Analysis of water availability of the Singkoyo River for the irrigation needs in the Banggai Regency, Indonesian

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Abstract. Indonesia relies on its food security by expanding the area and productivity of agricultural land. This condition requires water to irrigate existing rice fields, such as in the Singkoyo area. This study aims to determine the study area's surface water availability (Q80), irrigation needs, and water balance. Some methods are applied, such as Penman-Monteith for the evapotranspiration calculation, and the FJ Mock method for the dependable flow and water need based on the annual cropping plan. The result shows that the Singkoyo River, with a catchment area of 408.55 km², has an average flow rate for Q80 is 6.24 m³ sec⁻¹, whereas the most significant discharge occurs in July 15.48 m³ sec⁻¹ and the smallest occurs in November at 2.86 m³ sec⁻¹. On the other hand, applying the worst scenario with three times of planting per year with rice, the need for three irrigation areas vary according to the NFR during the plantation phase from 7.02 m³ sec⁻¹ at the 3rd planting season in October, and the lowest is 2.0 m³ sec⁻¹ at the 2nd planting season in February. The water balance is mostly surplus from December to August, but then deficit during September to November by -1.34 m³ sec⁻¹ on average.

Keywords: fj, mock, nfr, penman-monteith, Q80, singkoyo.

1. Introduction
Water balance compares the water availability and the demand(s) for water in a place in a certain period [1, 2]. Water demand for agriculture activities, especially for the paddy grows, depends on some factors: land preparation, consumptive use, percolation and seepage, water layer change, adequate rainfall, and irrigation efficiency [3]. A study on the availability and demand of water is intended to determine the water available in one hydrological period in the study area. Furthermore, to know whether the water availability is surplus (excess) or experiencing a deficit (shortage), especially in certain dry months [3]. By knowing the existing condition (surplus or deficit), the utilization of water can be regulated as well as possible [3, 4]. Analysis of the evaluation of water resources can determine the availability of water resources in a place. Analysis of water availability and demand is the basis for calculating the potential of water resources in an area [5, 6]. As a unit of analysis, it uses the area and shape of the land because it affects the characteristics and patterns of water movement and rain that fall in an area [7].
The study aims to determine the surface water availability (Q\textsubscript{80}) in the Singkoyo River for one year, water demand for irrigation, and the water balance based on those analyses. Therefore, some methods to achieve the balance are applied, such as the Penman-Monteith method for the evapotranspiration calculation and the FJ Mock method for the dependable flow and water need based on the annual cropping plan. Suppose the availability is greater than the need. In that case, it is considered as surplus, and the other way around, if the availability is lesser than the need, this circumstance is considered as a deficit, so the decision to adopt by adjusting the crop pattern, is essential.

2. Material and Methods

2.1. Study Area

Singkoyo catchment is one of the catchments situated in the Bongka-Mentawa River Basin Areas (WS) (Figure 1). The Singkoyo River has been used as a water resource for two technical irrigation schemes: Singkoyo and Upper and Lower Tolisu. The total area of the catchment is 408.55 km\textsuperscript{2}, whereas the area of the Singkoyo irrigation scheme is app. 3037 ha, and the Upper and Lower Tolisu irrigation scheme is app. 530 ha, respectively.

Figure 1. Study Area [8]

In general, the hydrological and climatic conditions of the Singkoyo catchment are typical of the tropics. The annual rainfall ranges from 2,000 to 4,000 mm, which varies according to the topographical conditions of the area. The upstream area that stretches to the south and southeast of the catchment reveals a high annual rainfall (average 3,500 mm). Typical rainfall in the upper Singkoyo catchment causes no significant difference between the rainy and dry seasons.

