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Analysis Water Availability and Water Balance in Irrigation Areas Rintau, District Sekayam

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Abstract

Indonesia's population is increasing yearly, which has led to a decrease in water supply in several places, including the Sekayam Sub-district, Sanggau District, and West Kalimantan Province. The Rintau irrigation area (D.I.Rintau), located in Sekayam Sub-district, has a potential size of 528.52 Ha. However, due to land conversion for communities and plantations, its functional area is only 224.94 Ha. In addition to reducing the amount of available land, Rintau irrigation has issues with crops and plants that do not match the water supply of the irrigation system.

This research aims to get the most suitable cropping pattern in Rintau irrigation related to water availability. The analysis includes water availability with the Mock Model, NFR analysis, water demand in the retrieval building (DR), and water balance analysis.

According to the analysis results, the maximum mainstay discharge of raw water sources used by Rintau irrigation is 707.512 l/sec, the minimum mainstay discharge is 114.200 l/sec, and the average mainstay discharge is 402.619 l/sec. The most suitable cropping pattern used in Rintau Irrigation is the rice-paddy-cucumber cropping pattern, with a maximum NFR value of 8.146 mm/day or 0.943 lt/sec, and the beginning of the first planting period in the first half of August and starting planting 2 in the first half of December. Thus, the Rice-Paddy-Cucumber cropping pattern can be applied to Rintau irrigation to increase food production. Its management must be pursued using appropriate cropping technology.

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1. Introduction

Irrigation is the application of controlled amounts of water to land to aid in the growth of crops, landscape plants, and lawns (Snyder, R. L.; Melo-Abreu, J. P., 2005). Irrigation's primary goal is to provide plants with the right amount of water at the right time (Seidel et al., 2017). Adequate water will impact the growth process, including seedbed preparation, germination, root growth, nutrient utilization, plant growth and regrowth, yield, and quality. Irrigation aids crop growth, landscape maintenance, and revegetation of disturbed soils in dry areas and during periods of below-average rainfall (Kozlowski, 2022).

The optimal use of irrigation and drainage networks is one agricultural development strategy that leads to increased productivity and economic benefits (Koech & Langat, 2018; Velasco-Muñoz et al., 2019; Radmehr & Bozorg-Haddad, 2022). In this regard, quantitative and qualitative studies of network drainage are critical for effective water management. This study simulated the Rintau irrigation network's cropping pattern to determine whether the water used for control was adequate. The goal of determining planting patterns is to align planting time with the season in a crop cultivation system (Sacks et al., 2010; Vitadiar et al., 2018). Plant growth can be aided by producing at the optimal time to achieve maximum yields (Bingfang & Qiangzi, 2011; Ahmed et al., 2020).

For Rintau irrigation, the existing cropping pattern is paddy-paddy-crop, with the types of crops grown varying: cucumber, eggplant, peanuts, and chili. Therefore, the simulation will determine which cropping pattern is most suitable for Rintau irrigation from the four existing cropping patterns: paddy-paddy-cucumber, paddy-paddy-eggplant, paddy-paddy-peanut, and paddy-paddy-chili based on water availability.

2. Materials and Methods

2.1. Theoretical Frame Work

Irrigation engineering entails the design of two complementary supply and drainage systems (Waller & Yitayew, 2015). The plans are responsible for promptly transporting water from a source and distributing it equitably over an agricultural area (Velasco-Muñoz et al., 2019).

However, the provision of water to crops becomes less effective and efficient due to the application of inappropriate cropping patterns, as found in the Rintau irrigation system.

Cropping patterns are planting efforts on a piece of land by arranging the layout and sequence of plants over a certain period, including tillage and non-planting periods during a specific period (Bingfang & Qiangzi, 2011; Mahlayeye, 2022). The preparation of cropping patterns in the tropics is usually for one year by considering rainfall, especially in areas or lands entirely dependent on rainfall (Priyambodo, 1983; Bardan, 2014; Iizumi & Ramankutty, 2015). So that, planting type/variety selection also needs to be adjusted to the state of water or rain available (Febby &Azwarman, 2018).

Determination of plant species based on suitability with the analysis of actual conditions, ability to grow in mixed patterns, types of production, benefits to the community, the added value of products, and adaptability by the community (Rosadi, 2015).

2.2. Research Location

This study was conducted in the Rintau irrigation area in Sekayam District, Sanggau Regency. Rintau Dam is between 0°50'26.6" North latitude and 110°28'35.7" East longitude.

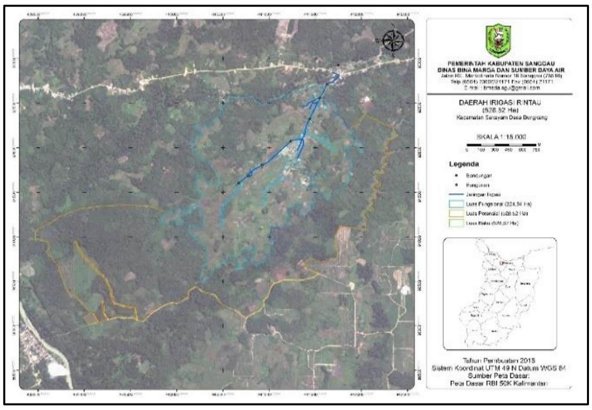

Fig. 1 Research Location

2.3. Data

This study used primary and secondary data. Preliminary data consisted of discharge measurement data, the global position of water buildings and channels, and documentation of the overall condition of Rintau irrigation. While secondary data consists of existing; maps of Rintau irrigation along with the catchment area of natural water sources, rainfall data, climatology data, Sekayam River discharge data in 2005 for calibration, and existing cropping patterns of Rintau irrigation.

2.4. Analysis Method

Once the necessary data was collected, it was analyzed to find the most suitable cropping pattern for Rintau irrigation.

a. Analysis of Potential Evapotranspiration

In this study, potential evapotranspiration analysis used the FAO Modified Penman method, with the equation:

$$Eto = \frac{\delta}{(\delta+\tau)} \text{ x } Rn + \frac{\tau}{(\delta+\tau)} \text{ x } [2{,}7(1+0{,}010\ U_2)\ (es-ea)] \quad \ldots(1)$$

δ : The slope of the vapor pressure versus temperature curve (δ,kPa/^{0}C), which is calculated;

: $\frac{4089 \text{ x es}}{(T+237{,}3)^2}$ ………………………(2)

Rn : Net radiation (Rn, mm/day)

: (Ra (1-α)(0,25+0,50 n/N))-Rb…....(3)

τ : psychometric constant (0.66 mb/^{0}C)

U_2 : Wind speed at 2 m above ground level (km/day).

