第 48 卷 第 10 期
2021 年 10 月

湖南大学学报（自然科学版）
Journal of Hunan University（Natural Sciences）

Vol. 48 No. 10
October 2021

Open Access Article

Optimization Model of Batutegi Reservoir Operation Pattern by Using Stochastic Dynamic Programming (SDP)

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Abstract: This research intends to build the optimization model of water usage downstream of the Way Sekampung River. It is hoped that the upper reservoir release can be optimally adding the discharge of the Way Sekampung River, where the upstream of the Argoguruh weir is reliable to be used as the water needed in the Way Sekampung irrigation area regarding the result of Alt-C cropping pattern manipulation with the area of 55,373 ha and also for intensification. The methodology is used the Stochastic Dynamic Programming (SDP). Using SDP, the optimization model in Batutegi reservoir is hoped to increase the crop intensity in the Rumbia Extension irrigation area of 5,000 ha and give the additional profit for the next (Rp) of the expected value. Based on the existing cropping pattern and the cropping pattern manipulation (crop intensification) in the previous research, the profit is Rp. 37,149,000 per year, which means that on 5% of the area, the cropping pattern manipulation is carried out or 1% of the yearly production for the whole watershed of Way Sekampung irrigation area. The next research using Stochastic Dynamic Programming (SDP) aims to extend the Rumbia extension of 5,000 ha. The results are as follows: the area that can be cropped is 1,082.420 ha, which is 21.68% of the 5,000 ha target or equivalent with the expected value in the amount of Rp. 64,415,350 (18.491%) from the target of Rp. 348,347,000. It is due to reaching the Rumbia extension irrigation area. The expected value based on the income of Alternative-C cropping pattern manipulation is Rp. 3,824,949. After the optimization by using SDP, the income is Rp. 3,879,362,000,000, or the profit is Rp. 64,415,350,000 (= 1.688%) in one crop period in one harvest year. The full profit by using Stochastic Dynamic Programming (SDP) in the Batutegi reservoir is Rp. 101,564,000,000 in one crop period in one harvest year. It is 2.688% of RAAT's existing crop pattern of 2018-2019, prepared by BBWS Mesuji Sekampung.

Keywords: Batutegi, optimization, stochastic dynamic programming, expected value.

巴图吉水库运行模式的随机动态规划（社会发展计划）优化模型

摘要：本研究旨在建立西甘榜路河下游用水的优化模型。希望上游水库泄水可以优化添加西甘榜路河的排放，阿古古鲁堰上游可靠地用作西甘榜路灌溉区所需的水，考虑到替代-C种植的结果模式操纵面积为55,373公顷，也用于集约化。该方法使用随机动态规划（社会发展计划）。使用社会发展计划，巴图吉水库的优化模型有望在5,000公顷的伦比亚扩展灌溉区增加作物强度，并为下一个(Rp)的预期值提供额外的利润。基于现有的种植模式和之前研究中的种植模式操纵（作物集约化），利润为Rp。每年37,149,000，这意味着在5%的面积上进行了种植模式操作，或者是西甘榜路灌区整个流域年产量的1%。使用随机动态规划(社会发展计划)的下一项研究旨在将伦比亚扩展区扩展到5,000公顷。结果如下：可种植面积为1,082.420 公顷，是 5,000 公顷目标的 21.68% 或与 Rp 量的预期值相当。64,415,350 (18.491%) 从 Rp的目标。348,347,000。这是由于到达伦比亚扩展灌溉区。基于备选方案-C种植模式操纵收益的期望值为Rp。3,824,949。使用社会发展计划优化后，收益为Rp。3,879,362,000,000，或利润为Rp。64,415,350,000(=1.688%)在一个收获年的一个收获期。在

Received: June 8, 2021 / Revised: August 6, 2021 / Accepted: September 12, 2021 / Published: October 30, 2021

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巴图吉水库中使用随机动态规划(社会发展计划)的全部利润为Rp。101,564,000,000在一个收获年的一个收获期。这是由 BBWS明筋实甘榜编制的RAAT2018-2019年现有作物模式的2.688%。

关键词：巴图吉，优化，随机动态规划，期望值。

1. Introduction

Water resources management is not an easy job, especially if the problem is national-wide. However, it certainly becomes harder and harder when the events and climate are unpredictable or if an area is considered unstable [1]. There is an interplay of the factual base of some information about the system, the methods to process this information, and the interpretation and estimation of the results [2]. The main objective of water resources system management is to solve the formula of water resources demand and supply for a specific area taking into account various dimensions: time, space, politics, economy, environment, and other aspects. In addition, water management means as the all users reconciliation, water preservation, and the related land resources, and the previous of enough water for constantly expanding needs [3].

Many rivers in Indonesia have been progressively developed recently. The restriction of surface water resources, especially in the dry season, intensifies the need for an optimum capacity and operation for the multi-purposes of reservoir systems [4, 5]. However, monitoring the surface water resources in quantity terms is needed to determine water availability, verify consumption norms, and analyze the substances' load leaving the catchment [6]. Therefore, it was necessary to allocate the water use as efficient and efficient as possible. For this target, it is required to build a model system for optimization. However, the optimization model and analysis would give more and more information for allocating water of each objective function [7].

The optimization method for solving the reservoir systems' high, dynamic, non-linear, and stochastic dimension characteristics has not yet been researched; however, the extension is applied to multi-objective optimization. This research intends to optimize the reservoir by carrying out the extensification to increase the crop intensity in the Rumbia extension irrigation area (5000 ha) by applying the Stochastic Dynamic Programming (SDP) due to the cropping pattern result [8]. The cropping pattern as the simulation results in [8] will become the base of water need. The water supply is fulfilled from the Argoguruh weir, and it is supported by the release of the Batutegi reservoir as the optimization result by using SDP. However, the optimal release that will be carried out will fulfill the irrigation water requirement in the Way Sekampung irrigation area that is about 55,373 ha. The main objective is to increase the crop intensity, i.e., to carry out the extensification in the Rumbia extension irrigation area by the target of 5,000 ha and to give the economic profit (expected value).

