The changes of the start in the wet season and dry season and potential electrical energy on wet season based on hydrology (Case: Kalijirak River, Karanganyar Regency)

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Abstract. Climate change causes changes at the beginning of the rainy season and the dry season. In Microhydro planning, determining the rainy season's right start is very important to determine the energy potential. The beginning of the dry season is an excellent time to start carrying out structural work. This research was conducted in Kalijirak River, Mount Bromo Forest and Karanganyar Regency, a forest protected by the Indonesian government. The survey shows that the river flow is up to 1,458 m³/s in the dry season. This discharge is the potential to generate electrical energy. The construction must build in the dry season. This research aims to determine the beginning of the rainfall season to know the potential energy can generate and the beginning of the dry season to schedule the construction—analysis of seasonal changes based on rainfall intensity while analyzing energy potential based on dependable discharge. The rainfall-runoff simulation uses the Mock method to produce a dependable discharge. The results show that the beginning of the November rainy season period second means that the rainy season shifts back four periods, and the beginning of the dry season in May period 2 means the dry season shifts back four periods). This means, if the season moves late, the start of construction is also late. It late up to four Periods. Besides that, it also shows that the annual energy potential is 64,774,372 kWh.

1. Introduction
Climate change has an impact on determining the beginning of the wet and dry seasons. Determining the wet and dry seasons is very important to determine the beginning of the project. The beginning of planting time is conducted based on the wet season. The beginning of the dry season is essential to determine the start of construction. Predicting the potential energy depend on streamflow along the wet season [1].
KHDTK Gunung Bromo UNS is a protected forest area. In forest areas, rivers flow, which in the dry season is still flowing 1.458 m³/sec based on the survey. It indicates that this flow has the potential to generate hydropower energy to design a hydropower plant. The problem is how much water potential that can generate electrical power. Then when is the right time to start constructing the HPP (Hydro Power Plant)? The research aims to know the beginning of the wet and dry seasons.

The hydrological analysis considers the hydrological phase with a duration of 10 days in a period. A year consists of 4 phases: the dry season, the transition from the dry season to the rainy season, the wet season, and the transition from the wet season to the dry season. Analysis parameters are Rainy Day (RD), rainfall (R). If R ≥ 50 mm and RD ≥ 3 days per period, it is stated at the beginning of the wet season (BWS). If R <50 mm and RD < 3 days each period, it describes as the beginning of the dry season (BDS) [1].

Micro Hydro Power Plant (MHPP) is a power generation system that can convert flow potential with a certain height and discharge into electricity, using water turbines and generators [2][3]. Micro hydropower plants depend on discharge (flow capacity) [4].

The energy potential is calculated based on the results of dependable discharge analysis. The analysis methods are the F.J Mock method, Nreca method, GR2M method [5][6]. Indonesian government regulations, the method used is the F.J. Mock and Nreca method [7]. Evapotranspiration is very influential in calculating dependable discharge [7]. Dependant discharge analysis using evapotranspiration by the Penmann-Monteith method [8]. The difference between rainfall and evapotranspiration results in direct runoff, groundwater, and storm runoff.

The data were as collected from the responsible agency of the Bengawan Solo River Basin. If the data series is missing, then filled in with the Reciprocal Method [9]. The rainfall data used is at the nearest station to the study's location, about 7.3 Km (based on the map). It is a rainfall gauge, Jumantono rainfall station.

The dependable discharge is streamflow that is expected to always exist throughout the year with an absolute risk of failure. In this study, it needs an 80% dependable Discharge [10]. It means that in 5 years, the prediction fails once. It is the river's minimum discharge with a possible discharge of 80% so that it can be used as the basis for the analysis of the amount of power that micro-hydro can produce [11]. How to find a dependable discharge can use equation (1) [10].

\[ P = \frac{i}{(n + 1)} \times 100\% \]  
(1)

With \( i \) = number of discharges, \( n \) = total of data, \( p \) = the probability of the expected set of values during the observation period (%).

