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WATER SUPPLY AND DEMAND ANALYSIS FOR RICE AND ORANGE CROPS IN DANDA BESAR SWAMP IRRIGATION AREA

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ABSTRACT

The Danda Besar Swamp Irrigation Area is situated in Danda Jaya Village, Rantau Badauh District, Barito Kuala Regency, South Kalimantan Province, Indonesia. It covers a land area of 2200 hectares. The productivity of this irrigation scheme is significantly poor, with a yearly rice production of about 2 tons per hectare. Furthermore, Danda Jaya Village is renowned for being a prominent hub for oranges in South Kalimantan. This study aims to analyze the water balance condition in the Danda Besar Swamp Irrigation Area. The climatological data that were used in this study were obtained from the Syamsudin Noor Meteorological Station. The calculation of evapotranspiration uses the Penman-Monteith Method, whereas water availability is determined using the F.J. Mock Method without calibration. The computation of water demand is derived from the Indonesian Irrigation Regulation Standard. Result of this research are water availability in first January reached its peak at 2.31 m^3/s, while in First half of September, it dropped to its lowest point at 0.06 m^3/s. The peak of water demand was recorded in November I, reaching 8.23 m^3/s, while the lowest demand was seen in March I, with 0 m^3/s. The deficit periods occur from January I to February I, and subsequently from May I to December II. The surplus period occurs from February II to April II.

KEY WORDS

Swamp irrigation, water balance, rice, oranges.

The agricultural sector remains a key pillar of South Kalimantan province's efforts to increase Regional Original Income, alongside the mining sector, particularly coal, and plantations [1]. The agricultural sector's capacity is being enhanced by the rehabilitation of wetlands irrigation channels, as part of ongoing development efforts [2]. The productivity of Danda Besar tidal swamp remains low. The annual rice production in this region is merely 2 tons per hectare [3]. Danda Besar Tidal Irrigation Network is characterized by a significant volume of tidal overflow, which classifies it under the B/C hydrotopography category [4]. Consequently, during the arid season, the tide is incapable of infiltrating the land. Consequently, farmers are limited to a single annual rice cultivation during the rainy season. Furthermore, Danda Jaya Village is renowned as a prominent hub for orange cultivation in South Kalimantan. Intercropping is a viable option for farmers to optimize their economic outcomes by utilizing their available land to the fullest extent.

The objective of this study is to examine the availability and demand for water in the Irrigation of Danda Besar, as well as assess the state of its water equilibrium. The climatological data utilized for the computation was obtained from the Syamsudin Noor Meteorological Station for 16 years. The equation used in this study ignores the impact of tidal wetlands and only considers the influence of rainfall. The key factor for enhancing farmers' income in Danda Jaya Village through rice and orange production is ensuring the sufficient availability of irrigation water in the fields.

LITERATURE REVIEW AND HYPOTHESIS DEVELOPMENT

The Penman-Monteith method is the best evapotranspiration estimation method recommended by FAO [5]. The main drawback of this method is that it requires a lot of meteorological data. Only a few weather stations provide hourly and daily data. Analysis of evapotranspiration Penman-Monteith method is calculated by the formula:

$$ET_o = \frac{0{,}408\,\Delta R_n + \gamma \frac{900}{(T+273)} U_2 (e_s - e_a)}{\Delta + \gamma(1 + 0{,}34\,U_2)} \quad (1)$$

With the Water Balance method of DR.F.J Mock, an empirical estimate can be obtained to obtain the mainstay discharge with the following formulas.