2. Material and Method

2.1. Research Location

The Batutegi dam is located in the Pekon Air Naningan, Air Naningan District, Tanggamus Regency, and Lampung province. The location is about 90 km southwest of Bandar Lampung city or 65 km upstream of the Argoguruh weir. Geographically, Batutegi is in the south longitude of 5º15'27,28" and east longitude of 104º46'38,39", and it is in the BBWS Mesuji Sekampung. The dam was inaugurated on March 8, 2004, with the normal volume of 690 million m^3, and the area of water inundation is 21 km^2.

The Batutegi Dam watershed upstream of the Way Sekampung River has a hilly topography. It is at the Bukit Barisan Barat Mountains with an elevation about 2,000 m over sea level. Most of the Way Sekampung River region is low land with a contour line of fewer than 100 m and has a 0-4% slope [9]. The research location is presented in Fig. 1.

2.2. Research Methodology

The design in this research is used the dependable discharge from Batutegi reservoir inflow and Argoguruh weir. It is due to three discharge criteria: normal year, dry year, and wet year (Table 1) [8]. However, the diagram of the river system is presented in Fig. 2.

Fig. 1 Research location (BBWS Mesuji Sekampung [9])

Table 1 Scenario of the dependable discharge (Santoso et.al. [8], RAAT Sungai Way Sekampung [9])

	Normal condition	Wet condition	Dry condition
Batutegi	$Q_{50\%}$	$Q_{40\%}$	$Q_{60\%}$
Argoguruh	$Q_{60\%}$	$Q_{40\%}$	$Q_{80\%}$

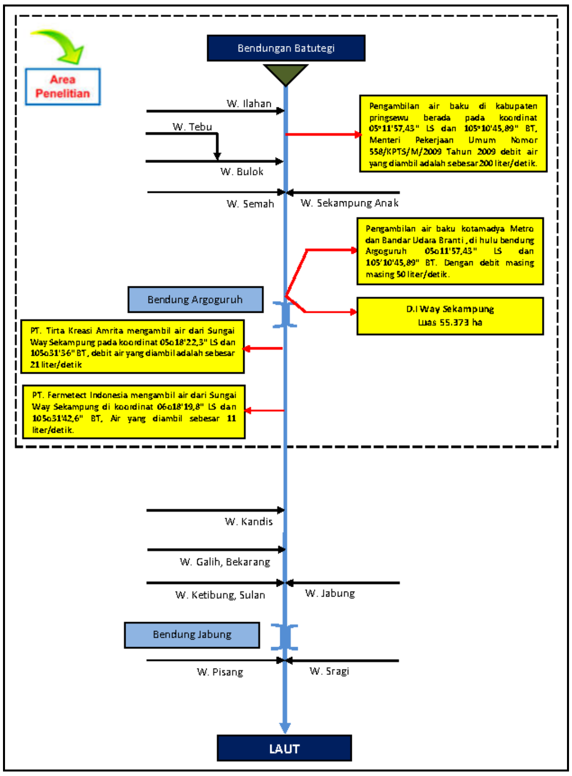

Fig. 2 Diagram of river system from Batutegi dam until Argoguruh weir (Santoso et al. [8], RAAT Sungai Way Sekampung [9])

2.2.1. The Arrangement of Reservoir Operation Pattern

The reservoir operation pattern refers to water regulation for operating the reservoirs agreed on by the water users and manager through the committee of water regulation arrangement (PTPA). The arrangement of reservoir operation pattern is intended as the rule of water regulation for fulfilling many water needs and flood control. In the arrangement of reservoir operation, there is needed to attend something below.

The basic equation in the reservoir simulation or water balance simulation in the reservoir is the function of inflow, outflow, and reservoir storage that can be formulated as follow [10]:

$$I - O = ds/dt \quad (1)$$

where:

I – inflow;

O – outflow;

$ds/dt = \Delta S$ = storage change.

The formula can be detailed as follow:

$$S_{t+1} = S_t + I_t + R_t - E_t - Lt - O_t - O_{st} \quad (2)$$

where:

S_t - reservoir storage at t-period;

S_{t+1} - reservoir storage at (t+1)-period;

I_t - inflow at t-period;

R_t - rainfall over the reservoir surface at t-period;

E_t - water losses due to the evaporation at t-period;

L_t - water losses due to the seepage and leakage;

O_t - total of water need;

O_{St} - outflow from weir.

The losses due to the evaporation (Et), seepage, leakage (Lt), and the additional rainfall (Rt) into the reservoir surface can be assumed to have negated each other, so the losses are zero [11]. Therefore the formula is becoming as follow:

$$S_{t+1} = St + I_t - O_t - O_{st} \quad (3)$$

2.2.2. Optimization Model of Reservoir Operation Pattern by Using SDP

The optimization model of water usage in Samboja reservoir uses the stochastic program; however, the analysis of water usage in the Batutegi reservoir is carried out by using the stochastic dynamic programming that uses the Microsoft Excel Macro software, and it is written with visual basic (vb) language as follow:

a) *Inflow:* Half-monthly inflow discharge is obtained from the daily inflow discharge that is averaged from the first day of the beginning of the month until the middle of the month.

b) Discretization of inflow and reservoir storage per-0.5 %

c) *The value of release (X)* is the irrigation water requirement, domestic and non-domestic water need. The domestic need is 0.25 m^3/s, the non-domestic need is 0.032 m^3/s, and the river maintenance is 1 m^3/s. Therefore, the total need without irrigation is 1.282 m^3/s. The irrigation water requirement is determined from the cropping pattern simulation researched by Santoso et al. [8].

