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Comparison of Cropping Intensity in Conventional and SRI Irrigation Water Delivery System at Batu Bulan Reservoir

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ABSTRACT

The irrigation water supply system in the Batu Bulan irrigation area uses a conventional system. The conventional method is the provision of water by inundation from the beginning of planting until the fruit ripens. The use of water with conventional systems is very wasteful and inefficient. The irrigation water supply method that can save water use is the System of Rice Intensification method. Calculations are carried out by simulating conventional irrigation water delivery systems and System of Rice Intensification based on crop water requirements, cropping patterns, irrigation area and water availability in Batu Bulan Reservoir. The calculation of inflow discharge scenarios for wet, normal and dry years uses historical discharge data from 1997 to 2022. Based on the simulation results and optimization calculations, different cropping intensities were obtained from the two methods. The percentage of cropping intensity with the conventional method is smaller than with the SRI method. The cropping intensity value for the dry year inflow discharge scenario is 181,85% for the conventional method and 185,82% for the SRI method. The k factor values that have met the maximum value limit for irrigation water and domestic water needs are 0,70 and 0,85. The reliability for each irrigation water and domestic water demand is 100%.

1. INTRODUCTION

Batu Bulan Reservoir is a water infrastructure that has a function to meet the irrigation water needs of 5,576.25 ha. Batu Bulan Reservoir is a water infrastructure located in Maman Village, Moyo Hulu District, Sumbawa Regency, West Nusa Tenggara Province, Indonesia. The reservoir has been operating for more than fifteen years to serve the Batu Bulan irrigation area. The irrigation canals are located in six sub-districts, namely Moyo Hulu, Moyo Hilir, Moyo Utara, Sumbawa, Unter Iwes and Lape Lopok. The source of water to supply the Batu Bulan irrigation area comes from the Lito River and Sebasang River. Batu Bulan reservoir has a catchment area of 194 km2. Batu Bulan irrigation area is one of the irrigation areas that lacks water availability. This problem can be seen from the imbalance between water availability and irrigation water needs. In the dry season, irrigation water needs in the Batu Bulan irrigation area cannot be met. Currently, Batu Bulan Reservoir can only fulfill two planting seasons, namely Planting Season 1 and Planting Season 2, with a planting intensity of less than 200% per year.

The irrigation water delivery method in the Batu Bulan irrigation area uses a conventional system. This irrigation method provides water by inundating from the beginning of planting until the fruit ripens. The use of water with this conventional system is quite wasteful and inefficient. The method of irrigation water delivery that can save water use is SRI (System of Rice Intensification) [9]. This method provides irrigation water by delivering water at regular intervals based on the age of the crop or days after planting [14]. The paddy plants will only be irrigated on days 5, 10, 15, 25, 45, 55, 65 and 75 after transplanting with a puddle height of ± 2 cm [17]. Based on the problem of lack of water availability, it is necessary to conduct a research on the comparative analysis of conventional irrigation water supply system and Rice Intensification System in Batu Bulan irrigation area.

2. MATERIALS AND METHOD

2.1 Water Availability

The availability of water in the reservoir can be implemented as a dependable flow [4]. The dependable flow has the objective of determining the flow of discharge that is always available in the river and becomes thr inflow into the reservoir [5]. The Weibull method is used to determine discharge with a length of inflow discharge data of more than ten years [16]. This method can be used to determine inflow discharge scenarios for wet year (Q35%), normal year (Q50%), and dry year (Q65%) flow conditions [1]. The inflow discharge scenarios are calculated by sorting the inflow discharge data from largest to the smallest. Therefore, in determining the probability, the Weibull method equation is used to determine the flow discharge for the mainstay of the semi-monthly period [18], namely:

$$P(X \geq x) = \frac{m}{n+1} \times 100\% \quad (1)$$

2.2 Conventional Method

Conventional watering system is a continuous watering system from planting to harvesting [12]. The depth of of the puddle is maintained up to three centimeters and an additional eight centimeters to collect rainwater [2]. The supply is carried out from the distribution channel through water absorption holes on the bunds to be flowed continuously to the rice fields [19]. The water supply system is continuously carried out continuously when the available water discharge Q > 65% of the maximum demand [8].

