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SUBMISSION LETTER

August 18th, 2022

Prof. Qinghua Qin
Editor-in-Chief
International Journal on Engineering Applications (IREA)

Dear Editor:

I wish to submit an original research article for publication in *International Journal on Engineering Applications (IREA)*, titled "**Optimization of Planting Patterns in South Sulawesi**" (Word count 5.637; tables 6; figures 5; references 23). The paper was coauthored by Irma Nur Afiah, Mahar Diana Hamid, Agus Lasse, Trifandy Musafir Wellang, and Muhammad Fachry Hafid.

This study investigated the water balance and recommended the optimal planting pattern using 3 simulations. We believe that this paper will be of interest to the readership of your journal because we performed a detailed investigation of the water balance and water requirement of irrigation area.

Further, this manuscript has not been published and that it has not been submitted simultaneously for publication elsewhere. We have read and understood your journal's policies, and we believe that neither the manuscript nor the study violates any of these. There are no conflicts of interest to declare.

Thank you for your consideration. I look forward to hearing from you.

Sincerely,

Dr. Ratna Musa
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Faculty of Engineering, Universitas Muslim Indonesia (UMI)
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SUBMISSION ACKNOWLEDGEMENT



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[IREA] Submission Acknowledgement

Eksternal

Kotak Masuk x



Editorial Staff <editorialstaff@praiseworthyprize.com>
kepada saya

Dr Ratna Musa:

Thank you for submitting your manuscript entitled "Optimization of Planting Patterns in South Sulawesi (A Case Study from Kiru-Kiru Irrigation Area in Barru Regency)" to our journal International Journal on Engineering Applications (IREA).

With the online journal management system that we are using, you will be able to track its progress through the editorial process by logging in to the journal web site:

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With this submission the review process starts.

According to the review procedures, your proposal will be sent to the Editor-in-Chief that, after evaluated the publication suitability of the paper, will indicate three reviewers for a full evaluation.

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If you have any questions, please don't hesitate to contact me. In all the correspondence please indicate in the subject of your e-mail the identification number of the paper that is Id 22406.

Thank you for considering this journal as a venue for your work.

Best regards,

Editorial Staff

International Journal on Engineering Applications (IREA)

FIRST DECISION FROM EDITOR



Ratna Musa <ratna.musa@umi.ac.id>

[IREA] Editor Decision

2 pesan

Editorial Staff <editorialstaff@praiseworthyprize.org>
Kepada: ratna.musa@umi.ac.id

30 Agustus 2022 21.52

Dear dr. Ratna Musa:

In order to evaluate your paper ID 22509 entitled "Optimization of Planting Patterns in South Sulawesi", it is requested the action listed below.

After that, please resubmit your paper for a second round of review.

Sincerely,
Dr. Qinghua Qin, Editor-in-Chief of International Journal on Engineering Applications (IREA)
qinghua.qin@smbu.edu.cn

Reviewer Responses:

- English grammar and style should be carefully revised. Check all the document for typos (even in tables, figures).
- At the beginning of the paper, before the Introduction section, a Nomenclature section, not numbered, should be added with a list, in alphabetic order, of all the used distinct symbols/acronyms and their meaning.
- At the end of the Introduction add a paragraph on how the rest of the paper is organized and developed, typically a summary on the rest.
- The conclusion is extremely weak. In the Conclusions, the authors should state the scope and the aims of this investigation, along with important research directions on this issue.
- You should add to the conclusions something about future evolution and enhancements of your approach.
- Please consider that in the International System of Units (IS) the time is measured in seconds and the symbol for the second is "s" not "sec" as reported in many part of the manuscript.
- Figures quality should be improved.
- The references should be extended to have a deep state of art with the newest titles (2019-to date). It is kindly suggested to the authors to visit our wide database of titles where they could search for references in this time frame, at the page
<https://www.praiseworthyprize.org/jsm/index.php?journal=index&page=search>

For any questions don't hesitate to contact us by means of the on-line submission system (Notify Editor button).

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RESPONSE LETTER FOR 1ST ROUND REVIEW

List of Changes

Manuscript:

Optimization of Planting Patterns in South Sulawesi

Response and Revision made by Author(s)

Reviewer #1:

No	Comments	Revision/Changes
1	English grammar and style should be carefully revised. Check all the document for typos (even in tables, figures).	Thank you for your comment. We have revised our manuscript including revised typos, grammar, and style.
2	At the beginning of the paper, before the Introduction section, a Nomenclature section, not numbered, should be added with a list, in alphabetic order, of all the used distinct symbols/acronyms and their meaning.	Thank you for your suggestion. We added a Nomenclature section at the beginning of our manuscript.
3	At the end of the Introduction add a paragraph on how the rest of the paper is organized and developed, typically a summary on the rest.	Thank you for your suggestion. We added a paragraph at the end of Introduction, as follows: <i>"The objectives of this study were to analyze the water balance and to identify the optimal planting pattern in Kuru-Kuru Irrigation Area, South Sulawesi. The article is divided into six sections: the first is the current introduction; the second refers to describing its methodology regarding water availability and irrigation water requirement; the third concerns the result and analysis of evapotranspiration, regional, rainfall, mainstay rainfall, effective rainfall, water availability analysis, irrigation water requirement, and water balance; conclusions and recommendations are presented in the last section."</i>
4	The conclusion is extremely weak. In the Conclusions, the authors should state the scope and the aims of this investigation, along with important research directions on this issue.	Thank you for your comments. We have revised the conclusion part.
5	You should add to the conclusions something about future evolution and enhancements of your approach.	Thank you for your comments. We have revised the conclusion part.
6	Please consider that in the International System of Units (IS) the time is measured in seconds and the symbol for the second is "s" not "sec" as reported in many parts of the manuscript.	Thank you for this correction. We have revised according to International System of Units (IS), from "sec" to "s".
7	Figures quality should be improved.	We changed Figure 1 and Figure 3, we hope it could be more clear.

8	The references should be extended to have a deep state of art with the newest title (2019-to date). It is kindly suggested to the authors to visit our wide database of titles where they could search for references in this time frame.	Thank you for your suggestion. We have added some new references from the database to have a deep state of the art of our manuscript.
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1ST SUBMISSION OF REVISED MANUSCRIPT

Optimization of Planting Patterns in South Sulawesi

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Abstract – South Sulawesi is one of nine provinces in Indonesia that has the highest contribution to the national income and its leading sector in agricultural crops including rice. The planning of planting patterns is highly dependent on the size of the intensity of rainfall in a particular area. Therefore, these conditions can have an impact on the level of suitability of crops to be planted. The purpose of this present study was to analyze the water balance and identify the optimal planting pattern. On the basis of rainfall data obtained from 4 rainfall stations, which are Mangkoso station, Manuba station, Mareppang station, and Ralla station, during the period of 25 years (1996 – 2020), then the analysis to determine the average semi-monthly rainfall can be carried out. The results show that the maximum value of irrigation water requirements for rice-rice-palawija planting pattern obtained for simulation 1 occurred on 1 September by 1.66 m³/s, while the minimum value occurred on 1 January, 2 May, and 2 December by 0.23 m³/s. As the conclusion, the maximum value in simulation 3 occurred on 2 October by 1.65 m³/s, while the minimum value occurred on 1 February and 1 June by 0.23 m³/s. The optimization results show that the most optimal cropping pattern is planting 100% of rice in the first and second planting seasons with an area of 717 Ha and 71% planted with palawija in the third planting season of 509.68 Ha. **Copyright © 2013 Praise Worthy Prize S.r.l. - All rights reserved.**

Keywords: Evapotranspiration, Water Availability, Mainstay Debit, Water Demand Irrigation, Water Balance.

Nomenclature

BF	Base flow (m ³ /s/km ²)	IR	Irrigation water requirement (mm/day)
c	Penman correction figure which includes the difference of values between day and night weather conditions	k _c	Crop coefficient
DR	Water withdrawal requirement at the water source (l/s/ha)	M	Water requirement to replace water loss due to evaporation and percolation in saturated rice fields (mm/day)
DRO	Direct run off (m ³ /s/km ²)	m	Data rating
e	Nafier coefficient (2.71828182846)	n	Number of data
ea	Saturated vapor pressure (mbar)	n	Number of rain gauge stations
ed	Actual vapor pressure (mbar)	NFR	Net Field Water Requirement; the need for clean water in the fields (mm/day)
ef	Overall irrigation efficiency	P	Percolation (mm/day)
ET _c	Plant evaporation (mm/day)	Q	Mainstay debit (m ³ /s)
ET _c	Consumptive water requirement (mm/day)	Q80	Mainstay debit with a possibility of not meeting 20% (l/s)
E ₀	Evaporation of open water (mm/day)	Re	Effective rainfall (mm/day)
ET ₀	Potential Evapotranspiration (mm/day)	R _s	Shortwave radiation in evaporation units (mm/day)
ET*	Actual evapotranspiration (mm/day)	Re _{rice}	Effective rainfall for rice plant (mm/day)
F	Catchment area (km ²)	Re _{palawija}	Effective rainfall for palawija plant (mm/day)
f(u)	Function of wind speed at the height of 2 m in units (m/s)	R _{n1}	longwave net radiation (mm/day)
IR	Water requirement in paddy field (mm/day)		

$\bar{R}$	Average region rainfall (mm)
$R_1, R_2 \dots R_n$	Rainfall at station n (mm)
R_{80}	Mainstay rainfall with a possibility of not meeting 20% (l/s)
w	Factor related to temperature (T) and elevation of the area. For areas of Indonesia with an elevation of 0-500 m
S	Water requirement for saturation added by water layer
T	Time period for land preparation
WLR	Water layer replacement (mm/day)
1/8.64	Unit conversion rate from mm/day to l/s/ha

I. Introduction

Irrigated agriculture is a vital resource in many parts of the world. This is driven or limited both by the availability of water and by the capital investment in irrigation related infrastructure including dams and largescale canals and, to a lesser extent, sprinkler system or field-based drip irrigation system [3]. Sustainable water management at the farm level has enormous relevance, i.e., in terms of implementing an adequate irrigation schedule, which should lead to optimal yields and agriculture as well as irrigation [5] [25].

South Sulawesi is one of nine provinces in Indonesia that has the highest contribution to the national income and its leading sector in agricultural crops including rice. One of the areas in South Sulawesi which is popular known as rice center region is Barru Regency. Barru Regency has several irrigation areas, one of which is Kiru-Kiru irrigation area and has potential area of 717 Ha and functional area of 628 Ha [1] which includes 2 urban villages and 3 villages, i.e., Kiru-kiru Village, Mangkoso Village, Siddo Village, Ajakkang Village and Lawallu Village. Based on data from the Central Bureau of Statistic [2], it is noticed that the annual rainfall is 3,975.9 mm/year. In this area, the rainy season lasts from October to April, while the dry season lasts from April September. As a consequence, the people in Soppeng Riaja District mostly work as farmers.

There are three sources of water loss which are evaporation from soil surface, water and plant surfaces that do not contribute to evapotranspiration of cultivated plants, and drainage loss (runoff) [4]. The growing season, also called the frost-free season, is the period of year in which the most favorable growing conditions for native vegetation and cultivated plants take place. It is a period in one year that is categorized as rainy season, the length of which varies according to space, time, and type of plant [6]. The availability of ground water will determine plant growth and yield directly because lack of water causes a decrease in the rate of photosynthesis and disturbance of assimilate distribution, and has negative impacts on plant growth in both the vegetative and generative phases [7].

The amount of water available and the amount of water needed will fluctuate from time to time. As a consequence, in one period there can be an excess of water and in another period, there is a shortage of water for plants [8]. One way to determine fluctuations in water availability from month to month is by utilizing water between the amount of rainwater input and the ability of soil water. One way to determine fluctuations in water availability from month to month is by utilizing water between the amount of rainwater input and the ability of soil to be evapotranspiration [9].

Water balance is useful for completing a general description of the state of water in an area (precipitation, evapotranspiration, water content, and changes in soil moisture), assessing the ability of an area to be planted by estimating the water requirement for plants, and testing the relationship of climate or weather with crop production [10]. The availability of water is very influential on the planting pattern of an area [11]. The planting pattern of agricultural land can be optimized according to the availability of water in the area. A planting pattern is a planting system that is utilized on an area of land which includes the method and types of plants as well as the planting schedule during a certain period of time [12].

Utomo [13] mentioned that planting patterns are designed to determine the time when plants can efficiently utilize the available water. Planting pattern includes the selection of plants the water requirement of which are in accordance with the distribution of rainfall, and crop rotation that is able to utilize rainfall efficiently. If the rainy season is short, the selected plants that are the short-lived ones. On the other hand, if the rainy season is long enough, the selected plants are long-lived, or two plants are selected where the second is taken because it is drought tolerant [13].

Furthermore, according to Unganji et al. [14], the diversity of land characteristics can affect plant growth and development, so they also affect the production of the plant itself. Plants that grow in suitable climatic and land conditions can yield optimally. On the other hand, plants that grow in unsuitable climatic conditions and land will be impacted on the decreasing production. Dwiratna et al. [15] declared that farmers usually apply planting patterns and schedules based on conventional habits which are often carried out during the same climatic conditions every year. However, global climate change can have an impact on the non-enforcement of these habits. Planting failure and crop failure are common problems experienced by farmers because of variations in rainfall that are not fixed every year, making it difficult to determine plants that are in accordance with the conditions of groundwater availability, especially since the water requirement of each type of plant is different.

Moreover, setting a planting pattern is an agricultural effort carried out in order to obtain maximum agricultural products and minimize the risk of crop failure by considering climatic and land conditions. The planning of planting patterns is highly dependent on the size of the intensity of rainfall in a particular area. Therefore, these

conditions can have an impact on the level of suitability of crops to be planted. Planning a planting pattern on the basis of the intensity of rainfall in accordance with the needs of the plant can result in better production.

Additionally, research about planting pattern has been conducted by several previous studies [16] [17]. These studies identified the potential planting seasons on irrigated or non-irrigated areas and involved water balance value to show the water deficit. Despite growing agreement regarding the existence of potential planting season, there is a lack of understanding regarding the necessity of irrigation water balance analysis and optimal planting pattern system using simulations and mainstay debit as its constrain.

The objectives of this study were to analyze the water balance and to identify the optimal planting pattern in Kiru-Kiru Irrigation Area, South Sulawesi. The article is divided into six sections: the first is the current introduction; the second refers to describing its methodology regarding water availability and irrigation water requirement; the third concerns the result and analysis of evapotranspiration, regional, rainfall, mainstay rainfall, effective rainfall, water availability analysis, irrigation water requirement, and water balance; conclusions and recommendations are presented in the last section.

II. Method

This research data was carried out from Kiru-Kiru Irrigation Area and located on the west coast of South Sulawesi Province between the coordinates of 4°05'49"-4°47'35" south latitude and 119°35'00"-119°49'16" east longitude covering an area of 1,174.72 km².

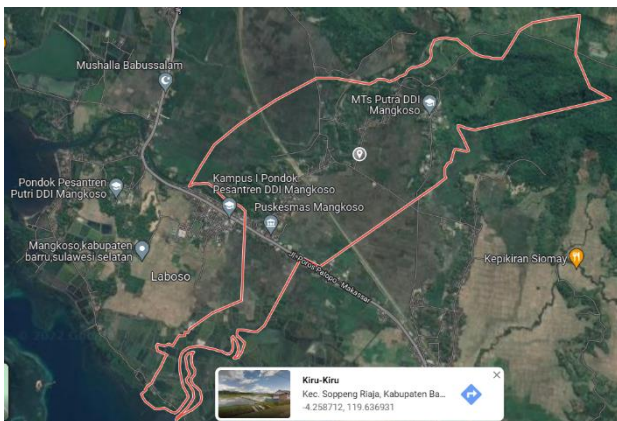


Figure 1. Research Site Map

II.1. Water Availability

a. Potential Evapotranspiration

The use of Modified Penman equation is recommended as a standard for reference evapotranspiration to provide values that are more consistent with the actual plant water use data worldwide [18]. The equation is described as follows:

$$ET_0 = c \times ET^* \quad (1)$$

$$ET^* = w (0.75 R_s - R_{n1}) + (1 - w)f(u)(e_a - e_d) \quad (2)$$

b. Regional Rainfall

The value of regional rainfall can be determined from several rainfall data in rain gauge stations by employing the average value of rainfall for stations located within the watershed and stations outside the watershed that are still close together which can be calculated as follows:

$$\bar{R} = \frac{1}{n} (R_1 + R_2 + \dots + R_n) \quad (3)$$

c. Mock's Method

Mock's method shows water balance analysis to calculate monthly debit values based on the transformation of monthly rainfall data, evapotranspiration, soil moisture, and groundwater reservoirs. The principle of this method states that the rain that falls on water catchment areas will partly be lost due to evapotranspiration [19].

The water balance using the F. J. Mock method is formulated as follows:

$$Q = (DRO + BF) F \quad (4)$$

d. Mainstay Debit

Mainstay debit is calculated using the Weibull method with an 80% chance of occurrence [20]. The semi-monthly debit data are sorted from the largest to the smallest data. Then, the probability of each data is calculated based on the data ranking using equation 5 below:

$$Q_{80} = \frac{m}{n+1} \times 100\% \quad (5)$$

II.2. Irrigation Water Requirement

The irrigation water requirement for rice is different from the irrigation water requirement for secondary crops (*palawija*). The field water requirement for rice is calculated using equation (6), while the irrigation water requirement is calculated using equation (7). The formula for calculating irrigation water requirement for secondary crops (*palawija*) can be observed in equation (8) [21]:

$$NFR = ET_c + P + WLR - Re \quad (6)$$

$$IR = \frac{NFR}{ef} \quad (7)$$

$$IR = \frac{(ET_c - Re)}{ef} \quad (8)$$

$$DR = \frac{IR}{8.64} \quad (9)$$

a. Effective Rainfall

The effective rainfall for rice and secondary crops (*palawija*) is calculated differently. The effective rainfall for rice is 70% of the average mid-month rainfall with a possibility of not meeting 20% (R_{80}). This rainfall with a possibility of not meeting 20% is calculated using the Weibull method as follow:

$$R_{80} = \frac{m}{n+1} \times 100\% \quad (10)$$

$$Re_{rice} = 0.7 \times R_{80} \quad (11)$$

$$Re_{palawija} = 0.7 \times R_{50} \quad (12)$$

b. Water Requirement for Land Cultivation

The calculation of water requirements during land cultivation used this following equation [2]:

$$IR = \frac{Me^k}{(E^k - 1)} \quad (13)$$

$$M = E_0 + P \quad (14)$$

$$E_0 = 1.1 \times ET_0 \quad (15)$$

$$K = M \times \left(\frac{T}{S}\right) \quad (16)$$

c. Water Requirement to Replace the Water Layer (Water Layer Requirement)

The water requirement to replace the water layer *Water Layer Requirement* (WLR) is determined based on the 2013 Indonesia Irrigation Planning Standard. The amount of water required for water layer replacement is 50 mm/month (or 3.3 mm/day for 1/2 months) for one month and two months after transplantation.

d. Consumptive Water Requirement

Consumptive water requirement is the water requirements for plants on the farm. Plant evapotranspiration (ET_c) is the actual evapotranspiration, which is very different from ET_0 , as a ground cover. The nature of plant canopy and the aerodynamic resistance of plant is different from that of grass [22]. After the reference plant evapotranspiration (ET_0) is obtained, the plant evapotranspiration can be estimated by the following equation [23] [24]:

$$ET_c = k_c \times ET_0 \quad (17)$$

e. Percolation (p) and Seepage

The percolation rate is highly dependent on the nature of the soil, and the nature of the soil generally depends on the activities of land use or cultivation. The percolation rate ranges from 1-3 mm/day.

f. Irrigation Efficiency (EI)

To account for water loss during transportation and application to the field, the efficiency factor was utilized in the calculation of irrigation water requirements [23]. This loss occurs as the result of exploitation, evaporation and seepage activities. In general, water loss in irrigation networks can be divided as the following [2]: 12.5-20% in the tertiary plots between tertiary tapping buildings and rice fields; 5-10% in the secondary channel; and 5-10% in the main channel.

II.3 Water Balance

Water balance is a way of analyzing the balance equation of water based on the law of conservation of mass which states that a substance cannot be created or destroyed, but a substance can change its form [18]. Water balance is an explanation of the relationship between inflow and outflow in a watershed for a certain period of water circulation process. As a consequence, it is possible to identify the excess (surplus) or shortage (deficit) on the amount of water.

III. Result and Analysis

III.1 Evapotranspiration

The evapotranspiration was analyzed using the FAO Modified Penman method. The calculation of the amount of evapotranspiration requires climatological data, such as: temperature, humidity, wind speed, and duration of sunlight. In this study, the climatological station employed was Tabo-Tabo Station, Pangkep Regency. The result of Evapotranspiration calculation could observe in Table 1.

TABLE 1
EVAPOTRANSPIRATION AT KIRU-KIRU IRRIGATION AREA (mm/day)

ET ₀	Jan	Feb	Mar	Apr	May	Jun
mm/day	3.39	3.65	4.00	3.23	3.48	2.72
ET ₀	Jul	Aug	Sept	Oct	Nov	Dec
mm/day	3.67	4.38	5.51	5.48	4.68	3.50

Based on table 1, the Evapotranspiration results show that the Maximum Evapotranspiration at Kiru-Kiru Irrigation Area occurred in October by 5.48 mm/day, while the Minimum evapotranspiration occurred in June by 2.72 mm/day.

III.2 Regional Rainfall

On the basis of rainfall data obtained from 4 rainfall

stations, which are Mangkoso station, Manuba station, Mareppang station, and Ralla station, during the period of 25 years (1996 – 2020), then the analysis to determine the average semi-monthly rainfall can be carried out. It can be observed that the maximum average rainfall in the Kiru-Kiru irrigation area occurred on 2 September by 13.65 mm/day while the minimum rainfall occurred on 2 August by 5.23 mm (Figure 2).

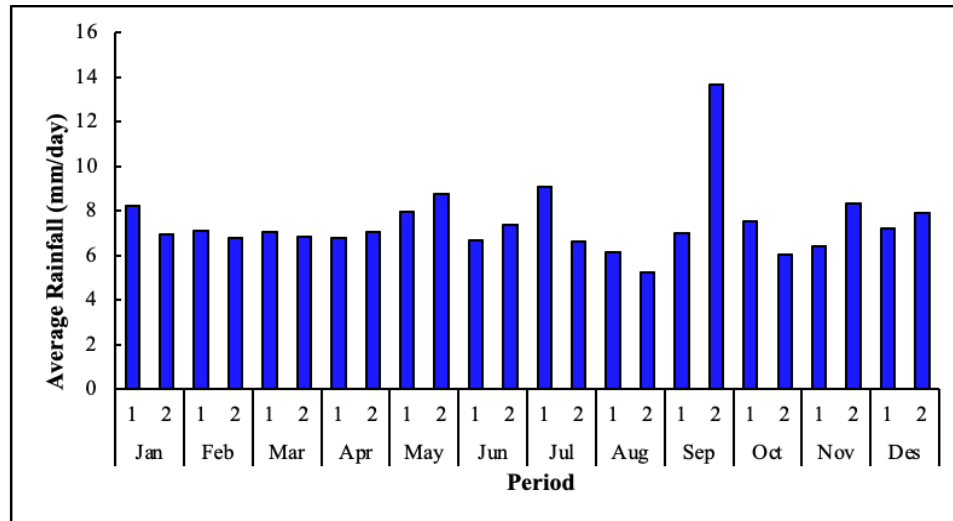


Fig. 2. Average Rainfall of Kuru-Kuru Irrigation Area in 1996-2020

III.3 Mainstay Rainfall

The mainstay rainfall for rice plants is set at 80% (R_{80}), while for secondary crops (*palawija*), it is set at 50% (R_{50}). The results of the mainstay rainfall calculations shows that rainfall with maximum reliability of 80% (R_{80}) occurred

on 1 January by 4.75 mm and the minimum one occurred on 1 September by 0 mm. Meanwhile, for the rainfall with maximum reliability of 50% (R_{50}), it occurred on 2 December by 7.75 mm and the minimum one occurred on 1 August and 1 September by 4.00 mm (Table 2).

TABLE 2
MAINSTAY RAINFALL FOR RICE AND SECONDARY CROPS (*Palawija*)

CH Mainstay (mm)	Jan		Feb		Mar		April		May		Jun	
	1	2	1	2	1	2	1	2	1	2	1	2
R_{80}	4.75	3.50	4.50	3.00	4.00	3.75	3.25	3.33	3.50	3.33	3.67	2.50
R_{50}	6.75	5.00	7.50	6.00	5.50	6.75	4.75	5.50	5.67	5.25	4.75	5.00
CH Mainstay (mm)	July		Aug		Sep		Oct		Nov		Dec	
	1	2	1	2	1	2	1	2	1	2	1	2
R_{80}	3.00	2.00	1.00	1.00	0.00	2.75	4.00	2.50	3.75	4.75	3.75	4.00
R_{50}	6.67	5.00	4.00	5.50	4.00	7.33	5.75	5.67	6.00	6.00	5.00	7.75

III.4 Effective Rainfall

In the calculation of the effective rainfall for rice, the result was 70% of R_{80} of the time in a period, while for the effective rainfall of secondary crops (*palawija*), it was 50% of R_{50} . The effective rainfall for paddy maximumly

occurred on 1 January and 2 November by 0.22 mm/day and the minimum value occurs on 1 September by 0 mm/day. Meanwhile, the effective rainfall for secondary crops (*palawija*) maximumly happened on 2 December by 0.26 mm/day and the minimum value occurred on 1 February and 1 March by 0.13 mm/day (Table 3).