Singkoyo River is typically a perennial river in which the flow is available continuously. The average discharge of the Singkoyo River is about 9.14 m\textsuperscript{3} sec\textsuperscript{-1} and at Q\textsubscript{80}, the average value is 6.24 m\textsuperscript{3} sec\textsuperscript{-1}. 
2.2. Flow availability
The hydrological and climatological data were analyzed by using the Penman Modified method. This method was used to determine the amount of reference evapotranspiration (ETo), which was then used to calculate the dependable discharge (Q80) of the Singkoyo River. For this purpose, the F J Mock is applied because this method is well known and widely used to calculate minimum discharge and reliable discharge in many watersheds in Indonesia. The minimum and reliable discharge calculation results

2.3. Method of F J Mock
F. J. Mock first introduced this method. This method calculates the amount of river flow from the rainfall data, evaporation, and hydrological characteristics of the drainage area (Figure 2). Overall, the mainstay discharge calculation using the F.J Mock Method refers to the water balance, where the total volume of water on earth is fixed, only the circulation and distribution varies [10, 11]
The formulas/equations for the F.J. Mock Model are as follow [10,11]:
a. Rainfall data used is the average monthly rainfall and the amount of rain.
b. Calculation of reference evapotranspiration using the Penman method.
c. The evapotranspiration value used is limited evapotranspiration. The relationship between reference evaporation and actual evaporation is calculated by the formula:

\[ Ea = \frac{ETo}{E} = \left(\frac{m}{20}\right) \times (18-n) \]

Where m is the open land factor (in %) with an increase in the dry month and a decrease in the wet month by 10%, and n is the amount of rainwater
d. Water balance on the ground
The water balance on the ground surface is calculated based on monthly rainfall reduced by monthly average limited evapotranspiration value. Water Surplus (WS) is the volume of water that will enter the ground surface. Rainwater that reaches the ground surface is calculated with the formula:

\[ WS = R - Ea \]
e. Groundwater storage
Groundwater storage can be calculated by applying equations as well as assumptions as follow [10]: The infiltration coefficient (I) is taken from 0.2 to 0.5, while the recession factor for groundwater flow (k) is from 0.4 to 0.7.
Volume of groundwater each month is calculated by the equation:

\[ V_n = 0.5 \left((1+k)i + (k \times V_{(n-1)})\right) \]

Where \( V_n \) is the volume of groundwater in the nth month, (mm), \( V_{(n-1)} \) is groundwater volume of the month-(n-1) (mm), K is qt*qo^{-1} = groundwater flow recession factor, qt is soil flow at time t (t month), qo is groundwater flow at the beginning (month 0), and ln is n month infiltration

\[ \Delta V_n = V_n - V_{(n-1)} \]

where \( \Delta V_n \) is a change in the volume of groundwater flow.
f. River Flow
The equation being used in calculating river flow in the F.J Mock method is:

\[ \text{Flow} = \text{Baseflow (BF)} + \text{Direct Runoff (DR)} \]

where:

\[ \text{Baseflow (BF)} = I - (\Delta V_n) \]
\[ \text{Direct Runoff (DR)} = \text{excess water (WS)} - I \]
Parameters and assumptions used to calculate of the dependable flow are: m = 20% with 10% increase/decrease in wet/dry months, soil moisture capacity = 200 mm, infiltration coefficient (I) = 0.50, flow recession factor (k) = 0.70, initial storage = 100 mm and runoff factor, Pf = 5%.

![Mock's schematic flow simulation model](image)

**Figure 2.** Mock’s schematic flow simulation model [9]

### 2.4. Water needs for the land preparation period

Land preparation is the wet management of the soil starting from the beginning of the first application of water, cleaning, etc., until the rice fields are ready to be planted [12,13,14]. Water requirement during land preparation is determined by a method developed by Van De Goor and Zijlstra in 1968 [12]. This method is based on a constant water rate in liters/second during the land preparation period with the following equation [9]:

\[
\text{IR} = M \cdot e_k (ek - 1)^{-1}
\]

Where, IR is water needs at the rice field (mm d⁻¹), M is water needs to replace loss due to evaporation and location in saturated rice fields (mm d⁻¹), \(M = E_o + P\) (mm d⁻¹), \(E_o\) is the evaporation of open water, \(P\) is percolation (mm d⁻¹), \(K\) is MT S⁻¹, \(T = \) time period for land preparation (days), \(S = \) water requirement, and \(e = \) euler number

