# Study of Irrigation Water Requirement to Increase Rice Planting Index in Rainfed Paddy Field

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**Abstract.** Achieving food self-sufficiency can be supported by expanding cultivated areas and optimizing land use. One effective strategy for land optimization is increasing the cropping index (CI) from 100 to 200 allowing two rice harvests per year. Rainfed paddy fields in Jambi Province, particularly in Muaro Jambi Regency, have significant potential for such improvement. However, limited water availability during the dry season restricts farmers to a single annual planting. The purposes of this study to analyze water availability in rainfed rice fields and assess the feasibility of increasing the cropping index from 100 to 200. Sungai Duren Village was selected as a representative area with potential for CI enhancement. Crop water requirements were calculated using the CROPWAT 8.0 model, based on data on rainfall, climate, soil texture, and percolation. The analysis indicates that rice planting in Sungai Duren Village can begin in early February based on available rainfall. A second planting season is feasible start in early July, provided supplemental irrigation is supplied using well pumps that lift water from the groundwater or water pools located around the rice fields during the dry season.

***Keywords:*** Cropping index, CROPWAT 8.0 model, Irrigation water requirement, Rainfed paddy fields, Supplemental irrigation

## 1. Introduction

Rice (*Oryza sativa* L.) is the main staple food for most of Indonesian population, making it critical component of national food security. Efforts to achieve food self-sufficiency and sustainability require not only expanding the cultivated area but also optimizing the productivity of existing agricultural land. One effective approach to optimizing land productivity is by increasing the cropping index (CI), which represents the number of crop cycles cultivated on the same land within a year. Increasing the CI from 100 to 200 enables farmers to harvest rice twice a year, thereby improving land use efficiency and farmers' income.

There are many rice fields used for rice cultivation in Indonesia, namely irrigated rice fields, tidal rice field, lowland rice fields, and rain-fed rice fields. So far, research has only focus on irrigated rice fields [1], tidal rice field [2], and lowland rice fields [3]. Research is still rarely conducted on rain-fed land, even though according to reports [4] rain-fed rice fields are the highest contributor to rice production after irrigated rice fields. Spatially, rain-fed rice fields in Indonesia are still quite extensive, namely around 53.5% or 3.8 million ha of the total rice field area [5]. One of the provinces that has rain-fed rice fields is Jambi Provinces. In Muaro Jambi Regency, the potential for rainfed paddy cultivation is significant; however, water scarcity during the dry season remains a major constraint. Farmers typically cultivate rice only once a year during the rainy season, leading to underutilization of the land during the dry months. To increase the cropping index in these areas, reliable assessment of water availability and irrigation water requirements is essential.

Water availability in rainfed areas depends on several factors, including rainfall distribution, soil characteristics, percolation rate, and access to supplementary water sources. The use of hydrological models such as CROPWAT 8.0 enables the estimation of crop water requirements and effective rainfall to plan efficient irrigation schedules [6]. By combining rainfall data with potential irrigation from nearby water bodies, it is possible to determine suitable planting schedules that support multiple cropping cycles in a year.

This study aims to analyze water availability in rainfed rice fields and evaluate the feasibility of increasing the cropping index from 100 to 200 in Muaro Jambi Regency, Jambi Province. Sungai Duren Village was selected as the study area due to its strategic location near the Batanghari River and its potential for land optimalization. The findings are expected to provide useful insights for developing water management strategies and irrigation planning to support double rice cropping in rainfed areas.

## 2. Research Methods

*2.1 Study Area*

The study was conducted in Sungai Duren Village, Muaro Jambi Regency, Jambi Province, Indonesia. The village is located near the Batanghari River, which serves as a potential supplementary water source during the dry season. The area is characterized by rainfed paddy fields that depend primarily on rainfall for irrigation. The topography is relatively flat, with an elevation ranging from 20 to 30 meters above sea level. The climate is tropical humid, with an average annual rainfall about 2,500 mm and a dry period from June to August.


**Figure 1.** Study area

*2.2 Data Collection*

Climatic data (rainfall, temperature, humidity, wind speed, and sunshine) were obtained from the Jambi Climatological Station. Soil texture, field capacity, and percolation rate were measured from field observations and secondary data. Crop coefficients (Kc) followed FAO guidelines. River water level and pumping capacity data were used to estimate supplementary irrigation potential.