TABLE 3
EFFECTIVE RAINFALL FOR RICE AND SECONDARY CROPS (*Palawija*)

Effective CH (mm/day)	Jan		Feb		Mar		April		May		Jun	
	1	2	1	2	1	2	1	2	1	2	1	2
Re Rice	0.22	0.16	0.21	0.14	0.19	0.18	0.15	0.16	0.16	0.16	0.17	0.12
Re Palawija	0.23	0.17	0.25	0.20	0.18	0.23	0.16	0.18	0.19	0.18	0.16	0.17
Effective CH (mm/day)	Jul		Aug		Sept		Oct		Nov		Des	
	1	2	1	2	1	2	1	2	1	2	1	2
Re Rice	0.14	0.09	0.05	0.05	0.00	0.13	0.19	0.12	0.18	0.22	0.18	0.19
Re Palawija	0.22	0.17	0.13	0.18	0.13	0.24	0.19	0.19	0.20	0.20	0.17	0.26

III.5 Water Availability Analysis and Mainstay Debit

To determine the value of water availability in Kuru-Kuru irrigation area, this study utilized the calculation result of the water debit in Kuru-Kuru watershed using Mock

Method. Water availability was calculated by determining the mainstay debit from the debit data (1996-2020) and processed the results into monthly data. The debit data was sorted from the largest to the smallest data. After that, the

probability of each data was calculated in accordance with the data rank. The 80% mainstay debit (Q_{80}) was maximumly occurred in December with a debit of 5.85

m^3/s , while the minimum debit occurred in July, August and October with a debit of $1.03 m^3/s$ (Table 4).

TABLE 4
MAINSTAY DEBIT WITH 80% PROBABILITY

Mainstay Debit (m^3/s)	Month											
	Jan	Feb	Mar	April	May	Jun	Jul	Aug	Sep	Oct	Nov	Des
Q_{80}	5.48	3.41	1.38	2.34	1.14	1.08	1.03	1.03	1.06	1.03	1.38	5.85

III.6 Irrigation Water Requirement

The results of irrigation water requirement analysis for Rice–Rice–*Palawija* planting pattern could be observed in Figure 3. The results show that the maximum value of irrigation water requirements for Rice–Rice–*Palawija* planting pattern obtained for simulation 1 occurred on 1 September by $1.66 m^3/s$, while the minimum value

occurred on 1 January, 2 May, and 2 December by $0.23 m^3/s$.

Additionally, the maximum value in simulation 2 occurred on 2 September by $1.65 m^3/s$, while the minimum value occurred on 1 January and 1 July by $0.23 m^3/s$. Finally, the maximum value in simulation 3 happened on 2 October by $1.64 m^3/s$, while the minimum value occurred on 1 February and 1 June by $0.23 m^3/s$.

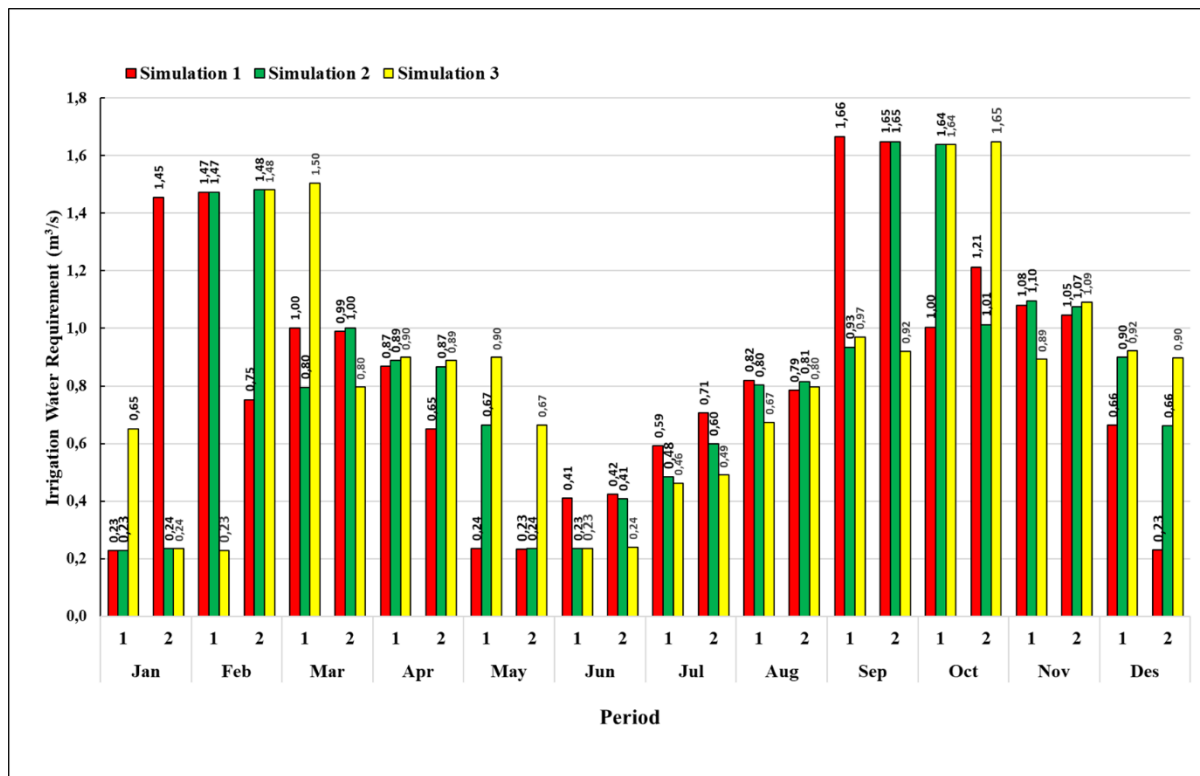


Fig. 3. Water Requirements of Kiru-Kiru Irrigation Area

III.7 Water Balance

Water balance is balance between the water coming in and coming out of a system. The results (Figure 4 and Table 5) show that the water balance for the Rice–Rice–*Palawija* planting pattern combination in the 1st simulation during the rainy season (1 September – 2 January) experienced a maximum surplus (S) of $5.62 m^3/s$ and a deficit (D) of $0.60 m^3/s$, while that during the dry season (1 February – 2 August) experienced a maximum surplus of $2.66 m^3/s$ and a minimum value or deficit of $0.21 m^3/s$. Meanwhile, for the 2nd simulation during the

rainy season (2 September – 1 February), it experienced a maximum surplus of $5.26 m^3/s$ and a deficit of $0.58 m^3/s$, while during the dry season (2 February – 1 October), it experienced a maximum surplus of $1.93 m^3/s$ and a deficit of $0.61 m^3/s$.

Then, in the 3rd simulation during the rainy season (1 October – 2 February), there was a maximum surplus of $5.25 m^3/s$ and it experienced a deficit of $0.62 m^3/s$, while during the dry season (1 March – 2 August), it experienced a maximum surplus of $1.45 m^3/s$ and a deficit of $0.13 m^3/s$.

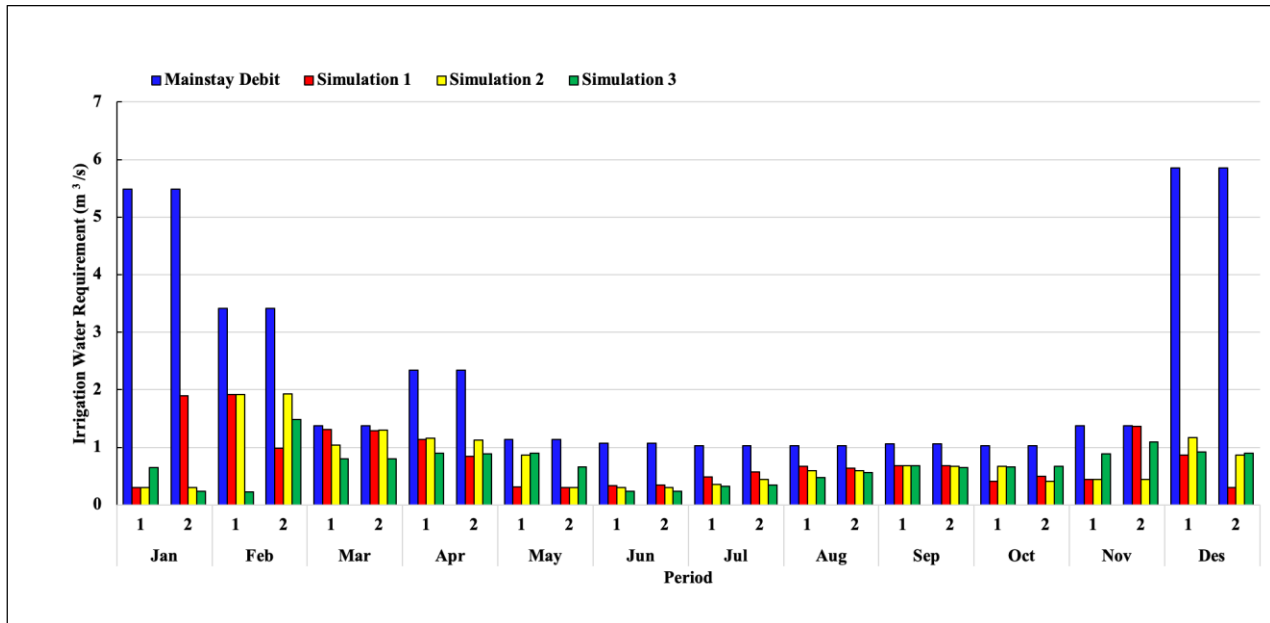


Fig. 4. Water Balance of Kiru-Kiru Irrigation Area

TABLE 5
WATER BALANCE OF KIRU-KIRU IRRIGATION AREA

Description	Month	Jan		Feb		Mar		Apr		May		Jun	
		1	2	1	2	1	2	1	2	1	2	1	2
1 st Simulation	Mainstay Debit (m ³ /s)	5.48	5.48	3.41	3.41	1.38	1.38	2.34	2.34	1.14	1.14	1.08	1.08
	Irrigation Water Requirement (m ³ /s)	0.23	1.45	1.47	0.75	1.00	0.99	0.87	0.65	0.24	0.23	0.41	0.42
	Water Balance	5.26	4.03	1.94	2.66	0.38	0.39	1.47	1.69	0.91	0.91	0.67	0.65
	Surplus/Defisit	S	S	S	S	S	S	S	S	S	S	S	S
	Month	Jul		Aug		Sep		Oct		Nov		Des	
		1	2	1	2	1	2	1	2	1	2	1	2
	Mainstay Debit (m ³ /s)	1.03	1.03	1.03	1.03	1.06	1.06	1.03	1.03	1.38	1.38	5.85	5.85
	Irrigation Water Requirement (m ³ /s)	0.59	0.71	0.82	0.79	1.66	1.65	1.00	1.21	1.08	1.05	0.66	0.23
	Water Balance	0.44	0.32	0.21	0.24	-0.60	-0.58	0.03	-0.18	0.30	0.33	5.19	5.62
	Surplus/Defisit	S	S	S	S	D	D	S	D	S	S	S	S
2 nd Simulation	Month	Jan		Feb		Mar		Apr		May		Jun	
		1	2	1	2	1	2	1	2	1	2	1	2
	Mainstay Debit (m ³ /s)	5.48	5.48	3.41	3.41	1.38	1.38	2.34	2.34	1.14	1.14	1.08	1.08
	Irrigation Water Requirement (m ³ /s)	0.23	0.24	1.47	1.48	0.80	1.00	0.89	0.87	0.67	0.24	0.23	0.41
	Water Balance	5.26	5.25	1.94	1.93	0.58	0.38	1.45	1.47	0.48	0.91	0.84	0.67
	Surplus/Defisit	S	S	S	S	S	S	S	S	S	S	S	S
	Month	Jul		Aug		Sep		Oct		Nov		Des	
		1	2	1	2	1	2	1	2	1	2	1	2
	Mainstay Debit (m ³ /s)	1.03	1.03	1.03	1.03	1.06	1.06	1.03	1.03	1.38	1.38	5.85	5.85
	Irrigation Water Requirement (m ³ /s)	0.48	0.60	0.80	0.81	0.93	1.65	1.64	1.01	1.10	1.07	0.90	0.66
	Water Balance	0.55	0.43	0.23	0.22	0.13	-0.58	-0.61	0.02	0.28	0.30	4.95	5.19
	Surplus/Defisit	S	S	S	S	S	D	D	S	S	S	S	S
3 rd Simulation	Month	Jan		Feb		Mar		Apr		May		Jun	
		1	2	1	2	1	2	1	2	1	2	1	2
	Mainstay Debit (m ³ /s)	5.48	5.48	3.41	3.41	1.38	1.38	2.34	2.34	1.14	1.14	1.08	1.08
	Irrigation Water Requirement (m ³ /s)	0.65	0.24	0.23	1.48	1.50	0.80	0.90	0.89	0.90	0.67	0.23	0.24
	Water Balance	4.83	5.25	3.19	1.93	-0.13	0.58	1.44	1.45	0.24	0.48	0.84	0.84
	Surplus/Defisit	S	S	S	S	D	S	S	S	S	S	S	S
	Month	Jul		Aug		Sep		Oct		Nov		Des	
		1	2	1	2	1	2	1	2	1	2	1	2
	Mainstay Debit (m ³ /s)	1.03	1.03	1.03	1.03	1.06	1.06	1.03	1.03	1.38	1.38	5.85	5.85
	Irrigation Water Requirement (m ³ /s)	0.46	0.49	0.67	0.80	0.97	0.92	1.64	1.65	0.89	1.09	0.92	0.90
	Water Balance	0.57	0.54	0.36	0.23	0.09	0.14	-0.61	-0.62	0.48	0.29	4.93	4.95
	Surplus/Defisit	S	S	S	S	S	S	D	D	S	S	S	S

On the basis of figure 4 and table 5 above, the results show that the water balance for the Rice-Rice-Palawija planting pattern in 1st simulation during the rainy season (1 September – 2 January) experienced a maximum surplus of 5.62 m³/s and a deficit of 0.60 m³/s, while that during the dry season (1 February – 2 August) experienced a maximum surplus of 2.66 m³/s and a minimum value of 0.21 m³/s. Meanwhile, in the 2nd simulation during the rainy season (2 September – 1 February), it experienced a maximum surplus of 5.26 m³/s and a deficit of 0.58 m³/s, while during the dry season (2 February – 1 October), it experienced a maximum surplus of 1.93 m³/s and a deficit of 0.61 m³/s.

While for the 3rd simulation during the rainy season (1 October – 2 February), there was a maximum surplus of 5.25 m³/s and it experienced a deficit of 0.62 m³/s, while during the dry season (1 March – 2 August), it experienced

a maximum surplus of 1.45 m³/s and a deficit of 0.13 m³/s. In accordance with the results of water balance in Kiru-Kiru irrigation area, it could be identified that Kiru-Kiru irrigation area experienced water deficit in several months. Furthermore, in this study, simulation selection is influenced by several factors, such as; water requirements, land preparation, water layer replacement, percolation, planting factors, and climate factors. The simulation that is close to the field conditions is simulation 3, which results in a water demand of 2.30 l/s/ha and a significant land area of 716 Ha with an existing potential land area of 717 ha.

As one of the efforts made in order that the irrigation water requirements could be fulfilled, then it necessitated an adjustment on the irrigation area to be developed by decreasing the irrigation area in the Irrigation Area in question as displayed in table 7 and figure 5 below.

TABLE 6
WATER BALANCE OF KIRU-KIRU IRRIGATION AREA AFTER OPTIMIZATION

Month	Period	Planting Period	Water Availability (l/s)	Water Irrigation Requirement (l/s/ha)		Area (Ha)	
				Rice	Palawija	Rice	Palawija
Jan	1	I	5483.89	4.96		717.00	
	2	I	5483.89	4.96		717.00	
Feb	1		3414.59	0.32		6920.69	
	2	II	3414.59	3.09		717.00	
Mar	1	II	1378.52	1.25		717.00	
	2	II	1378.52	1.25		717.00	
Apr	1	II	2336.72	2.11		717.00	
	2	II	2336.72	2.11		717.00	
May	1	II	1141.13	1.03		717.00	
	2	II	1141.13	1.03		717.00	
Jun	1	II	1076.03	0.97		717.00	
	2		1076.03		0.34		2076.50
Jul	1	III	1031.30		0.65		1035.00
	2	III	1031.30		0.68		976.86
Aug	1	III	1029.57		0.94		709.52
	2	III	1029.57		1.11		600.34
Sep	1	III	1063.89		1.35		509.68
	2	III	1063.89		0.96		717.00
Oct	1	I	1029.57	0.93		717.00	
	2	I	1029.57	0.93		717.00	
Nov	1	I	1377.09	1.24		717.00	
	2	I	1377.09	1.24		717.00	
Dec	1	I	5849.71	5.29		717.00	
	2	I	5849.71	5.29		717.00	

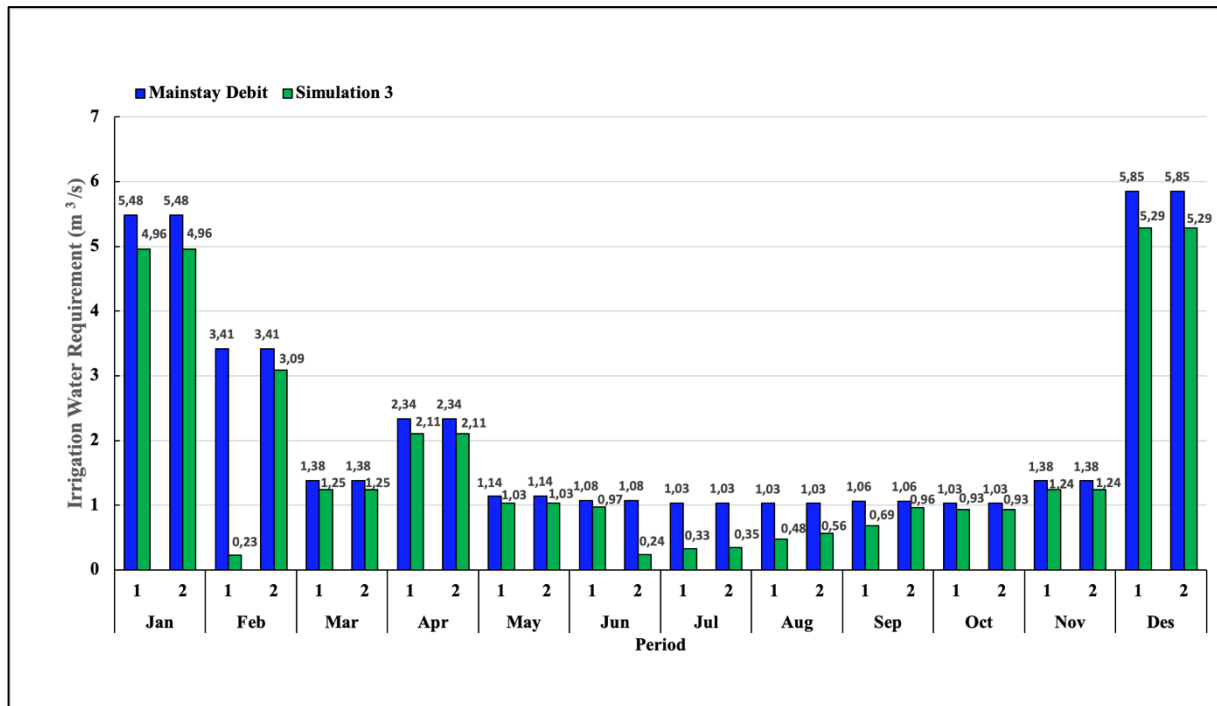


Fig. 5. Water Balance of Kiru-Kiru Irrigation Area After Optimization

Moreover, table 6 and Figure 4 showed that there are 3 planting seasons recommendation, namely; first planting season (I) is on 1st October to 2nd January and second planting season (II) is on 2nd February to 1st June. These planting seasons could reach its optimal planting patterns with 100% of rice or 717 Ha planted with rice. Finally, the last planting season (III) is on 1st July to 2nd September with optimal cropping pattern is *palawija* at 509.68 Ha.

IV. CONCLUSION

In this study, we analyzed the evapotranspiration and developed 3 simulation of irrigation water requirement. Using water balance consideration, this study simulated 3 recommendation planting patterns based on the maximum surplus and minimum value of water. Importantly, this study considered several necessary factors, namely; water requirements, land preparation, water layer replacement, percolation, planting factors, and climate factors.

The significance value among 3 simulations were found at the 3rd simulation as the optimal planting pattern. Irrigation water balance in Kiru-Kiru irrigation area on the existing condition (3rd simulation) experienced a deficit on 1 October, 2 October, and 1 March. The effort made in order to resolve water shortage problem is to carry out planting pattern optimization. Our result suggested that the most optimal cropping pattern is planting 100% of rice in the first and second planting seasons with an area of 717 Ha and 71% planted with *palawija* in the third planting season of 509.68 Ha.

Therefore, in future investigation, to provide more credible information to this field and to support the Indonesia Government programs, it would be interesting

to compare other irrigation area in Barru Regency with continual production of additional data.

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SECOND DECISION OF EDITOR



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[IREA] Editor Decision

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- Please place your figures/tables/equations objects with "inline wrapping" text style, as depicted in the template of the journal.

- The effectiveness of the discussion of the results should be improved.

- In Figs. 2-5, it should "Dec.", not "Des."

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RESPONSE LETTER FOR 2ND ROUND REVIEW

List of Changes

Manuscript:

Optimization of Planting Patterns in South Sulawesi

Response and Revision made by Author(s)

Reviewer #1:

No	Comments	Revision/Changes
1	English is comprehensible but needs correction of grammatical errors and style. We suggest to use our service "English Language Editing".	Thank you for your suggestion. We have decided to use the English Language Editing. Editorial Staff has guided us in order to purchase the service together with the print or electronic journal of paper.
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3	The effectiveness of the discussion of the results should be improved	We have added one paragraph at the end of Discussion part. We highlighted the changes by using colored text in red.
4	In Figs. 2-5, it should "Dec.", not "Des."	Thank you for your correction. We have changed the typo from "Des" to "Dec" in Figures 2-5.

2ND SUBMISSION OF REVISED MANUSCRIPT

Optimization of Planting Patterns in South Sulawesi

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Abstract – South Sulawesi is one of nine provinces in Indonesia that has the highest contribution to the national income and its leading sector in agricultural crops including rice. The planning of planting patterns is highly dependent on the size of the intensity of rainfall in a particular area. Therefore, these conditions can have an impact on the level of suitability of crops to be planted. The purpose of this present study was to analyze the water balance and identify the optimal planting pattern. On the basis of rainfall data obtained from 4 rainfall stations, which are Mangkoso station, Manuba station, Mareppang station, and Ralla station, during the period of 25 years (1996 – 2020), then the analysis to determine the average semi-monthly rainfall can be carried out. The results show that the maximum value of irrigation water requirements for rice-rice-palawija planting pattern obtained for simulation 1 occurred on 1 September by 1.66 m³/s, while the minimum value occurred on 1 January, 2 May, and 2 December by 0.23 m³/s. As the conclusion, the maximum value in simulation 3 occurred on 2 October by 1.65 m³/s, while the minimum value occurred on 1 February and 1 June by 0.23 m³/s. The optimization results show that the most optimal cropping pattern is planting 100% of rice in the first and second planting seasons with an area of 717 Ha and 71% planted with palawija in the third planting season of 509.68 Ha. **Copyright © 2013 Praise Worthy Prize S.r.l. - All rights reserved.**

Keywords: Evapotranspiration, Water Availability, Mainstay Debit, Water Demand Irrigation, Water Balance.

Nomenclature

BF	Base flow (m ³ /s/km ²)	IR	Irrigation water requirement (mm/day)
c	Penman correction figure which includes the difference of values between day and night weather conditions	k _c	Crop coefficient
DR	Water withdrawal requirement at the water source (l/s/ha)	M	Water requirement to replace water loss due to evaporation and percolation in saturated rice fields (mm/day)
DRO	Direct run off (m ³ /s/km ²)	m	Data rating
e	Nafier coefficient (2.71828182846)	n	Number of data
ea	Saturated vapor pressure (mbar)	n	Number of rain gauge stations
ed	Actual vapor pressure (mbar)	NFR	Net Field Water Requirement; the need for clean water in the fields (mm/day)
ef	Overall irrigation efficiency	P	Percolation (mm/day)
ET _c	Plant evaporation (mm/day)	Q	Mainstay debit (m ³ /s)
ET _c	Consumptive water requirement (mm/day)	Q80	Mainstay debit with a possibility of not meeting 20% (l/s)
E ₀	Evaporation of open water (mm/day)	Re	Effective rainfall (mm/day)
ET ₀	Potential Evapotranspiration (mm/day)	R _s	Shortwave radiation in evaporation units (mm/day)
ET*	Actual evapotranspiration (mm/day)	Re _{rice}	Effective rainfall for rice plant (mm/day)
F	Catchment area (km ²)	Re _{palawija}	Effective rainfall for palawija plant (mm/day)
f(u)	Function of wind speed at the height of 2 m in units (m/s)	R _{n1}	longwave net radiation (mm/day)
IR	Water requirement in paddy field (mm/day)		

$\bar{R}$	Average region rainfall (mm)
$R_1, R_2 \dots R_n$	Rainfall at station n (mm)
R_{80}	Mainstay rainfall with a possibility of not meeting 20% (l/s)
w	Factor related to temperature (T) and elevation of the area. For areas of Indonesia with an elevation of 0-500 m
S	Water requirement for saturation added by water layer
T	Time period for land preparation
WLR	Water layer replacement (mm/day)
1/8.64	Unit conversion rate from mm/day to l/s/ha

I. Introduction

Irrigated agriculture is a vital resource in many parts of the world. This is driven or limited both by the availability of water and by the capital investment in irrigation related infrastructure including dams and largescale canals and, to a lesser extent, sprinkler system or field-based drip irrigation system [3]. Sustainable water management at the farm level has enormous relevance, i.e., in terms of implementing an adequate irrigation schedule, which should lead to optimal yields and agriculture as well as irrigation [5] [25].

South Sulawesi is one of nine provinces in Indonesia that has the highest contribution to the national income and its leading sector in agricultural crops including rice. One of the areas in South Sulawesi which is popular known as rice center region is Barru Regency. Barru Regency has several irrigation areas, one of which is Kiru-Kiru irrigation area and has potential area of 717 Ha and functional area of 628 Ha [1] which includes 2 urban villages and 3 villages, i.e., Kiru-kiru Village, Mangkoso Village, Siddo Village, Ajakkang Village and Lawallu Village. Based on data from the Central Bureau of Statistic [2], it is noticed that the annual rainfall is 3,975.9 mm/year. In this area, the rainy season lasts from October to April, while the dry season lasts from April September. As a consequence, the people in Soppeng Riaja District mostly work as farmers.

