ATLANTIS PRESS
Advances in Biological Sciences Research, volume 19
Proceedings of the 2nd International Conference on Smart and Innovative Agriculture (ICoSIA 2021)

Soil Moisture Monitoring to Determine Irrigation Water Supply

Yulian Kusuma Ari Setiadi[1, *], Bayu Dwi Apri Nugroho[2] and Rizki Maftukhah[2,3]

[1]*Undergraduated student of Departement of Agricultural and Biosystem Engineering, Faculty of Agricultural Technology University of Gadjah Mada*
[2]*Departement of Agricultural and Biosystem Engineering, Faculty of Agricultural Technology University of Gadjah Mada*
[3]*Institute of Soil Research, University of Natural Resources and Life Sciences Vienna*
[*]*Corresponding author. Email: yulian.kusuma.ari@mail.ugm.ac.id*

ABSTRACT
Irrigation is important in the agricultural production system to support the growth of plants, hence it can improve the crop. Rice as a staple food in Indonesia commonly requires more water than other plants. It is not only to support the plant growth but also to support soil cultivation and to reduce weed growth. This research aimed to analyze irrigation water requirements in the rice field according to the climate factor to determine the total amount of water and times. The observation was conducted in the rice field located at Kawangu village, Pandawai District, Sumba Timur Regency, East Nusa Tenggara Province, Indonesia. The rice (IF-16 variety) was planted in the field with different planting systems: (1) one seed per hole and (2) two-three seeds per hole. Further, the researchers also used two different spacing in planting: (1) 30×30 and (2) *Jajar Legowo* 2:1. The climate data such as wind speed, rainfall, temperature, humidity, and solar radiation were taken during the rice season by using Automatic Weather Station (AWS). The data was taken according to the growth of the rice season from May to August 2021. The clean water requirement (*NFR*) of the rice in the study site was calculated in accordance with evapotranspiration (*ETc*), water layer replacement (*WLR*), percolation (*P*), and effective rainfall (*Re*). The result showed that *NFR* was different during the growth of the rice season, which the maximum value was found on June and July (10.22 and 10.08 mm/day). The *NFR* value can be used as guidance for the stakeholders in the Sumba Timur irrigation system to increase the efficiency and effectiveness of the irrigation for the rice field.

Keywords: *rice, water requirement, irrigation, climate factors, NFR*

1. INTRODUCTION

One of the basic human needs is food, in which to be able to carry out a human activity that requires a supply of energy to substitute wasted energy. The majority of the population in Indonesia consumes rice as a staple food. The rapid growth of the population has made the demand for food, especially rice, is continuously increasing. Therefore, the problem that occurs is that the increase in population may cause the increase of conversion of land functions as well.

East Nusa Tenggara has a lot of potential land for agriculture. East Nusa Tenggara is an area with a dry tropical climate where the dry season is longer than the rainy season. In this case, it surely has an impact on the availability of the existing water. In order to maximize the use of water in rice farming, several planting innovations and irrigation water were implemented. System of Rice Intensification (SRI) is a method of rice cultivation that can be used to save water. This method combines the treatment of planting space and the timing of irrigation water. System of Rice Intensification (SRI) has lower Kc Values, produced more grain due to aerobic condition under SRI method which provided optimal water and oxygen availability. Accordingly, with less irrigation water, SRI method has higher water productivity [1].

The water requirement of the rice plant in each growth phase is different. Therefore, it is necessary to monitor soil humidity levels to be able to determine the amount and timing of irrigation water. By cognizing the amount and timing of irrigation water, the use of water can be maximized to support food self-sufficiency.

2. METHODOLOGY

This research was conducted in a rice field that belongs to a farmer group in Kawangu Village, Pandawai District, Sumba Timur Regency, East Nusa Tenggara Province, Indonesia from May to August 2021. The data taken includes the climate data, namely wind speed, rainfall, temperature, humidity, and solar radiation.

2.1. Field Observation

The field observation was implemented by direct observation to the rice field that was used as a sample. The climate data was collected using Automatic Weather Station (AWS) which was installed in the rice field area while the soil sample was taken using a sample ring which was then taken for the analysis in the laboratory.