d) *The return value (ri):* The return value is a random variable in every month (in the middle of the month). There is the release function (Xi) in it which depends on the water need in the middle of the month, and it has been formulated as follow:

$$ri = ri\ (Xi) \quad (4)$$

$$ri = \text{factor of } k = Xi\ /\ Qri \quad (5)$$

where:
Xi - the value of release at stage-i;
ri - water need at stage-i;
k - achievement measure of water need fulfilling;
Achievement factor (k) - the ratio between release and water need.

e) *State Transformation Function:* The state transformation function is an equation of the transformation relation of the storage condition during the operation period (stage) formulated based on the continuity principle by doing the backward calculation. The formula is as follow:

$$St + 1 = St + It - Ot - Ost \quad (6)$$

f) Constraint of storage:

$$S_{min} \leq S_i \leq S_{max}, \text{ effective storage} \quad (7)$$

g) Recursive equation

$$f_i(S_i) = \max_{X_i} \left\{ \sum_{k=1}^{K} P_{ik} \cdot \left[\frac{1}{m} \left(r_i(X_i) + (m-1) \times f_{i-1}(S_{i-1}) \right) \right] \right\}$$

$$f_i(S_i) = \max_{X_i} \left\{ \sum_{k=1}^{K} P_{ik} \cdot \left[\frac{1}{m} \left(r_i(X_i) + (m-1) \times f_{i-1}(t_i(X_i)) \right) \right] \right\}$$

where:
Pik - inflow transition probability at stage-i and inflow class-k;
m - the position of the last stage when the iteration process runs x cycle stages.

h) *Criteria of iteration calculation convergence:* The optimization process is carried out in every stage during one operation cycle. The operation cycle is in the middle of every month in one year, so there are 24 stages in one operation cycle.

i) The optimization result qualified as convergence so that the optimization will be stopped. When the previous class of inflow in the middle of the month is low, the optimization process will be stopped on the third cycle by seeing the deviation of cumulative difference about the ratio between release and average water needs (the value of k) on the second and third cycle is zero or almost zero.

3. Results and Discussion

3.1. Cropping Pattern and Water Requirement

The irrigation requirement in the Sekampung irrigation area consists of the rest of cropping pattern III-2018 and cropping pattern 2018-2019. However, the irrigation water requirement in the Sekampung irrigation area is analyzed with the function area of 55,373 ha, and it is divided into two groups:

1) Cropping pattern manipulation as the result of intensification simulation consists of:

a) The rest of cropping pattern 2018;

b) Alt-C cropping pattern manipulation as the result of simulation-optimization: the water requirement of this cropping pattern during the crop period per half a month will be used as the water need, and it has to be minimum fulfilled;

2) Cropping pattern result as the application of Stochastic Dynamic Programming in Batutegi Reservoir with the extensification in Rumbia extension (5,000 ha) is analyzed as follow: the maximum water requirement is water requirement of Alt-C cropping pattern manipulation and half-monthly water requirement of Rumbia extension (5,000 ha) cropping pattern.

a) The rest of the cropping pattern of 2018 is presented in Table 2.

Table 2 The rest of the cropping-III (dry season), 2018 (RAAT Sungai Way Sekampung, 2018-2019 [9])

Water requirement of paddy			Location		Area (Ha.)		Second crop	Group	Sep – Mar (I, II per month)
Time	CP 1	CP II			CP I	CP II	CP II		
Preparation	30 days	1 month							
Growing	60 days	2 month	DI.Way Sekampung		14.177,0	-	-		
Cooking	30 days	1 month	FC II		14.177,0	-	-		
Water requirement in weir			UPTD. TRIMURJO	1	509				Paddy 509 Ha
Time	CP 1	CP II		2	769				Paddy 769 Ha
Preparation	1,65	1,35		3	993				Paddy 993 Ha
Growing	1,48	1,16		4	971				Paddy 971 Ha
Cooking	0,53	0,55	UPTD. PUNGGUR	1	145				Paddy 145 Ha
				2	423				Paddy 423 Ha
Time	CP I	CP II		3	701				Paddy 701 Ha
			UPTD. KOTA GAJAH	1	28				Paddy 28 Ha
Water requirement of second crop				2	347				Paddy 347 Ha
Time	CP I	CP II		3	1339				Paddy 1339 Ha
Growing	90 days	3 months		4	951				Padi 951 Ha
Water requirement in weir			UPTD. SEPUTIH RAMAN	1	191				Paddy 191 Ha
Time	MT.I	MT.II		2	871				Paddy 871 Ha
Growing		0,30		3	697				Paddy 697 Ha
				4	1029				Paddy 1029 Ha
				5	789				Paddy 789 Ha
			UPTD. RUKTI ENDAH	1	600				Paddy 600 Ha
				2	711				Paddy 711 Ha
				3	566				Paddy 566 Ha
			KPD. RANTAU FAJAR	1	12				Paddy 12 Ha
				2	67				Paddy 67 Ha
				3	387				Paddy 387 Ha
				4	509				Paddy 509 Ha
				5	407				Paddy 407 Ha
				6	165				Paddy 165 Ha
			J U M L A H		14.177	-	-		

Information

Preparation

Growing

Cooking

b) Alt-C cropping pattern manipulation (The result of simulation-optimization)

The simulation result of manipulating the cropping pattern (CP) is the most profitable of the simulation results of five other CPs. If compared with the existing CP of the 2018–2019 water allocation plan Rencana Alokasi Air Tahunan (RAAT), this CP manipulation is the most superior and profitable from the economic side, as it keeps fulfilling the rules of reservoir operation design.