U_2 : $U \times \frac{\text{Log } 100}{\left[\frac{\text{Log } 100h}{2}\right]}$ ....(4)

U : Monthly average wind speed data (U, km/day)

T : Monthly average temperature (°C)

es : Saturated vapor pressure (es, kPa).

Monthly average temperature (°C).

Ra : Solar radiation, whose value depends on the latitude of the location under review. The amount of Ra varies each month, as shown in Table 1.

Table 1. Solar radiation (Ra) at various latitudes

Hemisphere												
	Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
North Latitude												
10	13,2	14,2	15,3	15,7	15,5	15,3	15,3	15,5	15,3	14,7	13,6	12,9
8	13,6	14,5	15,3	15,6	15,3	15,0	15,1	15,4	15,3	14,8	13,9	13,3
6	13,9	14,8	15,4	15,4	15,1	14,7	14,9	15,2	15,3	15,0	14,2	13,7
4	14,3	15	15,5	15,5	14,9	14,4	14,6	15,1	15,3	15,1	14,5	14,1
2	14,7	15,3	15,6	15,3	14,6	14,2	14,3	14,9	15,3	15,3	14,8	14,4
0	15,0	15,5	15,7	15,3	14,4	13,9	14,1	14,8	15,3	15,4	15,1	14,8
South Latitude												
0	16,4	16,3	15,5	14,2	12,8	12,0	12,4	13,5	14,8	15,9	16,2	16,2
2	16,1	16,1	15,5	14,4	13,1	12,4	12,7	13,7	14,9	15,8	16,0	16,0
4	15,8	16,0	15,6	14,7	13,4	12,8	13,1	14,0	15,0	15,7	15,8	15,7
6	15,5	15,8	15,6	14,9	13,8	13,2	13,4	14,3	15,1	15,6	15,5	15,4
8	15,3	15,7	15,7	15,1	14,1	13,5	13,7	14,5	15,2	15,5	15,3	15,1
10	15,0	15,5	15,7	15,3	14,4	13,9	14,1	14,8	15,3	15,4	15,1	14,8

α : Reflection coefficient.
: 0.29+ 0.06 sin[30(M+0.0333N+2.25)] ....(5)
M : Month to-n
N : N is the number of month days in the month under review.
n/N : Relative sunshine duration relationship.
Rb : Long-wave radiation.
: 5-(1,12 $R^{0,20}$) MJ/m^2/Day.
MJ/m^2/Day = 0.408 mm/Day.
R : Rainfall (mm/month).

b. Analysis of water availability with the Mock Model

Mock Model is a hydrology model used to predict the hydrologic response of a watershed system to a user-defined rainfall and climatologic event. The Mock technique calculates discharge using water balance and boundary conditions (Fitriyanti, 2017).

The boundary conditions in the Mock model are the condition of the exposed surface (m), the magnitude of the infiltration coefficient (If) and the recession constant (K), and the influence of the percentage factor (PF) determined through calibration. These boundary condition parameters generally affect the amount of evapotranspiration, infiltration, groundwater storage, and storm runoff for each month

Exposed Surface (m) is the assumed percentage of the exterior Surface not covered by green vegetation in the dry season. The magnitude of this m price depends on the area observed. Mock classifies the observed area into three parts, namely primary or secondary forests, eroded areas, and agricultural fields. The magnitude of the exposed surface price ranges from 0% to 50%.

Infiltration Coefficient (If) is a coefficient based on soil porosity conditions and the slope of the drainage area. The infiltration coefficient has a significant value if the soil is porous (absorbs water), the nature of the month is dry, and the slope of the land is not steep because the nature of the moon influences it, so this can vary. In this calibration, the maximum infiltration coefficient price is 1.00, and the minimum is 0.01.

Flow Recession Constant (K) is the percentage of last month's groundwater present this month. K is higher in wet months; therefore, it varies month-to-month. In this calibration, the flow recession coefficient is from 1.00 to 0.01.

The percentage factor (PF) is the runoff percentage of rain. Mock's PF is 5%-10%, although it could rise periodically to 37.3%. If P falls below the soil moisture capacity mm/month, the runoff will include any Strom that flows..

c. Analysis of cropping pattern

Cropping patterns involve planting efforts by arranging the layout and sequence of plants over a certain period.

Monoculture and polyculture cropping patterns are the two types of cropping patterns available. Monoculture refers to growing the same crop in vast quantities. Rice fields, for example, are only planted with rice, corn, or soybeans. The Polyculture planting pattern involves planting various types of plants on one domain to achieve a greater level of sustainability (Banjarmahor & Simanjuntak, 2015).

In this study, the cropping pattern in Rintau irrigation is a polyculture cropping pattern consisting of rice-cucumber-paddy, rice-cucumber-eggplant, rice-paddy-peanut, and rice-paddy-chili.

Irrigation water supply assessment, irrigation water distribution assessment, irrigation water demand assessment, crop coefficients determination, percolation analysis, water layer replacement analysis, helpful rainfall review, and water balance review are all done initially in the study of cropping patterns.

3. Result and Discussion

3.1. Analysis of Potential Evapotranspiration Result

The amount of rainfall each month in each year is split into the first and second mid-month rains while analyzing evapotranspiration using the Penman Modified Fao Method. Calendar days, or the first 15 days, are the first mid-month, and the following 15 days are the second mid-month, serving as the basis for division in this analysis. For February, the second mid-month is 13 days or 14 days for leap years. As for months that have 31 days, the second monthly midpoint is 16 days.

The analysis results are as follows;