There are three sources of water loss which are evaporation from soil surface, water and plant surfaces that do not contribute to evapotranspiration of cultivated plants, and drainage loss (runoff) [4]. The growing season, also called the frost-free season, is the period of year in which the most favorable growing conditions for native vegetation and cultivated plants take place. It is a period in one year that is categorized as rainy season, the length of which varies according to space, time, and type of plant [6]. The availability of ground water will determine plant growth and yield directly because lack of water causes a decrease in the rate of photosynthesis and disturbance of assimilate distribution, and has negative impacts on plant growth in both the vegetative and generative phases [7].

The amount of water available and the amount of water needed will fluctuate from time to time. As a consequence, in one period there can be an excess of water and in another period, there is a shortage of water for plants [8]. One way to determine fluctuations in water availability from month to month is by utilizing water between the amount of rainwater input and the ability of soil water. One way to determine fluctuations in water availability from month to month is by utilizing water between the amount of rainwater input and the ability of soil to be evapotranspiration [9].

Water balance is useful for completing a general description of the state of water in an area (precipitation, evapotranspiration, water content, and changes in soil moisture), assessing the ability of an area to be planted by estimating the water requirement for plants, and testing the relationship of climate or weather with crop production [10]. The availability of water is very influential on the planting pattern of an area [11]. The planting pattern of agricultural land can be optimized according to the availability of water in the area. A planting pattern is a planting system that is utilized on an area of land which includes the method and types of plants as well as the planting schedule during a certain period of time [12].

Utomo [13] mentioned that planting patterns are designed to determine the time when plants can efficiently utilize the available water. Planting pattern includes the selection of plants the water requirement of which are in accordance with the distribution of rainfall, and crop rotation that is able to utilize rainfall efficiently. If the rainy season is short, the selected plants that are the short-lived ones. On the other hand, if the rainy season is long enough, the selected plants are long-lived, or two plants are selected where the second is taken because it is drought tolerant [13].

Furthermore, according to Unganji et al. [14], the diversity of land characteristics can affect plant growth and development, so they also affect the production of the plant itself. Plants that grow in suitable climatic and land conditions can yield optimally. On the other hand, plants that grow in unsuitable climatic conditions and land will be impacted on the decreasing production. Dwiratna et al. [15] declared that farmers usually apply planting patterns and schedules based on conventional habits which are often carried out during the same climatic conditions every year. However, global climate change can have an impact on the non-enforcement of these habits. Planting failure and crop failure are common problems experienced by farmers because of variations in rainfall that are not fixed every year, making it difficult to determine plants that are in accordance with the conditions of groundwater availability, especially since the water requirement of each type of plant is different.

Moreover, setting a planting pattern is an agricultural effort carried out in order to obtain maximum agricultural products and minimize the risk of crop failure by considering climatic and land conditions. The planning of planting patterns is highly dependent on the size of the intensity of rainfall in a particular area. Therefore, these

conditions can have an impact on the level of suitability of crops to be planted. Planning a planting pattern on the basis of the intensity of rainfall in accordance with the needs of the plant can result in better production.

Additionally, research about planting pattern has been conducted by several previous studies [16] [17]. These studies identified the potential planting seasons on irrigated or non-irrigated areas and involved water balance value to show the water deficit. Despite growing agreement regarding the existence of potential planting season, there is a lack of understanding regarding the necessity of irrigation water balance analysis and optimal planting pattern system using simulations and mainstay debit as its constrain.

The objectives of this study were to analyze the water balance and to identify the optimal planting pattern in Kiru-Kiru Irrigation Area, South Sulawesi. The article is divided into six sections: the first is the current introduction; the second refers to describing its methodology regarding water availability and irrigation water requirement; the third concerns the result and analysis of evapotranspiration, regional, rainfall, mainstay rainfall, effective rainfall, water availability analysis, irrigation water requirement, and water balance; conclusions and recommendations are presented in the last section.

II. Method

This research data was carried out from Kiru-Kiru Irrigation Area and located on the west coast of South Sulawesi Province between the coordinates of 40°5'49"-40°47'35" south latitude and 119°35'00"-119°49'16" east longitude covering an area of 1,174.72 km².



Figure 1. Research Site Map

II.1. Water Availability

a. Potential Evapotranspiration

The use of Modified Penman equation is recommended as a standard for reference evapotranspiration to provide values that are more consistent with the actual plant water use data worldwide [18]. The equation is described as follows:

$$ET_0 = c \times ET^* \quad (1)$$

$$ET^* = w (0.75 R_s - R_{n1}) + (1 - w)f(u)(ea - ed) \quad (2)$$

b. Regional Rainfall

The value of regional rainfall can be determined from several rainfall data in rain gauge stations by employing the average value of rainfall for stations located within the watershed and stations outside the watershed that are still close together which can be calculated as follows:

$$\bar{R} = \frac{1}{n} (R_1 + R_2 + \dots + R_n) \quad (3)$$

c. Mock's Method

Mock's method shows water balance analysis to calculate monthly debit values based on the transformation of monthly rainfall data, evapotranspiration, soil moisture, and groundwater reservoirs. The principle of this method states that the rain that falls on water catchment areas will partly be lost due to evapotranspiration [19].

The water balance using the F. J. Mock method is formulated as follows:

$$Q = (DRO + BF) F \quad (4)$$

d. Mainstay Debit

Mainstay debit is calculated using the Weibull method with an 80% chance of occurrence [20]. The semi-monthly debit data are sorted from the largest to the smallest data. Then, the probability of each data is calculated based on the data ranking using equation 5 below:

$$Q_{80} = \frac{m}{n+1} \times 100\% \quad (5)$$

II.2. Irrigation Water Requirement

The irrigation water requirement for rice is different from the irrigation water requirement for secondary crops (*palawija*). The field water requirement for rice is calculated using equation (6), while the irrigation water requirement is calculated using equation (7). The formula for calculating irrigation water requirement for secondary crops (*palawija*) can be observed in equation (8) [21]:

$$NFR = ET_c + P + WLR - Re \quad (6)$$

$$IR = \frac{NFR}{ef} \quad (7)$$

$$IR = \frac{(ET_c - Re)}{ef} \quad (8)$$

$$DR = \frac{IR}{8.64} \quad (9)$$

a. Effective Rainfall

The effective rainfall for rice and secondary crops (*palawija*) is calculated differently. The effective rainfall for rice is 70% of the average mid-month rainfall with a possibility of not meeting 20% (R_{80}). This rainfall with a possibility of not meeting 20% is calculated using the Weibull method as follow:

$$R_{80} = \frac{m}{n+1} \times 100\% \quad (10)$$

$$Re_{rice} = 0.7 \times R_{80} \quad (11)$$

$$Re_{palawija} = 0.7 \times R_{50} \quad (12)$$

b. Water Requirement for Land Cultivation

The calculation of water requirements during land cultivation used this following equation [2]:

$$IR = \frac{Me^k}{(E^k - 1)} \quad (13)$$

$$M = E_0 + P \quad (14)$$

$$E_0 = 1.1 \times ET_0 \quad (15)$$

$$K = M \times \left(\frac{T}{S}\right) \quad (16)$$

c. Water Requirement to Replace the Water Layer (Water Layer Requirement)

The water requirement to replace the water layer *Water Layer Requirement* (WLR) is determined based on the 2013 Indonesia Irrigation Planning Standard. The amount of water required for water layer replacement is 50 mm/month (or 3.3 mm/day for 1/2 months) for one month and two months after transplantation.

d. Consumptive Water Requirement

Consumptive water requirement is the water requirements for plants on the farm. Plant evapotranspiration (ET_c) is the actual evapotranspiration, which is very different from ET_0 , as a ground cover. The nature of plant canopy and the aerodynamic resistance of plant is different from that of grass [22]. After the reference plant evapotranspiration (ET_0) is obtained, the plant evapotranspiration can be estimated by the following equation [23] [24]:

$$ET_c = k_c \times ET_0 \quad (17)$$

e. Percolation (p) and Seepage

The percolation rate is highly dependent on the nature of the soil, and the nature of the soil generally depends on the activities of land use or cultivation. The percolation rate ranges from 1-3 mm/day.

f. Irrigation Efficiency (EI)

To account for water loss during transportation and application to the field, the efficiency factor was utilized in the calculation of irrigation water requirements [23]. This loss occurs as the result of exploitation, evaporation and seepage activities. In general, water loss in irrigation networks can be divided as the following [2]: 12.5-20% in the tertiary plots between tertiary tapping buildings and rice fields; 5-10% in the secondary channel; and 5-10% in the main channel.

II.3 Water Balance

Water balance is a way of analyzing the balance equation of water based on the law of conservation of mass which states that a substance cannot be created or destroyed, but a substance can change its form [18]. Water balance is an explanation of the relationship between inflow and outflow in a watershed for a certain period of water circulation process. As a consequence, it is possible to identify the excess (surplus) or shortage (deficit) on the amount of water.

III. Result and Analysis

III.1 Evapotranspiration

The evapotranspiration was analyzed using the FAO Modified Penman method. The calculation of the amount of evapotranspiration requires climatological data, such as: temperature, humidity, wind speed, and duration of sunlight. In this study, the climatological station employed was Tabo-Tabo Station, Pangkep Regency. The result of Evapotranspiration calculation could observe in Table 1.

TABLE 1
EVAPOTRANSPIRATION AT KIRU-KIRU IRRIGATION AREA (mm/day)

ET ₀	Jan	Feb	Mar	Apr	May	Jun
mm/day	3.39	3.65	4.00	3.23	3.48	2.72
ET ₀	Jul	Aug	Sept	Oct	Nov	Dec
mm/day	3.67	4.38	5.51	5.48	4.68	3.50

Based on table 1, the Evapotranspiration results show that the Maximum Evapotranspiration at Kiru-Kiru Irrigation Area occurred in October by 5.48 mm/day, while the Minimum evapotranspiration occurred in June by 2.72 mm/day.

III.2 Regional Rainfall

On the basis of rainfall data obtained from 4 rainfall

stations, which are Mangkoso station, Manuba station, Mareppang station, and Ralla station, during the period of 25 years (1996 – 2020), then the analysis to determine the average semi-monthly rainfall can be carried out. It can be observed that the maximum average rainfall in the Kiru-Kiru irrigation area occurred on 2 September by 13.65 mm/day while the minimum rainfall occurred on 2 August by 5.23 mm (Figure 2).

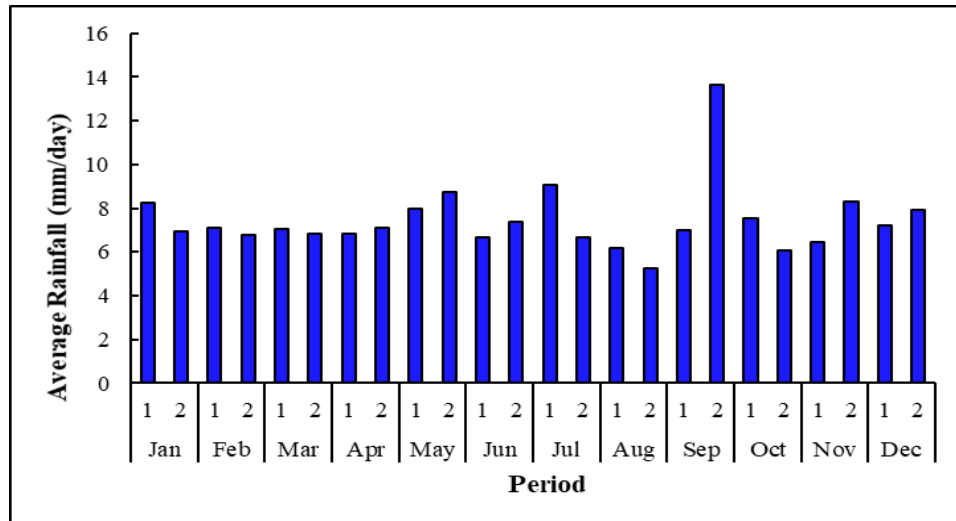


Fig. 2. Average Rainfall of Kuru-Kuru Irrigation Area in 1996-2020

III.3 Mainstay Rainfall

The mainstay rainfall for rice plants is set at 80% (R_{80}), while for secondary crops (*palawija*), it is set at 50% (R_{50}). The results of the mainstay rainfall calculations shows that rainfall with maximum reliability of 80% (R_{80}) occurred

on 1 January by 4.75 mm and the minimum one occurred on 1 September by 0 mm. Meanwhile, for the rainfall with maximum reliability of 50% (R_{50}), it occurred on 2 December by 7.75 mm and the minimum one occurred on 1 August and 1 September by 4.00 mm (Table 2).

TABLE 2
MAINSTAY RAINFALL FOR RICE AND SECONDARY CROPS (*Palawija*)

CH Mainstay (mm)	Jan		Feb		Mar		Apr		May		Jun	
	1	2	1	2	1	2	1	2	1	2	1	2
R_{80}	4.75	3.50	4.50	3.00	4.00	3.75	3.25	3.33	3.50	3.33	3.67	2.50
R_{50}	6.75	5.00	7.50	6.00	5.50	6.75	4.75	5.50	5.67	5.25	4.75	5.00
CH Mainstay (mm)	July		Aug		Sep		Oct		Nov		Dec	
	1	2	1	2	1	2	1	2	1	2	1	2
R_{80}	3.00	2.00	1.00	1.00	0.00	2.75	4.00	2.50	3.75	4.75	3.75	4.00
R_{50}	6.67	5.00	4.00	5.50	4.00	7.33	5.75	5.67	6.00	6.00	5.00	7.75

III.4 Effective Rainfall

In the calculation of the effective rainfall for rice, the result was 70% of R_{80} of the time in a period, while for the effective rainfall of secondary crops (*palawija*), it was 50% of R_{50} . The effective rainfall for paddy maximumly

occurred on 1 January and 2 November by 0.22 mm/day and the minimum value occurs on 1 September by 0 mm/day. Meanwhile, the effective rainfall for secondary crops (*palawija*) maximumly happened on 2 December by 0.26 mm/day and the minimum value occurred on 1 February and 1 March by 0.13 mm/day (Table 3).

TABLE 3
EFFECTIVE RAINFALL FOR RICE AND SECONDARY CROPS (*Palawija*)

Effective CH (mm/day)	Jan		Feb		Mar		Apr		May		Jun	
	1	2	1	2	1	2	1	2	1	2	1	2
Re Rice	0.22	0.16	0.21	0.14	0.19	0.18	0.15	0.16	0.16	0.16	0.17	0.12
Re Palawija	0.23	0.17	0.25	0.20	0.18	0.23	0.16	0.18	0.19	0.18	0.16	0.17
Effective CH (mm/day)	Jul		Aug		Sept		Oct		Nov		Dec	
	1	2	1	2	1	2	1	2	1	2	1	2
Re Rice	0.14	0.09	0.05	0.05	0.00	0.13	0.19	0.12	0.18	0.22	0.18	0.19
Re Palawija	0.22	0.17	0.13	0.18	0.13	0.24	0.19	0.19	0.20	0.20	0.17	0.26

III.5 Water Availability Analysis and Mainstay Debit

To determine the value of water availability in Kuru-Kuru irrigation area, this study utilized the calculation result of the water debit in Kuru-Kuru watershed using Mock

Method. Water availability was calculated by determining the mainstay debit from the debit data (1996-2020) and processed the results into monthly data. The debit data was sorted from the largest to the smallest data. After that, the

probability of each data was calculated in accordance with the data rank. The 80% mainstay debit (Q_{80}) was maximumly occurred in December with a debit of 5.85

m^3/s , while the minimum debit occurred in July, August and October with a debit of 1.03 m^3/s (Table 4).

TABLE 4
MAINSTAY DEBIT WITH 80% PROBABILITY

Mainstay Debit (m^3/s)	Month											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Q_{80}	5.48	3.41	1.38	2.34	1.14	1.08	1.03	1.03	1.06	1.03	1.38	5.85

III.6 Irrigation Water Requirement

The results of irrigation water requirement analysis for Rice–Rice–*Palawija* planting pattern could be observed in Figure 3. The results show that the maximum value of irrigation water requirements for Rice–Rice–*Palawija* planting pattern obtained for simulation 1 occurred on 1 September by 1.66 m^3/s , while the minimum value

occurred on 1 January, 2 May, and 2 December by 0.23 m^3/s .

Additionally, the maximum value in simulation 2 occurred on 2 September by 1.65 m^3/s , while the minimum value occurred on 1 January and 1 July by 0.23 m^3/s . Finally, the maximum value in simulation 3 happened on 2 October by 1.65 m^3/s , while the minimum value occurred on 1 February and 1 June by 0.23 m^3/s .

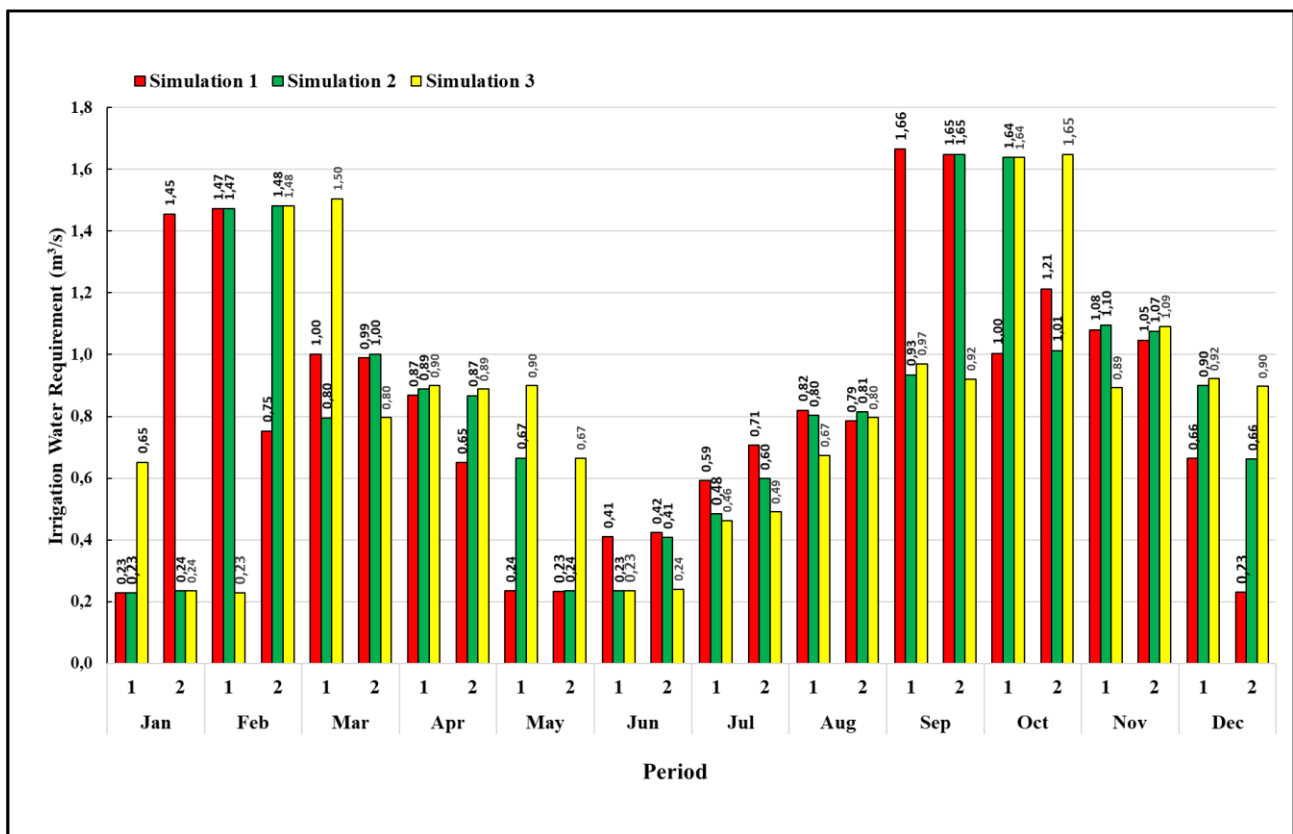


Fig. 3. Water Requirements of Kiru-Kiru Irrigation Area

III.7 Water Balance

Water balance is balance between the water coming in and coming out of a system. The results (Figure 4 and Table 5) show that the water balance for the Rice–Rice–*Palawija* planting pattern combination in the 1st simulation during the rainy season (1 September – 2 January) experienced a maximum surplus (S) of 5.62 m^3/s and a deficit (D) of 0.60 m^3/s , while that during the dry season (1 February – 2 August) experienced a maximum surplus of 2.66 m^3/s and a minimum value or deficit of

0.21 m^3/s . Meanwhile, for the 2nd simulation during the rainy season (2 September – 1 February), it experienced a maximum surplus of 5.26 m^3/s and a deficit of 0.58 m^3/s , while during the dry season (2 February – 1 October), it experienced a maximum surplus of 1.93 m^3/s and a deficit of 0.61 m^3/s .

Then, in the 3rd simulation during the rainy season (1 October – 2 February), there was a maximum surplus of 5.25 m^3/s and it experienced a deficit of 0.62 m^3/s , while

during the dry season (1 March – 2 August), it experienced a maximum surplus of 1.45 m³/s and a deficit of 0.13 m³/s.

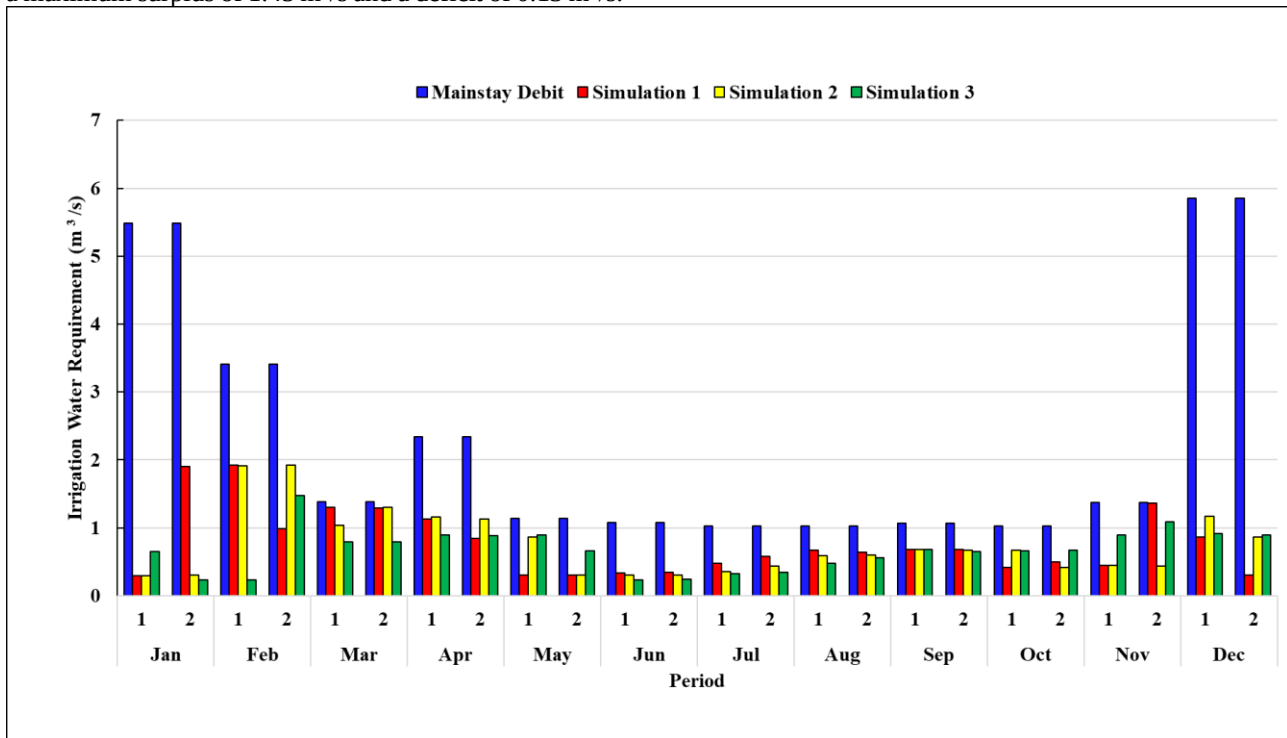


Fig. 4. Water Balance of Kiru-Kiru Irrigation Area

TABLE 5
WATER BALANCE OF KIRU-KIRU IRRIGATION AREA

Description	Month	Jan		Feb		Mar		Apr		May		Jun	
		1	2	1	2	1	2	1	2	1	2	1	2
1 st Simulation	Mainstay Debit (m ³ /s)	5.48	5.48	3.41	3.41	1.38	1.38	2.34	2.34	1.14	1.14	1.08	1.08
	Irrigation Water Requirement (m ³ /s)	0.23	1.45	1.47	0.75	1.00	0.99	0.87	0.65	0.24	0.23	0.41	0.42
	Water Balance	5.26	4.03	1.94	2.66	0.38	0.39	1.47	1.69	0.91	0.91	0.67	0.65
	Surplus/Defisit	S	S	S	S	S	S	S	S	S	S	S	S
	Month	Jul		Aug		Sep		Oct		Nov		Dec	
		1	2	1	2	1	2	1	2	1	2	1	2
	Mainstay Debit (m ³ /s)	1.03	1.03	1.03	1.03	1.06	1.06	1.03	1.03	1.38	1.38	5.85	5.85
	Irrigation Water Requirement (m ³ /s)	0.59	0.71	0.82	0.79	1.66	1.65	1.00	1.21	1.08	1.05	0.66	0.23
	Water Balance	0.44	0.32	0.21	0.24	-0.60	-0.58	0.03	-0.18	0.30	0.33	5.19	5.62
	Surplus/Defisit	S	S	S	S	D	D	S	D	S	S	S	S
2 nd Simulation	Month	Jan		Feb		Mar		Apr		May		Jun	
		1	2	1	2	1	2	1	2	1	2	1	2
	Mainstay Debit (m ³ /s)	5.48	5.48	3.41	3.41	1.38	1.38	2.34	2.34	1.14	1.14	1.08	1.08
	Irrigation Water Requirement (m ³ /s)	0.23	0.24	1.47	1.48	0.80	1.00	0.89	0.87	0.67	0.24	0.23	0.41
	Water Balance	5.26	5.25	1.94	1.93	0.58	0.38	1.45	1.47	0.48	0.91	0.84	0.67
	Surplus/Defisit	S	S	S	S	S	S	S	S	S	S	S	S
	Month	Jul		Aug		Sep		Oct		Nov		Dec	
		1	2	1	2	1	2	1	2	1	2	1	2
	Mainstay Debit (m ³ /s)	1.03	1.03	1.03	1.03	1.06	1.06	1.03	1.03	1.38	1.38	5.85	5.85
	Irrigation Water Requirement (m ³ /s)	0.48	0.60	0.80	0.81	0.93	1.65	1.64	1.01	1.10	1.07	0.90	0.66
3 rd Simulation	Water Balance	0.55	0.43	0.23	0.22	0.13	-0.58	-0.61	0.02	0.28	0.30	4.95	5.19
	Surplus/Defisit	S	S	S	S	S	D	D	S	S	S	S	S
	Month	Jan		Feb		Mar		Apr		May		Jun	
		1	2	1	2	1	2	1	2	1	2	1	2
	Mainstay Debit (m ³ /s)	5.48	5.48	3.41	3.41	1.38	1.38	2.34	2.34	1.14	1.14	1.08	1.08
	Irrigation Water Requirement (m ³ /s)	0.65	0.24	0.23	1.48	1.50	0.80	0.90	0.89	0.90	0.67	0.23	0.24
	Water Balance	4.83	5.25	3.19	1.93	-0.13	0.58	1.44	1.45	0.24	0.48	0.84	0.84
	Surplus/Defisit	S	S	S	S	D	S	S	S	S	S	S	S
	Month	Jul		Aug		Sep		Oct		Nov		Dec	
		1	2	1	2	1	2	1	2	1	2	1	2
	Mainstay Debit (m ³ /s)	1.03	1.03	1.03	1.03	1.06	1.06	1.03	1.03	1.38	1.38	5.85	5.85

Irrigation Water Requirement (m ³ /s)	0.46	0.49	0.67	0.80	0.97	0.92	1.64	1.65	0.89	1.09	0.92	0.90
Water Balance	0.57	0.54	0.36	0.23	0.09	0.14	-0.61	-0.62	0.48	0.29	4.93	4.95
Surplus/Defisit	S	S	S	S	S	S	D	D	S	S	S	S

On the basis of figure 4 and table 5 above, the results show that the water balance for the Rice-Rice-Palawija planting pattern in 1st simulation during the rainy season (1 September – 2 January) experienced a maximum surplus of 5.62 m³/s and a deficit of 0.60 m³/s, while that during the dry season (1 February – 2 August) experienced a maximum surplus of 2.66 m³/s and a minimum value of 0.21 m³/s. Meanwhile, in the 2nd simulation during the rainy season (2 September – 1 February), it experienced a maximum surplus of 5.26 m³/s and a deficit of 0.58 m³/s, while during the dry season (2 February – 1 October), it experienced a maximum surplus of 1.93 m³/s and a deficit of 0.61 m³/s.