### 2.5. Water needs for the growing period

The need for water for plant growth or consumptive use is to replace the water layer lost due to evapotranspiration and perlocation, starting from planting rice seeds until the rice begins to turn yellow[9,14]. Plant water requirement (Etc) depends on evapotranspiration multiplied by the plant coefficient (Kc). Water need for plant grows can be expressed as [9]:

\[
\text{Etc} = k_e \cdot \text{ETo}
\]

where ETo is water requirement for plants (mm d⁻¹), ETo is evapotranspiration (mm d⁻¹), and Kc is plant coefficient; depends on the type and age of the plant.

To determine the amount of water loss due to the evaporation process, it is necessary to calculate evapotranspiration. In calculating the value of evapotranspiration, climatological data is needed. Based on climatological data, the evapotranspiration value can be calculated using the following equation [6][11]:

\[
\text{ETo} = W \cdot R_a + (1 - W) f(u) \cdot (e_s - e)
\]

Furthermore, to get the value of evapotranspiration must be multiplied by a certain plant coefficient. The evapotranspiration value obtained is then used to calculate the water requirement for growth by including effective rainfall data.
2.6. Irrigated water needs
It is the amount of water needed to meet the needs in the paddy fields added with the loss of water that occurs during the delivery in the channel [9, 12]. However, it is important to provide the amount of water needed by calculating the requirement at the intake. The design of water requirement at the intake (DR) was calculated with the following equation is used:

\[ DR = \frac{NFR}{(e \times 8.64)} \]

where DR is plan flow at the intake (L/s·ha⁻¹), NFR is net field requirement (mm·d⁻¹), and e = total irrigation efficiency (taken 0.65). The required flow is the total amount of water required per unit time. In determining the flow rate, the following equation is applied:

\[ Q_r = (NFR \times A) \times (e \times 8640) \times 1 \]

where: Qr is required flow (m³·s⁻¹), NFR is net field requirement (mm·d⁻¹), A is an area to be irrigated (ha), and e is system efficiency (0.65).

2.7. Water balance
The water balance at the intake for each period of irrigated water can be calculated using the formula [9, 14, 15]:

\[ WB = Q_{\text{available}} - Q_{\text{needed}} \]

The equation used to determine the value of the K factor is as follows [9]:

\[ \text{Factor } K = \left( \frac{Q_{\text{available}}}{Q_{\text{needed}}} \right)^{-1} \]

Three circumstances could happen here:
From this equation, if K > 1, the water available is more than the needs or surplus state. On the other hand, if the value of K < 1, then the shortage or deficit of water occurs [9]. Therefore, scenarios or other plans must be applied, such as a grouping or rotation system.

3. Result and discussion

3.1. Calculation of Reference Evapotranspiration (ETo)
The Modified Penman method is used in calculating the reference evapotranspiration (ETo) [14]. In this case, data on temperature, humidity, wind, and sunlight for the last ten years (2008 – 2017) become parameters to be calculated. The calculation results can be seen in Table 1.

3.2. Water availability analysis
The data and parameters that become the parameters in determining the dependable discharge are:
   a. Rainfall data (monthly amount and days of rain)
   b. ETo from the calculation of Modified Penman.
Rainfall data used in this study is monthly rainfall data obtained from Singkoyo station with ten years of observation (2008 - 2017). In determining the availability of water or mainstay discharge in the Singkoyo catchment, the calculation is carried out using the FJ Mock method for each year for ten years of data. For the calculation of evapotranspiration (ETo), it is obtained from the previous calculation results using climatic data from Singkoyo weather station. From the results of the calculation of the dependable discharge every year, the average water availability for the Singkoyo River is obtained. The calculation results can be seen in Table 2.
Table 1. Calculation of the 10-year average Evapotranspiration (ETo) (2008-2017)