Table 2. Recapitulation of potential evapotranspiration calculation results

Year		Evapotranspiration											
		Jan	Feb	Mar	Apr	Mei	Jun	Jul	Aug	Sep	Okt	Nov	Dec
2000	I	3,94	3,82	3,95	3,10	3,67	3,31	3,68	3,67	3,93	4,23	4,05	3,66
	II	3,57	4,21	3,66	3,52	3,26	3,71	3,52	3,65	3,91	4,12	4,38	3,71
2001	I	3,85	3,89	4,32	3,34	3,41	3,42	3,72	3,71	3,77	4,23	4,50	3,38
	II	3,77	4,38	3,69	3,39	3,52	3,76	3,55	3,74	3,74	4,36	3,94	4,03
2002	I	3,70	3,73	4,26	3,21	3,18	3,60	3,65	3,01	3,99	4,42	4,49	4,04
	II	3,90	4,57	3,72	3,63	3,83	3,56	3,78	3,13	3,81	4,27	4,12	3,37
2003	I	3,79	4,19	4,01	3,36	3,74	3,77	3,57	3,77	3,94	4,71	4,20	1,92
	II	3,84	4,38	4,00	3,50	3,55	3,78	3,55	3,70	3,96	4,11	4,36	1,80
2004	I	3,56	4,14	3,84	3,20	2,87	3,54	3,49	3,72	3,71	4,56	4,18	3,76
	II	4,04	3,95	3,73	3,34	2,86	3,76	3,44	3,54	3,72	4,14	4,44	3,51
2005	I	3,84	4,10	3,87	3,07	3,25	3,53	3,35	3,69	3,78	4,50	4,24	3,36
	II	3,72	4,06	3,72	3,55	3,31	3,49	3,64	3,63	4,10	4,20	4,26	3,77
2006	I	4,09	4,34	3,98	3,23	3,32	3,28	3,63	3,63	3,42	4,52	4,35	3,76
	II	3,80	3,90	3,96	3,20	3,25	3,37	3,33	3,24	3,96	4,40	4,31	3,69
2007	I	3,31	4,16	3,79	3,34	2,92	3,31	3,53	3,56	3,68	4,30	4,23	3,85
	II	3,20	4,18	4,07	3,33	2,91	3,65	3,32	3,40	4,02	4,51	4,48	3,73
2008	I	3,75	4,32	3,81	3,45	3,56	3,54	3,56	3,56	3,86	4,38	4,04	3,53
	II	3,97	4,15	3,89	3,34	3,45	3,58	3,52	3,30	3,89	4,25	4,55	3,82
2009	I	3,87	4,80	4,04	3,45	3,46	3,46	3,49	3,70	4,25	4,53	4,54	4,00
	II	3,92	4,02	3,96	3,38	3,39	3,65	3,81	3,55	4,05	4,40	4,83	3,91
2010	I	4,45	4,42	4,20	3,66	3,44	3,58	3,72	3,58	4,00	4,77	4,66	3,91
	II	4,50	4,75	4,01	3,35	3,57	3,74	3,07	3,32	3,93	4,26	4,30	3,99
2011	I	4,23	4,65	4,13	3,65	3,62	3,68	3,76	3,48	3,99	4,81	4,54	3,98
	II	4,02	4,48	3,97	3,40	3,32	3,80	3,71	3,72	4,14	4,21	4,48	3,81
2012	I	4,32	4,29	3,87	3,43	3,80	3,49	3,49	3,68	4,26	4,58	4,52	3,81
	II	3,78	4,52	4,47	3,49	3,33	4,02	3,81	3,81	4,09	3,94	4,57	4,23
2013	I	4,82	3,97	4,78	3,30	3,59	3,87	3,71	3,61	3,95	5,32	4,93	4,20
	II	4,76	4,22	4,05	3,65	3,10	3,99	3,95	3,85	4,04	4,42	4,84	4,76
2014	I	4,35	5,06	4,39	3,61	3,38	3,71	3,99	3,45	3,98	4,79	4,78	3,98
	II	5,01	4,96	4,35	3,83	3,20	3,92	4,35	3,59	4,01	4,24	4,37	4,24
2015	I	4,13	4,70	4,41	3,25	3,49	3,10	3,98	3,79	4,14	4,32	4,67	4,25
	II	4,06	5,10	4,46	3,35	3,23	4,05	3,84	3,91	4,38	4,28	4,60	4,78
2016	I	4,50	4,59	3,75	3,28	3,46	3,72	3,80	3,78	3,73	4,79	4,55	4,20
	II	4,35	4,12	4,37	3,31	3,23	3,61	3,75	3,90	3,79	3,88	4,34	4,36
2017	I	4,51	4,92	4,06	3,28	3,11	3,48	3,25	3,08	3,60	4,36	4,41	3,59
	II	4,13	4,40	4,27	3,36	3,23	3,46	3,87	3,34	4,06	4,25	4,26	4,56
2018	I	4,15	4,56	3,82	3,41	3,20	3,84	3,65	3,71	3,76	4,24	4,34	3,72
	II	4,24	4,47	4,07	3,13	3,03	3,62	3,63	3,87	3,64	4,11	4,47	4,27
2019	I	4,18	4,11	4,31	3,38	3,64	3,23	3,62	3,91	4,43	4,58	4,68	3,40
	II	4,22	4,04	4,73	3,42	3,14	3,69	3,77	3,91	3,93	4,06	4,33	4,28
2020	I	4,31	4,34	4,27	3,17	3,53	3,25	3,11	3,43	3,40	4,57	4,40	3,98
	II	3,88	4,62	4,15	2,95	2,99	3,28	3,19	3,59	3,78	4,34	4,16	4,35
2021	I	3,85	4,56	4,07	3,52	3,29	3,53	3,35	3,25	3,55	4,87	4,54	4,15
	II	3,75	5,15	3,82	3,41	3,39	3,49	3,61	3,43	3,68	3,82	4,63	4,45
Ave		**4,27**	**4,54**	**4,20**	**3,40**	**3,35**	**3,63**	**3,67**	**3,62**	**3,93**	**4,41**	**4,52**	**4,14**

3.2. Analysis of water availability with the Mock Model Result

The Rintau irrigation water availability analysis begins with the calibration of Mock, m, If, K, and PF parameters. Calibration using a linear model with the help of the solver tool from MS Excel. The reference is the measured discharge downstream of the Sekayam River in 2005.

The results are as follows; for the previous wet month, the value of m is 23.33%, If equals 0.36, and K is 0.64. For the last dry month, m is 25.44%, If equals 0.64, and K is 0.36. Meanwhile, the PF value for the wet month is 0.21 and for the dry month is 0.054. Furthermore, by entering the values of the Mock parameters, the amount of monthly discharge is obtained using Mock.