*2.3 Estimation of Water Availability*

Water availability relies solely on available rainfall, where the data used is effective rainfall, which is the amount of rainfall falling in an area that can be directly used to meet plant water needs. The effective rainfall used is the effective rainfall for rice plants, using the formula (Eg. 1 and Eq. 2) [7]:

R80% = (n/5) +1
Re (rice) = 70% x R80
R80% = Rainfall with an 80% probability of being met or exceeded
Re = effective rainfall (mm)
n = number of years/periods

*2.4 Estimation of Crop Water Requirements*

Crop water requirements (CWR) and irrigation water requirement (IWR) were estimated using CROPWAT 8.0 software are computed as follows [8] :

CWR = ETo x Kc
IWR = (ETo x Kc) -ER
Where :
ETo = Reference evapotranspiration (ETo) was calculated using the FAO Penman–Monteith equation
ER = effective rainfall was estimated using the USDA Soil Conservation Service method.
Kc = crop coefficient, where values for rice vary at different growth stage: (1) Initial stage (germination to seedling): 0.4; (2) Vegetative stage (Tillering to panicle initiation): 0.8; (3) Reproductive stage (Heading to maturity): 1.2.

Rainfall and CWR data were analyzed to identify optimal planting months. The first planting season relied mainly on rainfall, while the second required supplemental irrigation from the Batanghari River.

*2.5 Data Analysis*

Data were processed using CROPWAT 8.0 and Microsoft Excel to analyze rainfall effectiveness, irrigation requirements, and planting schedules.

**3. Results and Discussion**

*3.1 Water Availability in Rainfed Paddy Fields*

The results of rainfall measurements from 2015 to 2024 (Fig. 2.) show rainfall distribution shows the equatorial pattern, with peaks occurring on November and March and a prolonged dry period from June to August. Effective rainfall calculations indicate that sufficient water for rice cultivation begins in early October. During this period, crop water requirements can be fully met by rainfall, enabling the first planting season (MT-I) to begin. After the peak of rainfall in March, there was a decrease from April to August and then it increased again in September.

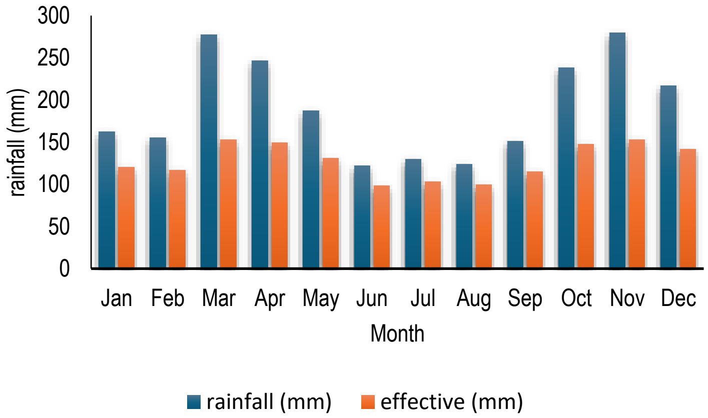


**Figure 2.** Rainfall rate per month from 2015 to 2024

*3.2 Crop Water Requirement*

Crop water requirements are calculated from evapotranspiration obtained from climate data from 2015 to 2024. The calculation results show that evaporation values ranged between 2.92 and 3.54 mm/day or 90.52 mm/month in December and 109.74 mm/month in August (Fig. 3). This evapotranspiration data is used to calculate the water requirements of rice plants which depend on the planting time and age of the plants.