| Items                                      | Month       |
|--------------------------------------------|-------------|
| Air temperature (°C)                       | Jan 2008    |
| Wind speed (U) km/day                      | 26.3        |
| Correction factor, Uday / Unight           | 0.25        |
| Actual sunshine, N                         | 4.29        |
| Saturated vapor pressure, ea (mbar)        | 4.26        |
| Actual vapor pressure, ed = ea x Rh/100    | 3.96        |
| ea - ed                                    | 1.00        |
| Factor W                                   | 1.00        |
| (1 - W)                                    | 0.22        |
| Extra solar radiation, Ra                  | 0.37        |
| Maksimum sunshine, N                       | 0.32        |
| n = N * sunshine                           | 0.35        |
| Cloud ratio, n/N                           | 0.35        |
| Rs = (0.25 + 0.5n/Ra)                      | 0.35        |
| Rns = (1-a) Rs, a=0.25                     | 0.35        |
| Temperature effect, f(T)                   | 0.35        |
| F(ed) = 0.34-0.044 (ed)^0.5                | 0.08        |
| f(u)/n/N                                   | 0.48        |
| Rnl = f(T). f(ed), f(u)/n/N                | 0.55        |
| Energi sisa, Rn = Rns - Rnl                | 0.55        |
| U (m/sec)                                  | 0.35        |
| Uday / Unight                              | 1.00        |
| Correction factor,C                         | 1.00        |
| ET0 = C(W/Rn + (1-W).f(u). (ed - ea))       | 1.98        |
| Eto converted (mm/month)                   | 61.5        |

Table 2. Recapitulation of dependable flow (Q0) using FJ Mock method (m³/s)

| No. | Year | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|-----|------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| 1   | 2008 | 4.89| 5.05| 4.07| 11.74|11.41|18.42|49.03|32.03|19.12|14.83|6.71|5.74|
| 2   | 2009 | 2.70| 4.06|4.59|3.81|7.44|9.73|7.63|7.80|2.42|4.84|3.02|1.79|
| 3   | 2010 | 4.90|2.55|3.95|3.01|6.87|16.79|14.44|22.87|9.31|7.48|5.64|6.15|
| 4   | 2011 | 4.20|3.75|4.17|7.01|8.99|23.71|25.95|20.12|24.10|7.79|5.91|4.90|
| 5   | 2012 | 4.91|3.81|2.99|6.25|14.80|14.14|26.29|16.39|8.36|5.24|3.95|3.33|
| 6   | 2013 | 4.92|4.26|3.96|3.93|5.38|6.99|19.73|13.16|9.18|4.55|2.21|4.49|
| 7   | 2014 | 2.96|2.79|1.61|7.91|16.75|15.74|27.78|7.82|5.28|4.48|4.95|
| 8   | 2015 | 3.02|4.99|4.31|4.22|17.99|20.74|19.87|7.18|4.22|3.10|2.10|3.14|
| 9   | 2016 | 6.09|6.74|4.83|5.47|11.36|16.10|9.51|7.01|6.42|4.63|8.11|
| 10  | 2017 | 4.86|4.69|4.13|3.19|9.00|20.78|18.60|26.48|16.67|9.48|6.33|4.69|
| Average | 4.35 | 4.27 | 3.86 | 5.08 | 9.39 | 16.16 | 21.34 | 18.33 | 10.82 | 6.90 | 4.48 | 4.73 |

| Q0   | 3.01 | 3.56 | 3.76 | 3.16 | 6.57 | 12.79 | 15.48 | 9.17 | 6.45 | 4.78 | 2.86 | 3.29 |
### Table 3. Effective rainfall for rice and other crops (mm)