Table 3. Recapitulation of Monthly Discharge from Mock Analysis

Tahun		Monthly Discharge											
		Jan	Feb	Mar	Apr	Mei	Jun	Jul	Aug	Sep	Okt	Nov	Dec
2000	I	1,25	1,46	1,12	1,87	0,29	0,80	0,37	0,14	0,21	0,65	1,14	1,36
	II	1,42	1,14	1,32	1,04	0,99	0,46	0,38	0,16	0,23	0,79	1,08	1,15
2001	I	1,47	1,32	0,50	1,21	0,65	0,76	0,32	0,13	0,31	0,75	0,84	1,79
	II	1,10	0,77	1,12	1,20	0,46	0,31	0,29	0,12	0,33	0,61	1,22	1,00
2002	I	1,23	1,52	0,63	1,68	1,08	0,67	0,39	0,20	0,11	0,45	0,78	0,79
	II	1,35	0,59	1,16	0,64	0,19	0,50	0,22	0,08	0,25	0,69	1,07	1,90
2003	I	1,13	1,15	0,93	1,19	0,22	0,28	0,22	0,09	0,15	0,14	0,72	1,21
	II	1,33	0,86	0,91	0,77	0,50	0,35	0,28	0,12	0,15	0,69	1,12	1,62
2004	I	1,56	1,28	1,24	1,86	0,83	0,77	0,49	0,20	0,41	0,44	0,89	1,34
	II	0,98	1,18	1,45	1,45	0,86	0,50	0,42	0,30	0,43	0,86	1,08	1,45
2005	I	1,22	1,34	1,12	1,98	0,91	0,74	0,72	0,30	0,47	0,48	0,83	1,81
	II	1,01	1,23	0,12	0,02	0,05	0,06	0,02	0,01	0,01	0,02	0,17	0,12
2006	I	0,97	0,91	0,90	1,42	0,73	0,98	0,54	0,27	0,87	0,78	1,13	1,13
	II	1,12	1,42	1,08	1,78	0,87	0,88	0,90	0,95	0,52	0,69	1,18	1,26
2007	I	0,97	1,13	1,25	1,20	0,66	0,91	0,54	0,28	0,56	0,80	1,27	1,20
	II	1,23	1,12	0,74	1,09	0,68	0,46	0,62	0,51	0,27	0,43	0,76	1,01
2008	I	1,43	1,02	1,21	1,16	0,47	0,61	0,40	0,24	0,35	0,59	1,19	1,59
	II	1,09	1,15	0,97	1,28	0,66	0,60	0,44	0,60	0,47	0,81	0,92	1,23
2009	I	1,27	0,34	0,71	0,83	0,64	0,84	0,67	0,28	0,12	0,39	0,75	0,95
	II	1,06	1,20	0,98	1,32	0,75	0,59	0,24	0,26	0,29	0,61	0,49	1,07
2010	I	0,87	0,86	0,49	0,25	0,66	0,61	0,25	0,15	0,16	0,20	0,50	0,97
	II	0,88	0,42	0,77	1,14	0,45	0,37	0,92	0,83	0,51	0,88	1,30	0,97
2011	I	0,55	0,40	0,51	0,14	0,35	0,42	0,18	0,26	0,27	0,18	0,69	0,94
	II	0,96	0,75	0,87	1,02	0,85	0,42	0,20	0,08	0,05	0,71	1,03	1,01
2012	I	0,49	0,85	1,05	0,94	0,30	0,71	0,57	0,24	0,09	0,33	0,73	1,01
	II	1,07	0,61	0,58	0,68	0,57	0,31	0,23	0,21	0,16	0,65	0,84	0,83
2013	I	0,08	0,95	0,16	1,00	0,31	0,24	0,12	0,09	0,13	0,05	0,14	0,40
	II	0,07	0,80	0,84	0,32	0,61	0,31	0,12	0,13	0,07	0,08	0,23	0,15
2014	I	0,41	0,17	0,20	0,09	0,75	0,54	0,22	0,33	0,31	0,21	0,32	0,86
	II	0,19	0,22	0,73	-0,08	0,56	0,31	0,11	0,42	0,32	0,36	0,91	1,06
2015	I	0,48	0,19	0,13	0,83	0,51	1,18	0,55	0,21	0,09	0,34	0,50	0,37
	II	0,58	0,12	0,43	0,64	0,47	0,28	0,22	0,11	0,04	0,03	0,48	0,18
2016	I	0,77	0,37	1,22	1,33	0,51	0,34	0,14	0,05	0,35	0,22	0,61	0,49
	II	0,47	1,17	0,72	1,21	0,41	0,44	0,33	0,16	0,31	0,76	1,15	0,84
2017	I	0,39	0,26	0,59	1,03	1,13	0,87	0,92	1,07	1,03	0,92	1,10	1,30
	II	0,80	0,71	0,77	0,90	0,43	0,70	0,31	0,72	0,36	0,33	1,08	0,51
2018	I	0,71	0,59	1,03	0,90	0,99	0,41	0,26	0,12	0,42	0,80	1,18	1,12
	II	0,50	0,65	1,04	1,42	0,74	0,59	0,58	0,34	0,69	0,61	0,92	0,91
2019	I	0,78	1,32	0,44	0,96	0,37	0,94	0,59	0,23	0,09	0,25	0,50	1,59
	II	0,65	1,41	0,32	0,75	0,71	0,47	0,36	0,21	0,32	0,48	1,08	0,92
2020	I	0,48	0,78	0,35	1,37	0,44	0,93	1,07	0,61	0,98	0,75	1,02	0,96
	II	1,19	0,48	1,02	1,97	0,88	0,99	1,09	0,77	0,61	0,38	0,89	0,88
2021	I	1,10	0,59	0,65	0,45	0,90	0,67	0,70	0,66	0,84	0,38	0,67	0,58
	II	0,98	0,28	1,25	1,13	0,24	0,55	0,52	0,65	0,67	0,89	0,87	0,66
Sum		**39,63**	**37,05**	**35,64**	**45,35**	**26,63**	**25,72**	**19,04**	**13,91**	**15,38**	**22,50**	**37,39**	**44,50**
Min		**0,07**	**0,12**	**0,12**	**-0,08**	**0,05**	**0,06**	**0,02**	**0,01**	**0,01**	**0,02**	**0,14**	**0,12**
Max		**1,56**	**1,52**	**1,45**	**1,98**	**1,13**	**1,18**	**1,09**	**1,07**	**1,03**	**0,92**	**1,30**	**1,90**
Average		**0,90**	**0,84**	**0,81**	**1,03**	**0,61**	**0,58**	**0,43**	**0,32**	**0,35**	**0,51**	**0,85**	**1,01**

Using the Weibull method, the probability of dependable discharge is as follows;

Table 4. Dependable discharge 80% of January-June

Month		80% Reliable Discharge	
		m^3/sec	lt/sec
Januari	I	0,482	481,723
	II	0,548	547,840
Febuari	I	0,357	356,518
	II	0,455	454,576
Maret	I	0,401	401,340
	II	0,667	667,356
April	I	0,675	675,017
	II	0,643	642,675
Mei	I	0,338	337,738
	II	0,418	418,457
Juni	I	0,419	418,650
	II	0,313	312,911

Table 5. Dependable discharge 80% of July-December

Month		80% Reliable Discharge	
		m^3/sec	lt/sec
Juli	I	0,217	216,523
	II	0,208	208,383
Agustus	I	0,158	157,562
	II	0,115	115,384
September	I	0,114	114,200
	II	0,117	116,728
Oktober	I	0,209	209,407
	II	0,346	346,153
November	I	0,504	503,521
	II	0,655	655,273
Desember	I	0,708	707,512
	II	0,597	597,410
Average Jan-Dec		**0,403**	**402,619**