2.3 System of Rice Intensification Method

The System of Rice Intensification method is one of the alternative cultivation technologies to increase paddy productivity [11]. Several factors affect paddy productivity, namely crop management, soil, water and nutrients [15]. Irrigation water requirements with the System of Rice Intensification method are obtained by calculating evapotranspiration, effective rainfall, consumptive use, net rice field needs, and determining the need for irrigation water at the intake or primary channel [21]. Inundation height is determined based on days after planting, percolation, consumptive use, filling of soil cracks and amount of rain [7]. Table 1 shows the standard inundation height of rice plants with the System of Rice Intensification method in West Nusa Tenggara Province.

Table 1 Standard height of inundation of paddy plants with the SRI method in West Nusa Tenggara Province

No	Indicator	Unit	Days After Planting

			5	10	15	25	35	45	55	65	75	85
1	Inundation height in growing season I	cm	2	2	5	5	3	3	3	3	3	3
2	Inundation height in growing season II	cm	2	2	5	5	5	5	5	5	5	5

The soil type in the Batu Bulan irrigation area is Inceptisol. This soil type is located in the sub-districts of Moyo Hulu, Moyo Hilir and Lape. Grumosol and Inceptisol soil types have similar soil characteristics, namely clay. Cracked soil conditions require additional inundation to fill the cracks [6]. The inundation height correction required to fill the cracks for percolation and consumptive use is as follows:

a. 2 cm inundation requirement – total inundation height requirement of 3,1 cm
b. 3 cm inundation requirement – total inundation height requirement of 3,9 cm
c. 5 cm inundation requirement – total inundation height requirement of 7,0 cm

2.4 Simulation and Optimization

Reservoir operation simulation takes into account several factors, namely inflow, reservoir capacity, total outflow and spillout from the spillway [3]. The purpose of the simulation method is to simulate reservoir operations based on hydrological data and water demand [10]. Simulation calculations are used to obtain reservoir operating rules [26].

Optimization methods are used to optimize the effective use of existing reservoir water potential [30]. In reservoir operation calculations, a combination of simulation and optimization methods can be used [25]. Some of the constraints taken into account in optimization techniques are water balance, maximum and minimum reservoir storage volume, evaporation and spillout [24]. The objective of reservoir optimization method is to optimize reservoir storage, economic cost, continuity of water availability and constraints [13]. The result of the best optimization method is the value that meets several constraints and is determined by the value of the objective function in the model [20]. To obtain optimal results with linear programming, the simplex method is used by considering the constraints and variables in linear programming problems [23].

3. CASE STUDY

Batu Bulan Reservoir is located in Maman Village, Moyo Hulu Sub-district, Sumbawa Regency, West Nusa Tenggara Province. Geographically, Batu Bulan Reservoir is located at coordinates 117º 27' 43.2" East Longitude and 8º 36' 42.98" South Latitude. Batu Bulan Reservoir has a catchment area of 194 km2. This reservoir has been operating for more than twenty-three years in serving the Batu Bulan irrigation area. Batu Bulan Reservoir serves an irrigation area of 5,162 ha. The maximum storage and conservation storage of Batu Bulan Reservoir are 53.6 MCM and 5.0 MCM respectively, with a maximum water surface area of 6.25 km2. Figure 1 shows survey documentation at Batu Bulan Reservoir located on Sumbawa Island, West Nusa Tenggara Province, Indonesia.

Figure 1 Batu Bulan Dam in Sumbawa Regency, West Nusa Tenggara Province, Indonesia

4. RESULTS AND DISCUSSION

4.1 Reservoir Water Availability

The value of water availability in the Batu Bulan Reservoir is calculated using the Weibull method. The data used is historical inflow discharge data. The length of inflow data used is thirteen years, starting from 2010 to 2022. The purpose of calculating water availability is to create wet, normal and dry year inflow discharge scenarios [29]. The probability used is 35% for wet year inflow discharge, 50% for normal year inflow discharge and 65% for dry year inflow discharge [22]. Based on the results of the water availability calculation, the largest wet year inflow discharge was 16,46 m3/s in February. The smallest inflow discharge value in a dry year with a 65% probability is 1,12 m3/s in May. Graphs for the wet, dry and normal year inflow discharge scenarios are shown in Figure 1.