Table 3 presents the CP plan: CP I (Rainy season) 2018–2019, CP II, and CP III (dry season) 2019, and the Alt-C CP manipulation.

Table 3 Cropping pattern (CP) plan and CP I (Rainy season), 2018-2019; CP II and CP III (Dry season), 2019; Alt-C cropping pattern manipulation (Own study)

Water reqm	Paddy		Location	Area (Ha.)		Second c	Group	September – January (I, II per month)
Time	CT I	CT II		CP I	CP II	CP II		
Preparation	30 days	1 month						
Growth	60 days	2 months	DI.Way Sekampung	55,373.0	55,373.0	-		
Maturation	30 days	1 month	FC I	#######	24,086.0	-		
Water reqm			UPTD. ARGOGURUH	2,230.0	2,230.0	-	I	Paddy 15.149 ha.; Paddy 15.149 ha.; Second crop .... ha
Time	CT I	CT II	UPTD. METRO	2,923.0	2,923.0	-	I	
Preparation	1.65	1.35	KPD. BATANGAHARI	3,920.0	3,920.0	-	I	
Growth	1.48	1.16	KPD. SEKAMPUNG	3,464.0	3,464.0	-	I	
Maturation	0.53	0.55	KPD PEKALONGAN	2,612.0	2,612.0	-	I	
			KPD. RAMAN UTARA	4,216.0	4,216.0	-	I	Paddy 4.216 ha; Paddy 4.216 ha; Second crop .... ha
Time	CT I	CT II	KPD. PURBOLINGGO	4,721.0	4,721.0	-	I	Paddy 4.721 ha; Paddy 4.721 ha; Second crop .... ha
			FC II	#######	31,287.0	-		
Water reqm			UPTD. TRIMURJO	5,136.0	5,136.0	-	III	Padi 21.181 Ha; Padidy 21.181 ha; Second crop .... ha
Time	CP I	CP II	UPTD. PUNGGUR	4,152.0	4,152.0	-	III	
Growth	90 days	3 months	UPTD. KOTA GAJAH	2,687.0	2,687.0	-	III	
Water reqm			UPTD. SEPUTIH RAMAN	4,035.0	4,035.0	-	III	
Time preparatio	MT.I	MT.II	UPTD. RUKTI ENDAH.	1,877.0	1,877.0	-	III	
Pertumbuhan		0.30	KPD. RANTAU FAJAR	3,294.0	3,294.0	-	III	
			UPTD. BEKRI	5,000.0	5,000.0	-	II	Paddy 10.106 ha; Paddy 10.106 ha; Second crop........... ha
			UPTD. RUMBIA	5,106.0	5,106.0	-	II	
			Total	55,373	55,373	-	200%	

Water requirement (l/s)	Unit	Sep I	Sep II	Oct I	Oct II	Nov I	Nov II	Dec I	Dec II	Jan I	Jan II	Feb I	Feb II	Mar I	Mar II	Apr I	Apr II
FC I																	
UPTD. ARGOGURUH										1,840	3,680	3,490	3,300	3,300	3,300	2,241	1,182
UPTD. METRO										2,411	4,823	4,574	4,326	4,326	4,326	2,938	1,549
KPD. BATANGAHARI										3,234	6,468	6,135	5,802	5,802	5,802	3,940	2,078
KPD. SEKAMPUNG										2,858	5,716	5,421	5,127	5,127	5,127	3,481	1,836
KPD PEKALONGAN										2,155	4,310	4,088	3,866	3,866	3,866	2,625	1,384
										-	-	-	-	-	-	-	-
KPD. RAMAN UTARA								-	-	3,478	6,956	6,598	6,240	6,240	6,240	4,237	2,234
Dependable discharge	l/s							2,400	4,470	6,394	6,270	5,542	5,513	5,308	4,971	4,188	3,848
Suply- KH 2	l/s							-	-	-	686	1,056	727	932	1,269	49	-
KPD. PURBOLINGGO								-	-	3,895	7,790	7,388	6,987	6,987	6,987	4,745	2,502
Dependable discharge	l/s							4,542	8,514	######	######	11,054	10,000	10,507	9,453	7,857	6,105
Supply KH 2	l/s							-	-	-	-	-	-	-	-	-	-
Water requirment FC I	l/s							-	-	12,498	25,682	24,764	23,147	23,352	23,689	15,274	8,029
FC II																	
UPTD. TRIMURJO														4,237	8,474	8,038	7,601
UPTD. PUNGGUR														3,425	6,851	6,498	6,145
UPTD. KOTA GAJAH														2,217	4,434	4,205	3,977
UPTD. SEPUTIH RAMAN														3,329	6,658	6,315	5,972
UPTD. RUKTI ENDAH.														1,549	3,097	2,938	2,778
KPD. RANTAU FAJAR														2,718	5,435	5,155	4,875
UPTD. BEKRI				4,125	8,250	7,825	7,400	7,400	7,400	5,025	2,650	4,700	6,750	6,275	5,800	5,800	5,800
UPTD. RUMBIA				4,212	8,425	7,991	7,557	7,557	7,557	5,132	2,706	4,800	6,893	6,408	5,923	5,923	5,923
Water requirement FC II	l/dt	-	-	8,337	16,675	15,816	14,957	14,957	14,957	10,157	5,356	9,500	13,643	30,157	46,672	44,871	43,071
TOTAL of taking in DI. SEKAMPUNG S.	l/dt	-	-	8,337	16,675	15,816	14,957	14,957	14,957	22,654	31,038	34,264	36,790	53,510	70,361	60,145	51,100