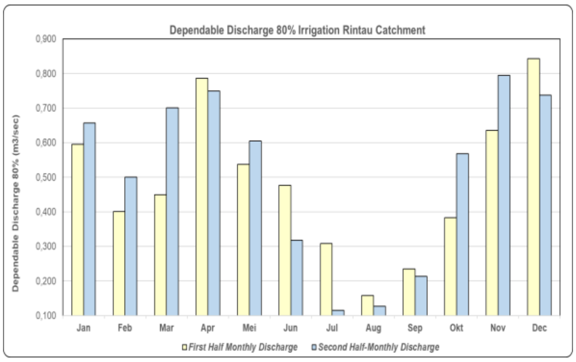

Fig. 2 Dependable Discharge 80% Irrigation Rintau Catchment

3.3. Analysis Cropping Pattern Result

3.3.1. Effective Rainfall Analysis

To grow, plants need water, soil, air, and sunlight. This water can get to the plants through rain or a combination of rain and watering. If it rains enough, the plant doesn't need to be watered. If it doesn't rain, the plants must be watered to get all the water they need. Suppose there is some rainfall but not enough to cover the crop's water needs.

Adequate rainfall is the amount of rainfall seen from the possibility of occurrence and the ability of soil capacity effectively make available/ water needs for plants.

In irrigation planning, the amount of rainfall that has a good chance of occurring is called the mainstay rainfall, which is the amount of rainfall that may occur in the period under review at the planned location. However, not all rainfall will be adequate because some leave the land as run-off, percolation, and evaporation. What is practical is the rainfall that can enter the soil and be stored in the root zone. Rain that is not heavy but long will be more effective than heavy but short rain.

The reliable rainfall parameter is based on the mid-month rainfall amount. The analysis to calculate this rainfall must be done based on daily rainfall data. The values of the rainfall rate are determined with a 20% probability of non-fulfillment using the frequency analysis method.

FAO's book Crop water Requirement discusses water requirements for crops in general. The calculation of adequate rainfall is done through two stages: calculating dependable rain and part of the mainstay rainfall, which becomes sufficient rainfall. The amount of dependable rainfall is calculated based on a probability of 75% (3 out of 4 data) or 80% (4 out of 5 data). The likelihood or reliability level is chosen based on the type and condition of the crop.

The calculation of adequate rainfall for rice plants grown in rice fields differs from the calculation for areas/dry land because bunds limit the puddles accommodated in rice fields. With bunds, all rainfall that falls into the rice field plot will be accommodated so that all the mainstay rain becomes effective. The higher the rainfall, the higher the increase of inundation in the rice field. Thus, adequate rainfall is only viewed on the possibility of occurrence; alternatively, in other words, the excellent rain on rice fields is as much as the mainstay rainfall.

In this study, adequate rainfall was also calculated into first-half-monthly rainfall and second-half-monthly rainfall. The results are as follows

Table 6. Rice Effective Rainfall (Re Paddy) January-June

m	$\frac{m}{n+1}$	Month											
		Jan		Feb		Mar		Apr		Mei		Jun	
		I	II	I	II	I	II	I	II	I	II	I	II
1	4%	288,1	282,9	284,5	254,9	197,3	275,0	255,9	284,0	218,3	179,6	250,0	165,0
2	9%	249,3	245,6	262,1	235,7	181,5	233,6	235,2	220,3	196,9	168,0	201,0	147,0
3	13%	241,2	231,7	232,1	220,9	166,8	218,4	199,0	186,5	177,0	158,6	177,0	132,7
4	17%	208,6	222,7	210,7	198,5	165,0	214,0	195,5	164,0	167,1	155,7	176,3	129,3
5	22%	207,1	220,0	180,4	191,4	164,3	208,7	192,8	164,0	165,0	151,7	165,0	112,0
6	26%	199,2	219,9	179,5	172,0	161,0	199,5	178,1	155,7	147,0	147,5	163,7	105,3
7	30%	196,7	195,9	169,7	170,7	150,4	194,0	175,7	155,5	139,7	145,3	150,7	101,6
8	35%	192,0	188,9	168,6	162,7	146,8	183,3	168,3	148,3	134,6	140,0	141,7	95,7
9	39%	167,2	188,0	162,4	153,1	134,8	173,0	167,3	142,6	124,7	138,3	135,5	94,0
10	43%	146,3	187,5	137,0	145,7	132,3	145,7	162,7	140,3	123,2	122,6	127,7	79,3
11	48%	141,0	180,7	132,7	118,3	120,3	140,7	148,9	136,3	119,7	122,0	127,7	72,3
12	52%	138,8	176,0	131,3	110,0	111,0	140,7	143,1	135,3	118,6	120,8	119,8	70,9
13	57%	134,5	152,3	129,0	108,7	107,3	139,5	139,0	133,5	100,7	115,0	111,7	68,5
14	61%	121,5	145,2	119,0	106,0	97,3	138,7	137,7	128,0	99,0	113,0	102,7	64,0
15	65%	112,3	141,7	93,0	105,3	86,0	135,3	133,7	125,5	93,4	97,0	102,0	58,2
16	70%	108,7	136,3	88,0	85,3	80,1	132,8	131,7	114,3	86,0	96,5	95,0	57,7
17	74%	105,0	125,3	75,0	73,9	67,5	129,0	125,7	103,4	75,5	91,9	84,7	54,0
18	78%	94,0	113,5	72,3	68,7	67,0	127,0	124,3	97,0	73,0	89,0	80,3	52,0
19	83%	92,3	94,7	60,3	68,0	60,7	109,2	96,0	92,8	67,0	88,7	59,3	41,7
20	87%	87,0	89,7	54,0	45,7	60,1	107,7	88,7	72,0	65,0	85,0	57,0	24,0
21	91%	63,3	34,0	33,3	14,5	45,3	105,3	76,7	71,7	63,2	56,0	46,3	12,3
22	96%	27,7	0,0	29,7	11,7	8,3	63,0	73,7	42,0	51,1	29,3	30,3	0,0
R_{80} (mm/month)		93,33	105,97	67,53	68,40	64,47	119,86	112,96	95,29	70,60	88,87	71,93	47,85
R_{80} (mm/days)		6,22	7,06	4,50	4,56	4,30	7,99	7,53	6,35	4,71	5,92	4,80	3,19
Re Paddy (mm/days) 0,7 x R_{80}		4,36	4,95	3,15	3,19	3,01	5,59	5,27	4,45	3,29	4,15	3,36	2,23