2.2. Measurement

The primary data collection was implemented to discover the value of evapotranspiration, rainfall, and irrigation water. The retrieval of the climate data was using AWS tools which are composed of several sensors, namely:

a. Cup anemometer, which has a function to measure wind speed and direction.

b. Solar radiation (PYR), which has a function to measure solar radiation.

c. VP-4, which has a function to measure humidity and air temperature.

d. Rain gauge ECRN-100, which has a function to measure rainfall.

e. 5-TE, which has a function to measure soil humidity, soil temperature, and soil electrical conductivity.

f. ZL6 data logger, which is a data storage device from a climate sensor installed in the field.

The recorded data was stored in the logger and uploaded every 10 minutes during the observation. The soil data was taken through the analysis implemented in the laboratory including texture and soil structure. These data were analyzed at the Soil Laboratory of the Faculty of Agricultural Technology, Universitas Gadjah Mada.

2.3. Data Processing

The water requirement in the field needs to be discovered to regulate the provision of water irrigation so that the water usage will be maximized. There was a difference in the requirement of water in the rice field for each phase of growth, especially for the rice plant. The calculation of the clean water requirement in the field was used the calculation formula:

a. The requirement for clean water in the field (NFR)

$$NFR = ETc + P + WLR - Re \quad (1)$$

Information:

NFR = Netto Field Water Requirement, clean water requirement in a rice field (mm/day)

Etc = Plant evapotranspiration (mm/day)

P = Percolation (mm/day)

WLR = Water layer replacement (mm/day)

Re = Effective rainfall (mm/day).

b. The requirement for irrigation water for rice

$$IR = \frac{NFR}{e} \quad (2)$$

Information:

IR = Irrigation water requirement (mm/day)

e = Overall irrigation efficiency

c. The requirement for water at the source

$$DR = \frac{IR}{8,64} \quad (3)$$

Information:

DR = The requirement for water extraction at the source (lt/s/ha)

1/8.64 = The unit conversion rate from mm/day to lt/s/ha

(Source: [3])

3. RESULT AND DISCUSSION

3.1. Consumptive Use

Consumptive use is the amount of water that the plant requires to implement photosynthesis. In the calculation, the crop coefficient is used to correlate the evapotranspiration (ETo) with the evapotranspiration of the reference plant (ETc) and is used in the utilization of the Penman formula. The coefficient used must be following the observation of various irrigation projects in the particular area. The consumptive use is used to fulfill the requirement of the plant obtained from the calculation of evapotranspiration multiplied by the crop coefficient. Consumptive use requires discovering the average amount in order to estimate the supply of irrigation water.

The value of evapotranspiration is the main source of water loss during the planting period and the value of evapotranspiration is different for each phase of plant growth [4]. Evapotranspiration is the loss of water due to evaporation that occurs on the surface of the water and through the plant. ETo is an evaporation condition according to the meteorological conditions as follows:

- Temperature

- Sunlight or radiation
- Humidity
- Wind

The evapotranspiration value was calculated through manual calculations using the modified Penman formula. The result of the evapotranspiration calculation is as follows:

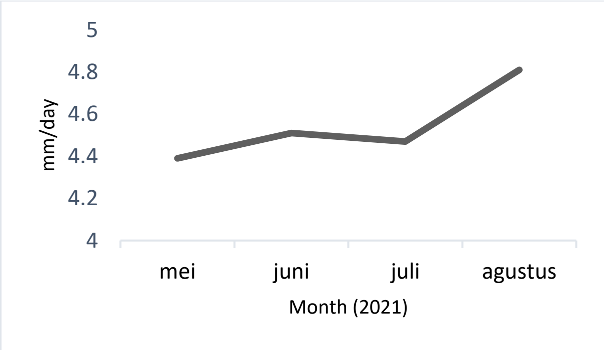

Figure 1 The Evapotranspiration Value.