Water requirement (l/s)	Unit	May I	May II	Jun I	Jun II	Jul I	Jul II	Aug I	Aug II	Sep I	Sep II	Oct I	Oct II	Nov I	Nov II	Dec I	Dec II	Jan I	Jan II
FC I																			
UPTD. ARGOGURUH		2,096	3,011	2,799	2,587	2,587	2,587	1,907	1,227	613									
UPTD. METRO		2,748	3,946	3,668	3,391	3,391	3,391	2,499	1,608	804									
KPD. BATANGAHARI		3,685	5,292	4,920	4,547	4,547	4,547	3,352	2,156	1,078									
KPD. SEKAMPUNG		3,256	4,676	4,347	4,018	4,018	4,018	2,962	1,905	953									
KPD PEKALONGAN		2,455	3,526	3,278	3,030	3,030	3,030	2,233	1,437	718									
		-	-	-	-	-	-	-	-	-									
KPD. RAMAN UTARA		3,963	5,692	5,291	4,891	4,891	4,891	3,605	2,319	1,159									
Dependable discharge	l/s	3,295	2,346	3,736	1,836	1,817	1,461	1,095	779	-									
Suply- KH 2	l/s	668	3,346	1,555	3,055	3,074	3,430	2,510	1,540	1,159	-	-	-	-	-	-	-	-	-
KPD. PURBOLINGGO		4,438	6,373	5,925	5,476	5,476	5,476	4,036	2,597	1,298	-	-	-	-	-	-	-	-	-
Dependable discharge	l/s	4,873	3,512	3,720	3,005	2,366	2,831	1,503	1,181	-	-	306	509	593	1,102	4,542	8,514	12,411	11,150
Supply KH 2	l/s	-	2,861	2,205	2,471	3,110	2,645	2,533	1,416	1,298	-	-	-	-	-	-	-	-	-
Water requirment FC I	l/s	14,908	26,658	22,772	23,099	23,757	23,648	17,996	11,287	6,624	-	-	-	-	-	-	-	-	-
FC II																			
UPTD. TRIMURJO		7,601	7,601	5,162	2,722	4,828	6,934	6,446	5,958	5,958	5,958	4,391	2,825	1,412					
UPTD. PUNGGUR		6,145	6,145	4,173	2,201	3,903	5,605	5,211	4,816	4,816	4,816	3,550	2,284	1,142					
UPTD. KOTA GAJAH		3,977	3,977	2,700	1,424	2,526	3,627	3,372	3,117	3,117	3,117	2,297	1,478	739					
UPTD. SEPUTIH RAMAN		5,972	5,972	4,055	2,139	3,793	5,447	5,064	4,681	4,681	4,681	3,450	2,219	1,110					
UPTD. RUKTI ENDAH.		2,778	2,778	1,886	995	1,764	2,534	2,356	2,177	2,177	2,177	1,605	1,032	516					
KPD. RANTAU FAJAR		4,875	4,875	3,310	1,746	3,096	4,447	4,134	3,821	3,821	3,821	2,816	1,812	906					
UPTD. BEKRI		4,275	2,750	1,375															
UPTD. RUMBIA		4,366	2,808	1,404															
Water requirement FC II	l/dt	39,989	36,906	24,066	11,226	19,910	28,594	26,582	24,570	24,570	24,570	18,110	11,650	5,825	-	-	-	-	-
TOTAL of taking in DI. SEKAMPUNG S.	l/dt	54,897	63,564	46,838	34,325	43,667	52,242	44,578	35,857	31,194	24,570	18,110	11,650	5,825	-	-	-	-	-

CP and water requirement in the Rumbia The CP is planned in 5,000 hectares (ha) of the Rumbia extension. For obtaining the target water requirement in the irrigation area of the Rumbia, the steps are as follows:

i. Calculate the total water needs per half month from September 2018 until December 2019 by using the water balance of the Alt-C cropping pattern manipulation. The discharge deficit balance will be released from the Batutegi reservoir; thus, in the half-month period, the following will be obtained: the release (m^3/s), reservoir volume (million m^3), and run-off to Argoguruh weir downstream (million m^3).

ii. Calculate the water contribution price by obtaining the average water contribution price and water contribution price in a half-month period. The calculation of water contribution in the Way Sekampung river in the Argoguruh weir upstream is Rp 2,990,000,000,000.

iii. Carry out optimization using the stochastic dynamic programming. The optimal value is Rp 1,780,380,000,00, and the total is Rp 3,879,363,000. The income difference from the Alt-C cropping pattern manipulation of Rp 3,814,949,000,000 is Rp 64,415,000,000.

iv. Calculate the harvest income that is in the amount of Rp 64,415,000,000 in the Rumbia Extension irrigation area. The harvest income for an area target of 5000 ha is Rp 348,347,000,000; thus, the value of Rp 64,415,000,000 is calculated by a trial of the area. Therefore, the realization of the crop in the Rumbia extension is in the amount of 1,082 ha.

Table 4 presents the analysis of the half-monthly water income contribution in intake FC I and FC II in the Bendung Argoguruh, normal Alt-C CP manipulation, 2018-2019. Table 5 presents water contribution analysis of Alt-C cropping pattern and SDP, 2018-2019.