Table 7. Rice Effective Rainfall (Re Paddy) July-December

m	$\frac{m}{n+1}$	Month											
		Jul		Aug		Sep		Okt		Nov		Des	
		I	II	I	II	I	II	I	II	I	II	I	II
1	4%	178,0	221,3	182,7	180,0	222,6	157,7	183,6	211,5	271,6	275,1	350,0	348,2
2	9%	159,7	218,0	116,5	160,8	215,0	125,5	179,7	211,3	256,0	235,4	341,6	286,1
3	13%	130,0	154,5	93,3	143,0	165,7	111,8	170,8	203,6	221,1	224,0	325,5	277,4
4	17%	129,6	133,5	82,3	130,3	162,0	105,7	170,5	198,7	212,6	199,3	283,4	242,1
5	22%	108,0	125,0	74,0	129,7	139,3	105,0	157,3	197,0	203,7	199,0	251,3	227,2
6	26%	97,7	114,0	58,9	121,3	125,0	99,3	147,8	195,7	198,5	196,3	245,6	212,4
7	30%	80,1	90,5	55,2	106,0	121,5	95,0	141,3	192,3	184,0	190,9	219,2	203,3
8	35%	76,2	90,0	54,6	93,4	116,3	91,4	129,9	185,0	181,0	186,5	216,0	199,9
9	39%	75,0	87,8	54,3	77,3	115,0	91,1	127,7	183,2	163,7	178,3	212,7	189,6
10	43%	73,9	87,0	52,7	73,7	100,5	84,7	118,3	181,1	162,0	172,7	195,1	182,3
11	48%	70,4	82,3	45,8	70,0	98,1	82,6	116,0	175,6	146,0	167,8	175,5	178,7
12	52%	69,8	77,8	45,0	68,1	81,0	82,0	116,0	157,3	143,1	167,7	166,0	161,0
13	57%	68,0	75,3	44,3	66,3	78,9	73,3	115,9	155,7	142,7	161,7	164,0	157,0
14	61%	65,7	74,3	39,3	61,5	78,3	72,6	110,9	151,5	139,7	157,3	157,0	150,0
15	65%	51,9	72,7	34,0	56,0	71,4	68,4	100,0	133,0	135,0	153,0	155,7	148,0
16	70%	48,7	55,0	32,9	53,0	68,7	60,7	84,7	127,3	132,7	140,0	154,3	144,7
17	74%	42,0	54,7	32,1	43,4	65,3	60,4	75,3	123,0	131,0	139,6	150,0	142,7
18	78%	41,7	50,7	28,9	32,7	54,7	55,0	73,5	108,0	115,0	133,0	134,2	138,1
19	83%	38,0	47,0	24,0	31,7	47,7	52,5	72,0	100,7	108,5	120,7	108,5	125,0
20	87%	32,3	44,1	22,3	29,7	47,0	51,3	71,0	88,0	107,0	116,5	97,3	96,7
21	91%	29,0	36,3	16,3	25,9	32,7	48,0	62,0	68,3	85,3	83,7	97,0	69,7
22	96%	12,7	15,3	12,5	10,8	13,5	16,3	12,3	56,0	65,0	78,3	86,7	65,7
R_{80} (mm/month)		40,24	49,20	26,92	32,29	51,87	54,01	72,88	105,07	112,40	128,07	123,90	132,86
R_{80} (mm/days)		2,68	3,28	1,79	2,15	3,46	3,60	4,86	7,00	7,49	8,54	8,26	8,86
Re Paddy (mm/days) 0,7 x R_{80}		1,88	2,30	1,26	1,51	2,42	2,52	3,40	4,90	5,25	5,98	5,78	6,20

Table 8. Rice Effective Rainfall (Re Crops) January-June

m	$\frac{m}{n+1}$	Month											
		Jan		Feb		Mar		Apr		Mei		Jun	
		I	II	I	II	I	II	I	II	I	II	I	II
1	4%	288,1	282,9	284,5	254,9	197,3	275,0	255,9	284,0	218,3	179,6	250,0	165,0
2	9%	249,3	245,6	262,1	235,7	181,5	233,6	235,2	220,3	196,9	168,0	201,0	147,0
3	13%	241,2	231,7	232,1	220,9	166,8	218,4	199,0	186,5	177,0	158,6	177,0	132,7
4	17%	208,6	222,7	210,7	198,5	165,0	214,0	195,5	164,0	167,1	155,7	176,3	129,3
5	22%	207,1	220,0	180,4	191,4	164,3	208,7	192,8	164,0	165,0	151,7	165,0	112,0
6	26%	199,2	219,9	179,5	172,0	161,0	199,5	178,1	155,7	147,0	147,5	163,7	105,3
7	30%	196,7	195,9	169,7	170,7	150,4	194,0	175,7	155,5	139,7	145,3	150,7	101,6
8	35%	192,0	188,9	168,6	162,7	146,8	183,3	168,3	148,3	134,6	140,0	141,7	95,7
9	39%	167,2	188,0	162,4	153,1	134,8	173,0	167,3	142,6	124,7	138,3	135,5	94,0
10	43%	146,3	187,5	137,0	145,7	132,3	145,7	162,7	140,3	123,2	122,6	127,7	79,3
11	48%	141,0	180,7	132,7	118,3	120,3	140,7	148,9	136,3	119,7	122,0	127,7	72,3
12	52%	138,8	176,0	131,3	110,0	111,0	140,7	143,1	135,3	118,6	120,8	119,8	70,9
13	57%	134,5	152,3	129,0	108,7	107,3	139,5	139,0	133,5	100,7	115,0	111,7	68,5
14	61%	121,5	145,2	119,0	106,0	97,3	138,7	137,7	128,0	99,0	113,0	102,7	64,0
15	65%	112,3	141,7	93,0	105,3	86,0	135,3	133,7	125,5	93,4	97,0	102,0	58,2
16	70%	108,7	136,3	88,0	85,3	80,1	132,8	131,7	114,3	86,0	96,5	95,0	57,7
17	74%	105,0	125,3	75,0	73,9	67,5	129,0	125,7	103,4	75,5	91,9	84,7	54,0
18	78%	94,0	113,5	72,3	68,7	67,0	127,0	124,3	97,0	73,0	89,0	80,3	52,0
19	83%	92,3	94,7	60,3	68,0	60,7	109,2	96,0	92,8	67,0	88,7	59,3	41,7
20	87%	87,0	89,7	54,0	45,7	60,1	107,7	88,7	72,0	65,0	85,0	57,0	24,0
21	91%	63,3	34,0	33,3	14,5	45,3	105,3	76,7	71,7	63,2	56,0	46,3	12,3
22	96%	27,7	0,0	29,7	11,7	8,3	63,0	73,7	42,0	51,1	29,3	30,3	0,0
R_{80} (mm/month)		93,333	105,967	67,533	68,400	64,467	119,864	112,960	95,287	70,600	88,867	71,933	47,847
R_{80} (mm/days)		6,222	7,064	4,502	4,560	4,298	7,991	7,531	6,352	4,707	5,924	4,796	3,190
Re Crops (mm/days) 0,5 x R_{80}		3,111	3,532	2,251	2,280	2,149	3,995	3,765	3,176	2,353	2,962	2,398	1,595