While for the 3rd simulation during the rainy season (1 October – 2 February), there was a maximum surplus of 5.25 m³/s and it experienced a deficit of 0.62 m³/s, while during the dry season (1 March – 2 August), it experienced

a maximum surplus of 1.45 m³/s and a deficit of 0.13 m³/s. In accordance with the results of water balance in Kiru-Kiru irrigation area, it could be identified that Kiru-Kiru irrigation area experienced water deficit in several months. Furthermore, in this study, simulation selection is influenced by several factors, such as; water requirements, land preparation, water layer replacement, percolation, planting factors, and climate factors. The simulation that is close to the field conditions is simulation 3, which results in a water demand of 2.30 l/s/ha and a significant land area of 716 Ha with an existing potential land area of 717 ha.

As one of the efforts made in order that the irrigation water requirements could be fulfilled, then it necessitated an adjustment on the irrigation area to be developed by decreasing the irrigation area in the Irrigation Area in question as displayed in table 7 and figure 5 below.

TABLE 6
WATER BALANCE OF KIRU-KIRU IRRIGATION AREA AFTER OPTIMIZATION

Month	Period	Planting Period	Water Availability (l/s)	Water Irrigation Requirement (l/s/ha)		Area (Ha)	
				Rice	Palawija	Rice	Palawija
Jan	1	I	5483.89	4.96		717.00	
	2	I	5483.89	4.96		717.00	
Feb	1		3414.59	0.32		6920.69	
	2	II	3414.59	3.09		717.00	
Mar	1	II	1378.52	1.25		717.00	
	2	II	1378.52	1.25		717.00	
Apr	1	II	2336.72	2.11		717.00	
	2	II	2336.72	2.11		717.00	
May	1	II	1141.13	1.03		717.00	
	2	II	1141.13	1.03		717.00	
Jun	1	II	1076.03	0.97		717.00	
	2		1076.03		0.34		2076.50
Jul	1	III	1031.30		0.65		1035.00
	2	III	1031.30		0.68		976.86
Aug	1	III	1029.57		0.94		709.52
	2	III	1029.57		1.11		600.34
Sep	1	III	1063.89		1.35		509.68
	2	III	1063.89		0.96		717.00
Oct	1	I	1029.57	0.93		717.00	
	2	I	1029.57	0.93		717.00	
Nov	1	I	1377.09	1.24		717.00	
	2	I	1377.09	1.24		717.00	
Dec	1	I	5849.71	5.29		717.00	
	2	I	5849.71	5.29		717.00	

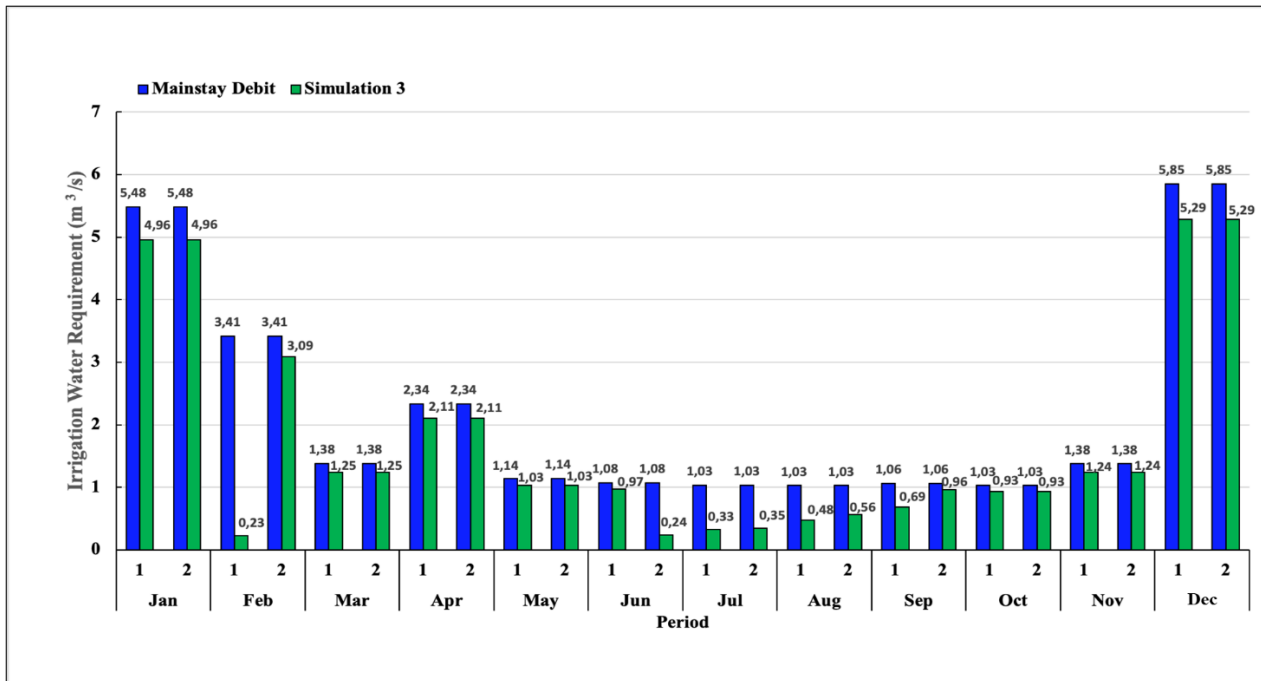


Fig. 5. Water Balance of Kiru-Kiru Irrigation Area After Optimization

Moreover, table 6 and Figure 4 showed that there are 3 planting seasons recommendation, namely; first planting season (I) is on 1st October to 2nd January and second planting season (II) is on 2nd February to 1st June. These planting seasons could reach its optimal planting patterns with 100% of rice or 717 Ha planted with rice. Finally, the last planting season (III) is on 1st July to 2nd September with optimal cropping pattern is *palawija* at 509.68 Ha.

Overall, this study should be regarded as a first step towards optimization planting pattern in South Sulawesi, although several works still need to be done on simulation verification. Moreover, this study involves the assessment of water that is really accessible for all uses and development and should be considered as a starting point in optimization of planting patterns in Indonesia. This study did not incorporate water quality aspect of the Kiru-Kiru Irrigation bust shall be taken up as part of the future scope.

IV. CONCLUSION

In this study, we analyzed the evapotranspiration and developed 3 simulation of irrigation water requirement. Using water balance consideration, this study simulated 3 recommendation planting patterns based on the maximum surplus and minimum value of water. Importantly, this study considered several necessary factors, namely; water requirements, land preparation, water layer replacement, percolation, planting factors, and climate factors.

The significance value among 3 simulations were found at the 3rd simulation as the optimal planting pattern. Irrigation water balance in Kiru-Kiru irrigation area on the existing condition (3rd simulation) experienced a deficit on 1 October, 2 October, and 1 March. The effort made in order to resolve water shortage problem is to carry out

planting pattern optimization. Our result suggested that the most optimal cropping pattern is planting 100% of rice in the first and second planting seasons with an area of 717 Ha and 71% planted with *palawija* in the third planting season of 509.68 Ha.

Therefore, in future investigation, to provide more credible information to this field and to support the Indonesia Government programs, it would be interesting to compare other irrigation area in Barru Regency with continual production of additional data.

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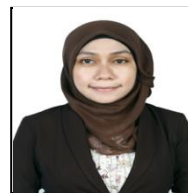
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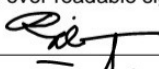
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PROOFREADING AND ENGLISH EDITING

Optimization of Planting Patterns in South Sulawesi

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Abstract – South Sulawesi is one of the nine provinces in Indonesia that has the highest contribution to the national income and its leading sector in agricultural crops including rice. The planning of planting patterns is highly dependent on the size of the intensity of rainfall in a particular area. Therefore, these conditions can have an impact on the level of suitability of crops to be planted. The purpose of this study has been to analyze the water balance and identify the optimal planting pattern. On the basis of rainfall data obtained from 4 rainfall stations, which are Mangkoso station, Manuba station, Mareppang station, and Ralla station, during the period of 25 years (1996 – 2020), the analysis to determine the average semi-monthly rainfall can be carried out. The results show that the maximum value of irrigation water requirements for rice-rice-palawija planting pattern obtained for simulation 1 has occurred on 1 September by 1.66 m³/s, while the minimum value has occurred on 1 January, 2 May, and 2 December by 0.23 m³/s. As a conclusion, the maximum value in simulation 3 has occurred on 2 October by 1.65 m³/s, while the minimum value has occurred on 1 February and 1 June by 0.23 m³/s. The optimization results show that the most optimal cropping pattern is planting 100% of rice in the first and second planting seasons with an area of 717 Ha and 71% planted with palawija in the third planting season of 509.68 Ha. Copyright © 2013 Praise Worthy Prize S.r.l. - All rights reserved.

Keywords: Evapotranspiration, Water Availability, Mainstay Debit, Water Demand Irrigation, Water Balance

Nomenclature			
		IR	Water requirement in paddy field (mm/day)
BF	Base flow (m ³ /s/km ²)	IR	Irrigation water requirement (mm/day)
c	Penman correction figure which includes the difference of values between day and night weather conditions	k _c	Crop coefficient
		M	Water requirement to replace water loss due to evaporation and percolation in saturated rice fields (mm/day)
DR	Water withdrawal requirement at the water source (l/s/ha)	m	Data rating
DRO	Direct run off (m ³ /s/km ²)	n	Number of data
e	Nafier coefficient (2.71828182846)	n	Number of rain gauge stations
ea	Saturated vapor pressure (mbar)	NFR	Net Field Water Requirement; the need for clean water in the fields (mm/day)
ed	Actual vapor pressure (mbar)	P	Percolation (mm/day)
ef	Overall irrigation efficiency	Q	Mainstay debit (m ³ /s)
ET _c	Plant evaporation (mm/day)	Q80	Mainstay debit with a possibility of not meeting 20% (l/s)
ET _c	Consumptive water requirement (mm/day)	Re	Effective rainfall (mm/day)
E ₀	Evaporation of open water (mm/day)	R _s	Shortwave radiation in evaporation units (mm/day)
ET ₀	Potential Evapotranspiration (mm/day)	Re _{rice}	Effective rainfall for rice plant (mm/day)
ET*	Actual evapotranspiration (mm/day)	Re _{palawija}	Effective rainfall for palawija plant (mm/day)
F	Catchment area (km ²)		
f(u)	Function of wind speed at the height of 2 m in units (m/s)	R _{n1}	longwave net radiation (mm/day)

$\bar{R}$	Average region rainfall (mm)
$R_1, R_2 \dots R_n$	Rainfall at station n (mm)
R_{80}	Mainstay rainfall with a possibility of not meeting 20% (l/s)
w	Factor related to temperature (T) and elevation of the area. For areas of Indonesia with an elevation of 0-500 m
S	Water requirement for saturation added by water layer
T	Time period for land preparation
WLR	Water layer replacement (mm/day)
1/8.64	Unit conversion rate from mm/day to l/s/ha

I. Introduction

Irrigated agriculture is a vital resource in many parts of the world. This is driven or limited both by the availability of water and by the capital investment in irrigation related infrastructure including dams and largescale canals and, to a lesser extent, sprinkler system or field-based drip irrigation system [3]. Sustainable water management at the farm level has enormous relevance, i.e., in terms of implementing an adequate irrigation schedule, which should lead to optimal yields and agriculture as well as irrigation [5] [25].

South Sulawesi is one of the nine provinces in Indonesia that has the highest contribution to the national income and its leading sector in agricultural crops including rice. One of the areas in South Sulawesi that is popular known as rice center region is Barru Regency. It has several irrigation areas, one of which is Kiru-Kiru irrigation area and has potential area of 717 Ha and functional area of 628 Ha [1] which includes 2 urban villages and 3 villages, i.e., Kiru-kiru Village, Mangkoso Village, Siddo Village, Ajakkang Village and Lawallu Village. Based on data from the Central Bureau of Statistic [2], it is noticed that the annual rainfall is 3.975,9 mm/year. In this area, the rainy season lasts from October to April, while the dry season lasts from April to September. Therefore, the people in Soppeng Riaja District mostly work as farmers.

There are three sources of water loss, which are evaporation from soil surface, water and plant surfaces that do not contribute to evapotranspiration of cultivated plants, and drainage loss (runoff) [4]. The growing season, also called the frost-free season, is the period of year in which the most favorable growing conditions for native vegetation and cultivated plants take place. It is a period in one year that is categorized as rainy season, whose length varies according to space, time, and type of plant [6]. The availability of ground water will determine plant growth and yield directly because lack of water causes a decrease in the rate of photosynthesis and disturbance of assimilate distribution, and has negative impacts on plant growth in both the vegetative and generative phases [7].

The amount of water available and the amount of water needed will fluctuate from time to time. Consequently, in one period, there can be an excess of water and in another period, there is a shortage of water for plants [8]. One way to determine fluctuations in water availability from month to month is by utilizing water between the amount of rainwater input and the ability of soil water. One way to determine fluctuations in water availability from month to month is by utilizing water between the amount of rainwater input and the ability of soil be evapotranspiration [9]. This sentence seems to be repeated twice and bad organized; please, rephrase it.

Water balance is useful for completing a general description of the state of water in an area (precipitation, evapotranspiration, water content, and changes in soil moisture), assessing the ability of an area to be planted by estimating the water requirement for plants, and testing the relationship of climate or weather with crop production [10]. The availability of water is very influential on the planting pattern of an area [11]. The planting pattern of agricultural land can be optimized according to the availability of water in the area. A planting pattern is a planting system that is utilized on an area of land, which includes the method and types of plants as well as the planting schedule during a certain period of time [12].

Utomo [13] has mentioned that planting patterns are designed to determine the time when plants can efficiently utilize the available water. Planting pattern includes the selection of plants whose water requirement is in accordance with the distribution of rainfall, and crop rotation that can utilize rainfall efficiently. If the rainy season is short, the selected plants that are the short-lived ones. On the other hand, if the rainy season is long enough, the selected plants are long-lived, or two plants are selected where the second is taken because it is drought tolerant [13].

Furthermore, according to Unganji et al. [14], the diversity of land characteristics can affect plant growth and development, so they also affect the production of the plant itself. Plants that grow in suitable climatic and land conditions can yield optimally. On the other hand, plants that grow in unsuitable climatic conditions and land will be impacted on the decreasing production. Dwiratna et al. [15] have declared that farmers usually apply planting patterns and schedules based on conventional habits, which are often carried out during the same climatic conditions every year. However, global climate change can have an impact on the non-enforcement of these habits. Planting failure and crop failure are common problems experienced by farmers because of variations in rainfall that are not fixed every year, making it difficult to determine plants that are in accordance with the conditions of groundwater availability, especially since the water requirement of each type of plant is different.

Moreover, setting a planting pattern is an agricultural effort carried out in order to obtain maximum agricultural products and minimize the risk of crop failure by

considering climatic and land conditions. The planning of planting patterns is highly dependent on the size of the intensity of rainfall in a particular area. Therefore, these conditions can have an impact on the level of suitability of crops to be planted. Planning a planting pattern based on the intensity of rainfall in accordance with the needs of the plant can result in better production.

Additionally, research about planting pattern has been conducted by several previous studies [16] [17]. These studies have identified the potential planting seasons on irrigated or non-irrigated areas and have involved water balance value to show the water deficit. Despite growing agreement regarding the existence of potential planting season, there is a lack of understanding regarding the necessity of irrigation water balance analysis and optimal planting pattern system using simulations and mainstay debit as its constrain.

The objectives of this study have been to analyze the water balance and to identify the optimal planting pattern in Kiru-Kiru Irrigation Area, South Sulawesi. The article is divided into six sections. The first one is the current introduction, the second one refers to describing its methodology regarding water availability and irrigation water requirement, the third one concerns the result and the analysis of evapotranspiration, regional, rainfall, mainstay rainfall, effective rainfall, water availability analysis, irrigation water requirement, and water balance. Conclusions and recommendations are presented in the last section.

II. Method

This research data has been carried out from Kiru-Kiru Irrigation Area and located on the west coast of South Sulawesi Province between the coordinates of 40°5'49"-40°47'35" south latitude and 119°35'00"-119°49'16" east longitude covering an area of 1,174.72 km².

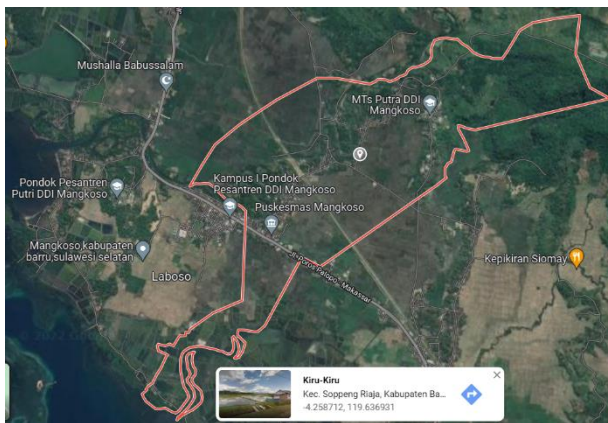


Figure 1. Research Site Map

II.1. Water Availability

a. Potential Evapotranspiration

The use of Modified Penman equation is recommended as a standard for reference evapotranspiration in order to provide values that are more consistent with the actual plant water use data worldwide [18]. The equation is described as follows:

$$ET_0 = c \times ET^* \quad (1)$$

$$ET^* = w (0.75 R_s - R_{n1}) + (1 - w)f(u)(ea - ed) \quad (2)$$

b. Regional Rainfall

The value of regional rainfall can be determined from several rainfall data in rain gauge stations by employing the average value of rainfall for stations located within the watershed and stations outside the watershed that are still close together which can be calculated as follows:

$$\bar{R} = \frac{1}{n} (R_1 + R_2 + \dots + R_n) \quad (3)$$

c. Mock's Method

Mock's method shows water balance analysis to calculate monthly debit values based on the transformation of monthly rainfall data, evapotranspiration, soil moisture, and groundwater reservoirs. The principle of this method states that the rain that falls on water catchment areas will partly be lost due to evapotranspiration [19].

The water balance using the F. J. Mock method is formulated as follows:

$$Q = (DRO + BF) F \quad (4)$$

d. Mainstay Debit

Mainstay debit is calculated using the Weibull method with an 80% chance of occurrence [20]. The semi-monthly debit data are sorted from the largest to the smallest data. Then, the probability of each data is calculated based on the data ranking using equation 5 below:

$$Q_{80} = \frac{m}{n+1} \times 100\% \quad (5)$$

II.2. Irrigation Water Requirement

The irrigation water requirement for rice is different from the irrigation water requirement for secondary crops (*palawija*). The field water requirement for rice is calculated using equation (6), while the irrigation water requirement is calculated using equation (7). The formula for calculating irrigation water requirement for secondary crops (*palawija*) can be observed in equation (8) [21]:

$$NFR = ET_c + P + WLR - Re \quad (6)$$

$$IR = \frac{NFR}{ef} \quad (7)$$

$$IR = \frac{(ET_c - Re)}{ef} \quad (8)$$

$$DR = \frac{IR}{8.64} \quad (9)$$

a. Effective Rainfall

The effective rainfall for rice and secondary crops (*palawija*) is calculated differently. The effective rainfall for rice is 70% of the average mid-month rainfall with a possibility of not meeting 20% (R_{80}). This rainfall with a possibility of not meeting 20% is calculated using the Weibull method as follows:

$$R_{80} = \frac{m}{n+1} \times 100\% \quad (10)$$

$$Re_{rice} = 0.7 \times R_{80} \quad (11)$$

$$Re_{palawija} = 0.7 \times R_{50} \quad (12)$$

b. Water Requirement for Land Cultivation

The calculation of water requirements during land cultivation is done by using the following equation [2]:

$$IR = \frac{Me^k}{(E^k - 1)} \quad (13)$$

$$M = E_0 + P \quad (14)$$

$$E_0 = 1.1 \times ET_0 \quad (15)$$

$$K = M \times \left(\frac{T}{S}\right) \quad (16)$$

c. Water Requirement to Replace the Water Layer (Water Layer Requirement)

The water requirement to replace the water layer (Water Layer Requirement (WLR)) is determined based on the 2013 Indonesia Irrigation Planning Standard. The amount of water required for water layer replacement is 50 mm/month (or 3.3 mm/day for 1/2 months) for one month and two months after transplantation.

d. Consumptive Water Requirement

Consumptive water requirement is the water requirements for plants on the farm. Plant evapotranspiration (ET_c) is the actual evapotranspiration, which is very different from ET_0 , as a ground cover. The nature of plant canopy and the aerodynamic resistance of plant are different from that of grass [22]. After the reference plant evapotranspiration (ET_0) is obtained, the plant evapotranspiration can be estimated by the following equation [23] [24]:

$$ET_c = k_c \times ET_0 \quad (17)$$

e. Percolation (p) and Seepage

The percolation rate is highly dependent on the nature of the soil, and the nature of the soil generally depends on the activities of land use or cultivation. The percolation rate ranges from 1-3 mm/day.

f. Irrigation Efficiency (EI)

In order to account for water loss during transportation and application to the field, the efficiency factor has been utilized in the calculation of irrigation water requirements [23]. This loss occurs as the result of exploitation, evaporation, and seepage activities. In general, water loss in irrigation networks can be divided as follows [2]: 12.5-20% in the tertiary plots between tertiary tapping buildings and rice fields; 5-10% in the secondary channel; and 5-10% in the main channel.

II.3 Water Balance

Water balance is a way of analyzing the balance equation of water based on the law of conservation of mass, which states that a substance cannot be created or destroyed, but a substance can change its form [18]. Water balance is an explanation of the relationship between inflow and outflow in a watershed for a certain period of water circulation process. Therefore, it is possible to identify the excess (surplus) or shortage (deficit) on the amount of water.

III. Result and Analysis

III.1 Evapotranspiration

The evapotranspiration has been analyzed using the FAO Modified Penman method. The calculation of the amount of evapotranspiration requires climatological data, such as temperature, humidity, wind speed, and duration of sunlight. In this study, the climatological station employed has been Tabo-Tabo Station, Pangkep Regency. The result of Evapotranspiration calculation can be seen in Table 1.

TABLE 1
EVAPOTRANSPIRATION AT KIRU-KIRU IRRIGATION AREA (mm/day)

ET ₀	Jan	Feb	Mar	Apr	May	Jun
mm/day	3.39	3.65	4.00	3.23	3.48	2.72
ET ₀	Jul	Aug	Sept	Oct	Nov	Dec
mm/day	3.67	4.38	5.51	5.48	4.68	3.50

Based on table 1, the Evapotranspiration results show that the Maximum Evapotranspiration at Kiru-Kiru Irrigation Area has occurred in October by 5.48 mm/day, while the Minimum evapotranspiration has occurred in June by 2.72 mm/ day.

III.2 Regional Rainfall

Based on of rainfall data obtained from 4 rainfall stations, which are Mangkoso station, Manuba station, Mareppang station, and Ralla station, during the period of 25 years (1996 – 2020), the analysis to determine the average semi-monthly rainfall can be carried out. It can be observed that the maximum average rainfall in the Kiru-Kiru irrigation area has occurred on 2 September by 13.65 mm/day while the minimum rainfall has occurred on 2 August by 5.23 mm (Figure 2).