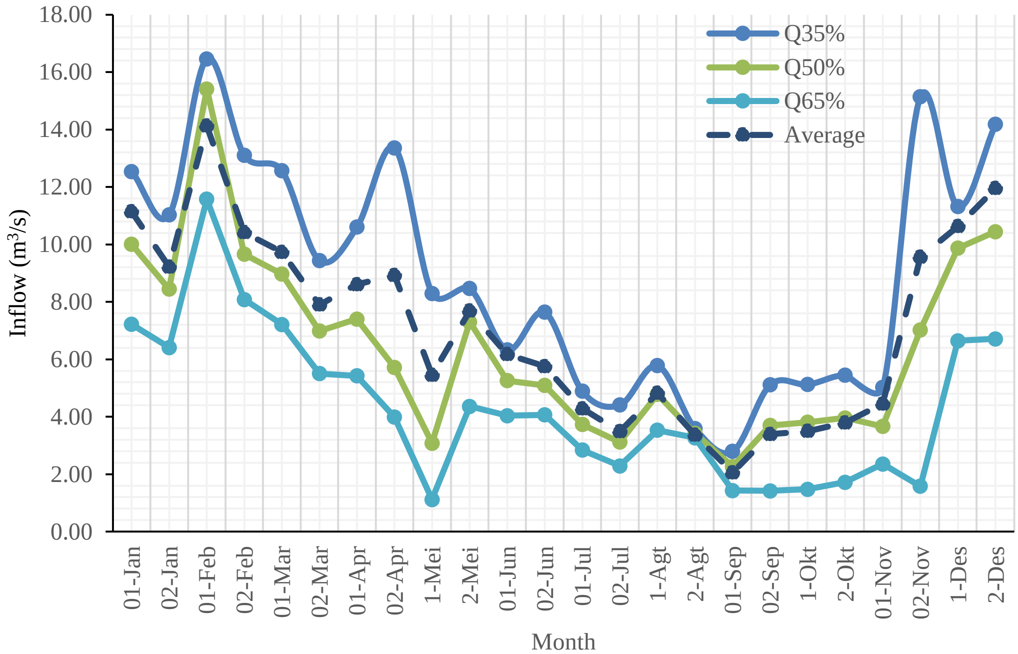

Figure 2 Scenarios of inflow discharge in the Batu Bulan Reservoir

4.2 Conventional Method Irrigation Water Requirement

Crop water requirements are calculated based on climatological factors, rainfall, temperature, crop coefficient, percolation, irrigation efficiency and seepage [27]. This calculation is based on the 2013 Irrigation Planning Criteria-01 guidelines. This guideline is used as a reference in irrigation planning and development in Indonesia [28]. Table 2 shows the results of the calculation of irrigation water requirements using conventional methods. The cropping pattern used in the Batu Bulan irrigation area is Paddy-Paddy-Vegetable. The planting schedule for Batu Bulan irrigation area is planned in November. Based on the calculation results, the largest irrigation water requirement is 2,370 m3/s in March for Paddy crops. The smallest irrigation water requirement is 0,297 m3/s in July for Vegetable crops.

Table 2 Irrigation water needs with conventional methods

Month	Number of days	Conventional Method			Month	Number of days	Conventional Method		
		Paddy lt/s/ha	Vegetable lt/s/ha	Total lt/s/ha			Paddy lt/s/ha	Vegetable lt/s/ha	Total lt/s/ha
Jan	15	0.926		0.926	Jul	15	0.357		0.357
	16	0.792		0.792		16		0.297	0.297
Feb	14	0.811		0.811	Aug	15		0.647	0.647
	14	0.760		0.760		16		1.102	1.102
Mar	15	1.880		1.880	Sep	15		1.429	1.429
	16	2.370		2.370		15		1.644	1.644
Apr	15	2.215		2.215	Oct	15		1.553	1.553
	15	1.661		1.661		16		0.665	0.665
May	15	1.828		1.828	Nov	15	2.198		2.198
	16	1.932		1.932		15	1.996		1.996
Jun	15	1.768		1.768	Dec	15	1.593		1.593
	15	0.886		0.886		16	0.900		0.900

4.3 SRI Method Irrigation Water Requirement

Table 3 shows the total irrigation water requirement for paddy and vegetables. Based on the calculation results, the largest irrigation water requirement is obtained using the System of Rice Intensification method, which is 2,370 m3/s in March for paddy. The smallest irrigation water requirement is 0,271 m3/s in July for paddy.

