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Management of the Jatiluwih Irrigation Area with Sustainable Planting Patterns and Water Balance in Tabanan Regency

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Abstract

Jatiluwih Village is located in Penebel District, Tabanan Regency, Bali. Jatiluwih Village is a highland village located at the foot of Mount Batukaru. This village is located at an altitude of 500-1500 meters above sea level and has an average rainfall of 2500 mm/year. Most of the population in the Jatiluwih area still relies on the economy of planting rice, with a good irrigation system. Rice fields in the Jatiluwih irrigation area need protection and preservation so that their area does not decrease. This priority is necessary because the meaning of land, including paddy fields is very important for humans, not only to own but also to live their lives. Irrigation is an effort made to obtain water by using intake buildings and carrier channels. The Jatiluwih Irrigation Area has water sources from several springs that flow in the Jatiluwih Area. Jatiluwih weir with water sources from Tukad Baat has an irrigation area of 390 ha. The subaks that are irrigated by the Jatiluwih Dam are Jatiluwih Subak, Subak Gunungsari, Subak Kedamaian and Subak Wangaya Betan. The development and management of irrigation networks will greatly assist water-using farmers in increasing the production of agricultural products, especially rice. A good irrigation network will improve the function of the network itself so that the process of water flow from upstream to the paddy fields does not experience obstacles. The amount of river water that is utilized at a point of collection no longer meets the principles of sustainability. The need for irrigation water in paddy fields is determined by several factors, including: land preparation; consumer use; percolation and seepage; replacement of water layers; effective rainfall and cropping pattern. Optimization of cropping patterns in an irrigation area is related to the need for the most efficient irrigation water. Analysis of the water balance shows that the Gunung Sari Irrigation Area shows the condition of water surplus throughout the year. The surplus conditions in the Gunung Sari Irrigation Area will be used to increase supply during the deficit months in the Jatiluwih Irrigation Area in June, August, September, October and November, and in the Aya Irrigation Area which occurs in June, August, September, October, November. Strengthening subak institutions is

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attempted by strengthening management, financial, and subsidies related to aspects of infrastructure improvement, technology, incentives and others, to suppress the conversion of agricultural land. The Gunung Sari Irrigation Area is recommended for planting schedule I (rice) on 1 February, planting schedule II (plant crops/vegetables) on 1 May and planting schedule III (rice) on 1 October. Jatiluwih Irrigation Area, Aya Irrigation Area and Penebel I rice planting schedule for March 1, second crops planting schedule for June 1 and III rice planting schedule for November 1.

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1 Introduction

Regional development is very closely related to the availability of water sources in a region. Water is one of the most important natural resources to be fulfilled to support human survival, therefore efforts to develop water sources and their management are the part that has the highest priority related to sustainable development efforts (Ismaya et al., 2016)

The development and management of irrigation networks will greatly assist water-using farmers in increasing the production of agricultural products, especially rice. A good irrigation network will improve the function of the network itself so that the process of water flow from upstream to the paddy fields does not experience obstacles. The amount of river water discharge that is used at a point of collection does not meet the sustainability rules (Zalewski, 2002; Suprapto, 2012).

The difficulty of maintaining a water level that can satisfy various needs is a constraint on water resources management. Therefore, it is necessary to guarantee the supply of water and regulate the distribution of water when the available water is small. This difficulty is anticipated by farmers with a tendency to hoard water in their plots of land. This action is a waste. Therefore, the management of water resources and water allocation needs to be controlled optimally (Wiasti, 2012).

The United Nations Educational, Scientific and Cultural Organization (UNESCO) has designated Jatiluwih and Subak Jatiluwih Villages, Penebel District, Tabanan Regency, Bali as part of the World Cultural Heritage (WBD) called the Subak Catur Angga Batukaru Landscape.

Rice fields in the Subak Jatiluwih area need protection and preservation so that their area does not decrease. This priority is necessary because the meaning of land, including paddy fields is very important for humans, not only to own but also to live their lives. The destruction of subak can be caused by the loss of one or more elements as a feature in the subak system. The elements referred to are the loss of the physical system including paddy fields, planting arrangements, irrigation network facilities and infrastructure, the loss of the social system due to paddy fields, the status of farmers and even land ownership changes (Wartaya, 2004).