Analysis of potential energy uses the head as a variable. The energy potential loss equation in the channel follows equation (2). Losing energy in the channel is also called primary energy loss. The energy loss at the pipe's input is also called secondary energy loss; following equation (3). Meanwhile, the head effective follows equation (4). Energy generation uses equation (5). The abundant energy produces power as in equation (6).

\[ hf = f \cdot \frac{L}{D} \cdot \frac{v^2}{2g} \]  
(2)

\[ h = K \cdot \frac{v^2}{2g} \]  
(3)

\[ H_{eff} = H_{brutto} - hf - h \]  
(4)

\[ P = g \times \eta t \times Q_{80} \times H_{eff} \]  
(5)
\[ E = P \times T \]  

(6)

With \( h_f \) = loss of primary energy (m), \( f \) = friction coefficient of Darcy-Weisbach, \( L \) = pipe length (m), \( v \) = flow velocity (m/s), \( g \) = gravity acceleration (m/s\(^2\)), \( h \) = loss of secondary energy (m), \( K \) = shape coefficient of pipe end, \( H_{\text{eff}} \) = effective head (m), \( H_{\text{Bruto}} \) = bruto head (m), \( h_f \) = loss of primary energy (m), \( P \) = power (kW), \( \eta_t \) = turbine efficiency, \( Q_{80} \) = dependable discharge in 80% (m\(^3\)/s), \( E \) = energy (kWh), \( P \) = power (kW), \( T \) = time of operation (hours)

2. Research method

The research location is in the Kalijirak River Basin, Karanganyar Regency, Central Java. Rainfall and climatological data, wind velocity, humidity, temperature, and solar radiation were collected from the Jumantono Station for ten years (1999-2018). The map analysis uses a Geospatial map body in the form of topographic maps of Karanganyar Regency, Sukoharjo Regency, and Surakarta City. Thiessen method is a method to analyze areal rainfall using Mapping in a topographic map. The closest rainfall stations are Tawangmangu Station 17.4 km, Pabelan Station 25.1, Jumantono Station 7.3 km, and Colo Station Dam 21.6 km.

The calculation begins with data validation. The method used the RAPS (Rescaled Adjusted Partial Sums). Then the rainfall-discharge analysis using the Mock method. The reliable discharge calculation with a certain probability uses the Weibull method [12].

The discharge calculation results become input in the energy calculation in equation (4) - equation (6).

3. Result and discussion

Based on Thiessen's analysis in Figure 1, only the Jumantono station impacts the Kalijirak watershed. Thus, in the next, the calculation is based on the Jumantono station. The area of the Kalijirak watershed is 18,708 km\(^2\).

Furthermore, the data validation test was calculated based on the Jumantono station. The \( Q_{\text{RAPS}} \) analysis shows that the maximum count ([Sk **] maximum) in 2010 is 2.516. The calculation of \( Q_{\text{RAPS}} \) hit (max) / \( \sqrt{n} \) = 0.563. This value is less than the critical value. With \( n = 20 \) and 95% confidence interval, the critical value, the \( Q_{\text{RAPS}} \) Criticism value = 1.220. It means the data series is valid.

Finding the hydrology period is depicted in Figure 2.

**Figure 1. Thiessen polygon at Karanganyar Regency**
Figure 2. The beginning of the wet and dry season

Figure 2 describes the rainfall intensity on each period, with the probability of 80%. It shows that the transition between the two seasons is a condition that indicates the beginning of the wet and dry seasons.

The transition period occurred when the number of Beginning of the Wet Season (BWS) and Beginning of the Dry Season (BDS) that occurred in 20 years was between 5-15 times. The transition occurred in April period III to May period I and October period III. After the April transition period III to May period I, it can be seen in May period II until the next transition met BDS's requirements, so in May period II, this was BDS occurred. After the October transition period in the last 20 years, many qualify for BWS compared to BDS. It can be concluded that in the November period, I was BWS. It can be concluded that the transition from the rainy season to the dry season occurred in April period III to May period I, and the transition from the dry season to the rainy season occurred in October period III. BDS occurred in May period II, and BWS occurred in November period I.

The results of dependable discharge calculations using the Mock method can be seen in Figure 3.

Figure 3. The discharge based on Mock Method

The survey showed in the second period of April (2019) showed that the river discharge was 1.458 m³/s. This figure is close to the calculation result using the Mock method, which is 1.462 m³/s. The result of the 80% dependable discharge calculation is shown in Figure 4.
Based on the dependable discharge, the energy calculation uses an equation (6), as in Figure 5.

![Figure 4. Dependable discharge, Q80, in Kalijirak catchment area](image)

![Figure 5. The potential energy, in every period](image)

Overall, the annual potential energy is 65,384,706 kWh.

4. Conclusion
The beginning of the dry season (BDS) occurs in May period II, and the beginning of the rainy season (BWS) occurs in November period I. The transition period from the wet season to the dry season occurs in April period III to May period I, and the transition from the dry season to the rainy season occur in October period III. It means the beginning of the wet season late in 2 periods and the dry season late in 4 periods, shifting four ten-daily. In the wet season, there is annual potential energy up to 65,384,706 kWh.
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