Table 3 Irrigation water needs with System of Rice Intensification

Month	Number of days	System of Rice Intensification			Month	Number of days	System of Rice Intensification		
		Paddy	Vegetable	Total			Paddy	Vegetable	Total
		lt/s/ha	lt/s/ha	lt/s/ha			lt/s/ha	lt/s/ha	lt/s/ha
Jan	15	0.490		0.490	Jul	15	0.271		0.271
	16	0.830		0.830		16		0.297	0.297
Feb	14	0.471		0.471	Aug	15		0.647	0.647
	14	0.382		0.382		16		1.102	1.102
Mar	15	1.880		1.880	Sep	15		1.429	1.429
	16	2.370		2.370		15		1.644	1.644
Apr	15	2.215		2.215	Oct	15		1.553	1.553
	15	1.758		1.758		16		0.665	0.665
May	15	1.040		1.040	Nov	15	2.198		2.198
	16	2.041		2.041		15	1.996		1.996
Jun	15	1.006		1.006	Dec	15	1.593		1.593
	15	1.402		1.402		16	0.564		0.564

Figure 3 shows an illustration of the daily inundation height for an irrigation system using the System of Rice Intensification method. The figure shows that the inundation height from the beginning of the planting period of the fifty-fifth day is 2,0 cm. The irrigation system uses a 0,5 cm inundation height after the fifty-fifth day.

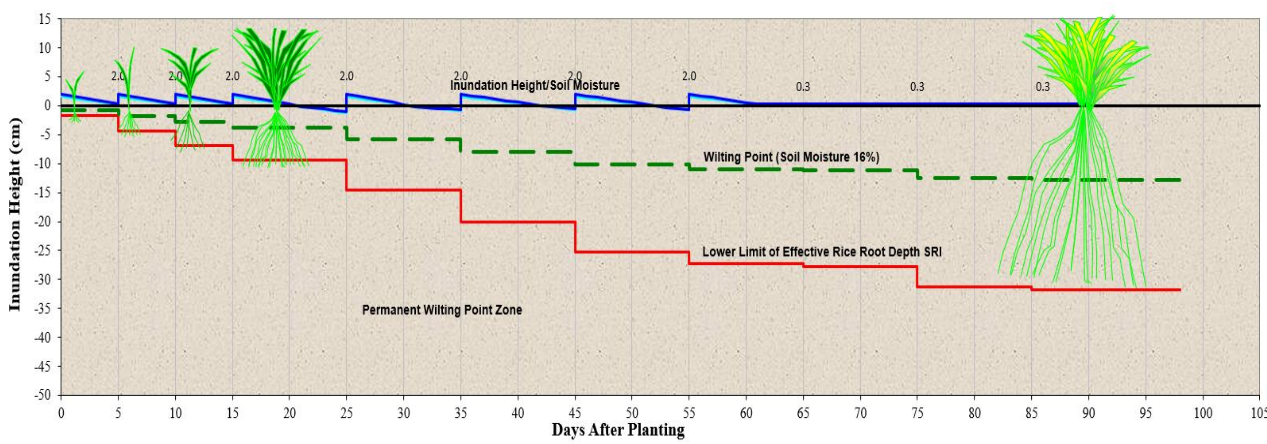

Figure 3 Graph of water application profile, wilting point depth and effective rooting depth of SRI paddy in the November-I planting season

4.4 Cropping Intensity and k Factor

Based on the calculation results, it is found that the value of cropping intensity with the conventional method is lower than the System of Rice Intensification method. This conclusion can be seen from the value of cropping intensity in the dry year of 181.85% for the conventional method and 185.82% for the System of Rice Intensification method. The area of irrigation that can be served with the conventional method is 9,386.89 ha and 9,591.77 ha with the System of Rice Intensification method. Optimization results using normal year inflow discharge obtained cropping intensity value of 247.59% for conventional methods and 254.79% for the System of Rice Intensification method. The area of irrigation that can be served by the normal year inflow discharge scenario is 12,780.40 ha for the conventional method and 13,152.31 ha for the System of Rice Intensification method. The cropping intensity value in the wet year inflow discharge scenario is 278.38% for the conventional method and 279.22% for the System of Rice Intensification method. The area of irrigation that can be served by the wet year inflow discharge scenario is 14,369.79 ha for the conventional method and 14,413.40 ha for the System of Rice Intensification method. The k factor value for irrigation water and domestic water needs has met the minimum limit of 0.70 and 0.85. The reliability value for irrigation and domestic water needs is 100%.

