Estimated time for supply and drainage of water for rice planting in freshwater swampland

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Abstract. Information about the timing of supply and drainage to the land is important. This aims to minimize crop failure and increase swamp rice productivity. The highest water requirement occurs in the first week of October, namely 1.21 mm day⁻¹, while the lowest water requirement occurs in January III to April week III. In the dry conditions, runoff that occurs 0.04 to 5.71 mm day⁻¹ is estimated to occur on January 1 to May 10 and November 22 to December 31. While the land will require water from 0.06 to 6.31 mm day⁻¹ on May 11 to November 21. In a normal conditions, runoff will occur 0.05 to 12.89 mm day⁻¹, estimated on January 1 to June 13 and October 26 to December 31, and requires a water supply of 0.04 to 4.20 mm day⁻¹ on June 14 to October 25. Meanwhile, in the rainy conditions there will be a runoff of 0.05 to 16.72 mm day⁻¹, estimated to occur on January 1 to July 9 and September 29 to December 31. As well as land will require water of 0.02 to 1.30 mm day⁻¹, is expected to occur on 10 July to 28 September.

1. Introduction
South Kalimantan Province has a relatively flat topography with mountainous areas and valleys between the Java Sea and the Makassar Strait. Various phenomena that result in the emergence of multiple climatic conditions both spatially and in zoning occur. This compound climatic condition causes a shift in the beginning of the planting season, especially for rice [1].

The typology of swamps in Indonesia consists of 8.92 million ha of tidal swampland and 25.21 million ha of freshwater swampland. Freshwater swampland reached 25.21 million ha, spread across Sumatra 9.91 million ha, Papua 7.44 million ha, Kalimantan 7.04 million ha, Sulawesi 0.73 million ha and Maluku 0.09 million ha, while in Java is not found (or found in a very small area). Based on the land, most of the swamplands (13.56 million ha) are peat soils, and 11.64 million ha are mineral soils. The swampy peat is spread across Sumatra 5.92 million ha, Kalimantan 4.09 million ha, Papua 3.53 million ha, and Sulawesi 23.884 ha. Apart from Java, peat swamp is not found in Maluku. The most extensive mineral reserves are found in Sumatra 3.99 million ha, Papua 3.92 million ha, and Kalimantan 2.94 million ha. In Sulawesi and Maluku, mineral abundance was found respectively 0.71 million ha and 0.09 million ha [2]. Freshwater swampland has stagnant water that always wets the land for a certain period. During the rainy season, it often causes water stagnation in the paddy fields, but during the dry season the paddy fields become very dry. This is the underlying reason why water balance calculations in swamplands are needed.

Climate change fluctuations such as periods of drought (El Nino years) and/or wetness (La Nina years) are less certain, resulting in shifts in the beginning and end of the planting season and have a
negative impact on crop productivity, especially rice [3]. Several indicators of climate change that can be observed are increasing air temperature, changing rainfall patterns, increasing sea level and increasing extreme climate events. Also, local wisdom and natural signs such as prey institutions are increasingly difficult to recognize and can no longer be used by the community [4].

Failure to plant up to a failure to harvest rice is the main problem that occurs in Agro Sciences Park Swampland. This is because water management is still not optimal. Therefore, research is needed that produces Description about the right time to drain and or supply the paddy field according to the availability and requirement. Description regarding the right time to supply or drainage land according to water availability and also water requirement is important. This aims to minimize crop failure and increase swamp rice productivity.

2. Materials and methods

2.1. Research Location
The research location is in freshwater swampland which are inside the Agro Sciences Park Swampland of Banjarbaru with an area of 5 ha. Position coordinates at 3°26'9.38"South and 114°47'47.66" East.

2.2. Data
Hydroclimatology data obtained from Meteorological Station Syamsuddin Noor Banjarmasin (data on rain, temperature, humidity). Rainfall data is further processed into an analysis of fluctuations in daily rainfall for the last 30 years. Meanwhile, the calculation of evapotranspiration uses data on maximum temperature, minimum temperature, average temperature, and average relative humidity.

2.3. Method
The climatological data for the last 30 years has become the basic material for conducting evapotranspiration analysis, water availability analysis (net rate), water demand analysis for rice plants, net rate estimation, water balance (analysis of drainage and irrigation times in land).