Problem formulation

The formulation of the problem from the research on the Management of the Jatiluwih Irrigation Area with a Model of Planting Pattern Based on a Sustainable Water Balance is how the cropping pattern is based on a Sustainable Water Balance in the Jatiluwih Area (Singh et al., 2001; Garg & Dadhich, 2014; Verburg & Veldkamp, 2001).

Purpose

To determine cropping patterns and irrigation water balance in World Cultural Heritage Subak, to conserve sustainable paddy fields to maintain the existence of Subak in the World Cultural Heritage Area.

Literature review

Need for irrigation

Taking into account the level of effectiveness and efficiency of the water distribution pattern, the need for irrigation water will be calculated based on 15 days, this period is effective and efficient enough to be implemented in the later operating pattern. The methods that will be used in this analysis are, (Kementrian Pekerjaan Umum, 2013).

1) Analysis of potential evapotranspiration (ETo) using the Modified Penman method
   ETo = ETo* . C
2) Analysis of effective rainfall using the Basic Year method, For Rice and For Palawija
3) Crop coefficient (Kc) based on FAO . method
4) Consumptive use (Etc)
   Etc = Kc . Eto
5) Efficient irrigation based on Planning Criteria
6) The need for clean water for rice is calculated based on the formula.
   IR1 = Etc1 + P + WLR + LP – Re
7) Water Needs for Palawija
   IR2 = Etc2 - Rep
8) Water in the intake

$$DR = \frac{IR_1 + IR_2}{Eff} 0{,}1157A$$

Water potential

Water potential is the amount of water contained in water bodies, both as surface water and as underground water. In the analysis of the amount of water potential, it can be obtained through data series from recording weir discharge, river or it could be based on the mainstay discharge analysis by using several methods of diverting the variance of rain associated with the conditions of the existing watershed. The method commonly used is the FJ Mock method or the NRECA method (Mock, 1973).

Strategy management

Strategic management is defined as a way to guide companies to achieve some goals, including corporate responsibilities, managerial capabilities, and administrative systems related to strategic decision-making, and operations. Strategic management is a series of fundamental decisions and actions from the highest management, which are applied by all members of an organization, for the realization of organizational goals (Andayani et al., 2023).

Population

Calculation of the population using arithmetic, geometric and least square formulas. To determine the method used in each sub-district, the smallest standard deviation value of the three approaches will be determined. (Minister of Public Works Regulation, 2007).

Sustainable water resources management

Sustainable water development has three dimensions which include: economic development, preserving ecology, and justice in accommodating and fulfilling the wishes of all parties. To be able to achieve this, there are at least five aspects that must be covered, among others, institutional aspects, economic aspects, social aspects, biological aspects, and physical aspects (Bagus, 1996; Sulistyani & Irianto, 2021).

2 Materials and Methods

Scope of research

a) Conduct irrigation surveys, irrigation facilities and infrastructure, water sources and the potential of the Jatiluwih Area.
b) Test the rainfall data at the rain gauge station using the RAPS (Rescaled Adjusted Partial Sums) and Multiple Mass Arc methods to determine whether there are deviations from the rainfall data so that it can be concluded whether the data is suitable for analysis or not.
c) Calculate the average rainfall in the study area rain stations, using the Theesen polygon method
d) Analysis of the mainstay discharge and analysis of the discharge data at the Jatiluwih Dam based on the data recording the discharge of the weir and rain.
e) Measure the instantaneous discharge with a current meter.
f) Assessing the Need for Irrigation Water for the Jatiluwih Irrigation Area.
g) Determination of cropping patterns in the Jatiluwih Irrigation Area.
h) Analyzing the water balance in the Jatiluwih Dam
i) Take inventory of Subak organizational problems by conducting interviews with farmers.