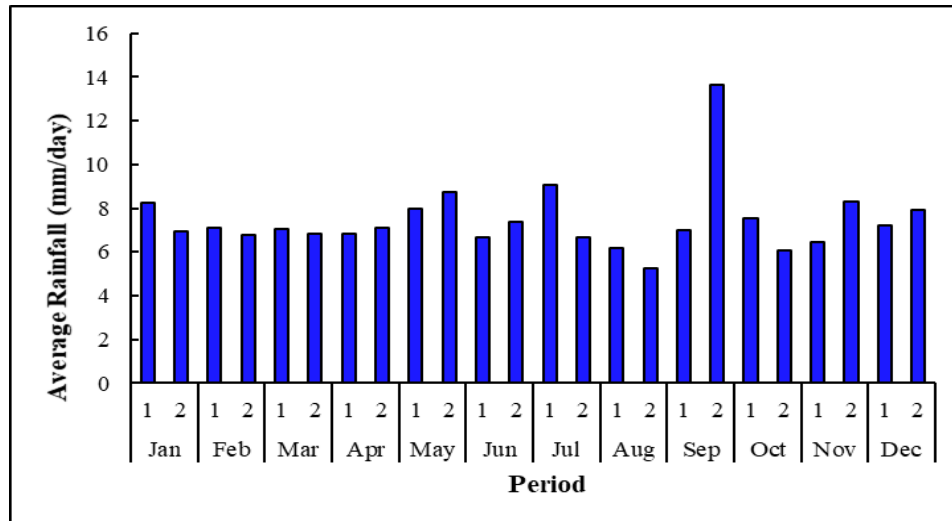


Fig. 2. Average Rainfall of Kuru-Kuru Irrigation Area in 1996-2020

III.3 Mainstay Rainfall

The mainstay rainfall for rice plants is set at 80% (R_{80}), while for secondary crops (*palawija*), it is set at 50% (R_{50}). The results of the mainstay rainfall calculations show that rainfall with maximum reliability of 80% (R_{80}) occurred on 1 January by 4.75 mm and the

minimum one occurred on 1 September by 0 mm. Meanwhile, for the rainfall with maximum reliability of 50% (R_{50}), it occurred on 2 December by 7.75 mm and the minimum one occurred on 1 August and 1 September by 4.00 mm (Table 2).

TABLE 2

CH Mainstay (mm)	MAINSTAY RAINFALL FOR RICE AND SECONDARY CROPS (<i>Palawija</i>)											
	Jan		Feb		Mar		Apr		May		Jun	
	1	2	1	2	1	2	1	2	1	2	1	2
R_{80}	4.75	3.50	4.50	3.00	4.00	3.75	3.25	3.33	3.50	3.33	3.67	2.50
R_{50}	6.75	5.00	7.50	6.00	5.50	6.75	4.75	5.50	5.67	5.25	4.75	5.00
CH Mainstay (mm)	July		Aug		Sep		Oct		Nov		Dec	
	1	2	1	2	1	2	1	2	1	2	1	2
R_{80}	3.00	2.00	1.00	1.00	0.00	2.75	4.00	2.50	3.75	4.75	3.75	4.00
R_{50}	6.67	5.00	4.00	5.50	4.00	7.33	5.75	5.67	6.00	6.00	5.00	7.75

III.4 Effective Rainfall

In the calculation of the effective rainfall for rice, the result has been 70% of R_{80} of the time in a period, while for the effective rainfall of secondary crops (*palawija*), it has been 50% of R_{50} . The effective rainfall for paddy maximally occurred on 1 January and 2 November by

0.22 mm/day and the minimum value occurs on 1 September by 0 mm/day. Meanwhile, the effective rainfall for secondary crops (*palawija*) maximally happened on 2 December by 0.26 mm/day and the minimum value occurred on 1 February and 1 March by 0.13 mm/day (Table 3).

TABLE 3

Effective CH (mm/day)	EFFECTIVE RAINFALL FOR RICE AND SECONDARY CROPS (<i>Palawija</i>)											
	Jan		Feb		Mar		Apr		May		Jun	
	1	2	1	2	1	2	1	2	1	2	1	2
Re Rice	0.22	0.16	0.21	0.14	0.19	0.18	0.15	0.16	0.16	0.16	0.17	0.12
Re Palawija	0.23	0.17	0.25	0.20	0.18	0.23	0.16	0.18	0.19	0.18	0.16	0.17
Effective CH (mm/day)	Jul		Aug		Sept		Oct		Nov		Dec	
	1	2	1	2	1	2	1	2	1	2	1	2
Re Rice	0.14	0.09	0.05	0.05	0.00	0.13	0.19	0.12	0.18	0.22	0.18	0.19
Re Palawija	0.22	0.17	0.13	0.18	0.13	0.24	0.19	0.19	0.20	0.20	0.17	0.26

III.5 Water Availability Analysis and Mainstay Debit

In order to determine the value of water availability in Kuru-Kuru irrigation area, this study has utilized the calculation result of the water debit in Kuru-Kuru watershed using Mock Method. Water availability has

been calculated by determining the mainstay debit from the debit data (1996-2020) and processed the results into monthly data. The debit data has been sorted from the largest to the smallest data. After that, the probability of each data has been calculated in accordance with the data rank. The 80% mainstay debit (Q_{80}) has maximally

occurred in December with a debit of 5.85 m³/s, while the minimum debit occurred in July, August and October

with a debit of 1.03 m³/s (Table 4).

TABLE 4
MAINSTAY DEBIT WITH 80% PROBABILITY

Mainstay Debit (m ³ /s)	Month											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Q ₈₀	5.48	3.41	1.38	2.34	1.14	1.08	1.03	1.03	1.06	1.03	1.38	5.85

III.6 Irrigation Water Requirement

The results of irrigation water requirement analysis for Rice-Rice-Palawija planting pattern could be observed in Figure 3. The results show that the maximum value of irrigation water requirements for Rice-Rice-Palawija planting pattern obtained for simulation 1 occurred on 1 September by 1.66 m³/s, while the minimum value

occurred on 1 January, 2 May, and 2 December by 0.23 m³/s. Additionally, the maximum value in simulation 2 occurred on 2 September by 1.65 m³/s, while the minimum value occurred on 1 January and 1 July by 0.23 m³/s. Finally, the maximum value in simulation 3 happened on 2 October by 1.65 m³/s, while the minimum value occurred on 1 February and 1 June by 0.23 m³/s.

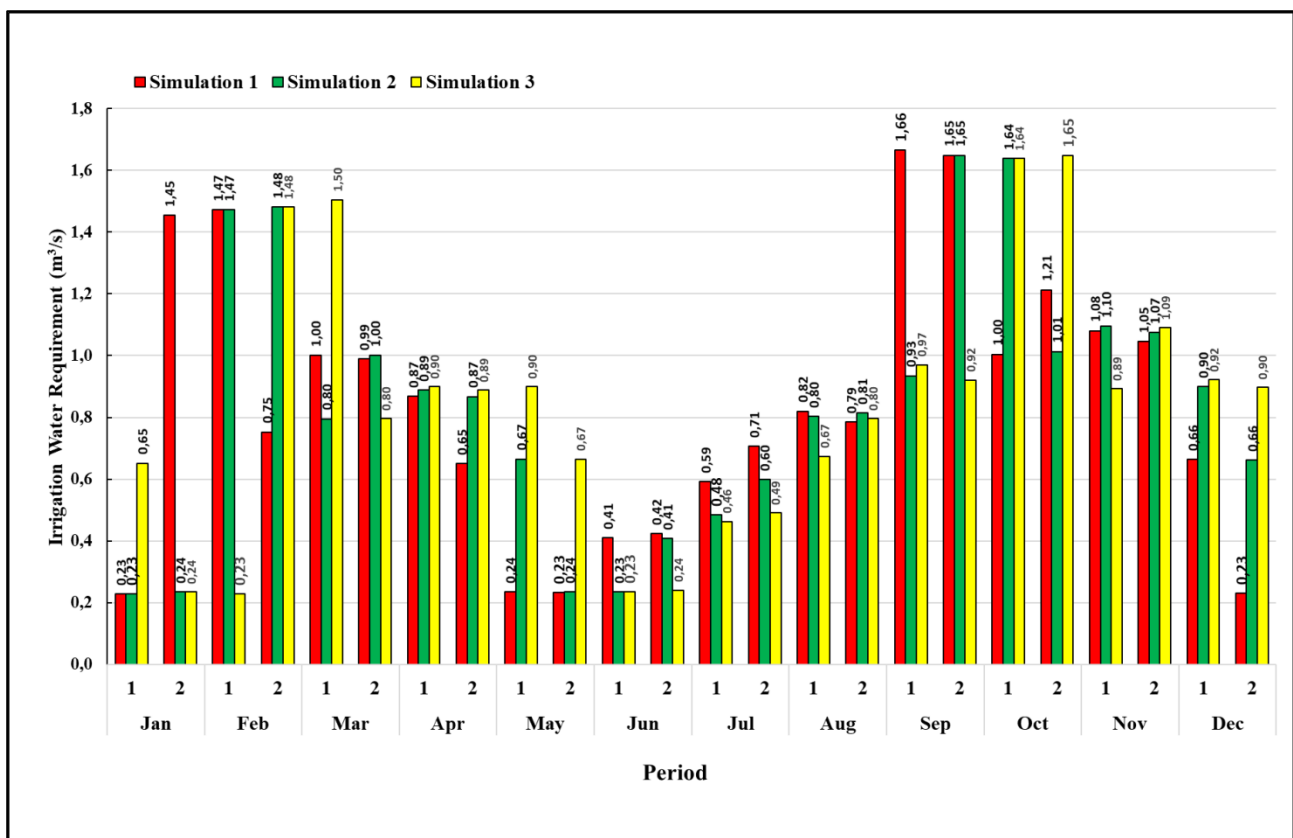


Fig. 3. Water Requirements of Kiru-Kiru Irrigation Area

III.7 Water Balance

Water balance is balance between the water coming in and coming out of a system. The results (Figure 4 and Table 5) show that the water balance for the Rice-Rice-Palawija planting pattern combination in the 1st simulation during the rainy season (1 September – 2 January) experienced a maximum surplus (S) of 5.62 m³/s and a deficit (D) of 0.60 m³/s, while that during the dry season (1 February – 2 August) experienced a maximum surplus of 2.66 m³/s and a minimum value or deficit of 0.21 m³/s. Meanwhile, for the 2nd simulation during the rainy season (2 September – 1 February), it

experienced a maximum surplus of 5.26 m³/s and a deficit of 0.58 m³/s, while during the dry season (2 February – 1 October), it experienced a maximum surplus of 1.93 m³/s and a deficit of 0.61 m³/s.

Then, in the 3rd simulation during the rainy season (1 October – 2 February), there **has been** a maximum surplus of 5.25 m³/s and it **has** experienced a deficit of 0.62 m³/s, while during the dry season (1 March – 2 August), it **has** experienced a maximum surplus of 1.45 m³/s and a deficit of 0.13 m³/s.

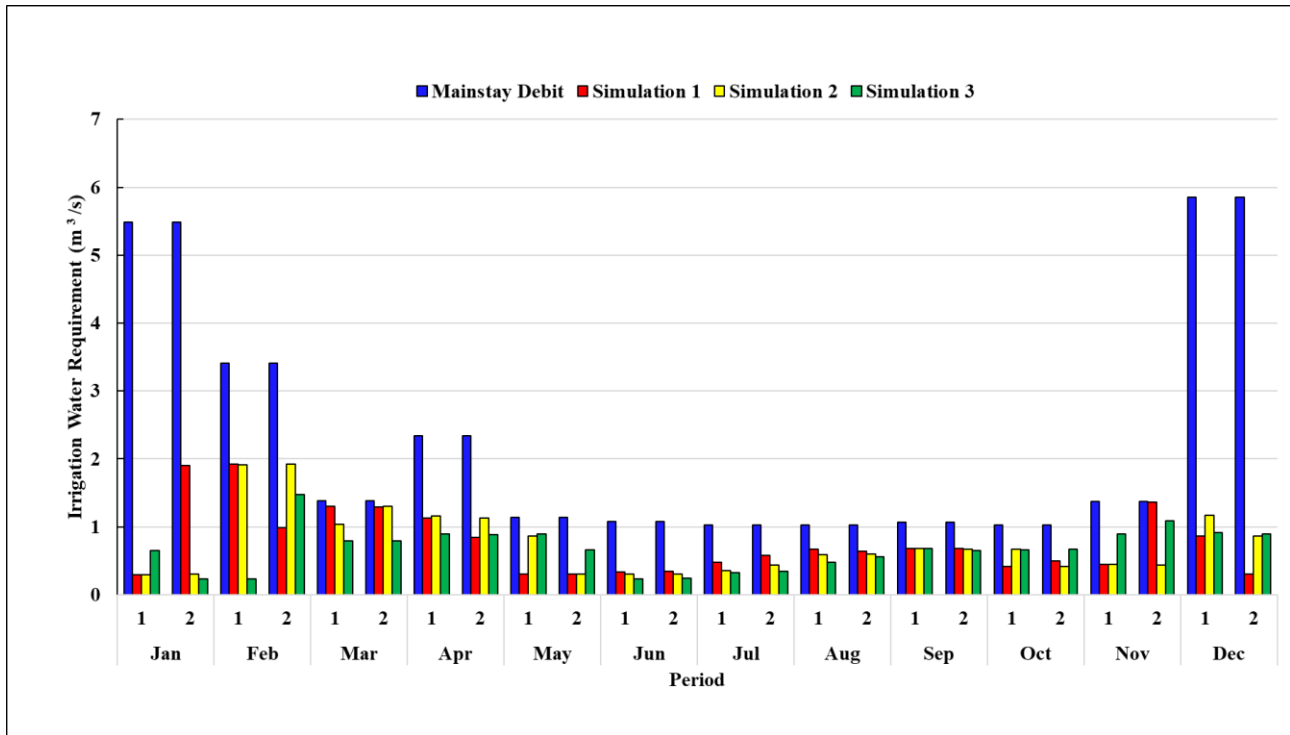


Fig. 4. Water Balance of Kiru-Kiru Irrigation Area

TABLE 5
WATER BALANCE OF KIRU-KIRU IRRIGATION AREA

Description	Month	Jan		Feb		Mar		Apr		May		Jun	
		1	2	1	2	1	2	1	2	1	2	1	2
1 st Simulation	Mainstay Debit (m ³ /s)	5.48	5.48	3.41	3.41	1.38	1.38	2.34	2.34	1.14	1.14	1.08	1.08
	Irrigation Water Requirement (m ³ /s)	0.23	1.45	1.47	0.75	1.00	0.99	0.87	0.65	0.24	0.23	0.41	0.42
	Water Balance	5.26	4.03	1.94	2.66	0.38	0.39	1.47	1.69	0.91	0.91	0.67	0.65
	Surplus/Defisit	S	S	S	S	S	S	S	S	S	S	S	S
	Month	Jul		Aug		Sep		Oct		Nov		Dec	
		1	2	1	2	1	2	1	2	1	2	1	2
	Mainstay Debit (m ³ /s)	1.03	1.03	1.03	1.03	1.06	1.06	1.03	1.03	1.38	1.38	5.85	5.85
	Irrigation Water Requirement (m ³ /s)	0.59	0.71	0.82	0.79	1.66	1.65	1.00	1.21	1.08	1.05	0.66	0.23
	Water Balance	0.44	0.32	0.21	0.24	-0.60	-0.58	0.03	-0.18	0.30	0.33	5.19	5.62
	Surplus/Defisit	S	S	S	S	D	D	S	D	S	S	S	S
2 nd Simulation	Month	Jan		Feb		Mar		Apr		May		Jun	
		1	2	1	2	1	2	1	2	1	2	1	2
	Mainstay Debit (m ³ /s)	5.48	5.48	3.41	3.41	1.38	1.38	2.34	2.34	1.14	1.14	1.08	1.08
	Irrigation Water Requirement (m ³ /s)	0.23	0.24	1.47	1.48	0.80	1.00	0.89	0.87	0.67	0.24	0.23	0.41
	Water Balance	5.26	5.25	1.94	1.93	0.58	0.38	1.45	1.47	0.48	0.91	0.84	0.67
	Surplus/Defisit	S	S	S	S	S	S	S	S	S	S	S	S
	Month	Jul		Aug		Sep		Oct		Nov		Dec	
		1	2	1	2	1	2	1	2	1	2	1	2
	Mainstay Debit (m ³ /s)	1.03	1.03	1.03	1.03	1.06	1.06	1.03	1.03	1.38	1.38	5.85	5.85
	Irrigation Water Requirement (m ³ /s)	0.48	0.60	0.80	0.81	0.93	1.65	1.64	1.01	1.10	1.07	0.90	0.66
	Water Balance	0.55	0.43	0.23	0.22	0.13	-0.58	-0.61	0.02	0.28	0.30	4.95	5.19
	Surplus/Defisit	S	S	S	S	S	D	D	S	S	S	S	S
3 rd Simulation	Month	Jan		Feb		Mar		Apr		May		Jun	
		1	2	1	2	1	2	1	2	1	2	1	2
	Mainstay Debit (m ³ /s)	5.48	5.48	3.41	3.41	1.38	1.38	2.34	2.34	1.14	1.14	1.08	1.08
	Irrigation Water Requirement (m ³ /s)	0.65	0.24	0.23	1.48	1.50	0.80	0.90	0.89	0.90	0.67	0.23	0.24
	Water Balance	4.83	5.25	3.19	1.93	-0.13	0.58	1.44	1.45	0.24	0.48	0.84	0.84
	Surplus/Defisit	S	S	S	S	D	S	S	S	S	S	S	S
	Month	Jul		Aug		Sep		Oct		Nov		Dec	
		1	2	1	2	1	2	1	2	1	2	1	2
	Mainstay Debit (m ³ /s)	1.03	1.03	1.03	1.03	1.06	1.06	1.03	1.03	1.38	1.38	5.85	5.85
	Irrigation Water Requirement (m ³ /s)	0.46	0.49	0.67	0.80	0.97	0.92	1.64	1.65	0.89	1.09	0.92	0.90
	Water Balance	0.57	0.54	0.36	0.23	0.09	0.14	-0.61	-0.62	0.48	0.29	4.93	4.95
	Surplus/Defisit	S	S	S	S	S	S	D	D	S	S	S	S

Based on figure 4 and table 5 above, the results show that the water balance for the Rice-Rice-Palawija planting pattern in 1st simulation during the rainy season (1 September – 2 January) experienced a maximum surplus of 5.62 m³/s and a deficit of 0.60 m³/s, while that during the dry season (1 February – 2 August) experienced a maximum surplus of 2.66 m³/s and a minimum value of 0.21 m³/s. Meanwhile, in the 2nd simulation during the rainy season (2 September – 1 February), it experienced a maximum surplus of 5.26 m³/s and a deficit of 0.58 m³/s, while during the dry season (2 February – 1 October), it experienced a maximum surplus of 1.93 m³/s and a deficit of 0.61 m³/s.

While for the 3rd simulation during the rainy season (1 October – 2 February), there has been a maximum surplus of 5.25 m³/s and it experienced a deficit of 0.62 m³/s, while during the dry season (1 March – 2 August), it experienced a maximum surplus of 1.45 m³/s and a

deficit of 0.13 m³/s. In accordance with the results of water balance in Kiru-Kiru irrigation area, it could be identified that Kiru-Kiru irrigation area has experienced water deficit in several months. Furthermore, in this study, simulation selection is influenced by several factors, such as water requirements, land preparation, water layer replacement, percolation, planting factors, and climate factors. The simulation that is close to the field conditions is simulation 3, which results in a water demand of 2.30 l/s/ha and a significant land area of 716 Ha with an existing potential land area of 717 ha.

As one of the efforts made in order to fulfil the irrigation water requirements, it has necessitated an adjustment on the irrigation area to be developed by decreasing the irrigation area in the Irrigation Area in question as displayed in table 7 and figure 5.

TABLE 6
WATER BALANCE OF KIRU-KIRU IRRIGATION AREA AFTER OPTIMIZATION

Month	Period	Planting Period	Water Availability (l/s)	Water Irrigation Requirement (l/s/ha)		Area (Ha)	
				Rice	Palawija	Rice	Palawija
Jan	1	I	5483.89	4.96		717.00	
	2	I	5483.89	4.96		717.00	
Feb	1		3414.59	0.32		6920.69	
	2	II	3414.59	3.09		717.00	
Mar	1	II	1378.52	1.25		717.00	
	2	II	1378.52	1.25		717.00	
Apr	1	II	2336.72	2.11		717.00	
	2	II	2336.72	2.11		717.00	
May	1	II	1141.13	1.03		717.00	
	2	II	1141.13	1.03		717.00	
Jun	1	II	1076.03	0.97		717.00	
	2		1076.03		0.34		2076.50
Jul	1	III	1031.30		0.65		1035.00
	2	III	1031.30		0.68		976.86
Aug	1	III	1029.57		0.94		709.52
	2	III	1029.57		1.11		600.34
Sep	1	III	1063.89		1.35		509.68
	2	III	1063.89		0.96		717.00
Oct	1	I	1029.57	0.93		717.00	
	2	I	1029.57	0.93		717.00	
Nov	1	I	1377.09	1.24		717.00	
	2	I	1377.09	1.24		717.00	
Dec	1	I	5849.71	5.29		717.00	
	2	I	5849.71	5.29		717.00	

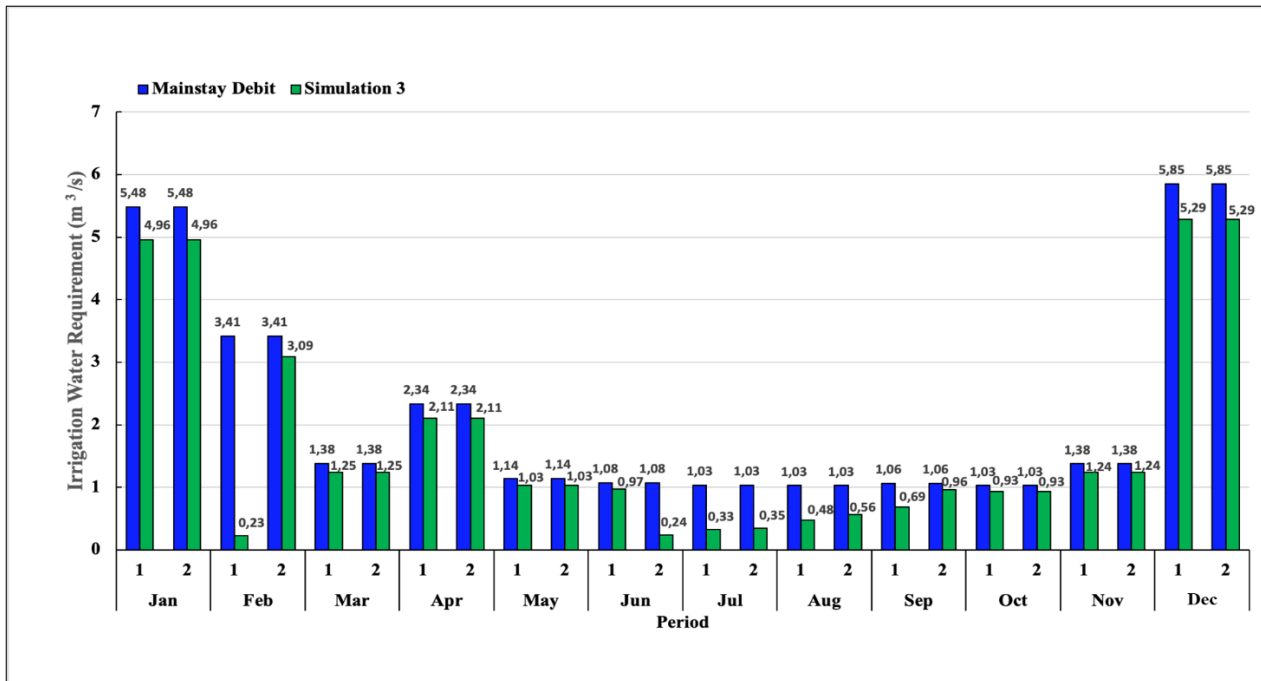


Fig. 5. Water Balance of Kiru-Kiru Irrigation Area After Optimization

Moreover, table 6 and Figure 4 show that there are 3 planting seasons recommendation, namely; first planting season (I) is on 1st October to 2nd January and second planting season (II) is on 2nd February to 1st June. These planting seasons could reach their optimal planting patterns with 100% of rice or 717 Ha planted with rice. Finally, the last planting season (III) is on 1st July to 2nd September with optimal cropping pattern is *palawija* at 509.68 Ha.

Overall, this study should be regarded as a first step towards optimization planting pattern in South Sulawesi, although several works still need to be done on simulation verification. Moreover, this study involves the assessment of water that is really accessible for all the uses and development and should be considered as a starting point in optimization of planting patterns in Indonesia. This study has not incorporated water quality aspect of the Kiru-Kiru Irrigation but it should be taken up as part of the future scope.

IV. CONCLUSION

In this study, the evapotranspiration has been analyzed and 3 simulations of irrigation water requirement have been developed. By using water balance consideration, this study has simulated 3 recommendation planting patterns based on the maximum surplus and minimum value of water. Importantly, this study has considered several necessary factors, namely water requirements, land preparation, water layer replacement, percolation, planting factors, and climate factors.

The significance values among the three simulations have been found at the 3rd simulation as the optimal planting pattern. Irrigation water balance in Kiru-Kiru irrigation area on the existing condition (3rd simulation)

experienced a deficit on 1 October, 2 October, and 1 March. The effort made in order to resolve water shortage problem is to carry out planting pattern optimization. The presented result has suggested that the most optimal cropping pattern is planting 100% of rice in the first and second planting seasons with an area of 717 Ha and 71% planted with *palawija* in the third planting season of 509.68 Ha.

Therefore, in future investigation, in order to provide information that are more credible to this field and to support the Indonesia Government programs, it would be interesting to compare other irrigation areas in Barru Regency with continual production of additional data.