2.3.1. Evapotranspiration \( (ET_0) \). Evapotranspiration is more often used to express evaporation that occurs in the field and can be estimated using the evapotranspiration model. Evapotranspiration is calculated using a method approach Hargreaves [5]. The \( ET_0 \) value is calculated based on air temperature data which is measured continuously by temperature and humidity sensors. This method was chosen because the approach used is almost the same as the measurement method with the evaporation pan with sufficient data available to use this method.

\[
ET_0 = 0.000939(T_{max}-T_{min})^{0.5}(T_{average}+17.8)R_a \tag{1}
\]

Description:
\( R_a \) : Ekstarerrestrial radiation (MJ m\(^{-2}\) h\(^{-1}\))
\( T_{max} \) : Maximum daily temperature (°C)
\( T_{min} \) : Minimum daily temperature (°C)
\( T_{average} \) : Average daily temperature (°C)

2.3.2. Net Rate. Any change in groundwater content over a period of time must equal the difference between the amount of water added to the soil and the amount of water that leaves the soil. The remaining water is called the net rate.

\[
\frac{\Delta \theta}{\Delta t} = \frac{\Delta h}{\Delta t} = (r - ro - et) + (gq - dp) + (qi - qd) \tag{2}
\]

Description:
\( \Delta \theta \) : Changes in volumetric groundwater content (cm\(^3\) cm\(^{-3}\));
\( \Delta h \) : Equivalent change in water depth (mm);
2.3.3. Water requirement for rice planting. There are three phases of rice plant growth. During this time, rice undergoes a vegetative phase (early healing until the formation of panicles or primordia), reproductive (primordia to flowering), and ripening (flowering until the grain is ripe). Water requirements in the three phases above vary, namely in the active tiller formation phase, maximum tillers, panicle formation initiation, pregnancy phase and flowering phase [6]. Swamp rice water requirements are determined in three growth phases; early vegetative, reproductive and maturation. It is calculated by entering the coefficient data of the rice plant at the time of planting that is tested [7].

For rice production, the calculation of irrigation water during land preparation is based on water requirements to replace water loss due to evaporation and percolation in saturated rice fields during the 30-day land preparation period, with standing water levels of 250 mm or 8.33 mm day\(^{-1}\). To determine the amount of water demand, the van de Goor and Zijlstra formula [8] is used as follows:

\[
IR : M.ek (ek^{-1})^{-1}
\]  

Description:
IR = Water requirements (mm day\(^{-1}\)).  
M = 1.1ETo + P (mm day\(^{-1}\)), top of requirements  
ETo = evaporation (mm day\(^{-1}\)).  
P = perkolation (mm day\(^{-1}\)).  
k = M.T S^{-1}  
T = period of land preparation (day).  
S = Water requirements for saturation

The rate of percolation depends on the properties of the soil, namely the type of soil and its processing characteristics. Percolation water is given during the plant growth period which aims to clear the sub-surface soil layer. The amount of percolated water ranges from 1 to 3 mm day\(^{-1}\). In this study the percolation was determined to be 2 mm day\(^{-1}\). Water layer replacement (WLR) is scheduled for 2 times of 50 mm each, namely one and two months after transplantation. Furthermore, consumptive water use is calculated by multiplying the coefficient of rice plants by evapotranspiration. Then calculated the water needs for replacing the water layer (WLR) and also the need for land preparation. The total amount of these is the value of the plant's water needs. The calculation of the water needs of rice plants is part of the simulation of planting time because of different planting times, so the water needs are also different. Also, the need for channel maintenance is also calculated by 5% of the highest value of the rain data [8].

Determination of when the planting season starts should take into account the amount of rainfall required for tillage and during the early growth period. The highest amount of water needed in a planting period is during soil cultivation. Paddy soil processing is carried out for 15 to 20 days with water requirements ranging from 150 to 250 mm [9].

2.3.4. Estimated net rate. The estimation is done by calculating the availability of rainwater after deducting evapotranspiration based on the percentage of water loss (80% for the dry year, 50% for the normal year, and 20% for the wet year) multiplied by the number of data years plus 1 [8,7].
2.3.5. Water balance (time to drainage/irrigation). Net rate estimation shows the value of water availability for dry, normal, or wet conditions. After that this value is reduced by the need for paddy water in the swamps. If the result is positive it means that the water in the land must be drained, and if the result negative, the water must be put into the land at that value.

3. Results and discussion

The availability of groundwater, which mostly comes from rainfall, is an important limiting factor for increasing the production of a plant [10]. The research shows that the rainy and dry season patterns in Banjarbaru City during the last 30 years have shifted every year. For the dry season, every year there is a shift backward in the range of 1 to 30 days for 3 consecutive years, then forwards once the range of 20 to 30 days, then back again to 1 to 10 days for 2 consecutive years [7].

The results of the evapotranspiration calculation showed that the highest evaporation value in the field was 5.7; the lowest was 2.2 and the mean was 4.2 (figure 1).

![Figure 1. Evapotranspiration graphic](image)

For water availability (net rate) shows the maximum value is 22.54 mm day⁻¹, the minimum is - 10.23 mm day⁻¹. The highest value occurred on January 1, 2020, and the lowest net rate value occurred on October 4, 2020 (figure 2).