Data source

The data source is a very important part related to the validity of the data. About the data to be retrieved, the data that will be needed are as follows:
a) Daily rain data for 10 years from Jatiluwih Rain Station, and Baturiti Rain Station
b) Data on debit recording at the Jatiluwih Weir and Aya Weir
c) Current cropping pattern data, planting area data, plant types and planting schedule
d) Subak institutional data
e) Demographic data of the population, socio-cultural facilities and infrastructure, tourism, and industry.
f) Clean water supply system data
g) Data on current sources of clean water
h) Clean water quality and quantity data

Measurement with current meter

The tool used to measure the flow velocity is a current-measuring instrument, which is commonly referred to as a current meter. The main equipment commonly used in measuring flow is a flow meter, including all its accessories, namely a timer and a rotation counter, a depth gauge, a width gauge, assembly equipment and some additional tools. The selection of the use of equipment and equipment must be adjusted to the physical condition of the river being measured (Beecher, 1995; Agarwal et al., 2000; Bunganaen et al., 2020).

Analysis of water availability

In calculating the mainstay discharge using the basic year planning method. The planning base year is a reliable debit pattern where the debit pattern has happened in previous years. The mainstay discharge calculation is intended to find the quantitative value of the available discharge throughout the year, in the dry season and the rainy season (Budiasa, 2010; Dewi, 2013).

Population analysis

Calculation of the population using arithmetic, geometric and least square formulas. To determine the method used in each sub-district, the smallest standard deviation value of the three approaches will be determined (Minister of Public Works Regulation, 2007).

Clean water needs analysis

The Directorate General of Human Settlements has set the water usage standard for metropolitan cities at 190 liters/person/day, standard water requirements for large cities at 170 liters/person/day, medium cities at 150 liters/person/day, and small cities at 130 liters people/day.

Water balance

The water balance is intended to determine how much potential is available each month, as well as how much water is needed. The Water Balance will know the months of surfing as well as the months that are in deficit. Mathematically, the calculation method for obtaining the residual water discharge in this water balance analysis is the mainstay discharge minus the demand discharge (Bouman et al., 2007; Sun et al., 2006; Sun et al., 2010).

Water supply system strategy

The water supply system strategy is carried out using a literature study, with the development of the concept of sustainable water source management, based on the condition of the current system that has been running, taking into account the sustainability of water supply in the future. Inventory of existing water sources and clean water sources that are in the process of being built (Khan et al., 2006; Kang et al., 2000).

3 Results and Discussions

3.1 Irrigation water needs

Irrigation is an effort made to obtain water by using intake buildings and carrier channels. The Jatiluwih Irrigation Area has water sources from several springs that flow in the Jatiluwih Area. Jatiluwih weir with water sources from Tukad Baat has an irrigation area of 390 ha. The subaks that are irrigated by the Jatiluwih Dam are Jatiluwih Subak, Subak Gunungsari, Subak Kedamaian and Subak Wangaya Betan. From the various alternative cropping patterns, the cropping pattern that has the least irrigation water requirement in the Jatiluwih area is alternative I.

Table 1
Calculation of irrigation water needs taken based on alternative planting patterns

Bulan	Kebutuhan Air Irigasi (l/dt/ha)				
	I	II	III	IV	V
Januari	0,000	0,000	0,000	0,000	0,072
	0,315	0,000	0,000	0,000	0,000
Februari	0,848	0,624	0,000	0,000	0,000
	0,036	0,686	0,461	0,000	0,000
Maret	0,591	0,312	0,999	0,785	0,088
	0,045	0,650	0,371	1,058	0,844
April	0,130	0,130	0,734	0,399	0,977
	0,106	0,130	0,130	0,734	0,399
Mei	0,359	0,472	0,493	0,493	1,096
	0,375	0,416	0,530	0,550	0,550
Juni	0,127	0,808	0,853	0,977	0,999
	0,184	0,127	0,808	0,853	0,977
Juli	0,446	0,487	0,430	0,549	0,595
	0,364	0,491	0,533	0,475	0,360
Agustus	0,274	0,692	0,844	0,894	0,825
	0,000	0,310	0,727	0,880	0,930
September	0,481	0,000	0,283	0,665	0,812
	1,519	0,481	0,000	0,283	0,665
Oktober	1,859	1,542	0,477	0,000	0,000
	1,225	1,864	1,548	0,483	0,039
Nopember	0,977	0,685	1,329	1,012	0,000
	0,370	0,977	0,685	1,329	1,012
Desember	0,000	0,000	0,344	0,046	0,679
	0,000	0,000	0,000	0,490	0,193
Nilai Mak.	1,859	1,864	1,548	1,329	1,096
Jumlah	10,630	11,884	12,577	12,955	12,112