Calculate Actual Evapotranspiration:

$$\Delta E = ETo \cdot \left(\frac{m}{20}\right) \times \left(\frac{18}{n}\right) \quad (2)$$

$$Ea = ETo - \Delta E \quad (3)$$

Calculate the Water Balance at the Ground Level:

$$S = R - Ea \quad (4)$$

Calculate Runoff and Groundwater Storage:

$$I = i \times Ws \quad (5)$$

$$V_n = k \,.\, V_{n-1} + \tfrac{1}{2} \,.\, (1+k) \,.\, i \quad (6)$$

$$\Delta V_n = V_n - V_{n-1} \quad (7)$$

$$BF = I - \Delta V_n \quad (8)$$

$$Dro = Ws - I \quad (9)$$

$$Ron = BF + Dro \quad (10)$$

Calculate Effective Discharge:

$$Qn = Ron \text{ x } A \quad (11)$$

The mainstay discharge is a discharge that must occur with a probability of 80% based on 16 years of historical data by sorting the data from large to small. The probability analysis approach used is the Weilbul Method:

$$P(Xm) = \frac{m}{n+1} \text{ x } 100 \quad (12)$$

The calculation of irrigation water requirements will also depend on the pattern of water distribution in rice fields whether a 1-month, 15-day or 10-day period is taken, according to the gate operating period of the Irrigation Area in the field. The need for irrigation water in rice fields is determined by several factors as follows.

Effective Rainfall:

$$R_{80} = \frac{m}{n+1} \text{ x } 100 \quad (13)$$

$$Re = 70\% \text{ x } (R80 / \text{observation period}) \quad (14)$$

The percolation rate given for rice fields is 3.0 mm/day in the dry season and 2.0 mm/day in the wet season [6].

Consumptive Water Usage (ETc):

$$ETc = Kc \text{ x } Eto \quad (15)$$

Replace twice, 50 mm each (or 3.3 mm/day for ½ month) during the month and two months after transplantation. (KP-01, 2013).

Water Requirements for Land Preparation:

$$IR = \frac{M\,e^k}{e^k\text{-}1} \quad (16)$$
$$M = Eo + P \quad (17)$$
$$K = \frac{M\,T}{S} \quad (18)$$

Water Requirements of Plants:

$$NFR = ETc + P – Re + WLR \quad (19)$$
$$NFR\ per\ Ha = NFR\ x\ Cathment\ Area \quad (20)$$
$$\mathrm{DI = NFR\ per\ Ha\ /\ Ef} \quad (21)$$

Water Requirements of Plants:

$$Water\ Balance = Q_{water\ supply} – Q_{water\ demand} \quad (22)$$

METHODS OF RESEARCH

The research site is situated in Danda Jaya Village, Rantau Badauh District, South Kalimantan Province. The distance between the village and Banjarmasin City is approximately 27.4 kilometers [7]. Prior to conducting the research, a comprehensive review of existing literature was carried out followed by the collecting of relevant data. A comprehensive literature review was conducted by collecting and examining information from various internet sources such as news articles, scholarly publications, and reports. The focus of the analysis was on topics relating to this research, such as Iriigation Scheme Danda Besar and water balance. The necessary data comprised primary data and secondary data. The collection of primary data involves conducting interviews with local people regarding the yield of rice harvesting. Secondary data is acquired from other relevant agencies or entities. The secondary data included in this work encompasses agricultural maps, climatological data, and existing cropping patterns, which are used to determine crop coefficients.

The research requires hydrological analysis, encompassing the computation of mean precipitation per biweekly and calculating effective rainfall. The analysis of evapotranspiration and water availability involves calculating the water balance at the surface, determining groundwater flow and storage, and estimating the main outflow. Afterward, analyze the irrigation water requirements. This will involve determining the appropriate cropping patterns, calculating the amount of water needed for land preparation, estimating the consumptive use of water, calculating the water requirements specifically for rice and oranges, and determining the overall irrigation area water requirements. The final component is the analysis of water balance. The final phase of this study yielded a definitive conclusion about the water balance status at Danda Besar Irrigation Network.