For the April to September period, rice seedlings have been implemented in May I to II weeks. Start planting in June week I to August week III. Then it is continued for the October to March period, the rice seedlings are carried out in the first week of September and the planting plan is in the first week of October. Land processing is carried out for 30 days before planting or almost at the same time as the time for the seedlings. The highest water demand is in the first week of October at 1.21 mm day⁻¹, while the lowest water demand occurs in the third of January to the third of April. In January there are still plants from the October to March planting period of the previous year, so they still need water.
The estimated net rate is calculated by considering three conditions, namely dry conditions with a loss of 80%; normal conditions with a loss of 50%; and wet conditions with a loss of only 20% [7], using 30 years of data analysis as shown in the graph below.

In the calculation of the water balance, a positive value indicates runoff which means a surplus of water. Meanwhile, a negative value indicates a lack of water or deficit. The results of the water balance in freshwater swampland show that in the dry year the water will run off by 0.04 to 5.71 mm day$^{-1}$ and water will be supplied by 0.06 to 6.31 mm day$^{-1}$. In a normal year, water will run off by 0.05 to 12.89 mm day$^{-1}$ and water will be supplied by 0.04 to 4.20 mm day$^{-1}$. Whereas in the rainy year the water will run over 0.05 to 16.72 mm day$^{-1}$ and water will be supplied by 0.02 to 1.30 mm day$^{-1}$.

Based on the results of the analysis and calculation of the water balance, the following schedule is generated (table 2):

**Figure 2. Net rate of water available**

**Figure 3. Estimated net rate graphic**
Table 1. Water requirement for rice plants in swamps

| Month   | 10 days | Water requirement |
|---------|---------|-------------------|
|         | mm per 10 days | mm day⁻¹ |
| January | 1       | 3,162             | 0,316   |
|         | 2       | 1,030             | 0,103   |
|         | 3       | 0,000             | 0,000   |
| February| 1       | 0,000             | 0,000   |
|         | 2       | 0,000             | 0,000   |
|         | 3       | 0,000             | 0,000   |
| March   | 1       | 0,000             | 0,000   |
|         | 2       | 0,000             | 0,000   |
|         | 3       | 0,000             | 0,000   |
| April   | 1       | 0,000             | 0,000   |
|         | 2       | 0,000             | 0,000   |
|         | 3       | 0,000             | 0,000   |
| May     | 1       | 1,995             | 0,199   |
|         | 2       | 5,984             | 0,598   |
|         | 3       | 9,973             | 0,907   |
| June    | 1       | 10,878            | 1,088   |
|         | 2       | 9,006             | 0,901   |
|         | 3       | 7,134             | 0,713   |
| July    | 1       | 6,548             | 0,655   |
|         | 2       | 7,061             | 0,706   |
|         | 3       | 7,552             | 0,687   |
| August  | 1       | 8,614             | 0,861   |
|         | 2       | 8,031             | 0,803   |
|         | 3       | 7,420             | 0,675   |
| September| 1    | 8,494             | 0,849   |
|          | 2      | 10,249            | 1,025   |
|          | 3      | 12,076            | 1,208   |
| October | 1      | 12,102            | 1,210   |
|          | 2      | 10,442            | 1,044   |
|          | 3      | 8,782             | 0,798   |
| November| 1      | 7,920             | 0,792   |
|          | 2      | 8,418             | 0,842   |
|          | 3      | 8,888             | 0,889   |
| December| 1      | 8,179             | 0,818   |
|          | 2      | 7,598             | 0,760   |
|          | 3      | 7,042             | 0,640   |
Figure 4. Water balance graphic

Table 2. Time to drainage or irrigation

| No | Activity | Dry Time Schedule | Normal Time Schedule | Wet Time Schedule |
|----|----------|-------------------|----------------------|------------------|
| 1  | Drainage | January 1 to May 10 | January 1 to June 13 | January 1 to July 9 |
|    |          | November 22 to December 31 | October 26 to December 31 | September 29 to December 31 |
| 2  | Irrigation | May 11 to November 21 | June 14 to October 25 | July 10 to September 28 |

4. Conclusions
From the overall analysis, it can be concluded that by using data for 30 years, it shows that the highest water demand occurs in the first week of October at 1.21 mm day$^{-1}$, while the lowest water demand occurs in the third January to April third week. In January there are still plants from the October to March planting period of the previous year, so they still need water.

In dry conditions, water must be drained at 0.04 to 5.71 mm day$^{-1}$ on January 1 to May 10 and November 22 to December 31. Water will be supplied to the paddy fields at 0.06 to 6.31 mm day$^{-1}$ on May 11 to November 21. Under normal conditions there will be a runoff of 0.05 to 12.89 mm day$^{-1}$ on January 1 to June 13 and October 26 to December 31. Water will be supplied by 0.04 to 4.20 mm day$^{-1}$ on June 14 to October 25. Meanwhile, in wet conditions, the water will run over 0.05 to 16.72 mm day$^{-1}$ on January 1 to July 9 and September 29 to December 31. Meanwhile, water will be supplied to the paddy fields at 0.02 to 1.30 mm day$^{-1}$ from July 10 to September 28.

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