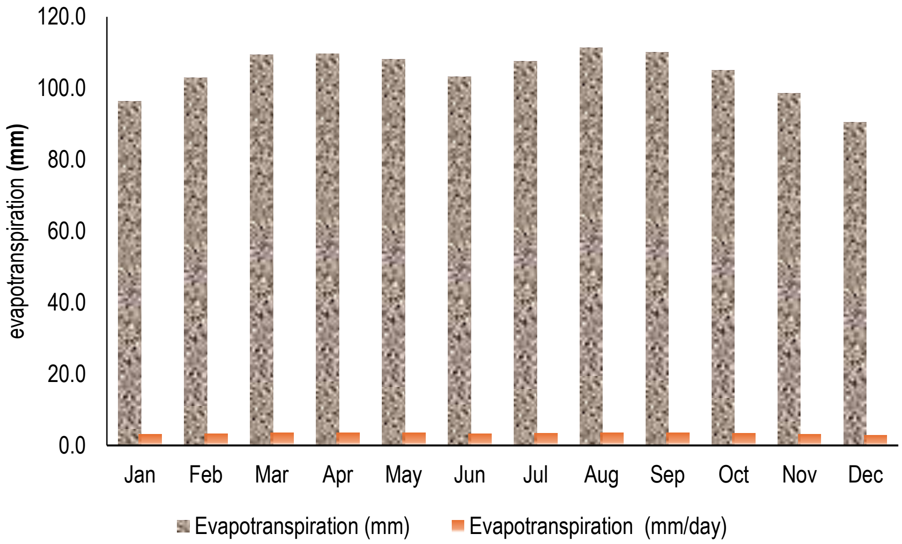


**Figure 3.** Evapotranspiration rate from 2015 to 2024

*3.3 Optimal Planting Time*

Farmers at this research site typically plant only once a year due to excessive water during the rainy season and water shortages during the dry season. Planting typically begins in June and harvests in October. Land preparation and nursery planting begin in May.

Planting schedule optimization can be performed through CROPWAT 8.0 simulations by systematically shifting the planting start date to find a schedule that maximizes the match between effective rainfall availability and rice plant water requirements at each growth phase. This computer simulation-based optimization approach is an effective and efficient method for planning optimal planting schedules, especially in rainfed rice fields where synchronization between plant water requirements and rainfall availability is key to successful cultivation [9]. The optimization results produce two optimal planting schedule scenarios that allow for two rice planting seasons per year: Optimal MT 1 (February–July) and Optimal MT 2 (July–November), as presented in Figures 4 and 5.

Figure 4 shows the relationship between plant water requirements (Etc), the amount of effective rainfall, and irrigation water requirements in the first planting season, while Figure 5 shows the relationship between plant water requirements (Etc), the amount of effective rainfall, and irrigation water requirements in the second planting season.

Figure 4 shows that the first planting season can be carried out from February (seedlings and land preparation), planting in March and harvesting at the end of July. The water needs of plants in this planting season are always seen to be smaller than the amount of effective rainfall so that plants will not lack water during the planting season, although the water needs for land preparation (decade 3, February 1 and 2) before planting are seen to be greater. To overcome this problem, a well can be made to compensate for the lack of water during land preparation. [10] recommend the use of groundwater pumps during periods of water deficit to support sustainable cropping patterns. Selecting rice varieties with a maturity of 100–120 days is also a factor that must be considered when implementing this schedule to avoid water shortages when needed [11]. These water resources can be used to build water infrastructure to meet water needs. The type of irrigation infrastructure can be tailored to be availability of local water resources [12-13].