RESULTS AND DISCUSSION

The Penman-Monteith Method is used in the present study to calculate potential evapotranspiration (Eto). The required climatological data includes maximum temperature, minimum temperature, maximum humidity, minimum humidity, wind velocity, duration of sunshine, elevation, and latitude. The calculation is performed half-monthly for each year. Potential evapotranspiration data was collected half-monthly over a period of 16 years. The following are the results of calculating the average half-monthly potential evapotranspiration:

This study considers the availability of irrigation water only based on the impact of rainfall, specifically referring to the dependable discharge that has an 80% probability of being accessible. To determine the main discharge value, the yearly effective discharge is determined by considering several factors such as water balance, soil moisture, excess water, infiltration, storage volume, changes in groundwater flow, base flow, and direct flow. Following are the findings of the calculation for the discharge of Danda Besar Irrigation Network.

Table 1 – Recapitulation of Average Potential Evapotranspiration

Bln	Jan I	Jan II	Feb I	Feb II	Mar I	Mar II	Apr I	Apr II	May I	May II	Jun I	Jun II
ETo	2.9	3.05	3.08	3.11	3.16	3.37	3.21	3.24	3.21	3.05	2.90	2.78
Bln	Jul I	Jul II	Aug I	Aug II	Sept I	Sept II	Oct I	Oct II	Nov I	Nov II	Dec I	Dec II
ETo	2.86	3.01	3.16	3.33	3.39	3.39	3.38	3.37	3.29	3.29	2.93	2.87

Table 2 – Danda Besar Dependable Discharge

R	P (%)	Jan I	Jan II	Feb I	Feb II	Mar I	Mar II	Apr I	Apr II	May I	May II	Jun I	Jun II
1	6%	10.78	4.91	6.54	5.61	4.41	5.48	5.68	3.67	2.15	2.98	2.23	2.8
2	12%	4.91	4.28	4.91	3.77	4.3	4.68	3.35	3.32	2.05	2.23	2.2	2.69
3	18%	4.69	3.9	4.04	3.67	3.63	3.72	3.18	3.04	1.99	2.14	2.04	1.66
4	24%	3.73	3.89	4.01	3.6	3.62	3.48	2.7	2.73	1.94	2.07	1.88	1.63
5	29%	3.69	3.62	3.09	3.55	3.38	3.31	2.62	2.53	1.86	2.02	1.8	1.57
6	35%	3.6	3.55	3.07	3.44	2.95	3.13	2.54	2.18	1.84	1.84	1.76	1.56
7	41%	3.49	3.3	2.98	3.43	2.84	3.12	2.35	1.8	1.7	1.72	1.53	1.21
8	47%	3.42	2.87	2.91	2.64	2.78	2.73	2.25	1.43	1.65	1.4	1.38	1.01
9	53%	3.39	2.57	2.83	2.46	2.56	2.69	2.19	1.26	1.48	1.39	1.24	1
10	59%	3.16	2.16	2.73	2.33	2.17	2.52	2.17	1.23	1.06	1.26	0.83	0.81
11	65%	3.12	2.11	2.48	1.99	2.04	1.89	1.79	1.21	0.96	1.15	0.82	0.75
12	71%	2.65	2.06	2.14	1.92	1.96	1.35	1.72	1.03	0.95	1.04	0.79	0.63
13	76%	2.55	1.93	1.94	1.6	1.77	1.34	1.54	0.97	0.73	0.94	0.71	0.62
14	82%	2.15	1.92	1.83	1.51	1.72	0.97	1.54	0.83	0.68	0.9	0.59	0.61
15	88%	1.87	1.46	1.62	1.31	1.55	0.63	1	0.63	0.58	0.85	0.41	0.58
16	94%	1.71	1.25	1.61	1.05	1.43	0.45	0.78	0.49	0.57	0.49	0.34	0.55
Q80%		2.31	1.92	1.87	1.55	1.74	1.12	1.54	0.89	0.7	0.91	0.64	0.62