Table 4 Analysis of water income contribution per half a month in intake FC I and FC II in the Bendung Argoguruh. Normal Alt-C CP manipulation, 2018-2019 (Own study)

NO	Description	Unit	Jul-18		Aug-18		Sep-18		Oct-18		Nov-18		Dec-18	
			I	II	I	II	I	II	I	II	I	II	I	II
			15	16	15	16	15	15	15	16	15	15	15	16
1	Harvest area of crop rest 2018	ha	-	-	-	-	-	-	-	-	-	-	-	-
2	Harvest area of CP manipulation-Alt-C	ha	-	-	-	-	-	-	-	-	-	-	-	-
3	Total of crop area	ha	-	-	-	-	-	-	-	-	-	-	-	-
4	Cumulative of harvest area	ha	-	-	-	-	-	-	-	-	-	-	-	-
5	Price per-kg- GKG	Rp.	-	-	-	-	5,399	5,399	5,467	5,467	5,646	5,646	5,714	5,714
6	Harvest productivity per-ha	kg	-	-	-	-	5,500	5,500	5,500	5,500	5,500	5,500	5,500	5,500
7	Income total of crop rest 2018	mil rp	-	-	-	-	-	-	-	-	-	-	-	-
8	Income total of manipulation CP-Alt-(	mil rp	-	-	-	-	-	-	-	-	-	-	-	-
9	Income total	mil rp	-	-	-	-	-	-	-	-	-	-	-	-
10	Income cumulative in 1 year	mil rp	-	-	-	-	-	-	-	-	-	-	-	-
11	Income average per-ha	mil rp	-	-	-	-	30.538	30.538	30.538	30.538	30.538	30.538	30.538	30.538
12	Water reqm in intake-crop rest 2018	l/s	-	-	-	-	390	2,722	7,423	12,285	15,928	17,245	16,573	15,231
13	Water reqm in intake-manioulation CP	l/s	-	-	-	-	-	-	8,337	16,675	15,816	14,957	14,957	14,957
14	Water reqm total [12 + 13]	l/s	-	-	-	-	390	2,722	15,760	28,960	31,744	32,202	31,530	30,188
15	Water reqm in intake (Eff. 65 %) FC I	m3/s	-	-	-	-	0.390	2.722	15.760	28.960	31.744	32.202	31.530	30.188
16	Water reqm in intake (Eff. 65 %) FC I	mil m3	-	-	-	-	0.506	3.528	20.425	40.035	41.140	41.733	40.863	41.732
17	Water reqm in intake	mil m3	-	-	-	-	0.506	4.034	24.459	64.494	105.634	147.367	188.230	229.961
18	Mean of water use per-ha (16 months)	m3	-	-	-	-								
19	Mean of water price per-m3	RUPIAH	-	-	-	-	2,829	2,829	2,829	2,829	2,829	2,829	2,829	2,829
20	Price of GKG every year per-kg	RUPIAH	-	-	-	-	5,399	5,399	5,467	5,467	5,646	5,646	5,714	5,714
21	Real water price	RUPIAH					2,757	2,757	2,792	2,792	2,883	2,883	2,918	2,918

NO	Description	Unit	Jan-19		February		March		April		May		June	
			I	II	I	II	I	II	I	II	I	II	I	II
			15	16	15	13	15	16	15	15	15	16	15	15
1	Harvest area of crop rest 2018	ha	578	2,877	4,169	3,520	2,868	165	-	-	-	-	-	-
2	Harvest area of CP manipulation-Alt-C	ha	-	-	10,106	-	-	-	-	-	24,086	-	10,106	-
3	Total of crop area	ha	578	2,877	14,275	3,520	2,868	165	-	-	24,086	-	10,106	-
4	Cumulative of harvest area	ha	578	3,455	17,730	21,250	24,118	24,283	24,283	24,283	48,369	48,369	58,475	58,475
5	Price per-kg- GKG	Rp.	5,903	5,903	5,952	5,952	5,654	5,654	5,221	5,221	5,298	5,298	5,361	5,361
6	Harvest productivity per-ha	kg	5,500	5,500	5,500	5,500	5,500	5,500	5,500	5,500	5,500	5,500	5,500	5,500
7	Income total of crop rest 2018	mil rp	18,764	93,400	136,475	115,230	89,186	5,131	-	-	-	-	-	-
8	Income total of manipulation CP-Alt-(	mil rp	-	-	330,828	-	-	-	-		701,868	-	297,975	-
9	Income total	mil rp	18,764	93,400	467,303	115,230	89,186	5,131	-	-	701,868	-	297,975	-
10	Income cumulative in 1 year	mil rp	18,764	112,165	579,468	694,698	783,884	789,015	789,015	789,015	1,490,884	1,490,884	1,788,858	1,788,858
11	Income average per-ha	mil rp	30.538	30.538	30.538	30.538	30.538	30.538	30.538	30.538	30.538	30.538	30.538	30.538
12	Water reqm in intake-crop rest 2018	l/s	12,907	9,612	5,726	2,686	879	45	-	-	-	-	-	-
13	Water reqm in intake-manioulation CP	l/s	22,654	31,038	34,264	36,790	53,510	70,361	60,145	51,100	54,897	63,564	46,838	34,325
14	Water reqm total [12 + 13]	l/s	35,562	40,650	39,990	39,477	54,389	70,406	60,145	51,100	54,897	63,564	46,838	34,325
15	Water reqm in intake (Eff. 65 %) FC I	m3/s	35.562	40.650	39.990	39.477	54.389	70.406	60.145	51.100	54.897	63.564	46.838	34.325
16	Water reqm in intake (Eff. 65 %) FC I	mil m3	46.088	56.195	51.827	44.340	70.488	97.330	77.948	66.226	71.146	87.871	60.702	44.485
17	Water reqm in intake	mil m3	276.049	332.244	384.071	428.412	498.900	596.230	674.178	740.403	811.549	899.420	960.122	1,004.607
18	Mean of water use per-ha (16 months)	m3												
19	Mean of water price per-m3	RUPIAH	2,829	2,829	2,829	2,829	2,829	2,829	2,829	2,829	2,829	2,829	2,829	2,829
20	Price of GKG every year per-kg	RUPIAH	5,903	5,903	5,952	5,952	5,654	5,654	5,221	5,221	5,298	5,298	5,361	5,361
21	Real water price	RUPIAH	3,014	3,014	3,039	3,039	2,887	2,887	2,666	2,666	2,705	2,705	2,737	2,737