Table 2
The smallest planting pattern in the Jatiluwih area

	Mulai Tanam		
Pola tanam	Padi I	Palawija	Padi II
Jadwal tanam	1 Februari	1 Mei	1 Oktober

Jan		Feb		Mar		Apr		Mei		Jun		Jul		Agust		Sep		Okt		Nop		Des	
I	II	I	II	I	II	I	II	I	II	I	II	I	II	I	II	I	II	I	II	I	II	I	II

LP Padi I Palawija Bero LP Padi II

The Gunung Sari Irrigation Area is recommended for the first planting schedule on February 1, the second vegetable or palawija planting schedule on May 1 and the third rice planting schedule on October 1. The Jatiluwih Irrigation Area, Aya Irrigation Area and Penebel are scheduled for the first rice planting on March 1, the second crop planting schedule is on June 1 and the third rice planting schedule is on November 1.

3.2 Plan flood

The following table presents the planned flood discharge and flood hydrograph images at each weir location in the Jatiluwih Area.

Table 3
Plan flood in the Jatiluwih area

No	Lokasi Bendung	Debit Banjir Rencana Dengan Berbagai Kala Ulang (m^3/dt)							
		Q_2	Q_5	Q_{10}	Q_{25}	Q_{50}	Q_{100}	Q_{200}	Q_{1000}
1	Gunung Sari	82,95	100,38	116,67	142,93	166,97	195,31	228,72	331,00
2	Aya	106,71	128,62	149,08	182,08	212,28	247,90	289,88	418,39
3	Jatiluwih	43,76	52,75	61,15	74,70	87,10	101,72	118,96	171,72
4	Penebel	144,87	174,99	203,13	248,51	290,05	339,02	396,76	573,49

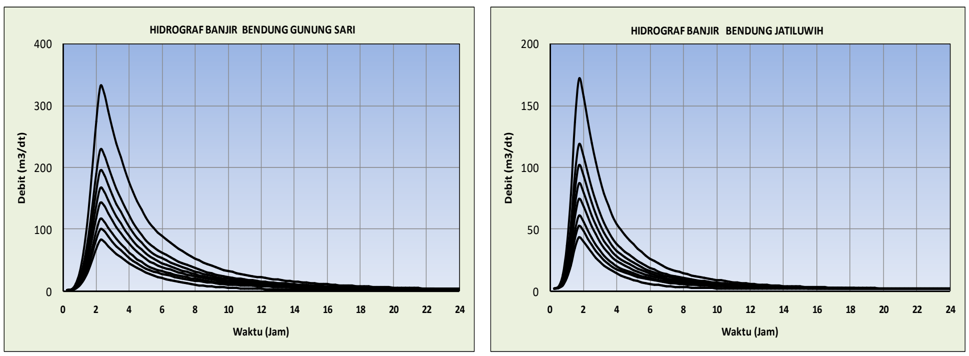

Figure 1. Hydrograph of planned flood in Jatiluwih area

3.3 Water balance

The mainstay discharge is intended to find the quantitative value of the available discharge throughout the year, both during the dry season and in the rainy season.