R	P (%)	Jul I	Jul II	Aug I	Aug II	Sept I	Sept II	Oct I	Oct II	Nov I	Nov II	Dec I	Dec II
1	6%	3.17	2.25	1.93	1.42	1.31	2.08	2.14	2.32	4.55	5.08	4.64	6.38
2	12%	2.11	2.07	1.70	1.31	1.27	1.45	1.45	2.16	3.60	3.59	3.85	4.74
3	18%	1.99	1.73	1.59	0.90	1.08	1.13	1.20	2.11	3.46	3.48	3.79	4.71
4	24%	1.22	1.66	1.51	0.84	1.08	1.01	1.09	2.07	3.23	3.33	3.52	4.55
5	29%	1.09	1.60	1.14	0.78	1.08	0.95	1.07	2.06	2.70	3.03	3.40	4.39
6	35%	1.08	1.29	0.60	0.72	0.55	0.65	0.91	1.85	2.46	2.66	3.36	4.07
7	41%	0.92	0.76	0.51	0.68	0.55	0.45	0.83	1.54	2.41	2.51	3.29	3.97
8	47%	0.88	0.63	0.40	0.59	0.37	0.45	0.77	1.44	2.31	2.35	3.12	3.51
9	53%	0.69	0.37	0.39	0.54	0.27	0.40	0.73	1.09	2.27	2.30	3.07	2.90
10	59%	0.66	0.28	0.35	0.42	0.22	0.13	0.71	0.76	1.83	1.82	3.05	2.62
11	65%	0.52	0.26	0.31	0.28	0.21	0.10	0.32	0.47	1.61	1.52	2.56	2.60
12	71%	0.47	0.17	0.31	0.27	0.16	0.09	0.25	0.43	1.33	1.32	2.48	2.45
13	76%	0.34	0.16	0.23	0.26	0.07	0.08	0.24	0.40	0.89	1.11	1.99	2.33
14	82%	0.31	0.16	0.19	0.24	0.05	0.08	0.22	0.22	0.88	0.91	1.31	1.85
15	88%	0.28	0.09	0.08	0.20	0.05	0.03	0.04	0.14	0.72	0.47	1.16	1.61
16	94%	0.24	0.08	0.07	0.16	0.03	0.01	0.01	0.02	0.24	0.33	0.58	1.20
Q80%		0.32	0.16	0.21	0.25	0.06	0.08	0.23	0.29	0.88	0.99	1.58	2.04

The planting schedule utilized for the Danda Besar Swamp Irrigation Area is categorized into two distinct planting phases. The Rice I planting pattern involves commencing field preparation in November I and initiating the planting process in December I. The land preparation time for the Rice II planting pattern commences on May 1st, while the planting period begins on June 1st. The second rice planting pattern involves commencing the land preparation phase in May I, followed by the planting phase in June I.

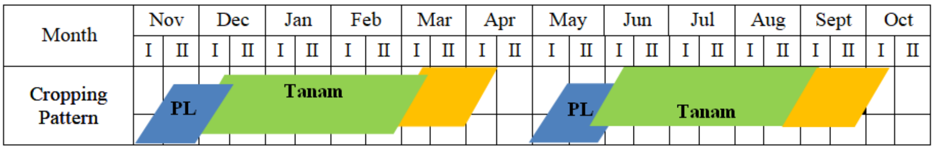

Figure 1 – Paddy Planting Pattern of Danda Besar Irrigation Network

For the Orange planting pattern schedule, it is assumed that it is year-round considering that the existing conditions are already planted with Orange with a *surjan* (Indonesian traditional type) planting system. So the water requirement for Orange plants is also calculated throughout the year.

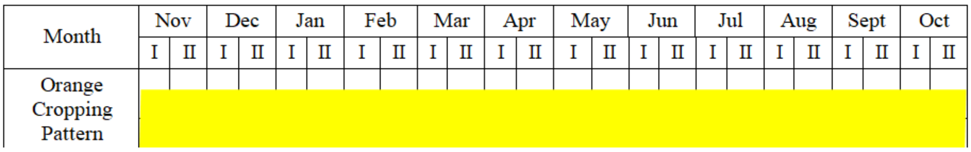

Figure 2 – Orange Planting Pattern of Danda Besar Irrigation Network

After the cropping pattern is obtained, the calculation of water requirements for land preparation is continued, including the calculation of open water evaporation (Eo), percolation (P), and water requirements for saturation. Furthermore, the calculation of water needs in rice fields per Ha and the water needs of irrigation areas. The recapitulation of the Danda Besar water demands shows in the table 3.