NO	Description	Unit	July		August		September		October		November		Dec-19	
			I	II	I	II	I	II	I	II	I	II	I	II
			15	16	15	16	15	15	15	16	15	15	15	16
1	Harvest area of crop rest 2018	ha	-	-	-	-	-	-	-	-	-	-	-	-
2	Harvest area of CP manipulation-Alt-C	ha	21,181	-	-	-	24,086	-	-	-	21,181	-	-	-
3	Total of crop area	ha	21,181	-	-	-	24,086	-	-	-	21,181	-	-	-
4	Cumulative of harvest area	ha	79,656	79,656	79,656	79,656	103,742	103,742	103,742	103,742	124,923	124,923	124,923	124,923
5	Price per-kg- GKG	Rp.	5,385	5,385	5,423	5,423	5,522	5,522	5,119	5,119	5,728	5,728	5,856	5,856
6	Harvest productivity per-ha	kg	5,500	5,500	5,500	5,500	5,500	5,500	5,500	5,500	5,500	5,500	5,500	5,500
7	Income total of crop rest 2018	mil rp	-	-	-	-	-	-	-	-	-	-	-	-
8	Income total of manipulation CP-Alt-(	mil rp	627,299	-	-	-	731,501	-	-	-	667,290	-	-	-
9	Income total	mil rp	627,299	-	-	-	731,501	-	-	-	667,290	-	-	-
10	Income cumulative in 1 year	mil rp	2,416,158	2,416,158	2,416,158	2,416,158	3,147,659	3,147,659	3,147,659	3,147,659	3,814,949	3,814,949	3,814,949	3,814,949
11	Income average per-ha	mil rp	30.538	30.538	30.538	30.538	30.538	30.538	30.538	30.538	30.538	30.538	30.538	30.538
12	Water reqm in intake-crop rest 2018	l/s	-	-	-	-	-	-	-	-	-	-	-	-
13	Water reqm in intake-manioulation CP	l/s	43,667	52,242	44,578	35,857	31,194	24,570	18,110	11,650	5,825	-	-	-
14	Water reqm total [12 + 13]	l/s	43,667	52,242	44,578	35,857	31,194	24,570	18,110	11,650	5,825	-	-	-
15	Water reqm in intake (Eff. 65 %) FC I	m3/s	43.667	52.242	44.578	35.857	31.194	24.570	18.110	11.650	5.825	-	-	-
16	Water reqm in intake (Eff. 65 %) FC I	mil m3	56.592	72.219	57.773	49.569	40.427	31.843	23.470	16.104	7.549	-	-	-
17	Water reqm in intake	mil m3	1,061.200	1,133.419	1,191.192	1,240.761	1,281.188	1,313.030	1,336.501	1,352.605	1,360.154	1,360.154	1,360.154	1,360.154
18	Mean of water use per-ha (16 months)	m3												10,888
19	Mean of water price per-m3	RUPIAH	2,829	2,829	2,829	2,829	2,829	2,829	2,829	2,829	2,829	2,829	2,829	2,829
20	Price of GKG every year per-kg	RUPIAH	5,385	5,385	5,423	5,423	5,522	5,522	5,119	5,119	5,728	5,728	5,856	5,856
21	Real water price	RUPIAH	2,749	2,749	2,769	2,769	2,819	2,819	2,614	2,614	2,889	2,889	2,990	2,990

Table 5 Water contribution analysis of cropping pattern-Alt-C and SDP, 2018-2019 (Own study)

Description		Sep-18		Oct		Nov		Des		Total of harvest Alt. manipulation C
		1	2	1	2	1	2	1	2	
		15	15	15	16	15	15	15	16	
Total of water requirement	m^3/s	1.67	4.00	17.04	30.24	33.03	33.48	32.81	31.47	
Suply from Batutegi	m^3/s	-	-	12.29	22.88	24.35	21.82	16.00	2.89	
Water supply in S. Way Skpng	m^3/s	1.67	4.00	4.75	7.36	8.68	11.66	16.81	28.58	
Water supply in S. Way Skpng	mil m^3	2.17	5.19	6.15	10.17	11.25	15.12	21.78	39.51	
Water price	Rp	2,757	2,757	2,792	2,792	2,883	2,883	2,918	2,918	
Total of income	mil Rp	5,974	14,307	17,181	28,398	32,428	43,576	63,555	115,274	
Cumulative of income	mil Rp	5,974	20,281	37,462	65,861	98,289	141,865	205,421	320,695	
Release result of SDP program	mil Rp									
SDP vs CP manipul alt-C	mil Rp									
Profit Release SDP vs manp C	mil Rp									
Profit percentage of SDP	%									

Description		Jan-19		Feb		March		April		Total of harvest Alt. manipulation C
		1	2	1	2	1	2	1	2	
		15	16	15	13	15	16	15	15	
Total of water requirement	m^3/s	36.84	41.93	41.27	40.76	55.67	54.84	61.43	52.38	
Suply from Batutegi	m^3/s	0.00	0.00	0.00	0.00	0.00	2.42	12.72	21.80	
Water supply in S. Way Skpng	m^3/s	36.84	41.93	41.27	40.76	55.67	52.42	48.70	30.58	
Water supply in S. Way Skpng	mil m^3	47.75	57.97	53.49	45.78	72.15	72.46	63.12	39.63	
Water price	Rp	3,014	3,014	3,039	3,039	2,887	2,887	2,666	2,666	
Total of income	mil Rp	143,902	174,696	162,563	139,136	208,301	209,195	168,279	105,656	
Cumulative of income	mil Rp	464,597	639,293	801,856	940,992	1,149,293	1,358,488	1,526,767	1,632,423	
Release result of SDP program	mil Rp									
SDP vs CP manipul alt-C	mil Rp									
Profit Release SDP vs manp C	mil Rp									
Profit percentage of SDP	%									