Table 4 Results of reservoir optimization with conventional method and SRI method

Indicator	Conventional Method			SRI Method		
	Dry	Normal	Wet	Dry	Normal	Wet
Irrigation Planting Area (Ha)	9,386.89	12,780.40	14,369.79	9,591.77	13,152.31	14,413.40
Crop Intensity (%)	181.85%	247.59%	278.38%	185.82%	254.79%	279.22%
k Factor Irrigation	0.70	0.70	0.70	0.70	0.70	0.70
k Factor Domestic Water	0.85	0.85	0.85	0.85	0.85	0.85
Irrigation Water Reliability (%)	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%
Domestic Water Reliability (%)	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%

Figure 4 shows the rule curve of the reservoir using the System of Rice Intensification method.

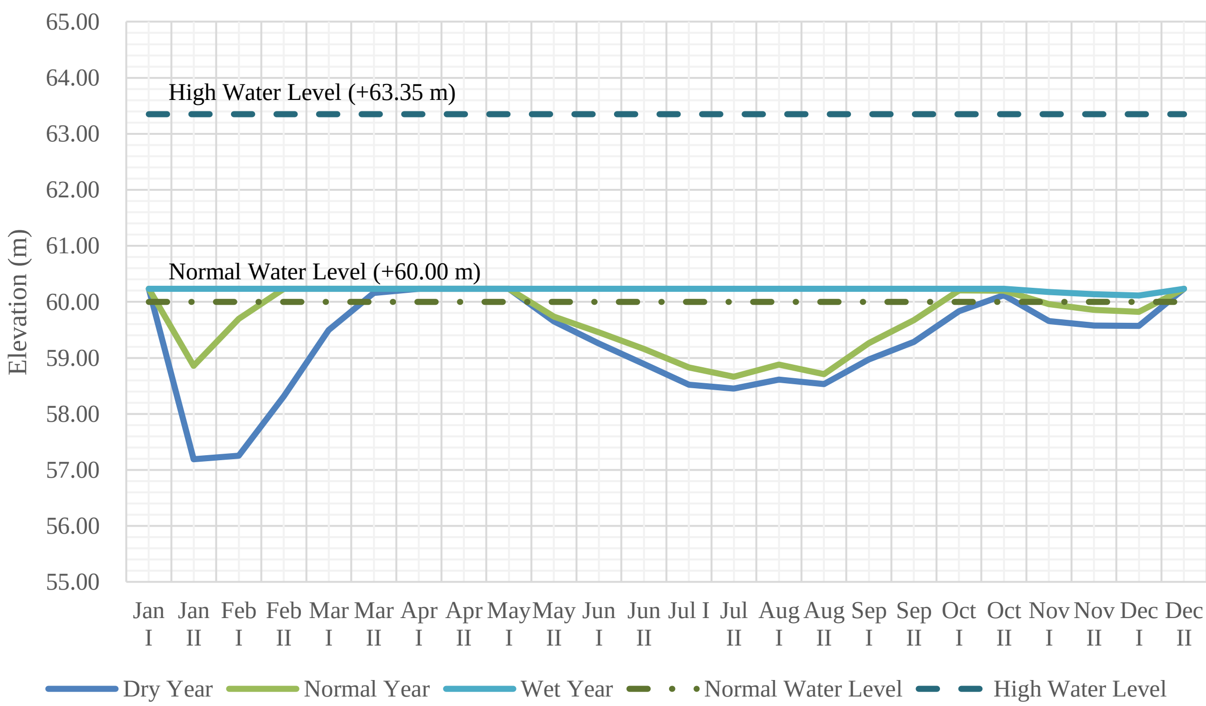

Figure 4 Rule curve of Batu Bulan Reservoir with System of Rice Intensification methods

5. CONCLUSION

Irrigation water needs with conventional methods have a higher value when compared with the System of Rice Intensification method. Based on the results of the calculation of irrigation water demand optimization with conventional methods and System of Rice Intensification, the highest cropping intensity is obtained in the System of Rice Intensification method. The k factor value for irrigation and domestic water needs is 0.70

and 0.85 with 100% reliability. Reservoir sedimentation management is needed to determine changes in storage capacity and increase reservoir storage volume.

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