Table 4
Mainstay discharge in the Jatiluwih area

No	Bendung	Deb											
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	Rata-rata
1	Gunung Sari	2,735	2,228	1,996	1,342	1,007	0,477	0,518	0,230	0,119	0,504	0,580	1,807	13,542	1,129
2	Aya	3,809	3,002	2,607	1,717	1,237	0,531	0,602	0,254	0,105	0,657	0,801	2,491	17,815	1,485
3	Jatiluwih	1,010	0,823	0,737	0,495	0,372	0,176	0,191	0,085	0,044	0,186	0,214	0,667	5,001	0,417

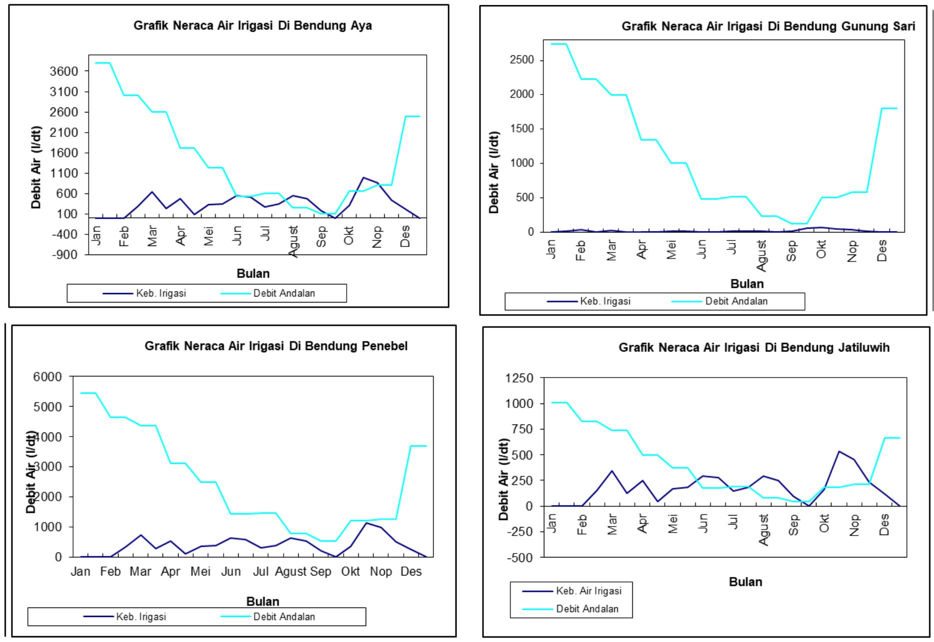

Figure 2. Water balance

3.4 Institutional water use organization

Subak is an independent organization or institution engaged in the management of irrigation water and is socio-agrarian, economically and religiously independent. Several efforts to realize the preservation of subak in Bali include: green tourism, and limiting land conversion. Empowering subak institutions with irrigation and agricultural infrastructure outreach approaches. Facilitate the development of subak into agribusiness-oriented, agro-tourism and eco-tourism-oriented irrigation institutions to increase their financial capability (Pereira et al., 2002; Geerts & Raes, 2009).

4 Conclusion

a) The recommended cropping pattern for a year in the Jatiluwih area is the first planting season for rice, the second planting season for vegetables/plant crops, and the third planting season for rice.
b) The Gunung Sari Irrigation Area is recommended for the first planting schedule on February 1, the second vegetable or palawija planting schedule on May 1 and the third rice planting schedule on October 1. The Jatiluwih Irrigation Area, Aya Irrigation Area and Penebel are scheduled for the first rice planting on March 1, the second crop planting schedule is on June 1 and the third rice planting schedule is on November 1.
c) Analysis of the water balance in the Gunung Sari Irrigation Area shows the condition of water surplus throughout the year.
d) The surplus conditions in the Gunung Sari Irrigation Area will be used to increase supply during the deficit months in the Jatiluwih Irrigation Area in June, August, September, October and November, and in the Aya Irrigation Area which occurs in June, August, September, October, November.
e) The supply channel infrastructure in the Jatiluwih Irrigation Area is already available, improvements need to be made to ensure smooth water supply from DI Gunung Sari to DI Jatiluwih.
f) Strengthening subak institutions is attempted by strengthening management, financial, and subsidies related to aspects of infrastructure improvement, technology, incentives and others, to suppress the conversion of agricultural land.

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Conflict of interest statement
The authors declared that they have no competing interests.

Statement of authorship
The authors have a responsibility for the conception and design of the study. The authors have approved the final article.

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