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FINAL SUBMISSION

Optimization of Planting Patterns in South Sulawesi

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Abstract – South Sulawesi is one of the nine provinces in Indonesia that has the highest contribution to the national income and its leading sector in agricultural crops including rice. The planning of planting patterns is highly dependent on the size of the intensity of rainfall in a particular area. Therefore, these conditions can have an impact on the level of suitability of crops to be planted. The purpose of this study has been to analyze the water balance and identify the optimal planting pattern. On the basis of rainfall data obtained from 4 rainfall stations, which are Mangkoso station, Manuba station, Mareppang station, and Ralla station, during the period of 25 years (1996 – 2020), the analysis to determine the average semi-monthly rainfall can be carried out. The results show that the maximum value of irrigation water requirements for rice-rice-palawija planting pattern obtained for simulation 1 has occurred on 1 September by 1.66 m³/s, while the minimum value has occurred on 1 January, 2 May, and 2 December by 0.23 m³/s. As a conclusion, the maximum value in simulation 3 has occurred on 2 October by 1.65 m³/s, while the minimum value has occurred on 1 February and 1 June by 0.23 m³/s. The optimization results show that the most optimal cropping pattern is planting 100% of rice in the first and second planting seasons with an area of 717 Ha and 71% planted with palawija in the third planting season of 509.68 Ha. Copyright © 2013 Praise Worthy Prize S.r.l. - All rights reserved.

Keywords: Evapotranspiration, Water Availability, Mainstay Debit, Water Demand Irrigation, Water Balance

Nomenclature			
		IR	Water requirement in paddy field (mm/day)
BF	Base flow (m ³ /km ²)	IR	Irrigation water requirement (mm/day)
c	Penman correction figure which includes the difference of values between day and night weather conditions	k _c	Crop coefficient
		M	Water requirement to replace water loss due to evaporation and percolation in saturated rice fields (mm/day)
DR	Water withdrawal requirement at the water source (l/s/ha)	m	Data rating
DRO	Direct run off (m ³ /s/km ²)	n	Number of data
e	Nafier coefficient (2.71828182846)	n	Number of rain gauge stations
ea	Saturated vapor pressure (mbar)	NFR	Net Field Water Requirement; the need for clean water in the fields (mm/day)
ed	Actual vapor pressure (mbar)	P	Percolation (mm/day)
ef	Overall irrigation efficiency	Q	Mainstay debit (m ³ /s)
ET _c	Plant evaporation (mm/day)	Q80	Mainstay debit with a possibility of not meeting 20% (l/s)
ET _c	Consumptive water requirement (mm/day)	Re	Effective rainfall (mm/day)
E ₀	Evaporation of open water (mm/day)	R _s	Shortwave radiation in evaporation units (mm/day)
ET ₀	Potential Evapotranspiration (mm/day)	Re _{rice}	Effective rainfall for rice plant (mm/day)
ET*	Actual evapotranspiration (mm/day)	Re _{palawija}	Effective rainfall for palawija plant (mm/day)
F	Catchment area (km ²)		
f(u)	Function of wind speed at the height of 2 m in units (m/s)	R _{n1}	longwave net radiation (mm/day)

$\bar{R}$	Average region rainfall (mm)
$R_1, R_2 \dots R_n$	Rainfall at station n (mm)
R_{80}	Mainstay rainfall with a possibility of not meeting 20% (l/s)
w	Factor related to temperature (T) and elevation of the area. For areas of Indonesia with an elevation of 0-500 m
S	Water requirement for saturation added by water layer
T	Time period for land preparation
WLR	Water layer replacement (mm/day)
1/8.64	Unit conversion rate from mm/day to l/s/ha

I. Introduction

Irrigated agriculture is a vital resource in many parts of the world. This is driven or limited both by the availability of water and by the capital investment in irrigation related infrastructure including dams and largescale canals and, to a lesser extent, sprinkler system or field-based drip irrigation system [3]. Sustainable water management at the farm level has enormous relevance, i.e., in terms of implementing an adequate irrigation schedule, which should lead to optimal yields and agriculture as well as irrigation [5] [25].

South Sulawesi is one of the nine provinces in Indonesia that has the highest contribution to the national income and its leading sector in agricultural crops including rice. One of the areas in South Sulawesi that is popular known as rice center region is Barru Regency. It has several irrigation areas, one of which is Kiru-Kiru irrigation area and has potential area of 717 Ha and functional area of 628 Ha [1] which includes 2 urban villages and 3 villages, i.e., Kiru-kiru Village, Mangkoso Village, Siddo Village, Ajakkang Village and Lawallu Village. Based on data from the Central Bureau of Statistic [2], it is noticed that the annual rainfall is 3.975,9 mm/year. In this area, the rainy season lasts from October to April, while the dry season lasts from April to September. Therefore, the people in Soppeng Riaja District mostly work as farmers.

There are three sources of water loss, which are evaporation from soil surface, water and plant surfaces that do not contribute to evapotranspiration of cultivated plants, and drainage loss (runoff) [4]. The growing season, also called the frost-free season, is the period of year in which the most favorable growing conditions for native vegetation and cultivated plants take place. It is a period in one year that is categorized as rainy season, whose length varies according to space, time, and type of plant [6]. The availability of ground water will determine plant growth and yield directly because lack of water causes a decrease in the rate of photosynthesis and disturbance of assimilate distribution, and has negative impacts on plant growth in both the vegetative and generative phases [7].

The amount of water available and the amount of water needed will fluctuate from time to time. Consequently, in one period, there can be an excess of water and in another period, there is a shortage of water for plants [8]. One way to determine fluctuations in water availability from month to month is by utilizing water between the amount of rainwater input and the ability of soil water [9].

Water balance is useful for completing a general description of the state of water in an area (precipitation, evapotranspiration, water content, and changes in soil moisture), assessing the ability of an area to be planted by estimating the water requirement for plants, and testing the relationship of climate or weather with crop production [10]. The availability of water is very influential on the planting pattern of an area [11]. The planting pattern of agricultural land can be optimized according to the availability of water in the area. A planting pattern is a planting system that is utilized on an area of land, which includes the method and types of plants as well as the planting schedule during a certain period of time [12].

Utomo [13] has mentioned that planting patterns are designed to determine the time when plants can efficiently utilize the available water. Planting pattern includes the selection of plants whose water requirement is in accordance with the distribution of rainfall, and crop rotation that can utilize rainfall efficiently. If the rainy season is short, the selected plants that are the short-lived ones. On the other hand, if the rainy season is long enough, the selected plants are long-lived, or two plants are selected where the second is taken because it is drought tolerant [13].

Furthermore, according to Unganji et al. [14], the diversity of land characteristics can affect plant growth and development, so they also affect the production of the plant itself. Plants that grow in suitable climatic and land conditions can yield optimally. On the other hand, plants that grow in unsuitable climatic conditions and land will be impacted on the decreasing production. Dwiratna et al. [15] have declared that farmers usually apply planting patterns and schedules based on conventional habits, which are often carried out during the same climatic conditions every year. However, global climate change can have an impact on the non-enforcement of these habits. Planting failure and crop failure are common problems experienced by farmers because of variations in rainfall that are not fixed every year, making it difficult to determine plants that are in accordance with the conditions of groundwater availability, especially since the water requirement of each type of plant is different.

Moreover, setting a planting pattern is an agricultural effort carried out in order to obtain maximum agricultural products and minimize the risk of crop failure by considering climatic and land conditions. The planning of planting patterns is highly dependent on the size of the intensity of rainfall in a particular area. Therefore, these conditions can have an impact on the level of suitability

of crops to be planted. Planning a planting pattern based on the intensity of rainfall in accordance with the needs of the plant can result in better production.

Additionally, research about planting pattern has been conducted by several previous studies [16] [17]. These studies have identified the potential planting seasons on irrigated or non-irrigated areas and have involved water balance value to show the water deficit. Despite growing agreement regarding the existence of potential planting season, there is a lack of understanding regarding the necessity of irrigation water balance analysis and optimal planting pattern system using simulations and mainstay debit as its constrain.

The objectives of this study have been to analyze the water balance and to identify the optimal planting pattern in Kiru-Kiru Irrigation Area, South Sulawesi. The article is divided into six sections. The first one is the current introduction, the second one refers to describing its methodology regarding water availability and irrigation water requirement, the third one concerns the result and the analysis of evapotranspiration, regional, rainfall, mainstay rainfall, effective rainfall, water availability analysis, irrigation water requirement, and water balance. Conclusions and recommendations are presented in the last section.

II. Method

This research data has been carried out from Kiru-Kiru Irrigation Area and located on the west coast of South Sulawesi Province between the coordinates of 40°5'49"-40°47'35" south latitude and 119°35'00"-119°49'16" east longitude covering an area of 1,174.72 km².

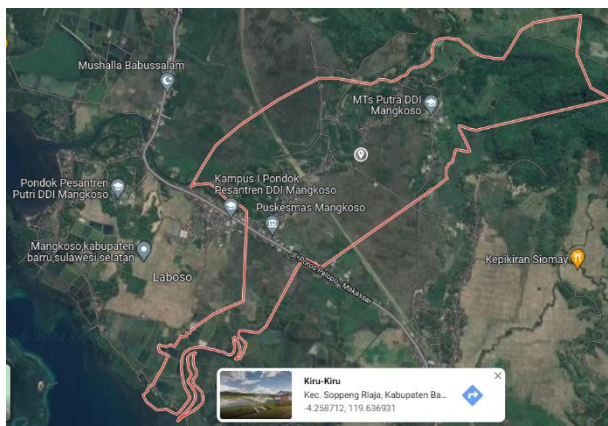


Figure 1. Research Site Map

II.1. Water Availability

a. Potential Evaporatranspiration

The use of Modified Penman equation is recommended as a standard for reference evapotranspiration in order to provide values that are more consistent with the actual plant water use data worldwide [18]. The equation is described as follows:

$$ET_0 = c \times ET^* \quad (1)$$

$$ET^* = w (0.75 R_s - R_{n1}) + (1 - w)f(u)(ea - ed) \quad (2)$$

b. Regional Rainfall

The value of regional rainfall can be determined from several rainfall data in rain gauge stations by employing the average value of rainfall for stations located within the watershed and stations outside the watershed that are still close together which can be calculated as follows:

$$\bar{R} = \frac{1}{n} (R_1 + R_2 + \dots + R_n) \quad (3)$$

c. Mock's Method

Mock's method shows water balance analysis to calculate monthly debit values based on the transformation of monthly rainfall data, evapotranspiration, soil moisture, and groundwater reservoirs. The principle of this method states that the rain that falls on water catchment areas will partly be lost due to evapotranspiration [19].

The water balance using the F. J. Mock method is formulated as follows:

$$Q = (DRO + BF) F \quad (4)$$

d. Mainstay Debit

Mainstay debit is calculated using the Weibull method with an 80% chance of occurrence [20]. The semi-monthly debit data are sorted from the largest to the smallest data. Then, the probability of each data is calculated based on the data ranking using equation 5 below:

$$Q_{80} = \frac{m}{n+1} \times 100\% \quad (5)$$

II.2. Irrigation Water Requirement

The irrigation water requirement for rice is different from the irrigation water requirement for secondary crops (*palawija*). The field water requirement for rice is calculated using equation (6), while the irrigation water requirement is calculated using equation (7). The formula for calculating irrigation water requirement for secondary crops (*palawija*) can be observed in equation (8) [21]:

$$NFR = ET_c + P + WLR - Re \quad (6)$$

$$IR = \frac{NFR}{ef} \quad (7)$$

$$IR = \frac{(ET_c - Re)}{ef} \quad (8)$$

$$DR = \frac{IR}{8.64} \quad (9)$$

a. Effective Rainfall

The effective rainfall for rice and secondary crops (*palawija*) is calculated differently. The effective rainfall for rice is 70% of the average mid-month rainfall with a possibility of not meeting 20% (R_{80}). This rainfall with a possibility of not meeting 20% is calculated using the Weibull method as follows:

$$R_{80} = \frac{m}{n+1} \times 100\% \quad (10)$$

$$Re_{rice} = 0.7 \times R_{80} \quad (11)$$

$$Re_{palawija} = 0.7 \times R_{50} \quad (12)$$

b. Water Requirement for Land Cultivation

The calculation of water requirements during land cultivation is done by using the following equation [2]:

$$IR = \frac{Me^k}{(E^k - 1)} \quad (13)$$

$$M = E_0 + P \quad (14)$$

$$E_0 = 1.1 \times ET_0 \quad (15)$$

$$K = M \times \left(\frac{T}{S}\right) \quad (16)$$

c. Water Requirement to Replace the Water Layer (Water Layer Requirement)

The water requirement to replace the water layer (Water Layer Requirement (WLR)) is determined based on the 2013 Indonesia Irrigation Planning Standard. The amount of water required for water layer replacement is 50 mm/month (or 3.3 mm/day for 1/2 months) for one month and two months after transplantation.

d. Consumptive Water Requirement

Consumptive water requirement is the water requirements for plants on the farm. Plant evapotranspiration (ET_c) is the actual evapotranspiration, which is very different from ET_0 , as a ground cover. The nature of plant canopy and the aerodynamic resistance of plant are different from that of grass [22]. After the reference plant evapotranspiration (ET_0) is obtained, the plant evapotranspiration can be estimated by the following equation [23] [24]:

$$ET_c = k_c \times ET_0 \quad (17)$$

e. Percolation (p) and Seepage

The percolation rate is highly dependent on the nature of the soil, and the nature of the soil generally depends on the activities of land use or cultivation. The percolation rate ranges from 1-3 mm/day.

f. Irrigation Efficiency (EI)

In order to account for water loss during transportation and application to the field, the efficiency factor has been utilized in the calculation of irrigation water requirements [23]. This loss occurs as the result of exploitation, evaporation, and seepage activities. In general, water loss in irrigation networks can be divided as follows [2]: 12.5-20% in the tertiary plots between tertiary tapping buildings and rice fields; 5-10% in the secondary channel; and 5-10% in the main channel.

II.3 Water Balance

Water balance is a way of analyzing the balance equation of water based on the law of conservation of mass, which states that a substance cannot be created or destroyed, but a substance can change its form [18]. Water balance is an explanation of the relationship between inflow and outflow in a watershed for a certain period of water circulation process. Therefore, it is possible to identify the excess (surplus) or shortage (deficit) on the amount of water.

III. Result and Analysis

III.1 Evapotranspiration

The evapotranspiration has been analyzed using the FAO Modified Penman method. The calculation of the amount of evapotranspiration requires climatological data, such as temperature, humidity, wind speed, and duration of sunlight. In this study, the climatological station employed has been Tabo-Tabo Station, Pangkep Regency. The result of Evapotranspiration calculation can be seen in Table 1.

TABLE 1
EVAPOTRANSPIRATION AT KIRU-KIRU IRRIGATION AREA (mm/day)

ET ₀	Jan	Feb	Mar	Apr	May	Jun
mm/day	3.39	3.65	4.00	3.23	3.48	2.72
ET ₀	Jul	Aug	Sept	Oct	Nov	Dec
mm/day	3.67	4.38	5.51	5.48	4.68	3.50

Based on table 1, the Evapotranspiration results show that the Maximum Evapotranspiration at Kiru-Kiru Irrigation Area has occurred in October by 5.48 mm/day, while the Minimum evapotranspiration has occurred in June by 2.72 mm/day.

III.2 Regional Rainfall

Based on of rainfall data obtained from 4 rainfall stations, which are Mangkoso station, Manuba station, Mareppang station, and Ralla station, during the period of 25 years (1996 – 2020), the analysis to determine the average semi-monthly rainfall can be carried out. It can be observed that the maximum average rainfall in the Kiru-Kiru irrigation area has occurred on 2 September by 13.65 mm/day while the minimum rainfall has occurred on 2 August by 5.23 mm (Figure 2).

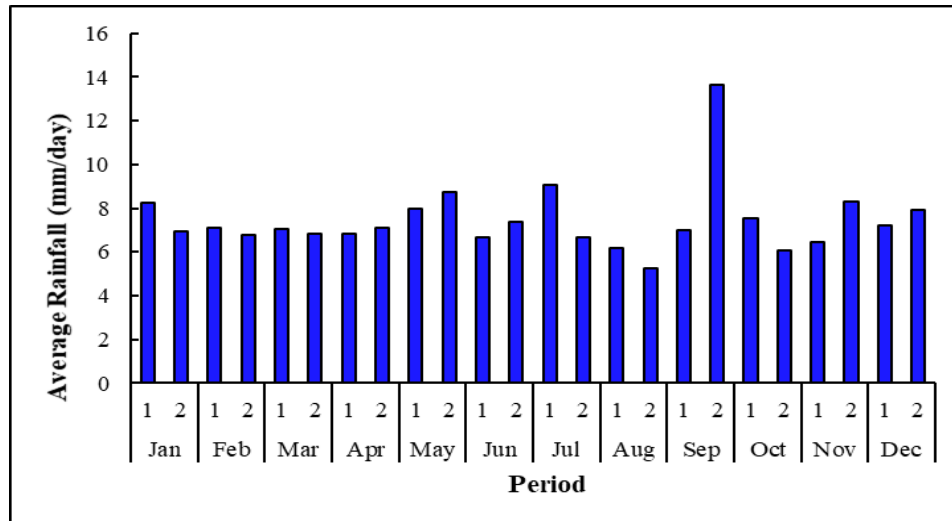


Fig. 2. Average Rainfall of Kiru-Kiru Irrigation Area in 1996-2020

III.3 Mainstay Rainfall

The mainstay rainfall for rice plants is set at 80% (R_{80}), while for secondary crops (*palawija*), it is set at 50% (R_{50}). The results of the mainstay rainfall calculations show that rainfall with maximum reliability of 80% (R_{80}) occurred on 1 January by 4.75 mm and the

minimum one occurred on 1 September by 0 mm. Meanwhile, for the rainfall with maximum reliability of 50% (R_{50}), it occurred on 2 December by 7.75 mm and the minimum one occurred on 1 August and 1 September by 4.00 mm (Table 2).

TABLE 2

CH Mainstay (mm)	MAINSTAY RAINFALL FOR RICE AND SECONDARY CROPS (<i>Palawija</i>)											
	Jan		Feb		Mar		Apr		May		Jun	
	1	2	1	2	1	2	1	2	1	2	1	2
R_{80}	4.75	3.50	4.50	3.00	4.00	3.75	3.25	3.33	3.50	3.33	3.67	2.50
R_{50}	6.75	5.00	7.50	6.00	5.50	6.75	4.75	5.50	5.67	5.25	4.75	5.00
CH Mainstay (mm)	July		Aug		Sep		Oct		Nov		Dec	
	1	2	1	2	1	2	1	2	1	2	1	2
R_{80}	3.00	2.00	1.00	1.00	0.00	2.75	4.00	2.50	3.75	4.75	3.75	4.00
R_{50}	6.67	5.00	4.00	5.50	4.00	7.33	5.75	5.67	6.00	6.00	5.00	7.75

III.4 Effective Rainfall

In the calculation of the effective rainfall for rice, the result has been 70% of R_{80} of the time in a period, while for the effective rainfall of secondary crops (*palawija*), it has been 50% of R_{50} . The effective rainfall for paddy maximally occurred on 1 January and 2 November by

0.22 mm/day and the minimum value occurs on 1 September by 0 mm/day. Meanwhile, the effective rainfall for secondary crops (*palawija*) maximally happened on 2 December by 0.26 mm/day and the minimum value occurred on 1 February and 1 March by 0.13 mm/day (Table 3).

TABLE 3

Effective CH (mm/day)	EFFECTIVE RAINFALL FOR RICE AND SECONDARY CROPS (<i>Palawija</i>)											
	Jan		Feb		Mar		Apr		May		Jun	
	1	2	1	2	1	2	1	2	1	2	1	2
Re Rice	0.22	0.16	0.21	0.14	0.19	0.18	0.15	0.16	0.16	0.16	0.17	0.12
Re Palawija	0.23	0.17	0.25	0.20	0.18	0.23	0.16	0.18	0.19	0.18	0.16	0.17
Effective CH (mm/day)	Jul		Aug		Sept		Oct		Nov		Dec	
	1	2	1	2	1	2	1	2	1	2	1	2
Re Rice	0.14	0.09	0.05	0.05	0.00	0.13	0.19	0.12	0.18	0.22	0.18	0.19
Re Palawija	0.22	0.17	0.13	0.18	0.13	0.24	0.19	0.19	0.20	0.20	0.17	0.26

III.5 Water Availability Analysis and Mainstay Debit

In order to determine the value of water availability in Kiru-Kiru irrigation area, this study has utilized the calculation result of the water debit in Kiru-Kiru watershed using Mock Method. Water availability has

been calculated by determining the mainstay debit from the debit data (1996-2020) and processed the results into monthly data. The debit data has been sorted from the largest to the smallest data. After that, the probability of each data has been calculated in accordance with the data rank. The 80% mainstay debit (Q_{80}) has maximally

occurred in December with a debit of 5.85 m³/s, while the minimum debit occurred in July, August and October

with a debit of 1.03 m³/s (Table 4).

TABLE 4
MAINSTAY DEBIT WITH 80% PROBABILITY

Mainstay Debit (m ³ /s)	Month											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Q ₈₀	5.48	3.41	1.38	2.34	1.14	1.08	1.03	1.03	1.06	1.03	1.38	5.85

III.6 Irrigation Water Requirement

The results of irrigation water requirement analysis for Rice-Rice-Palawija planting pattern could be observed in Figure 3. The results show that the maximum value of irrigation water requirements for Rice-Rice-Palawija planting pattern obtained for simulation 1 occurred on 1 September by 1.66 m³/s, while the minimum value

occurred on 1 January, 2 May, and 2 December by 0.23 m³/s. Additionally, the maximum value in simulation 2 occurred on 2 September by 1.65 m³/s, while the minimum value occurred on 1 January and 1 July by 0.23 m³/s. Finally, the maximum value in simulation 3 happened on 2 October by 1.65 m³/s, while the minimum value occurred on 1 February and 1 June by 0.23 m³/s.

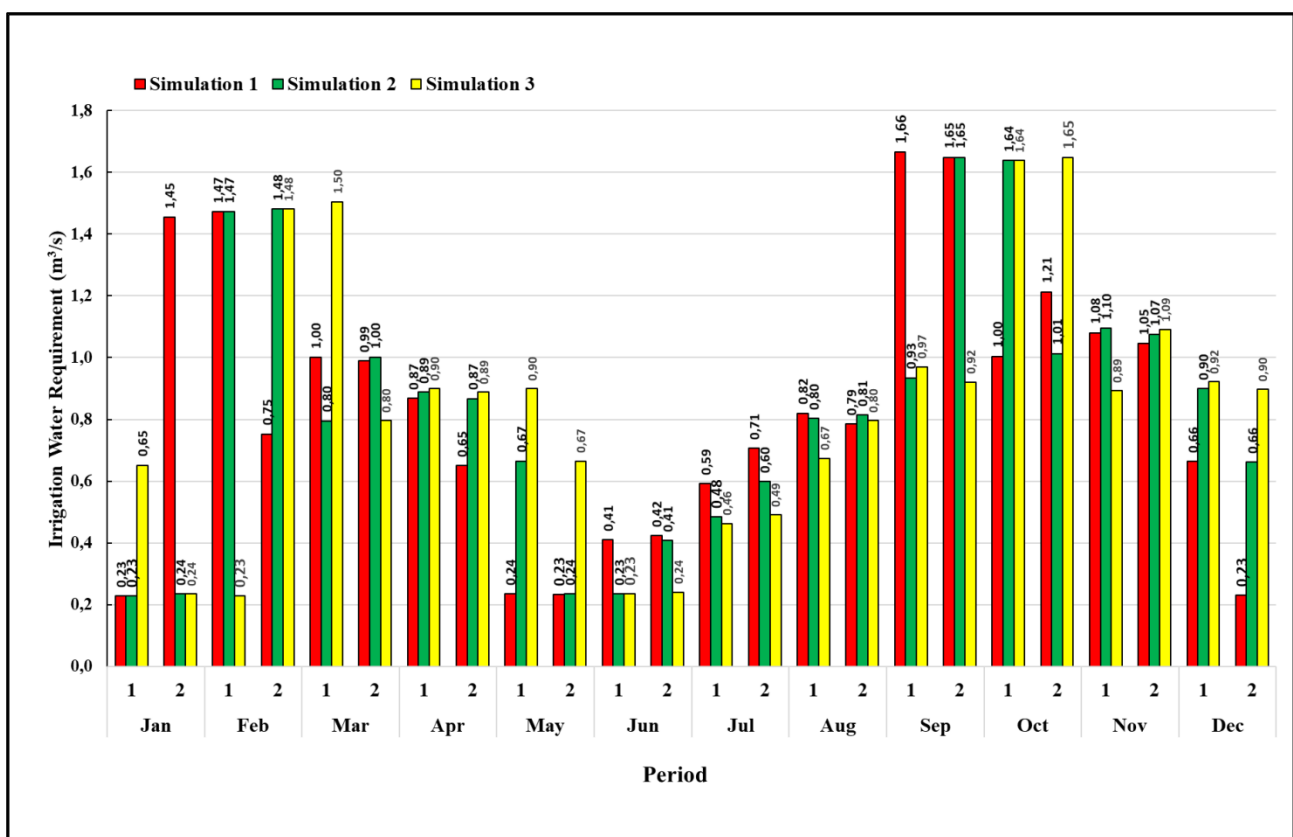


Fig. 3. Water Requirements of Kiru-Kiru Irrigation Area

III.7 Water Balance

Water balance is balance between the water coming in and coming out of a system. The results (Figure 4 and Table 5) show that the water balance for the Rice-Rice-Palawija planting pattern combination in the 1st simulation during the rainy season (1 September – 2 January) experienced a maximum surplus (S) of 5.62 m³/s and a deficit (D) of 0.60 m³/s, while that during the dry season (1 February – 2 August) experienced a maximum surplus of 2.66 m³/s and a minimum value or deficit of 0.21 m³/s. Meanwhile, for the 2nd simulation during the rainy season (2 September – 1 February), it

experienced a maximum surplus of 5.26 m³/s and a deficit of 0.58 m³/s, while during the dry season (2 February – 1 October), it experienced a maximum surplus of 1.93 m³/s and a deficit of 0.61 m³/s.

Then, in the 3rd simulation during the rainy season (1 October – 2 February), there **has been** a maximum surplus of 5.25 m³/s and it **has** experienced a deficit of 0.62 m³/s, while during the dry season (1 March – 2 August), it **has** experienced a maximum surplus of 1.45 m³/s and a deficit of 0.13 m³/s.