| Month | R80 (rice) | Reff\(^a\) | R60 (other cr) | Reff (other cr)\(^b\) |
|-------|------------|------------|----------------|------------------------|
| Jan   | 1          | 4.96       | 0.23           | 85.26                  | 2.27                   |
|       | 2          | 22.76      | 1.06           |                        |                        |
| Feb   | 1          | 23.20      | 1.08           | 104.26                 | 2.78                   |
|       | 2          | 24.60      | 1.15           |                        |                        |
| Mar   | 1          | 89.24      | 4.16           | 205.53                 | 5.48                   |
|       | 2          | 72.26      | 3.37           |                        |                        |
| Apr   | 1          | 69.92      | 3.26           | 213.50                 | 5.69                   |
|       | 2          | 87.40      | 4.08           |                        |                        |
| May   | 1          | 69.10      | 3.22           | 224.90                 | 6.00                   |
|       | 2          | 112.84     | 5.27           |                        |                        |
| Jun   | 1          | 104.58     | 4.88           | 270.70                 | 7.22                   |
|       | 2          | 64.54      | 3.01           |                        |                        |
| Jul   | 1          | 47.84      | 2.23           | 128.80                 | 3.43                   |
|       | 2          | 21.00      | 0.98           |                        |                        |
| Aug   | 1          | 31.88      | 1.49           | 148.70                 | 3.97                   |
|       | 2          | 22.52      | 1.05           |                        |                        |
| Sep   | 1          | 3.44       | 0.16           | 109.55                 | 2.92                   |
|       | 2          | 1.60       | 0.07           |                        |                        |
| Oct   | 1          | 1.68       | 0.08           | 121.35                 | 3.24                   |
|       | 2          | 38.12      | 1.78           |                        |                        |
| Nov   | 1          | 22.00      | 1.03           | 166.35                 | 4.44                   |
|       | 2          | 56.86      | 2.65           |                        |                        |
| Dec   | 1          | 48.34      | 2.26           | 138.85                 | 3.70                   |
|       | 2          | 28.30      | 1.32           |                        |                        |

\(a = (0.7 \times R80)(15)^{-1}\)

\(b = (0.8 \times R60)(30)^{-1}\)

3.3. Water needs analysis

3.3.1. Effective Rainfall

In determining the effective rainfall, the data used is semi-monthly rainfall data from the Singkoyo rainfall station (Table 3). In determining effective rainfall, crop patterns should be taken into consideration. It should be noted that this analysis is determined by taking into account the type of plants that will be planted in a planned pattern. The possibility of being fulfilled 80% or not being fulfilled by 20% (\(R_{80}\)) is used to determine the rainfall every half month for rice plants. As for palawijaya plants, monthly rainfall is taken by looking at the possibility of 60% (\(R_{60}\)).

3.3.2. Irrigation Water Needs

Based on the agreement on the planting season at the Singkoyo irrigation area and at the Upper and Lower Tolisu irrigation area, analysis is done to obtain irrigation water requirements for the entire area, both for Singkoyo and Upper and Lower Tolisu. Several scenarios and alternatives are proposed in the analysis to obtain the highest of water demand [14, 15]:

a. Planting is carried out simultaneously for all rice fields with a tolerance difference of half a month
b. Planting season 3 times a year
c. Each planting season consists of three stages: land preparation, plant growth, and harvesting time
d. There are six alternative planting combinations in each planting season.
e. Combination with the largest water demand is selected to be compared with the available discharge or the \(Q_{80}\) dependable flow
f. The first planting season starts in January.

The need for water for each alternative planting combination can be seen in Table 4. From Table 4, it can be seen that the largest planned water need is in alternative 1 with an average value is 3.39 m³ s⁻¹.
Therefore, an alternative one is chosen to calculate the water need for the agriculture activity in the study area.