Table 3 – Recapitulation of Danda Besar Irrigation Network Water Demand

Month	Nov I	Nov II	Dec I	Dec II	Jan I	Jan II	Feb I	Feb II	Mar I	Mar II	Apr I	Apr II
Q (m^3/s)	4.54	8.23	3.71	2.74	2.49	2.79	2.16	1.11	-0.96	0.77	0.19	0.85
Month	Mei I	Mei II	Jun I	Jun II	Jul I	Jul II	Aug I	Aug II	Sept I	Sept II	Oct I	Oct II
Q (m^3/s)	4.95	8.01	5.02	3.93	4.29	4.32	3.93	2.74	0.85	1.67	1.42	1.36

Table 4 – Water Balance Condition at Danda Besar Irrigation Network

No	Month	Water Availability (m^3/s)	Irrigation Water Demand (m^3/s)	Water Balance	Deficit/Surplus
1	Jan I	2.31	2.49	-0.19	Deficit
2	Jan II	1.92	2.79	-0.87	Deficit
3	Feb I	1.87	2.16	-0.29	Deficit
4	Feb II	1.55	1.11	0.44	Surplus
5	Mar I	1.74	0.00	1.74	Surplus
6	Mar II	1.12	0.77	0.35	Surplus
7	Apr I	1.54	0.19	1.35	Surplus
8	Apr II	0.89	0.85	0.03	Surplus
9	May I	0.70	4.95	-4.25	Deficit
10	May II	0.91	8.01	-7.09	Deficit
11	Jun I	0.64	5.02	-4.38	Deficit
12	Jun II	0.62	3.93	-3.32	Deficit
13	Jul I	0.32	4.29	-3.97	Deficit
14	Jul II	0.16	4.32	-4.16	Deficit
15	Aug I	0.21	3.93	-3.72	Deficit
16	Aug II	0.25	2.74	-2.49	Deficit
17	Sept I	0.06	0.85	-0.80	Deficit
18	Sept II	0.08	1.67	-1.59	Deficit
19	Oct I	0.23	1.42	-1.20	Deficit
20	Oct II	0.29	1.36	-1.07	Deficit
21	Nov I	0.88	4.54	-3.66	Deficit
22	Nov II	0.99	8.23	-7.23	Deficit
23	Dec I	1.58	3.71	-2.12	Deficit
24	Dec II	2.04	2.74	-0.70	Deficit

The water balance is calculated by dividing the value of the water availability discharge by the value of the irrigation water demand discharge Danda Besar Irrigation Network. The water balance indicates a deficit or lack of water throughout January I (-0.19 m^3/s) to February I (-0.29 m^3/s). A similar situation occurs from May I (-4.25 m^3/s) until December II (-0.70 m^3/s). The water balance between February II (0.44 m^3/s) and April II (0.03 m^3/s) indicates a surplus or excess of water. The highest water availability was 2.31 m3 / second in January I, and the lowest was 0.06 m^3/s in September I. This is because the rainfall intensity in January was greater than in the previous months. And the intensity of the rainfall in September I was lower than in the previous months. The highest water demand was in November I, at 8.23 m^3/s, while the lowest was in March I, at 0 m^3/s. The farming pattern utilized generated the increased water demand in November I. Water is required for ground preparation throughout the entire rice field area in November. In March I, harvest time was already, and effective rainfall for plants was sufficient to meet water needs in rice fields. In other words, water is abundant this month.

CONCLUSION

The average dependable discharge (Q_{80}) is 0.95 m^3/s, while the average water requirement for rice and Orange crops is 3 m^3/s. The water balance in DIR Danda Besar is primarily deficient for rice and Orange crops. This suggests that the water available in DIR Danda Besar is insufficient to meet the demands. The gap occurs from January I to February I, then from May I to December II. The surplus period lasts from February II to April II.

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