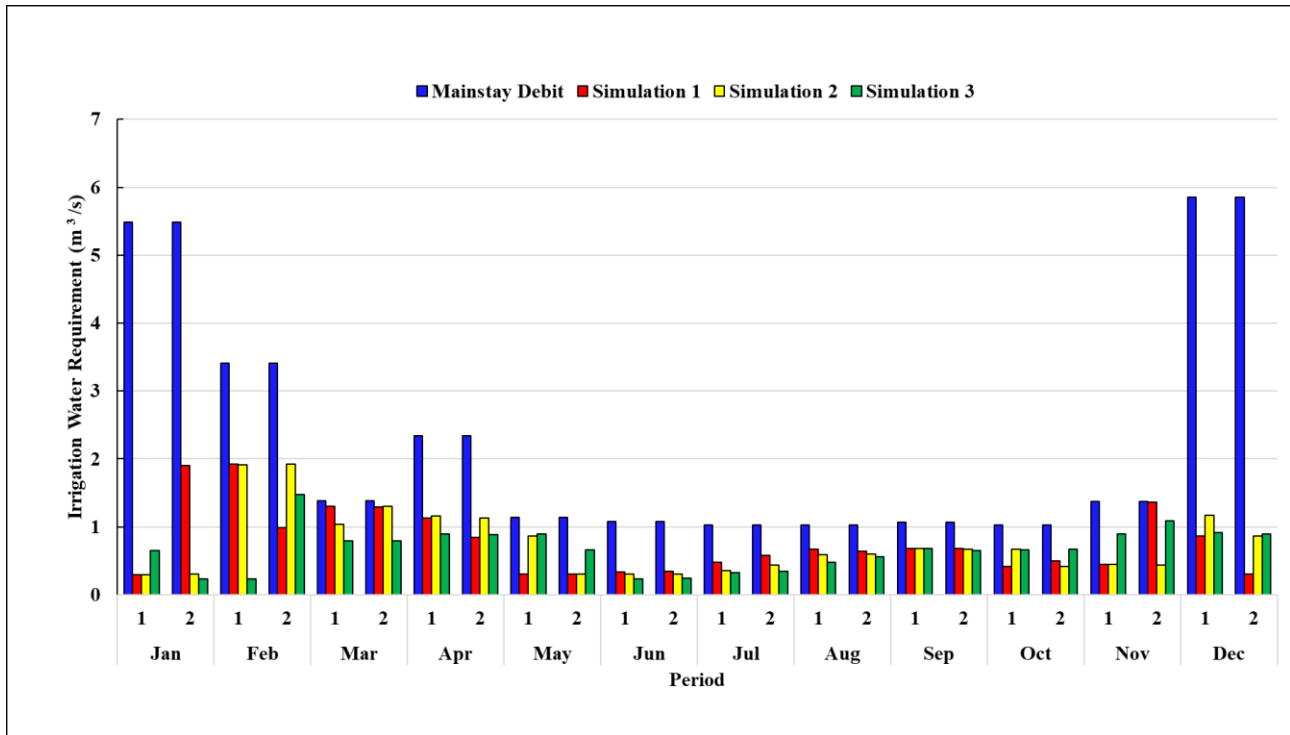


Fig. 4. Water Balance of Kiru-Kiru Irrigation Area

TABLE 5
WATER BALANCE OF KIRU-KIRU IRRIGATION AREA

Description	Month	Jan		Feb		Mar		Apr		May		Jun	
		1	2	1	2	1	2	1	2	1	2	1	2
1 st Simulation	Mainstay Debit (m ³ /s)	5.48	5.48	3.41	3.41	1.38	1.38	2.34	2.34	1.14	1.14	1.08	1.08
	Irrigation Water Requirement (m ³ /s)	0.23	1.45	1.47	0.75	1.00	0.99	0.87	0.65	0.24	0.23	0.41	0.42
	Water Balance	5.26	4.03	1.94	2.66	0.38	0.39	1.47	1.69	0.91	0.91	0.67	0.65
	Surplus/Defisit	S	S	S	S	S	S	S	S	S	S	S	S
	Month	Jul		Aug		Sep		Oct		Nov		Dec	
		1	2	1	2	1	2	1	2	1	2	1	2
	Mainstay Debit (m ³ /s)	1.03	1.03	1.03	1.03	1.06	1.06	1.03	1.03	1.38	1.38	5.85	5.85
	Irrigation Water Requirement (m ³ /s)	0.59	0.71	0.82	0.79	1.66	1.65	1.00	1.21	1.08	1.05	0.66	0.23
	Water Balance	0.44	0.32	0.21	0.24	-0.60	-0.58	0.03	-0.18	0.30	0.33	5.19	5.62
	Surplus/Defisit	S	S	S	S	D	D	S	D	S	S	S	S
2 nd Simulation	Month	Jan		Feb		Mar		Apr		May		Jun	
		1	2	1	2	1	2	1	2	1	2	1	2
	Mainstay Debit (m ³ /s)	5.48	5.48	3.41	3.41	1.38	1.38	2.34	2.34	1.14	1.14	1.08	1.08
	Irrigation Water Requirement (m ³ /s)	0.23	0.24	1.47	1.48	0.80	1.00	0.89	0.87	0.67	0.24	0.23	0.41
	Water Balance	5.26	5.25	1.94	1.93	0.58	0.38	1.45	1.47	0.48	0.91	0.84	0.67
	Surplus/Defisit	S	S	S	S	S	S	S	S	S	S	S	S
	Month	Jul		Aug		Sep		Oct		Nov		Dec	
		1	2	1	2	1	2	1	2	1	2	1	2
	Mainstay Debit (m ³ /s)	1.03	1.03	1.03	1.03	1.06	1.06	1.03	1.03	1.38	1.38	5.85	5.85
	Irrigation Water Requirement (m ³ /s)	0.48	0.60	0.80	0.81	0.93	1.65	1.64	1.01	1.10	1.07	0.90	0.66
	Water Balance	0.55	0.43	0.23	0.22	0.13	-0.58	-0.61	0.02	0.28	0.30	4.95	5.19
	Surplus/Defisit	S	S	S	S	S	D	D	S	S	S	S	S
3 rd Simulation	Month	Jan		Feb		Mar		Apr		May		Jun	
		1	2	1	2	1	2	1	2	1	2	1	2
	Mainstay Debit (m ³ /s)	5.48	5.48	3.41	3.41	1.38	1.38	2.34	2.34	1.14	1.14	1.08	1.08
	Irrigation Water Requirement (m ³ /s)	0.65	0.24	0.23	1.48	1.50	0.80	0.90	0.89	0.90	0.67	0.23	0.24
	Water Balance	4.83	5.25	3.19	1.93	-0.13	0.58	1.44	1.45	0.24	0.48	0.84	0.84
	Surplus/Defisit	S	S	S	S	D	S	S	S	S	S	S	S
	Month	Jul		Aug		Sep		Oct		Nov		Dec	
		1	2	1	2	1	2	1	2	1	2	1	2
	Mainstay Debit (m ³ /s)	1.03	1.03	1.03	1.03	1.06	1.06	1.03	1.03	1.38	1.38	5.85	5.85
	Irrigation Water Requirement (m ³ /s)	0.46	0.49	0.67	0.80	0.97	0.92	1.64	1.65	0.89	1.09	0.92	0.90
	Water Balance	0.57	0.54	0.36	0.23	0.09	0.14	-0.61	-0.62	0.48	0.29	4.93	4.95
	Surplus/Defisit	S	S	S	S	S	S	D	D	S	S	S	S

Based on figure 4 and table 5 above, the results show that the water balance for the Rice-Rice-Palawija planting pattern in 1st simulation during the rainy season (1 September – 2 January) experienced a maximum surplus of 5.62 m³/s and a deficit of 0.60 m³/s, while that during the dry season (1 February – 2 August) experienced a maximum surplus of 2.66 m³/s and a minimum value of 0.21 m³/s. Meanwhile, in the 2nd simulation during the rainy season (2 September – 1 February), it experienced a maximum surplus of 5.26 m³/s and a deficit of 0.58 m³/s, while during the dry season (2 February – 1 October), it experienced a maximum surplus of 1.93 m³/s and a deficit of 0.61 m³/s.

While for the 3rd simulation during the rainy season (1 October – 2 February), there has been a maximum surplus of 5.25 m³/s and it experienced a deficit of 0.62 m³/s, while during the dry season (1 March – 2 August), it experienced a maximum surplus of 1.45 m³/s and a

deficit of 0.13 m³/s. In accordance with the results of water balance in Kiru-Kiru irrigation area, it could be identified that Kiru-Kiru irrigation area has experienced water deficit in several months. Furthermore, in this study, simulation selection is influenced by several factors, such as water requirements, land preparation, water layer replacement, percolation, planting factors, and climate factors. The simulation that is close to the field conditions is simulation 3, which results in a water demand of 2.30 l/s/ha and a significant land area of 716 Ha with an existing potential land area of 717 ha.

As one of the efforts made in order to fulfil the irrigation water requirements, it has necessitated an adjustment on the irrigation area to be developed by decreasing the irrigation area in the Irrigation Area in question as displayed in table 7 and figure 5.

TABLE 6
WATER BALANCE OF KIRU-KIRU IRRIGATION AREA AFTER OPTIMIZATION

Month	Period	Planting Period	Water Availability (l/s)	Water Irrigation Requirement (l/s/ha)		Area (Ha)	
				Rice	Palawija	Rice	Palawija
Jan	1	I	5483.89	4.96		717.00	
	2	I	5483.89	4.96		717.00	
Feb	1		3414.59	0.32		6920.69	
	2	II	3414.59	3.09		717.00	
Mar	1	II	1378.52	1.25		717.00	
	2	II	1378.52	1.25		717.00	
Apr	1	II	2336.72	2.11		717.00	
	2	II	2336.72	2.11		717.00	
May	1	II	1141.13	1.03		717.00	
	2	II	1141.13	1.03		717.00	
Jun	1	II	1076.03	0.97		717.00	
	2		1076.03		0.34		2076.50
Jul	1	III	1031.30		0.65		1035.00
	2	III	1031.30		0.68		976.86
Aug	1	III	1029.57		0.94		709.52
	2	III	1029.57		1.11		600.34
Sep	1	III	1063.89		1.35		509.68
	2	III	1063.89		0.96		717.00
Oct	1	I	1029.57	0.93		717.00	
	2	I	1029.57	0.93		717.00	
Nov	1	I	1377.09	1.24		717.00	
	2	I	1377.09	1.24		717.00	
Dec	1	I	5849.71	5.29		717.00	
	2	I	5849.71	5.29		717.00	

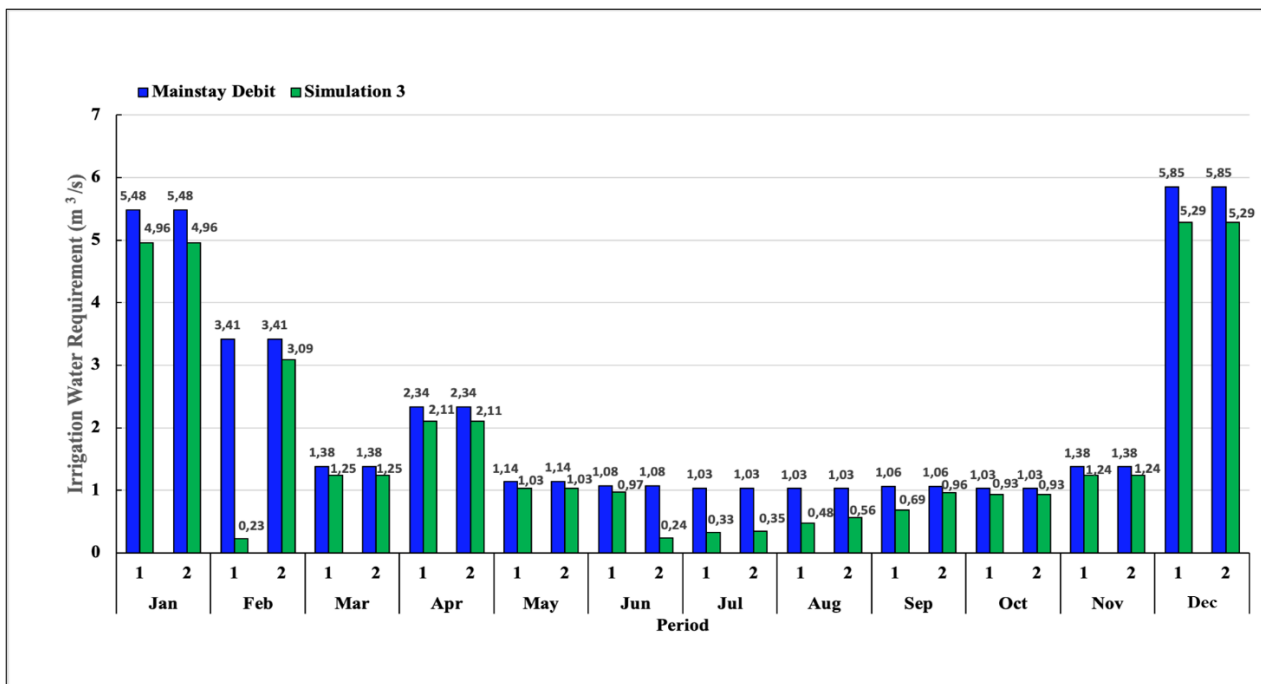


Fig. 5. Water Balance of Kiru-Kiru Irrigation Area After Optimization

Moreover, table 6 and Figure 4 show that there are 3 planting seasons recommendation, namely; first planting season (I) is on 1st October to 2nd January and second planting season (II) is on 2nd February to 1st June. These planting seasons could reach their optimal planting patterns with 100% of rice or 717 Ha planted with rice. Finally, the last planting season (III) is on 1st July to 2nd September with optimal cropping pattern is *palawija* at 509.68 Ha.

Overall, this study should be regarded as a first step towards optimization planting pattern in South Sulawesi, although several works still need to be done on simulation verification. Moreover, this study involves the assessment of water that is really accessible for all the uses and development and should be considered as a starting point in optimization of planting patterns in Indonesia. This study has not incorporated water quality aspect of the Kiru-Kiru Irrigation but it should be taken up as part of the future scope.

IV. CONCLUSION

In this study, the evapotranspiration has been analyzed and 3 simulations of irrigation water requirement have been developed. By using water balance consideration, this study has simulated 3 recommendation planting patterns based on the maximum surplus and minimum value of water. Importantly, this study has considered several necessary factors, namely water requirements, land preparation, water layer replacement, percolation, planting factors, and climate factors.

The significance values among the three simulations have been found at the 3rd simulation as the optimal planting pattern. Irrigation water balance in Kiru-Kiru irrigation area on the existing condition (3rd simulation)

experienced a deficit on 1 October, 2 October, and 1 March. The effort made in order to resolve water shortage problem is to carry out planting pattern optimization. The presented result has suggested that the most optimal cropping pattern is planting 100% of rice in the first and second planting seasons with an area of 717 Ha and 71% planted with *palawija* in the third planting season of 509.68 Ha.

Therefore, in future investigation, in order to provide information that are more credible to this field and to support the Indonesia Government programs, it would be interesting to compare other irrigation areas in Barru Regency with continual production of additional data.

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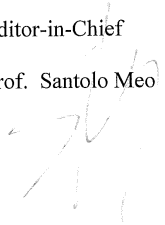
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Optimization of Planting Patterns in South Sulawesi

Ratna Musa¹, Irma Nur Afiah², Mahar Diana Hamid³, Agus Lasse¹,
Trifandy Musafir Wellang⁴, Muhammad Fachry Hafid²

Abstract – South Sulawesi is one of the nine provinces in Indonesia that has the highest contribution to the national income and its leading sector in agricultural crops including rice. The planning of planting patterns is highly dependent on the size of the intensity of rainfall in a particular area. Therefore, these conditions can have an impact on the level of suitability of crops to be planted. The purpose of this study has been to analyze the water balance and identify the optimal planting pattern. On the basis of rainfall data obtained from 4 rainfall stations, which are Mangkoso station, Manuba station, Mareppang station, and Ralla station, during the period of 25 years (1996 – 2020), the analysis to determine the average semi-monthly rainfall can be carried out. The results show that the maximum value of irrigation water requirements for rice-rice-palawija planting pattern obtained for simulation 1 has occurred on 1 September by 1.66 m³/s, while the minimum value has occurred on 1 January, 2 May, and 2 December by 0.23 m³/s. As a conclusion, the maximum value in simulation 3 has occurred on 2 October by 1.65 m³/s, while the minimum value has occurred on 1 February and 1 June by 0.23 m³/s. The optimization results show that the most optimal cropping pattern is planting 100% of rice in the first and second planting seasons with an area of 717 Ha and 71% planted with palawija in the third planting season of 509.68 Ha. **Copyright © 2022 Praise Worthy Prize S.r.l. - All rights reserved.**

Keywords: Evapotranspiration, Water Availability, Mainstay Debit, Water Demand Irrigation, Water Balance

Nomenclature

BF	Base Flow [m ³ /s/km ²]	P	Percolation [mm/day]
c	Penman correction figure which includes the difference of values between day and night weather conditions	Q	Mainstay debit [m ³ /s]
		Q_{80}	Mainstay debit with a possibility of not meeting 20% [l/s]
DR	Water withdrawal requirement at the water source [l/s/ha]	Re	Effective rainfall [mm/day]
DRO	Direct Run Off [m ³ /s/km ²]	R_s	Shortwave radiation in evaporation units [mm/day]
ea	Saturated vapor pressure [mbar]	Re_{rice}	Effective rainfall for rice plant [mm/day]
ed	Actual vapor pressure [mbar]	$Re_{palawija}$	Effective rainfall for palawija plant [mm/day]
ef	Overall irrigation efficiency	R_{n1}	Longwave net radiation [mm/day]
ET_c	Plant evaporation [mm/day]	$\bar{R}$	Average region rainfall [mm]
E_0	Evaporation of open water [mm/day]	$R_1, R_2, \dots, R_n$	Rainfall at station n [mm]
ET_0	Potential Evapotranspiration [mm/day]	R_{80}	Mainstay rainfall with a possibility of not meeting 20% [l/s]
ET^*	Actual evapotranspiration [mm/day]	w	Factor related to temperature (T) and elevation of the area. For areas of Indonesia with an elevation of 0-500 m
F	Catchment area [km ²]	S	Water requirement for saturation added by water layer
$f(u)$	Function of wind speed at the height of 2 m in units [m/s]	T	Time period for land preparation
IR	Irrigation water requirement [mm/day]	WLR	Water Layer Replacement [mm/day]
k_c	Crop coefficient	$1/8.64$	Unit conversion rate from mm/day to l/s/ha
M	Water requirement to replace water loss due to evaporation and percolation in saturated rice fields [mm/day]		
m	Data rating		
n	Number of rain gauge stations		
NFR	Net Field Water Requirement; the need for clean water in the fields [mm/day]		

I. Introduction

Irrigated agriculture is a vital resource in many parts

of the world [1]-[27]. This is driven or limited both by the availability of water and by the capital investment in irrigation related infrastructure including dams and largescale canals and, to a lesser extent, sprinkler system or field-based drip irrigation system [3]. Sustainable water management at the farm level has enormous relevance, i.e., in terms of implementing an adequate irrigation schedule, which should lead to optimal yields and agriculture as well as irrigation [5], [25]. South Sulawesi is one of the nine provinces in Indonesia that has the highest contribution to the national income and its leading sector in agricultural crops including rice. One of the areas in South Sulawesi that is popular known as rice center region is Barru Regency. It has several irrigation areas, one of which is Kiru-Kiru irrigation area and has potential area of 717 Ha and functional area of 628 Ha [1] which includes 2 urban villages and 3 villages, i.e., Kiru-kiru Village, Mangkoso Village, Siddo Village, Ajakkang Village and Lawallu Village. Based on data from the Central Bureau of Statistic [2], it is noticed that the annual rainfall is 3.975,9 mm/year. In this area, the rainy season lasts from October to April, while the dry season lasts from April to September.

Therefore, the people in Soppeng Riaja District mostly work as farmers. There are three sources of water loss, which are evaporation from soil surface, water and plant surfaces that do not contribute to evapotranspiration of cultivated plants, and drainage loss (runoff) [4]. The growing season, also called the frost-free season, is the period of year in which the most favorable growing conditions for native vegetation and cultivated plants take place. It is a period in one year that is categorized as rainy season, whose length varies according to space, time, and type of plant [6]. The availability of ground water will determine plant growth and yield directly because lack of water causes a decrease in the rate of photosynthesis and disturbance of assimilate distribution, and has negative impacts on plant growth in both the vegetative and generative phases [7]. The amount of water available and the amount of water needed will fluctuate from time to time. Consequently, in one period, there can be an excess of water and in another period, there is a shortage of water for plants [8]. One way to determine fluctuations in water availability from month to month is by utilizing water between the amount of rainwater input and the ability of soil water [9]. Water balance is useful for completing a general description of the state of water in an area (precipitation, evapotranspiration, water content, and changes in soil moisture), assessing the ability of an area to be planted by estimating the water requirement for plants, and testing the relationship of climate or weather with crop production [10]. The availability of water is very influential on the planting pattern of an area [11]. The planting pattern of agricultural land can be optimized according to the availability of water in the area. A planting pattern is a planting system that is utilized on an area of land, which includes the method and types of plants as well as the planting schedule during a certain

period of time [12]. Utomo [13] has mentioned that planting patterns are designed to determine the time when plants can efficiently utilize the available water.

Planting pattern includes the selection of plants whose water requirement is in accordance with the distribution of rainfall, and crop rotation that can utilize rainfall efficiently. If the rainy season is short, the selected plants that are the short-lived ones. On the other hand, if the rainy season is long enough, the selected plants are long-lived, or two plants are selected where the second is taken because it is drought tolerant [13]. Furthermore, according to Unganji et al. [14], the diversity of land characteristics can affect plant growth and development, so they also affect the production of the plant itself.

Plants that grow in suitable climatic and land conditions can yield optimally. On the other hand, plants that grow in unsuitable climatic conditions and land will be impacted on the decreasing production. Dwiratna et al. [15] have declared that farmers usually apply planting patterns and schedules based on conventional habits, which are often carried out during the same climatic conditions every year. However, global climate change can have an impact on the non-enforcement of these habits. Planting failure and crop failure are common problems experienced by farmers because of variations in rainfall that are not fixed every year, making it difficult to determine plants that are in accordance with the conditions of groundwater availability, especially since the water requirement of each type of plant is different.

Moreover, setting a planting pattern is an agricultural effort carried out in order to obtain maximum agricultural products and minimize the risk of crop failure by considering climatic and land conditions. The planning of planting patterns is highly dependent on the size of the intensity of rainfall in a particular area. Therefore, these conditions can have an impact on the level of suitability of crops to be planted. Planning a planting pattern based on the intensity of rainfall in accordance with the needs of the plant can result in better production. Additionally, research about planting pattern has been conducted by several previous studies [16], [17]. These studies have identified the potential planting seasons on irrigated or non-irrigated areas and have involved water balance value to show the water deficit. Despite growing agreement regarding the existence of potential planting season, there is a lack of understanding regarding the necessity of irrigation water balance analysis and optimal planting pattern system using simulations and mainstay debit as its constrain. The objectives of this study have been to analyze the water balance and to identify the optimal planting pattern in Kiru-Kiru Irrigation Area, South Sulawesi.

The article is divided into six sections. The first one is the current introduction, the second one refers to describing its methodology regarding water availability and irrigation water requirement, the third one concerns the result and the analysis of evapotranspiration, regional, rainfall, mainstay rainfall, effective rainfall, water availability analysis, irrigation water requirement,

and water balance. Conclusions and recommendations are presented in the last section.

II. Method

This research data has been carried out from Kiru-Kiru Irrigation Area and located on the west coast of South Sulawesi Province between the coordinates of 40°5'49"-40°47'35" south latitude and 119°35'00"-119°49'16" east longitude covering an area of 1,174.72 km².

II.1. Water Availability

II.1.1. Potential Evapotranspiration

The use of Modified Penman equation is recommended as a standard for reference evapotranspiration in order to provide values that are more consistent with the actual plant water use data worldwide [18]. The equation is described as follows:

$$ET_0 = c \times ET^* \quad (1)$$

$$ET^* = w (0.75 R_s - R_{n1}) + (1 - w)f(u)(ea - ed) \quad (2)$$

II.1.2. Regional Rainfall

The value of regional rainfall can be determined from several rainfall data in rain gauge stations by employing the average value of rainfall for stations located within the watershed and stations outside the watershed that are still close together which can be calculated as follows:

$$\bar{R} = \frac{1}{n} (R_1 + R_2 + \dots + R_n) \quad (3)$$

II.1.3. Mock's Method

Mock's method shows water balance analysis to calculate monthly debit values based on the transformation of monthly rainfall data, evapotranspiration, soil moisture, and groundwater reservoirs.



Fig. 1. Research Site Map

The principle of this method states that the rain that falls on water catchment areas will partly be lost due to evapotranspiration [19]. The water balance using the F. J. Mock method is formulated as follows:

$$Q = (DRO + BF)F \quad (4)$$

II.1.4. Mainstay Debit

Mainstay debit is calculated using the Weibull method with an 80% chance of occurrence [20]. The semi-monthly debit data are sorted from the largest to the smallest data. Then, the probability of each data is calculated based on the data ranking using Equation (5) below:

$$Q_{80} = \frac{m}{n+1} \times 100\% \quad (5)$$

II.2. Irrigation Water Requirement

The irrigation water requirement for rice is different from the irrigation water requirement for secondary crops (palawija). The field water requirement for rice is calculated using Equation (6), while the irrigation water requirement is calculated using Equation (7). The formula for calculating irrigation water requirement for secondary crops (palawija) can be observed in Equation (8) [21]:

$$NFR = ET_c + P + WLR - Re \quad (6)$$

$$IR = \frac{NFR}{ef} \quad (7)$$

$$IR = \frac{(ET_c - Re)}{ef} \quad (8)$$

$$DR = \frac{IR}{8.64} \quad (9)$$

II.2.1. Effective Rainfall

The effective rainfall for rice and secondary crops (palawija) is calculated differently. The effective rainfall for rice is 70% of the average mid-month rainfall with a possibility of not meeting 20% (R_{80}). This rainfall with a possibility of not meeting 20% is calculated using the Weibull method as follows:

$$R_{80} = \frac{m}{n+1} \times 100\% \quad (10)$$

$$Re_{rice} = 0.7 \times R_{80} \quad (11)$$

$$Re_{palawija} = 0.7 \times R_{50} \quad (12)$$

II.2.2. Water Requirement for Land Cultivation

The calculation of water requirements during land

cultivation is done by using the following equation [2]:

$$IR = \frac{Me^k}{(E^k - 1)} \quad (13)$$

$$M = E_0 + P \quad (14)$$

$$E_0 = 1.1 \times ET_0 \quad (15)$$

$$K = M \times \left(\frac{T}{S}\right) \quad (16)$$

II.2.3. Water Requirement to Replace the Water Layer (Water Layer Requirement)

The water requirement to replace the water layer (Water Layer Requirement (WLR)) is determined based on the 2013 Indonesia Irrigation Planning Standard. The amount of water required for water layer replacement is 50 mm/month (or 3.3 mm/day for 1/2 months) for one month and two months after transplantation.