### Table 4. Planned water needs of each alternative planting pattern

| Month | Alt. 1 (m$^3$/s$^1$) | Alt. 2 (m$^3$/s$^1$) | Alt. 3 (m$^3$/s$^1$) | Alt. 4 (m$^3$/s$^1$) | Alt. 5 (m$^3$/s$^1$) | Alt. 6 (m$^3$/s$^1$) |
|-------|----------------------|----------------------|----------------------|----------------------|----------------------|----------------------|
| Jan   | 2.74                 | 2.74                 | 2.74                 | 2.74                 | 2.74                 | 2.74                 |
|       | 2.13                 | 2.13                 | 2.13                 | 2.13                 | 2.13                 | 2.13                 |
| Feb   | 2.09                 | 2.09                 | 2.09                 | 2.09                 | 2.09                 | 2.09                 |
|       | 2.02                 | 2.02                 | 2.02                 | 2.02                 | 2.02                 | 2.02                 |
| Mar   | 3.04                 | 3.04                 | 3.04                 | 3.04                 | 3.04                 | 3.04                 |
|       | 3.14                 | 3.14                 | 3.14                 | 3.14                 | 3.14                 | 3.14                 |
| Apr   | 0.00                 | 0.00                 | 0.00                 | 0.00                 | 0.00                 | 0.00                 |
|       | 2.18                 | 2.18                 | 2.18                 | 2.18                 | 2.18                 | 2.18                 |
| May   | 4.01                 | 4.01                 | 4.02                 | 4.01                 | 4.02                 | 4.02                 |
|       | 2.54                 | 2.54                 | 2.54                 | 2.54                 | 2.54                 | 2.54                 |
| Jun   | 2.37                 | 2.37                 | 2.37                 | 2.37                 | 2.37                 | 2.37                 |
|       | 3.63                 | 3.63                 | 3.63                 | 3.63                 | 3.63                 | 3.63                 |
| Jul   | 2.62                 | 2.62                 | 2.62                 | 2.62                 | 2.62                 | 2.62                 |
|       | 4.19                 | 4.19                 | 4.19                 | 4.19                 | 4.19                 | 4.19                 |
| Aug   | 1.00                 | 0.00                 | 0.00                 | 0.00                 | 0.00                 | 0.00                 |
|       | 4.15                 | 4.15                 | 4.15                 | 4.15                 | 4.15                 | 4.15                 |
| Sep   | 6.93                 | 3.57                 | 0.00                 | 5.25                 | 1.79                 | 3.50                 |
|       | 6.92                 | 4.14                 | 0.00                 | 5.53                 | 2.07                 | 3.69                 |
| Oct   | 7.20                 | 4.54                 | 0.00                 | 5.87                 | 2.27                 | 3.91                 |
|       | 5.96                 | 2.73                 | 0.00                 | 4.35                 | 1.37                 | 2.90                 |
| Nov   | 5.39                 | 1.97                 | 0.00                 | 3.68                 | 0.98                 | 2.45                 |
|       | 3.78                 | 0.01                 | 0.00                 | 1.89                 | 0.00                 | 1.26                 |
| Dec   | 3.26                 | 3.26                 | 3.26                 | 3.26                 | 3.26                 | 3.26                 |
|       | 0.00                 | 0.00                 | 0.00                 | 0.00                 | 0.00                 | 0.00                 |
| Sum   | 81.31                | 62.07                | 45.12                | 71.69                | 53.59                | 62.83                |