The evapotranspiration value ranged from 4 to 5 mm/day. The amount of evapotranspiration can be affected by several climatic factors, such as temperature, solar radiation, humidity, and wind. The value of evapotranspiration was quite high as the result of the data collection process entered the dry season. The high temperature value during the day reached 32.3°C and the low temperature at night reached 16.2°C with an average of 25.4°C during the planting period. The average irradiation time was 11.6 hours/day with an average humidity of 72.4% and high wind speed with an average of 1.4 m/sec. The increase in the value of evapotranspiration that occurred in August was due to the increase in average temperature and low humidity.

The consumptive use of each growth phase was discovered by multiplying the evapotranspiration value and the plant coefficient value. The plant coefficient value used was in accordance with the value issued by FAO as shown in the following table.

Table 1. The Value of Rice Plant Coefficient.

Month	FAO	
	Ordinary Variety	Superior Variety
0.5	1.10	1.10
1.0	1.10	1.10
1.5	1.10	1.05
2.0	1.10	1.05
2.5	1.10	0.95
3.0	1.05	0
3.5	0.95	
4.0	0	

(Source: *KP-01*, 1986)

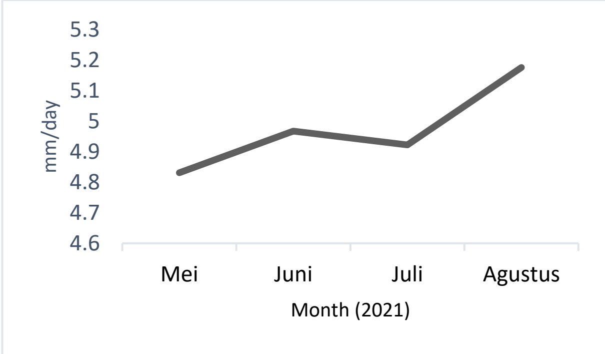

Figure 2. The Consumptive Use.

A high consumptive use at the beginning of the planting period was caused by plants that require a lot of intakes for growth in the vegetative and generative periods. However, it was slightly decreased in the middle of the growth period, and it increased again during the ripening process. The amount of consumptive use was strongly affected by the evapotranspiration that occurred.

3.2. Percolation

Percolation is the downward movement of water from the unsaturated zone, which is compressed between the soil surface to the groundwater-surface (saturated zone). Percolation power (P) is the maximum possible percolation rate, where the value of the percolation power is affected by the unsaturated condition of the soil located between the soil surface and the groundwater surface. According to the implemented sample analysis, the soil in the rice field was classified as clay soil hence it has a percolation value of 1-2 mm/day.

Table 2. Percolation Value According to the Type of Soil.

Number	Type of Soil	Percolation Value (mm/day)
1.	Clay Soil	1-2
2.	Sandy Clay Soil	2-3
3.	Sandy Soil	3-6

(Source: [2])

3.3. Water Layer Replacement

The replacement of the water layer occurred after the fertilization for soil aeration and drainage. The water layer was replaced twice, each 50 mm (or 3.3 mm/day for a month) for a month and two months after transplantation.

3.4. Effective Rainfall

Effective rainfall is the amount of rainwater that absorbs in the soil in a particular area that is used by plants as the main source in fulfilling water requirements. Effective rainfall is calculated by sorting the semi-monthly daily rainfall figures from the highest to the lowest value, after discovering the 80% probability value (R80) of the semi-monthly daily rainfall. R80 was the amount of rainfall that can be exceeded by 80% or in other words, it exceeded 8 times out of 10 events.

Effective rainfall for rice plants was 70% of the semi-monthly rainfall which was exceeded 80% of the period [2]. In this research, the amount of effective rainfall calculated can be seen in Table 3 below.

Table 3. Effective Rainfall.

Month	Effective Rainfall (mm/day)
May	0
June	0.046
July	0.135
August	1.011

The data collection process was implemented from May to August 2021, according to the table it can be seen that the value of effective rainfall was low as the result of the data was taken during the dry season.

3.5. The Calculation of Water Requirements in a Rice Field

The clean water requirement in the rice field (NFR) was calculated by considering several factors, such as evapotranspiration that occurred, percolation, replacement of water layers, and effective rainfall. According to the calculation result obtained, the value of clean water requirements in the rice field can be seen in Table 4 below.

