of surface water resources, particularly in the dry season. Even though surface water resources experience a surplus in the rainy season, the use of water resources in five of the seven sub-basins has reached more than 50% of the water resource availability. This condition results in most of the water resources having reached near critical and critical levels even during the rainy season and is aggravated in the dry season because almost all SWs have reached a very critical level. This critical level shows that in Kediri, the need for water for agriculture is not proportional to water availability.

Priorities for managing or handling surface water can be determined on the basis of the critical index. For example, the Konto and Ngobo-Serinjing SWs showed the highest critical index in the dry and rainy seasons, respectively.

TABLE 2. Surface runoff potential by season in Kediri Regency.

SW	Rainy season (m^3/month)	Dry season (m^3/month)	Dry–rainy season difference (m^3/month)	Dry–rainy season ratio (%)
Abab	7,895,023	1,732,778	−6,162,244.90	21.95%
Badak-Sukorejo	42,095,382	8,203,319	−33,892,062.37	19.49%
Catut-Kedak	16,666,899	3,998,089	−12,668,810.13	23.99%
Konto	28,701,766	5,674,114	−23,027,652.23	19.77%
Ngobo-Serinjing	91,526,036	15,120,855	−76,405,181.63	16.52%
Ngrowo	7,904,559	1,616,739	−6,287,820.49	20.45%
Widas	26,621,743	3,967,657	−22,654,086.27	14.90%

Source: Calculation results 2021

TABLE 3. Agricultural Water Requirement.

SW	Irrigated rice fields (m^3/month)	Rainfed rice fields (m^3/month)	Nonrice fields (m^3/month)	Total (m^3/month)
Abab	4,716,990	8,751	135,850	4,861,591
Badak-Sukorejo	17,021,062	413,137	1,643,249	19,077,448
Catut-Kedak	4,245,825	69,914	2,509,978	6,825,717
Konto	22,275,991	14,436	1,901,546	24,191,974
Ngobo-Serinjing	72,182,725	482,714	2,966,222	75,631,661
Ngrowo	917,269	5,560	755,495	1,678,325
Widas	12,040,873	49,120	2,073,065	14,163,059

Source: Calculation results 2021

TABLE 4. Surface Water Balance in Kediri Regency.

SW	Surface water availability (m^3/month)	Agriculture water demand(m^3/month)	Water balance (m^3/month)	Status
Abab	4,813,900	4,861,591	−47,691	Deficit
Badak-Sukorejo	25,149,351	19,077,448	6,071,902	Surplus
Catut-Kedak	10,332,494	6,825,717	3,506,777	Surplus
Konto	17,187,940	24,191,974	−7,004,034	Deficit
Ngobo-Serinjing	53,323,446	75,631,661	−22,308,216	Deficit
Ngrowo	4,760,649	1,678,325	3,082,324	Surplus
Widas	15,294,700	14,163,059	1,131,641	Surplus

Source: Calculation results

TABLE 5. Surface Water Balance in Kediri Regency in Rainy Seasons.

SW	Water availability (m^3/month)	Agriculture water demand (m^3/month)	Water balance (m^3/month)	Status
Abab	7,895,023	5,671,856	2,223,166	Surplus
Badak-Sukorejo	42,095,382	22,257,023	19,838,359	Surplus
Catut-Kedak	16,666,899	7,963,337	8,703,562	Surplus
Konto	28,701,766	28,223,970	477,796	Surplus
Ngobo-Serinjing	91,526,036	88,244,490	3,281,546	Surplus
Ngrowo	7,904,559	1,958,046	5,946,513	Surplus
Widas	26,621,743	16,523,569	10,098,174	Surplus

Source: Calculation results

TABLE 6. Surface Water Balance in Kediri Regency in Rainy Seasons.

SW	Water availability (m^3/month)	Agriculture water demand (m^3/month)	Water balance (m^3/month)	Status
Abab	1,732,778	4,051,326	−2,318,548	Deficit
Badak-Sukorejo	8,203,319	15,897,873	−7,694,554	Deficit
Catut-Kedak	3,998,089	5,688,098	−1,690,009	Deficit
Konto	5,674,114	20,159,979	−14,485,865	Deficit
Ngobo-Serinjing	15,120,855	63,031,779	−47,910,924	Deficit
Ngrowo	1,616,739	1,398,604	218,135	Surplus
Widas	3,967,657	11,802,549	−7,834,892	Deficit

Source: Calculation results 2021

TABLE 7. Surface Water Critical Indexes in the Rainy Season.

SW	Water availability (m^3/month)	Agriculture water demand (m^3/month)	Critical index	Status
Abab	7,895,023	5,671,856	72%	Critical
Badak-Sukorejo	42,095,382	22,257,023	53%	Almost critical
Catut-Kedak	16,666,899	7,963,337	48%	Not critical
Konto	28,701,766	28,223,970	98%	Critical
Ngobo-Serinjing	91,526,036	88,244,490	96%	Critical
Ngrowo	7,904,559	1,958,046	25%	Not critical
Widas	26,621,743	16,523,569	62%	Almost critical

Source: Calculation results 2021

Both of these locations are located on the footslope of Kelud Volcano in the eastern side, which has lower rainfall than Wilis Mountain in the western side. Although the eastern part is considered more fertile because its geological and geomorphological conditions support favorable soil development, its lower amount of rainfall becomes the major limiting factor for agriculture. The spatial analysis of rainfall in this study illustrates that the eastern side of the study area receives less rainfall than the western side. The management of cropping patterns in areas that are classified as critical and severely critical can be a solution to the critical water issues in the regency. In addition, because surface water resources are relatively limited when fully used for irrigation, sustainable water management, agriculture management, and land-use management must be carefully planned to reach a balance between water availability and demand.

Several assumptions are used in this study. First, runoff

TABLE 8. Surface Water Critical Indexes in the Dry Season.

SW	Water availability (m^3/month)	Agriculture water demand (m^3/month)	Critical index	Status
Abab	1,732,778	4,051,326	234%	Severely critical
Badak-Sukorejo	8,203,319	15,897,873	194%	Severely critical
Catut-Kedak	3,998,089	5,688,098	142%	Severely critical
Konto	5,674,114	20,159,979	355%	Severely critical
Ngobo-Serinjing	15,120,855	63,031,779	417%	Severely critical
Ngrowo	1,616,739	1,398,604	87%	Critical
Widas	3,967,657	11,802,549	297%	Severely critical

Source: Calculation results 2021

modeling with the Thorthwaite–Mather method assumes that 50% of water stored during this month will be released in the following month. This assumption may vary in different regions due to geological conditions. Watershed-based analysis based on the watershed also excludes groundwater flows outside the watershed boundary. In addition to data collection, the field activities also consisted of FGDs with local governments to confirm the criticality of surface water resources. The FGD results showed that areas with high criticality of water resources often experience agricultural drought in the dry season.

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AUTHORS' CONTRIBUTIONS

Conceptualization, S.P. and A.B.S.; methodology, A.C. and N.A.; validation, A.J.F.; formal analysis, E.F. and E.N.; investigation, A.M., C.L.,; resources, N.D.S and A.C.; writing—original draft preparation, A.B.S. and A.J.F.; visualization, A.J.F., A.C., and E.F.; supervision, S. P; project administration, E.N. and S.P.; funding acquisition, E.N.

COMPETING INTERESTS

The authors declare no competing interest.

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