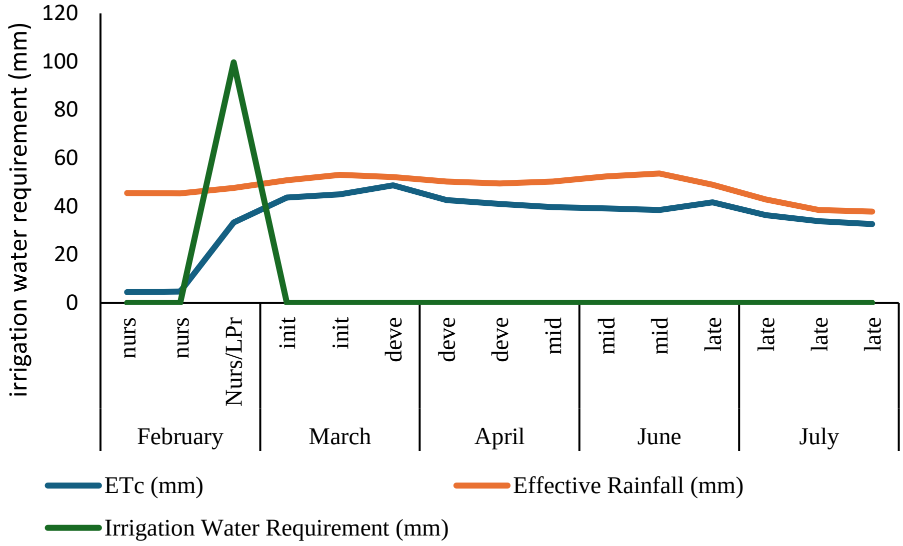


**Figure 4.** Irrigation water requirements for the first planting season (February-July)

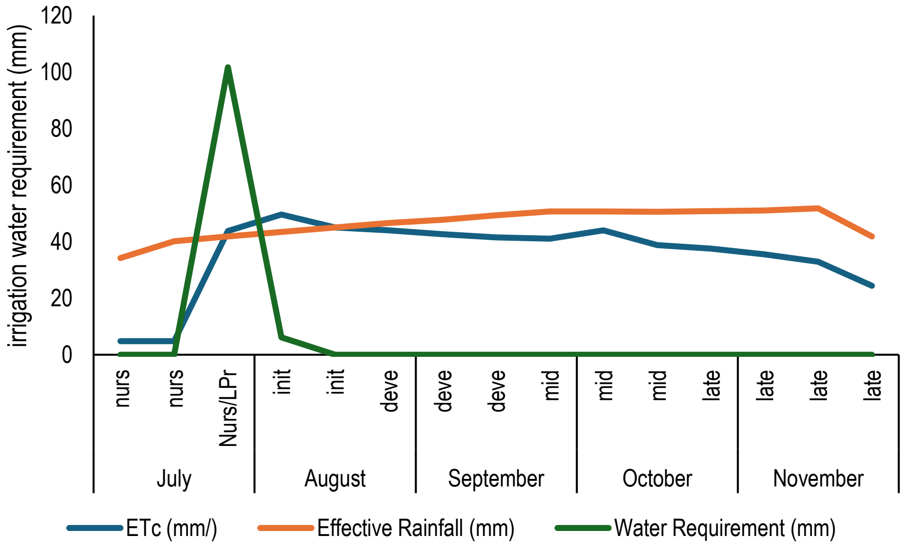


**Figure 5.** Irrigation water requirements for the second planting season (July-November)

Increasing planting from a planting index of 100 to 200 can be implemented as shown in Figure 5. Figure 5 shows a similar pattern to MT 1 Optimal (Figure 4), where irrigation requirements are very limited. In the nursery phase (July 3rd decade and August 1st decade), irrigation requirements are zero because effective rainfall (34.2 mm and 40.1 mm/decadance) is more than sufficient for the very low seedling requirements (4.8 mm/decadance). Land preparation irrigation requirements of 101.7 mm occur in July 3rd decade, while the only irrigation requirement outside of land preparation is 6.2 mm in August 1st decade (the initial phase), where ETc (49.6 mm) slightly exceeds effective rainfall (43.4 mm). After that decade, from August 2nd decade until the end of the planting season in November 3rd decade, irrigation requirements are zero, as the Second Wet Period enters, characterized by high effective rainfall (41.8–51.8 mm/decadance) that consistently exceeds ETc (24.4–45.0 mm/decadance).

The solution to problems that occur during the land preparation phase and early plant growth (July 3rd to August 1st) can be overcome by making a pump well or groundwater well that has occurred during MT 1. If the amount of water is not sufficient through the pump well, another alternative is to utilize the water pools located around the rice fields. Implementing pump-based irrigation is considered practical and cost-effective compare to constructing large irrigation infrastructure.

This opinion is in line with the statement [14-15] which states that groundwater intervention as irrigation water is assumed to be able to significantly increase agricultural productivity. According [16-17] by implementing an effective irrigation water management strategy, farmers can maximize crop yields, reduce the effects of seasonal rainfall variations, and water scarcity.

## 4. Conclusions

Based on the results of the analysis of water availability and crop water requirements in Sungai Duren Village, it can be concluded that increasing the cropping index from 100 to 200 is technically feasible. The rainfall pattern in this area follows an equatorial pattern with two rainy season peaks in November and March and a dry period from June to August. Optimization of the planting schedule using CROPWAT 8.0 simulations shows that the first planting season (MT-I) can begin from February to July, while the second planting season (MT-II) can be carried out from July to November. In both planting seasons, crop water requirements can largely be met by effective rainfall, except during the land preparation and early growth stages which require additional irrigation water. The water deficit during these critical periods can be overcome by utilizing groundwater pumps or water pools around the fields, which are considered more practical and economical compared to constructing large-scale irrigation infrastructure. The successful implementation of this double cropping system also requires the selection of short-duration rice varieties (100–120 days) and planned water management. Thus, rainfed paddy fields in Muaro Jambi have great potential to increase their productivity through proper planting pattern arrangement and supplemental irrigation support.

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