Table 4. The Clean Water Requirement in the Rice Field.

Month	*NFR* (mm/day)
May	6.83
June	10.22
July	10.08
August	6.16

This result was in accordance with previous research which stated that the loss of clean water in the rice field ranged between 6-10 mm/day and 180-300 mm/month [7]. In June and July, there was an increase in water demand due to the replacement of the water layer by 3.3 mm/day for one and two months after the planting.

3.6. The Irrigation Water Requirements

The amount of the irrigation water requirement is as much as the volume of the water required to fulfill the needs of evaporation, water loss, water needs for plants by taking into the effective rainfall and the contribution of groundwater. The irrigation water for the rice plant includes the requirement of evapotranspiration, water loss due to percolation and seepage, and a certain amount of water for soil saturation[8]. For plants other than the rice plant, the percolation and seepage are not calculated for irrigation water requirements. The water in rice plants is used to regulate and maintain the temperature, humidity, and can affect the growth and yield of rice plants. The requirement of the irrigation water can be calculated after cognizing the need for clean water in the rice field.

Table 5. The Irrigation Water Requirement.

Month	*IR* (mm/day)	*DR* (lt/s/ha)
May	10.5	
June	15.72	
July	15.52	1.48
August	9.48	
Average	12.8	

The value of irrigation water requirements was obtained by dividing the requirement of clean water in the rice field by the irrigation efficiency so that the average irrigation water requirement was 12.80 mm/day. According to the value of this irrigation water requirement, then it was obtained that the amount of water withdrawal requirements was 1.48 lt/s/ha.

4. CONCLUSION

The present research shows that the irrigation water requirement in Kawangu Village, Pandawai District, East Sumba Regency is an average of 12.80 mm/day with the water withdrawal of 1.48 lt/sec/ha. The provision of irrigation water should be done periodically until the soil is in a muddy condition. This can be done in consideration of the high value of evapotranspiration that occurs when inundation is implemented. The use of irrigation pipes is recommended in order to minimize the water loss due to evaporation.

ACKNOWLEDGMENTS

We would like to thank the Directorate of Research at Universitas Gadjah Mada in the Final Project Recognition Research Scheme 2021 for funding this research. Also, we would like to thank the Department of Agriculture in East Sumba Regency and the landowner who helped in the process of writing the research so that this research can be finished.

REFERENCES

[1] Arif, C., Toriyama, K., Nugroho, B.D., & Mizoguchi, M. (2015). Crop Coefficient and Water Productivity in Conventional and System of Rice Intensification (SRI) Irrigation Regimes of Terrace Rice Fields in Indonesia. *Jurnal Teknologi*, 75 (17) : 97-102.

[2] Department of Public Works, *Standar Perencanaan Irigasi Kriteria Perencanaan*

Bagian Bangunan KP-01, Jakarta, Badan Penerbit Pekerjaan Umum, 1986.
[3] Directorate General of Water Resources, *Standar Perencanaan Irigasi Kriteria Perencanaan Bagian Jaringan Irigasi KP-01*, 2010.
[4] Nazeer, Muhammad, Sensitivity Analysis of Fao Penman-Monteith, Lambert Academy Publishing, 2012.
[5] Prastowo, *Irigasi Tetes, Teori dan Aplikasi*. Bogor, IPB Press, 2010.
[6] Soemarto C. D., *Hidrologi Teknik*: Usaha Nasional, Surabaya, National Business, 1987.
[7] Subagyono, K., Dariah, A., Kurnia, U., & Surmaini, E, *Pengelolaan Air pada Tanah Sawah*, 2005, DOI: http://books.google.co.id/books/about/Pengeloaan_Air_pada_Tanah_Sawah.html
[8] Winarso, *Penentuan kebutuhan air tanaman padi dan efisiensi irigasi pada musim kemarau di petak tersier percontohan 1 proyek irigasi Wonogiri Surakarta* (Skripsi), 1985, DOI: http://repository. ipb.ac.id/handle/123456789/30415.