II.2.4. Consumptive Water Requirement

Consumptive water requirement is the water requirements for plants on the farm. Plant evapotranspiration (ET_c) is the actual evapotranspiration, which is very different from ET_0 , as a ground cover. The nature of plant canopy and the aerodynamic resistance of plant are different from that of grass [22]. After the reference plant evapotranspiration (ET_0) is obtained, the plant evapotranspiration can be estimated by the following equation [23], [24]:

$$ET_c = k_c \times ET_0 \quad (17)$$

II.2.5. Percolation (p) and Seepage

The percolation rate is highly dependent on the nature of the soil, and the nature of the soil generally depends on the activities of land use or cultivation. The percolation rate ranges from 1-3 mm/day.

II.2.6. Irrigation Efficiency (EI)

In order to account for water loss during transportation and application to the field, the efficiency factor has been utilized in the calculation of irrigation water requirements [23]. This loss occurs as the result of exploitation, evaporation, and seepage activities. In general, water loss in irrigation networks can be divided as follows [2]: 12.5-20% in the tertiary plots between tertiary tapping buildings and rice fields; 5-10% in the

secondary channel; and 5-10% in the main channel.

II.3. Water Balance

Water balance is a way of analyzing the balance equation of water based on the law of conservation of mass, which states that a substance cannot be created or destroyed, but a substance can change its form [18].

Water balance is an explanation of the relationship between inflow and outflow in a watershed for a certain period of water circulation process. Therefore, it is possible to identify the excess (surplus) or shortage (deficit) on the amount of water.

III. Result and Analysis

III.1. Evapotranspiration

The evapotranspiration has been analyzed using the FAO Modified Penman method. The calculation of the amount of evapotranspiration requires climatological data, such as temperature, humidity, wind speed, and duration of sunlight. In this study, the climatological station employed has been Tabo-Tabo Station, Pangkep Regency. The result of Evapotranspiration calculation can be seen in Table I. Based on Table I, the Evapotranspiration results show that the Maximum Evapotranspiration at Kiru-Kiru Irrigation Area has occurred in October by 5.48 mm/day, while the Minimum evapotranspiration has occurred in June by 2.72 mm/day.

III.2. Regional Rainfall

Based on of rainfall data obtained from 4 rainfall stations, which are Mangkoso station, Manuba station, Mareppang station, and Ralla station, during the period of 25 years (1996 – 2020), the analysis to determine the average semi-monthly rainfall can be carried out. It can be observed that the maximum average rainfall in the Kiru-Kiru irrigation area has occurred on 2 September by 13.65 mm/day while the minimum rainfall has occurred on 2 August by 5.23 mm (Figure 2).

III.3. Mainstay Rainfall

The mainstay rainfall for rice plants is set at 80% (R_{80}), while for secondary crops (palawija), it is set at 50% (R_{50}). The results of the mainstay rainfall calculations show that rainfall with maximum reliability of 80% (R_{80}) occurred on 1 January by 4.75 mm and the minimum one occurred on 1 September by 0 mm.

TABLE I
EVAPOTRANSPIRATION AT KIRU-KIRU IRRIGATION AREA (mm/day)

ET ₀	Jan	Feb	Mar	Apr	May	Jun
mm/day	3.39	3.65	4.00	3.23	3.48	2.72
ET ₀	Jul	Aug	Sept	Oct	Nov	Dec
mm/day	3.67	4.38	5.51	5.48	4.68	3.50

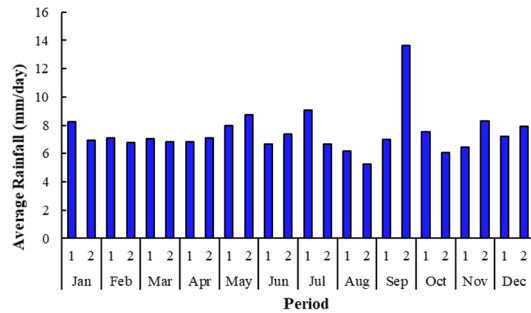


Fig. 2. Average Rainfall of Kiru-Kiru Irrigation Area in 1996-2020

Meanwhile, for the rainfall with maximum reliability of 50% (R_{50}), it occurred on 2 December by 7.75 mm and the minimum one occurred on 1 August and 1 September by 4.00 mm (Table II).

III.4. Effective Rainfall

In the calculation of the effective rainfall for rice, the result has been 70% of R_{80} of the time in a period, while for the effective rainfall of secondary crops (palawija), it has been 50% of R_{50} . The effective rainfall for paddy maximally occurred on 1 January and 2 November by 0.22 mm/day and the minimum value occurs on 1 September by 0 mm/day. Meanwhile, the effective rainfall for secondary crops (palawija) maximally happened on 2 December by 0.26 mm/day and the minimum value occurred on 1 February and 1 March by 0.13 mm/day (Table III).

III.5. Water Availability Analysis and Mainstay Debit

In order to determine the value of water availability in

Kiru-Kiru irrigation area, this study has utilized the calculation result of the water debit in Kiru-Kiru watershed using Mock Method. Water availability has been calculated by determining the mainstay debit from the debit data (1996-2020) and processed the results into monthly data. The debit data has been sorted from the largest to the smallest data. After that, the probability of each data has been calculated in accordance with the data rank. The 80% mainstay debit (Q_{80}) has maximally occurred in December with a debit of 5.85 m³/s, while the minimum debit occurred in July, August and October with a debit of 1.03 m³/s (Table IV).

III.6. Irrigation Water Requirement

The results of irrigation water requirement analysis for Rice-Rice-Palawija planting pattern could be observed in Figure 3. The results show that the maximum value of irrigation water requirements for Rice-Rice-Palawija planting pattern obtained for simulation 1 occurred on 1 September by 1.66 m³/s, while the minimum value occurred on 1 January, 2 May, and 2 December by 0.23 m³/s.

Additionally, the maximum value in simulation 2 occurred on 2 September by 1.65 m³/s, while the minimum value occurred on 1 January and 1 July by 0.23 m³/s. Finally, the maximum value in simulation 3 happened on 2 October by 1.65 m³/s, while the minimum value occurred on 1 February and 1 June by 0.23 m³/s.

III.7. Water Balance

Water balance is balance between the water coming in and coming out of a system.

TABLE II
MAINSTAY RAINFALL FOR RICE AND SECONDARY CROPS (PALAWIJA)

CH Mainstay (mm)	Jan		Feb		Mar		Apr		May		Jun	
	1	2	1	2	1	2	1	2	1	2	1	2
R_{80}	4.75	3.50	4.50	3.00	4.00	3.75	3.25	3.33	3.50	3.33	3.67	2.50
R_{50}	6.75	5.00	7.50	6.00	5.50	6.75	4.75	5.50	5.67	5.25	4.75	5.00
CH Mainstay (mm)	July		Aug		Sep		Oct		Nov		Dec	
	1	2	1	2	1	2	1	2	1	2	1	2
R_{80}	3.00	2.00	1.00	1.00	0.00	2.75	4.00	2.50	3.75	4.75	3.75	4.00
R_{50}	6.67	5.00	4.00	5.50	4.00	7.33	5.75	5.67	6.00	6.00	5.00	7.75

TABLE III
EFFECTIVE RAINFALL FOR RICE AND SECONDARY CROPS (PALAWIJA)

Effective CH (mm/day)	Jan		Feb		Mar		Apr		May		Jun	
	1	2	1	2	1	2	1	2	1	2	1	2
Re Rice	0.22	0.16	0.21	0.14	0.19	0.18	0.15	0.16	0.16	0.16	0.17	0.12
Re Palawija	0.23	0.17	0.25	0.20	0.18	0.23	0.16	0.18	0.19	0.18	0.16	0.17
Effective CH (mm/day)	Jul		Aug		Sept		Oct		Nov		Dec	
	1	2	1	2	1	2	1	2	1	2	1	2
Re Rice	0.14	0.09	0.05	0.05	0.00	0.13	0.19	0.12	0.18	0.22	0.18	0.19
Re Palawija	0.22	0.17	0.13	0.18	0.13	0.24	0.19	0.19	0.20	0.20	0.17	0.26

TABLE IV
MAINSTAY DEBIT WITH 80% PROBABILITY

Mainstay Debit (m ³ /s)	Month											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Q_{80}	5.48	3.41	1.38	2.34	1.14	1.08	1.03	1.03	1.06	1.03	1.38	5.85

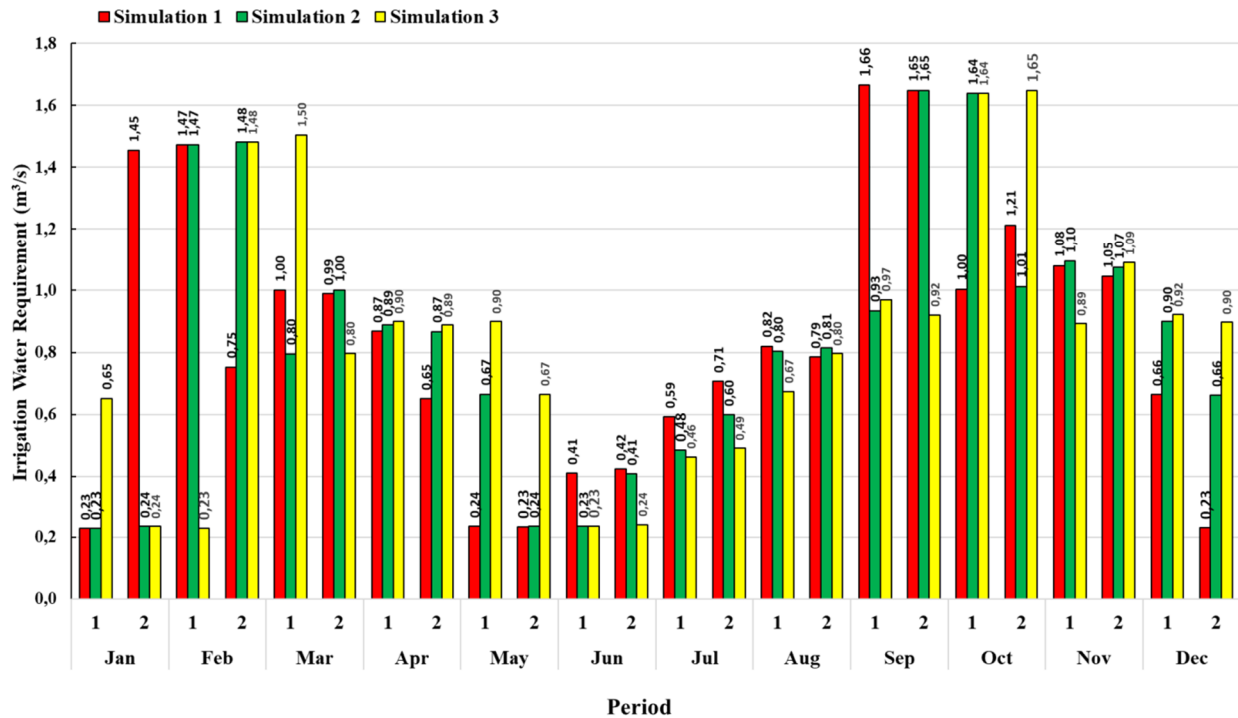


Fig. 3. Water Requirements of Kuru-Kuru Irrigation Area

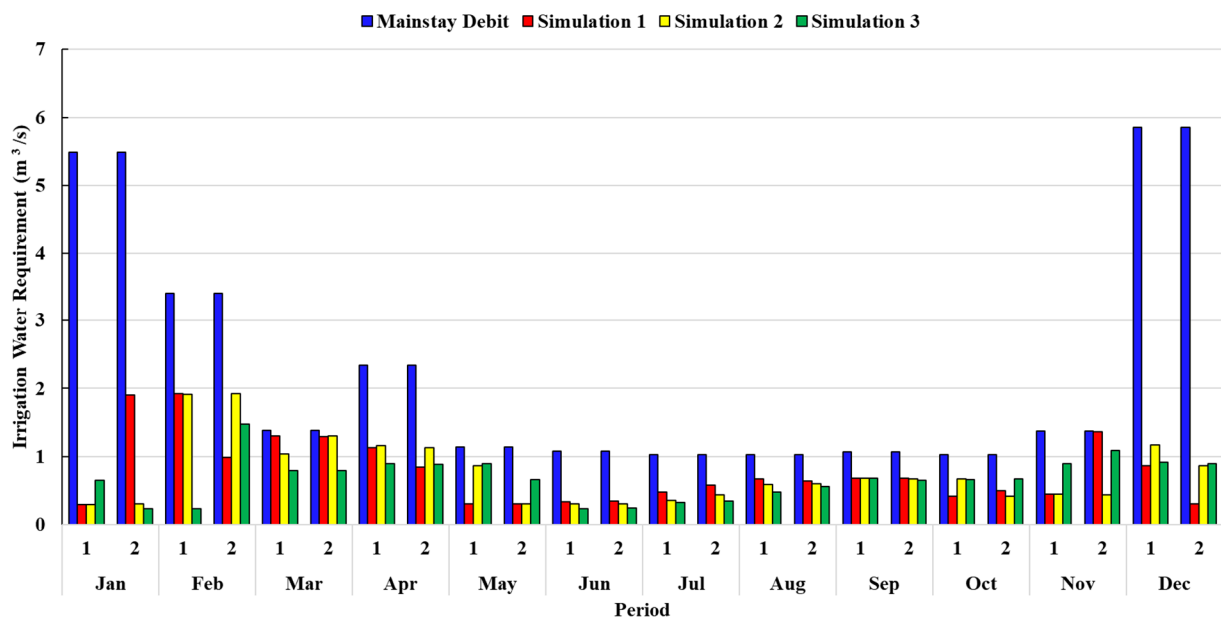


Fig. 4. Water Balance of Kuru-Kuru Irrigation Area

The results (Figure 4 and Table V) show that the water balance for the Rice-Rice-Palawija planting pattern combination in the 1st simulation during the rainy season (1 September – 2 January) experienced a maximum surplus (S) of 5.62 m³/s and a deficit (D) of 0.60 m³/s, while that during the dry season (1 February – 2 August) experienced a maximum surplus of 2.66 m³/s and a minimum value or deficit of 0.21 m³/s.

Meanwhile, for the 2nd simulation during the rainy season (2 September – 1 February), it experienced a

maximum surplus of 5.26 m³/s and a deficit of 0.58 m³/s, while during the dry season (2 February – 1 October), it experienced a maximum surplus of 1.93 m³/s and a deficit of 0.61 m³/s.

Then, in the 3rd simulation during the rainy season (1 October – 2 February), there has been a maximum surplus of 5.25 m³/s and it has experienced a deficit of 0.62 m³/s, while during the dry season (1 March – 2 August), it has experienced a maximum surplus of 1.45 m³/s and a deficit of 0.13 m³/s.

TABLE V
WATER BALANCE OF KIRU-KIRU IRRIGATION AREA

Description	Month	Jan		Feb		Mar		Apr		May		Jun	
		1	2	1	2	1	2	1	2	1	2	1	2
1 st Simulation	Mainstay Debit (m ³ /s)	5.48	5.48	3.41	3.41	1.38	1.38	2.34	2.34	1.14	1.14	1.08	1.08
	Irrigation Water Requirement (m ³ /s)	0.23	1.45	1.47	0.75	1.00	0.99	0.87	0.65	0.24	0.23	0.41	0.42
	Water Balance	5.26	4.03	1.94	2.66	0.38	0.39	1.47	1.69	0.91	0.91	0.67	0.65
	Surplus/Deficit	S	S	S	S	S	S	S	S	S	S	S	S
	Month	Jul		Aug		Sep		Oct		Nov		Dec	
		1	2	1	2	1	2	1	2	1	2	1	2
	Mainstay Debit (m ³ /s)	1.03	1.03	1.03	1.03	1.06	1.06	1.03	1.03	1.38	1.38	5.85	5.85
	Irrigation Water Requirement (m ³ /s)	0.59	0.71	0.82	0.79	1.66	1.65	1.00	1.21	1.08	1.05	0.66	0.23
	Water Balance	0.44	0.32	0.21	0.24	-0.60	-0.58	0.03	-0.18	0.30	0.33	5.19	5.62
	Surplus/Deficit	S	S	S	S	D	D	S	D	S	S	S	S
2 nd Simulation	Month	Jan		Feb		Mar		Apr		May		Jun	
		1	2	1	2	1	2	1	2	1	2	1	2
	Mainstay Debit (m ³ /s)	5.48	5.48	3.41	3.41	1.38	1.38	2.34	2.34	1.14	1.14	1.08	1.08
	Irrigation Water Requirement (m ³ /s)	0.23	0.24	1.47	1.48	0.80	1.00	0.89	0.87	0.67	0.24	0.23	0.41
	Water Balance	5.26	5.25	1.94	1.93	0.58	0.38	1.45	1.47	0.48	0.91	0.84	0.67
	Surplus/Deficit	S	S	S	S	S	S	S	S	S	S	S	S
	Month	Jul		Aug		Sep		Oct		Nov		Dec	
		1	2	1	2	1	2	1	2	1	2	1	2
	Mainstay Debit (m ³ /s)	1.03	1.03	1.03	1.03	1.06	1.06	1.03	1.03	1.38	1.38	5.85	5.85
	Irrigation Water Requirement (m ³ /s)	0.48	0.60	0.80	0.81	0.93	1.65	1.64	1.01	1.10	1.07	0.90	0.66
3 rd Simulation	Water Balance	0.55	0.43	0.23	0.22	0.13	-0.58	-0.61	0.02	0.28	0.30	4.95	5.19
	Surplus/Deficit	S	S	S	S	S	D	D	S	S	S	S	S
	Month	Jan		Feb		Mar		Apr		May		Jun	
		1	2	1	2	1	2	1	2	1	2	1	2
	Mainstay Debit (m ³ /s)	5.48	5.48	3.41	3.41	1.38	1.38	2.34	2.34	1.14	1.14	1.08	1.08
	Irrigation Water Requirement (m ³ /s)	0.65	0.24	0.23	1.48	1.50	0.80	0.90	0.89	0.90	0.67	0.23	0.24
	Water Balance	4.83	5.25	3.19	1.93	-0.13	0.58	1.44	1.45	0.24	0.48	0.84	0.84
	Surplus/Deficit	S	S	S	S	D	S	S	S	S	S	S	S
	Month	Jul		Aug		Sep		Oct		Nov		Dec	
		1	2	1	2	1	2	1	2	1	2	1	2
	Mainstay Debit (m ³ /s)	1.03	1.03	1.03	1.03	1.06	1.06	1.03	1.03	1.38	1.38	5.85	5.85
	Irrigation Water Requirement (m ³ /s)	0.46	0.49	0.67	0.80	0.97	0.92	1.64	1.65	0.89	1.09	0.92	0.90
	Water Balance	0.57	0.54	0.36	0.23	0.09	0.14	-0.61	-0.62	0.48	0.29	4.93	4.95
	Surplus/Deficit	S	S	S	S	S	S	D	D	S	S	S	S

Based on figure 4 and Table V above, the results show that the water balance for the Rice-Rice-Palawija planting pattern in 1st simulation during the rainy season (1 September – 2 January) experienced a maximum surplus of 5.62 m³/s and a deficit of 0.60 m³/s, while that during the dry season (1 February – 2 August) experienced a maximum surplus of 2.66 m³/s and a minimum value of 0.21 m³/s. Meanwhile, in the 2nd simulation during the rainy season (2 September – 1 February), it experienced a maximum surplus of 5.26 m³/s and a deficit of 0.58 m³/s, while during the dry season (2 February – 1 October), it experienced a maximum surplus of 1.93 m³/s and a deficit of 0.61 m³/s.

While for the 3rd simulation during the rainy season (1 October – 2 February), there has been a maximum surplus of 5.25 m³/s and it experienced a deficit of 0.62 m³/s, while during the dry season (1 March – 2 August), it experienced a maximum surplus of 1.45 m³/s and a deficit of 0.13 m³/s.

In accordance with the results of water balance in Kiru-Kiru irrigation area, it could be identified that Kiru-Kiru irrigation area has experienced water deficit in several months.

Furthermore, in this study, simulation selection is influenced by several factors, such as water requirements, land preparation, water layer replacement, percolation, planting factors, and climate factors. The simulation that is close to the field conditions is

simulation 3, which results in a water demand of 2.30 l/s/ha and a significant land area of 716 Ha with an existing potential land area of 717 ha. As one of the efforts made in order to fulfil the irrigation water requirements, it has necessitated an adjustment on the irrigation area to be developed by decreasing the irrigation area in the Irrigation Area in question as displayed in Table VI and Figure 5.

Moreover, Table VI and Figure 4 show that there are 3 planting seasons recommendation, namely; first planting season (I) is on 1st October to 2nd January and second planting season (II) is on 2nd February to 1st June. These planting seasons could reach their optimal planting patterns with 100% of rice or 717 Ha planted with rice.

Finally, the last planting season (III) is on 1st July to 2nd September with optimal cropping pattern is palawija at 509.68 Ha. Overall, this study should be regarded as a first step towards optimization planting pattern in South Sulawesi, although several works still need to be done on simulation verification.

Moreover, this study involves the assessment of water that is really accessible for all the uses and development and should be considered as a starting point in optimization of planting patterns in Indonesia. This study has not incorporated water quality aspect of the Kiru-Kiru Irrigation but it should be taken up as part of the future scope.

TABLE VI
WATER BALANCE OF KIRU-KIRU IRRIGATION AREA AFTER OPTIMIZATION

Month	Period	Planting Period	Water Availability (l/s)	Water Irrigation Requirement (l/s/ha)		Area (Ha)	
				Rice	Palawija	Rice	Palawija
Jan	1	I	5483.89	4.96		717.00	
	2	I	5483.89	4.96		717.00	
Feb	1		3414.59	0.32		6920.69	
	2	II	3414.59	3.09		717.00	
Mar	1	II	1378.52	1.25		717.00	
	2	II	1378.52	1.25		717.00	
Apr	1	II	2336.72	2.11		717.00	
	2	II	2336.72	2.11		717.00	
May	1	II	1141.13	1.03		717.00	
	2	II	1141.13	1.03		717.00	
Jun	1	II	1076.03	0.97		717.00	
	2		1076.03		0.34		2076.50
Jul	1	III	1031.30		0.65		1035.00
	2	III	1031.30		0.68		976.86
Aug	1	III	1029.57		0.94		709.52
	2	III	1029.57		1.11		600.34
Sep	1	III	1063.89		1.35		509.68
	2	III	1063.89		0.96		717.00
Oct	1	I	1029.57	0.93		717.00	
	2	I	1029.57	0.93		717.00	
Nov	1	I	1377.09	1.24		717.00	
	2	I	1377.09	1.24		717.00	
Dec	1	I	5849.71	5.29		717.00	
	2	I	5849.71	5.29		717.00	

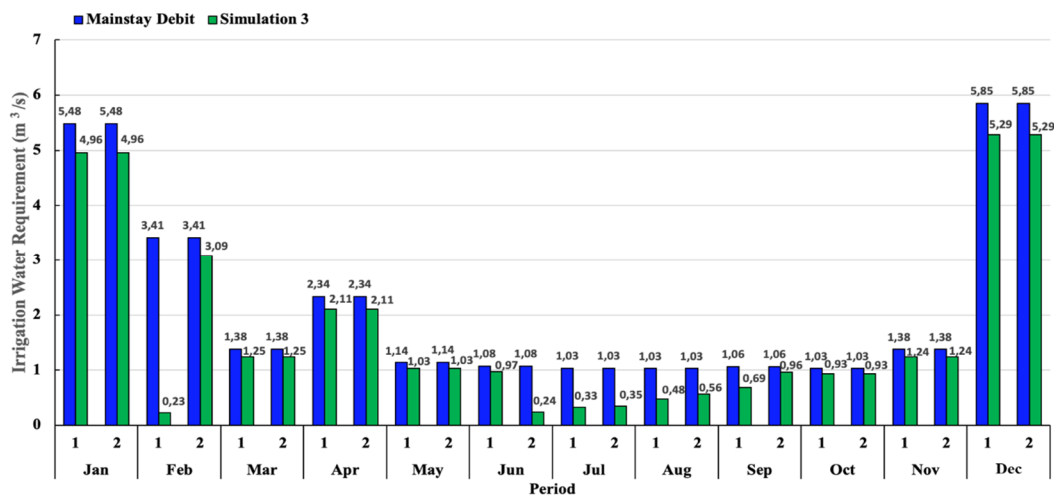


Fig. 5. Water Balance of Kiru-Kiru Irrigation Area After Optimization

IV. Conclusion

In this study, the evapotranspiration has been analyzed and 3 simulations of irrigation water requirement have been developed. By using water balance consideration, this study has simulated 3 recommendation planting patterns based on the maximum surplus and minimum value of water. Importantly, this study has considered several necessary factors, namely water requirements, land preparation, water layer replacement, percolation, planting factors, and climate factors. The significance values among the three simulations have been found at the 3rd simulation as the optimal planting pattern.

Irrigation water balance in Kiru-Kiru irrigation area on the existing condition (3rd simulation) experienced a deficit on 1 October, 2 October, and 1 March. The effort made in order to resolve water shortage problem is to

carry out planting pattern optimization. The presented result has suggested that the most optimal cropping pattern is planting 100% of rice in the first and second planting seasons with an area of 717 Ha and 71% planted with *palawija* in the third planting season of 509.68 Ha.

Therefore, in future investigation, in order to provide information that are more credible to this field and to support the Indonesia Government programs, it would be interesting to compare other irrigation areas in Barru Regency with continual production of additional data.

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