Table 9. Rice Effective Rainfall (Re Crops) July-December

m	$\frac{m}{n+1}$	Month											
		Jul		Aug		Sep		Okt		Nov		Des	
		I	II	I	II	I	II	I	II	I	II	I	II
1	4%	178,0	221,3	182,7	180,0	222,6	157,7	183,6	211,5	271,6	275,1	350,0	348,2
2	9%	159,7	218,0	116,5	160,8	215,0	125,5	179,7	211,3	256,0	235,4	341,6	286,1
3	13%	130,0	154,5	93,3	143,0	165,7	111,8	170,8	203,6	221,1	224,0	325,5	277,4
4	17%	129,6	133,5	82,3	130,3	162,0	105,7	170,5	198,7	212,6	199,3	283,4	242,1
5	22%	108,0	125,0	74,0	129,7	139,3	105,0	157,3	197,0	203,7	199,0	251,3	227,2
6	26%	97,7	114,0	58,9	121,3	125,0	99,3	147,8	195,7	198,5	196,3	245,6	212,4
7	30%	80,1	90,5	55,2	106,0	121,5	95,0	141,3	192,3	184,0	190,9	219,2	203,3
8	35%	76,2	90,0	54,6	93,4	116,3	91,4	129,9	185,0	181,0	186,5	216,0	199,9
9	39%	75,0	87,8	54,3	77,3	115,0	91,1	127,7	183,2	163,7	178,3	212,7	189,6
10	43%	73,9	87,0	52,7	73,7	100,5	84,7	118,3	181,1	162,0	172,7	195,1	182,3
11	48%	70,4	82,3	45,8	70,0	98,1	82,6	116,0	175,6	146,0	167,8	175,5	178,7
12	52%	69,8	77,8	45,0	68,1	81,0	82,0	116,0	157,3	143,1	167,7	166,0	161,0
13	57%	68,0	75,3	44,3	66,3	78,9	73,3	115,9	155,7	142,7	161,7	164,0	157,0
14	61%	65,7	74,3	39,3	61,5	78,3	72,6	110,9	151,5	139,7	157,3	157,0	150,0
15	65%	51,9	72,7	34,0	56,0	71,4	68,4	100,0	133,0	135,0	153,0	155,7	148,0
16	70%	48,7	55,0	32,9	53,0	68,7	60,7	84,7	127,3	132,7	140,0	154,3	144,7
17	74%	42,0	54,7	32,1	43,4	65,3	60,4	75,3	123,0	131,0	139,6	150,0	142,7
18	78%	41,7	50,7	28,9	32,7	54,7	55,0	73,5	108,0	115,0	133,0	134,2	138,1
19	83%	38,0	47,0	24,0	31,7	47,7	52,5	72,0	100,7	108,5	120,7	108,5	125,0
20	87%	32,3	44,1	22,3	29,7	47,0	51,3	71,0	88,0	107,0	116,5	97,3	96,7
21	91%	29,0	36,3	16,3	25,9	32,7	48,0	62,0	68,3	85,3	83,7	97,0	69,7
22	96%	12,7	15,3	12,5	10,8	13,5	16,3	12,3	56,0	65,0	78,3	86,7	65,7
R_{80} (mm/month)		40,240	49,200	26,920	32,288	51,869	54,013	72,880	105,067	112,400	128,067	123,900	132,860
R_{80} (mm/days)		2,683	3,280	1,795	2,153	3,458	3,601	4,859	7,004	7,493	8,538	8,260	8,857
Re Crops (mm/days) 0,5 x R_{80}		1,341	1,640	0,897	1,076	1,729	1,800	2,429	3,502	3,747	4,269	4,130	4,429

3.3.2. Results of Water Demand Analysis in Rice Fields

According to the Direktorat Irigasi, calculating irrigation water needs in the field must be calculated every 15 days. Thus, the data used should also be 15 daily data. For rainfall data, for example, this 15-day rainfall data can be calculated based on daily rainfall data. However, not all stations provide daily rainfall data, commonly as monthly rainfall. Therefore, calculating irrigation water requirements is often taken as 15-day rainfall, which is half of the monthly rainfall. Likewise, other data should be used daily, then made into half-monthly data. However, the crop coefficient must be taken half monthly so that the water supply is also calculated half monthly.

Since there are four cropping patterns in this study, namely paddy-paddy-cucumber, paddy-paddy-eggplant, paddy-paddy-peanut, and paddy-paddy-chili, then each of these cropping patterns is calculated for its irrigation water requirement.

The analysis results are as follows

Table 10. Recapitulation Water Demand Analysis

No	Cropping Patterns	Start Planting	Min		Max		Average			
							Min		Max	
			NFR	DR	NFR	DR	NFR	DR	NFR	DR
1	Paddy-paddy-cucumber	Aug I	0,37	129,17	0,94	327,30	0,76	64,29	0,76	264,37
2	Paddy-paddy	Oct I	0,00	0,00	0,90	312,88	-0,16	-54,09	0,68	236,21
3	Paddy-Cucumber-Paddy	Nov I	0,37	129,17	0,94	327,30	0,18	63,82	0,76	264,37
4	Cucumber-Paady-Paddy	Jul I	0,37	129,17	0,94	327,30	0,16	55,51	0,76	264,37
5	Paddy-Cucumber	Oct I	0,00	0,00	0,94	327,30	-0,21	-73,22	0,76	264,37
6	Cucumber-Paddy	Aug I	0,00	0,00	0,94	327,30	-0,21	-73,22	0,76	264,37
7	Paddy-paddy-eggplant	Aug I	0,07	25,21	0,87	303,29	0,49	171,72	0,49	171,72
8	Paddy-Paddy-Peanut	Aug I	0,07	25,21	0,87	303,29	0,49	171,72	0,49	171,72
9	Paddy-paddy-Chili	Aug I	0,07	25,21	0,87	303,29	0,51	176,36	0,51	176,36

From the analysis of crop water requirements in each existing planting pattern of Rintau Irrigation, the most suitable planting pattern is paddy-paddy-cucumber. Conversely, although applying other cropping patterns is still suitable, the planting period exceeds the planting time of one year. So the use of cropping patterns other than rice-paddy-cucumber is not recommended.