### Table 5. Water availability, needs and the water balance in Singkoyo River.

| Month | Avail.(Q$_{aw}$) (m$^3$/s$^1$) | Req. (Q$_r$) (m$^3$/s$^1$) | Q$_{aw}$ - Q$_r$ | Factor K | Result |
|-------|--------------------------------|-----------------------------|-----------------|----------|--------|
| Jan   | 3.01                           | 2.74                        | 0.27            | 1.10     | surplus|
|       | 3.01                           | 2.13                        | 0.88            | 1.41     | surplus|
| Feb   | 3.56                           | 2.09                        | 1.47            | 1.70     | surplus|
|       | 3.56                           | 2.02                        | 1.54            | 2.76     | surplus|
| Mar   | 3.76                           | 3.04                        | 0.72            | 1.24     | surplus|
|       | 3.76                           | 3.14                        | 0.62            | 1.20     | surplus|
| Apr   | 3.16                           | 3.16                        | 0.00            | na       | surplus|
|       | 3.16                           | 2.18                        | 0.98            | 1.45     | surplus|
| May   | 6.57                           | 4.01                        | 2.56            | 1.64     | surplus|
|       | 6.57                           | 2.54                        | 4.03            | 2.59     | surplus|
| Jun   | 12.79                          | 2.37                        | 10.42           | 5.40     | surplus|
|       | 12.79                          | 3.63                        | 9.16            | 3.52     | surplus|
| Jul   | 15.48                          | 3.62                        | 11.86           | 4.28     | surplus|
|       | 15.48                          | 4.19                        | 11.29           | 3.69     | surplus|
| Aug   | 9.17                           | 9.17                        | 0.00            | na       | surplus|
|       | 9.17                           | 4.15                        | 5.02            | 2.21     | surplus|
| Sep   | 6.45                           | 6.93                        | -0.48           | 0.93     | deficit|
|       | 6.45                           | 6.92                        | -0.47           | 0.93     | deficit|
| Oct   | 4.78                           | 7.20                        | 2.42            | 0.66     | deficit|
|       | 4.78                           | 5.96                        | -1.18           | 0.80     | deficit|
| Nov   | 2.86                           | 5.39                        | -2.53           | 0.53     | deficit|
|       | 2.86                           | 3.78                        | -0.92           | 0.76     | deficit|
| Dec   | 3.29                           | 3.29                        | 0.00            | na       | surplus|
|       | 3.29                           | 3.26                        | 0.03            | 1.01     | surplus|
| Average| 6.24                           | 3.39                        |                 |          |        |
3.4. Water balance
From Table 5 above, it can be affirmed that the average value of the Q₈₀, which is used for the needs during the planting phases at the upper and lower Singkoyo and Tolisu irrigation areas, the availability is still greater throughout December to August, but there is a slight deficit in September until November. On average, the water surplus during the year is approximately 2.85 m³ s⁻¹. The biggest surplus occurred in the first half of July (11.86 m³ s⁻¹), while the largest deficit occurred in the first half of November (-2.53 m³ s⁻¹) (Figure 3).

Here it can be envisaged that the demand for water for the entire paddy field area is quite high. At the same time, water availability is decreasing during the dry season event. Therefore, it is better to do a water supply management system, especially in dry months where the need for irrigation water is relatively high. Three options can be discussed in terms of the adaptation by the farmers to face the shortage.

a. Grouping system of supply
In this option, the water is irrigated based on the group of land or irrigation areas. The planting season is not uniform for that three irrigation areas. Preferably the planting time is made with two weeks of interval time. Therefore, the entire group or area period is about one and a half months in the study area. That is enough to meet the water need until the water availability increases again.

b. The rotating system of supply
This option is slightly different from the previous one. In this option, the alternate for water supply is made. Ideally, the turn for one tertiary irrigated area takes two or three days. Then, it is turned to the other area, based on the water availability, until all the area is fulfilled. It is also necessary to apply the rice intensification (SRI) system to optimize the cultivation of land.

c. Applying the rice-rice-other scheme
Another option is applying the planting scheme with rice – rice – other. Since rice needs more water than other crops, the crops with fewer water needs during the growing phase can be promoted, such as vegetables, corn, sorghums, etc. Consequently, farmers must be accustomed to planting other crops besides rice.

4. Conclusion
The result shows that the Singkoyo River, which has a basin area of 408.55 km², has an average flow rate for dependable flow $Q_{90}$ is app. 6.24 m³ sec⁻¹. The largest discharge occurs in July, equal to 15.48 m³ sec⁻¹ and the smallest occurs in November at 2.86 m³ sec⁻¹. The total area of irrigated land for rice is app. 3837 ha. Applying the worst scenario with three times of planting seasons per year with rice, the need for water in three irrigation areas varies according to the net field requirement during the plantation phase from 7.20 m³ sec⁻¹ at the 3rd planting season in October. The lowest is 2.0 m³ sec⁻¹ at the 2nd planting season in February. The water balance is mostly surplus from December to August. However, the deficit during September-November is -1.34 m³ sec⁻¹ on average due to the higher demand for water for the plant growing. At the same time, the availability decreases because of the dry season. It is recommended to install a hydrometric device (AWLR) in the Singkoyo River to obtain continuous and real-time data of water level and flow rate that can be used as a control in simulating and analyzing water balances based on hydrological and climatological data.

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