4. Conclusion

Based on the outcomes of the preceding computations and analyses, the following conclusions may be drawn:

a) Rintau irrigation mainstay discharge based on simulations with the Mock Model is the maximum; 707,512 L/sec, which is the discharge in the first half of December; minimum; 114,200 L/sec, which is the first half monthly discharge in September, and the average discharge of 402,619 L/sec.

b) The water requirement of plants in rice fields in the Rintau Irrigation Area with the most optimal planting pattern, namely the Paddy-Paddy-Cucumber planting pattern, obtained the maximum NFR value of 8.146 mm/day or 0.943 L/sec.

c) Water balance at the beginning of planting in August with a planting pattern of Paddy-Paddy-Cucumber Crops in the Rintau Irrigation, water needs were not met or experienced a water shortage (deficit) in the last half month of August, which amounted to 205.201 L/sec.

5. Author's Note

Everything written in this article is original because it sums up my studies with Dr. Ir. Ir. Kartini, M.T., IPU., ASEAN Eng., ACPE, and Dr. Stefanus Barlian Soeryamassoeka, S.T., M.T., IPM. The contents of this article have been reviewed in a thesis defense at the Department of Civil Engineering, The University of Tanjungpura, on 18 October 2022 by Danang Gunarto, S.T., M.T., IPM and Eko Yulianto, S.T., M.T., IPM.

I, as the author of this journal, state that no conflict occurs in the publication of this journal, and no other party publishes this journal; this journal is free from plagiarism.

6. References

Agus Suryanto. (2019). **Pola Tanam**. Universitas Brawijaya Press.

Badan Pusat Statistik Kabupaten Sanggau. (2022). **Kabupaten Sanggau Dalam Angka 2021**.

Ahmed M. I. Meleha, A. F. Hassan, Maha A. El-Bialy, and Mona A. M. El-Mansoury. (2020). **Effect of Planting Dates and Planting Methods on Water Relations of Wheat**. International Journal of Agronomy.

Banjarnahor D, Simanjuntak B.H. (2015). **Pola Tanam Kabupaten Sumba Tengah yang Sesuai DenganCurah Hujan Setempat**. Hlm 97-107. Prosiding Konser Karya Ilmiah Nasional 2015. Fakultas Pertanian dan Bisnis, Universitas Kristen Satya Wacana,Salatiga.

Bingfang Wu, Qiangzi Li. (2011). **Crop planting and type proportion method for crop acreage estimation of complex agricultural landscapes**. International Journal of Applied Earth Observation and Geoinformation. Vol. 16 (2012) 101–112.

Bardan, M. (2014). **Irigasi.** Cetakan Ke-1.. Graha Ilmu.Yogyakarta

Febby P, F. N & Azwarman. (2018). **Perencanaan Jaringan Irigasi Batang Asai Kabupaten Sarolangun**. Jurnal Talenta Sipil. Vol 1, No.1. e-ISSN 2615-1634

Fitriyanti, Z. (2018). **Analisis Hidrologi Untuk Penentuan Debit Banjir Di Wilayah DAS Sungai Karang Mumus**. Jurnal Keilmuan dan Aplikasi Teknik Sipil. Vol. 1. No. 1.

Iizumi , T & N. Ramankutty. (2015). **How do weather and climate influence cropping area and intensity? Global Food Security**. Volume 4, March 2015, Pages 46-50

Koech, R & Philip Langat. (2018). **Improving Irrigation Water Use Efficiency: A Review of Advances, Challenges, and Opportunities in the Australian Context**. Water, Vol. 10(12), 1771.

Priyambodo. (1983). **Diktat Kuliah Irigasi 1**. Fakultas Teknik, Universitas Tanjungpura. Pontianak.

Radmehr, A.; Omid Bozorg-Haddad. (2022). **Developing Strategies for Agricultural Water Management of Large Irrigation and Drainage Networks with Fuzzy MCDM**. Water Resources Management 36(13):1-28. Springer.

Rosadi, R. Achmad Bustomi. (2015). **Dasar-Dasar Teknik Irigasi**. Cetakan Pertama. Graha Ilmu. Yogyakarta.

Sacks, William J.;Delphine Deryng; Jonathan A. Foley; Navin Ramankutty. (2010). **Crop planting dates: an analysis of global patterns**. Global Ecology and Biogeography. Vol 19 (5). 607-620.

S.J.Seidel; S.Werisch; N. Schütze; H.Laberc. (2017). **Impact of irrigation on plant growth and development of white cabbage**. Agricultural Water Management. Volume 187, June 2017, Pages 99-111

Snyder, R. L.; Melo-Abreu, J. P. (2005). **Frost protection: fundamentals, practice, and economics**. Vol. 1. Food and Agriculture Organization of the United Nations. ISBN 978-92-5-105328-7. ISSN 1684-8241.

T.T. Kozlowski. (2022). **Physiological ecology of natural regeneration of harvested and disturbed forest stands: implications for forest management**. Forest Ecology and Management. Volume 158, Issues 1–3, 15 March 2002, Pages 195-221.

Standar Perencanaan Irigasi **Kriteria Perencanaan Bagian Jaringan Irigasi, KP-01**. (2013). Direktorat Jenderal Sumber Daya Air.

Sudirman, Saidah, H., Tumpu, M., Yasa, I. W., Nenny, Ihsan, M., Nurnawaty, & Tamrin. (2021). **Sistem Irigasi dan Bangunan Air**. Cetakan Ke-1. (A. Karim, Ed.; hal 107). Yayasan Kita Menulis.

Velasco-Muñoz, Juan F.; José A. Aznar-Sánchez; Ana Batlles-delaFuente and Maria Dolores Fidelibus. (2019). **Sustainable Irrigation in Agriculture: An Analysis of Global Research**. Water, Vol. 11(9), 1758.

Vitadiar, Tanhella Zein, Farikhin, Surarso, B. (2018). **Production Planning and Planting Pattern Scheduling Information System for Horticulture** (The 2nd International Conference on Energy, Environmental and Information System (ICENIS 2017)). E3S Web of Conferences 31:10004. Vol.31. EDP Sciences.

Waller, P & M. Yitayew. (2015). **Irrigation and Drainage Engineering. Agricultural and Biosystems Engineering**, University of Arizona, Tucson, USA. ISBN: 978-3-319-05698-2. Springer Cham