Description		May		June		July		August		Total of harvest Alt. manipulation C
		1	2	1	2	1	2	1	2	
		15	16	15	15	15	16	15	16	
Total of water requirement	m^3/s	56.18	64.85	48.12	35.61	44.95	53.52	45.86	37.14	
Suply from Batutegi	m^3/s	38.10	39.46	30.84	23.57	38.19	46.84	41.64	32.72	
Water supply in S. Way Skpng	m^3/s	18.08	25.38	17.28	12.04	6.75	6.68	4.22	4.42	
Water supply in S. Way Skpng	mil m^3	23.44	35.09	22.39	15.60	8.75	9.24	5.47	6.11	
Water price	Rp	2,705	2,705	2,737	2,737	2,749	2,749	2,769	2,769	
Total of income	mil Rp	63,399	94,929	61,283	42,705	24,065	25,405	15,152	16,918	
Cumulative of income	mil Rp	1,695,822	1,790,752	1,852,034	1,894,740	1,918,804	1,944,209	1,959,361	1,976,280	
Release result of SDP program	mil Rp									
SDP vs CP manipul alt-C	mil Rp									
Profit Release SDP vs manp C	mil Rp									
Profit percentage of SDP	%									

Description		Sep		Oct		Nov		Dec		Total of harvest Alt. manipulation C
		1	2	1	2	1	2	1	2	
		15	15	15	16	15	15	15	16	
Total of water requirement	m^3/s	32.48	25.85	19.39	12.93	7.11	1.28	1.28	1.28	
Suply from Batutegi	m^3/s	26.50	21.33	14.64	5.57	0.00	0.00	0.00	0.00	
Water supply in S. Way Skpng	m^3/s	5.98	4.52	4.75	7.36	7.11	1.28	1.28	1.28	
Water supply in S. Way Skpng	mil m^3	7.75	5.86	6.15	10.17	9.21	1.66	1.66	1.77	
Water price	Rp	2,819	2,819	2,614	2,614	2,889	2,889	2,990	2,990	
Total of income	mil Rp	21,844	16,509	16,088	26,591	26,606	4,799	4,968	5,299	
Cumulative of income	mil Rp	1,998,124	2,014,632	2,030,720	2,057,310	2,083,916	2,088,716	2,093,684	2,098,983	
Release result of SDP program	mil Rp								1,780,380	
SDP vs CP manipul alt-C	mil Rp								3,879,363	3,814,949
Profit Release SDP vs manp C	mil Rp								64,415	
Profit percentage of SDP	%								1.688	

Table 6 Plan and realization of extension cropping pattern (Own study)

Water requirement for paddy			Location	Area (ha.)		Sec crp	Gol	Jan		Feb		Mar		Apr		May		Jun		Jul		Aug		Sep		Oct		Nov		Dec	
Time	CP I	CP II		CP I	CP II	CP III		I	II	I	II	I	II	I	II	I	II	I	II	I	II	I	II	I	II	I	II	I	II	I	II
Preparation	30 days	1 month																													
Growth	60 days	2 months	DI.Way Sekampung	5,000	5,000	-																									
Maturation	30 days	1 month	FC II	5,000	5,000	-																									
Water need in weir			UPTD Rumbia Ext.	5,000	5,000	-	II				Paddy 5,000 ha.								Paddy 5,000 ha.								Second crop ......ha				
Time	CP I	CP II																													
Preparation	1.65	1.35																													
Growth	1.48	1.16																													
Maturation	0.53	0.55	Percentage	100%	100%	-	200%																								
			Water req FC II	l/s	Plan (Target of SDP)			4,125	8,250	7,825	7,400	7,400	7,400	5,025	2,650	4,700	6,750	6,275	5,800	5,800	5,800	4,275	2,750	1,375	-	-	-	-	-	-	-
Time	CP I	CP II	Total of need	l/s				4,125	8,250	7,825	7,400	7,400	7,400	5,025	2,650	4,700	6,750	6,275	5,800	5,800	5,800	4,275	2,750	1,375	-	-	-	-	-	-	-
			Number of day					15	16	14	14	15	16	15	15	15	16	15	15	15	16	15	16	15	15	15	16	15	15	15	16
Water req for second crop																									-	-	-	-	-	-	-
Time	CP I	CP II	Total of need	m3/s				4.125	8.250	7.825	7.400	7.400	7.400	5.025	2.650	4.700	6.750	6.275	5.800	5.800	5.800	4.275	2.750	1.375	-	-	-	-	-	-	-
Growth	90 days	3 months	Total of need	mil m3				5.346	11.405	9.465	8.951	9.590	10.230	6.512	3.434	6.091	9.331	8.132	7.517	7.517	8.018	5.540	3.802	1.782	-	-	-	-	-	-	-
Water need in weir			FC II	1,082	1,082	-					Paddy 1,082 ha.								Paddy 1,082 ha.												
Time	CP I	CP II	UPTD Rumbia Ext.	1,082	1,082	-																									
Growth		0.30																													
			Percentage	100%	100%	-	200%																								
			Water req. FC II	l/s	Realization of SDP			893	1,785	1,693	1,601	1,601	1,601	1,087	573	1,017	1,461	1,358	1,255	1,255	1,255	925	595	298	-	-	-	-	-	-	-
			Total of need	l/s				893	1,785	1,693	1,601	1,601	1,601	1,087	573	1,017	1,461	1,358	1,255	1,255	1,255	925	595	298	-	-	-	-	-	-	-
			number of day					15	16	14	14	15	16	15	15	15	16	15	15	15	16	15	16	15	15	15	16	15	15	15	16
																									-	-	-	-	-	-	-
			Total of need	m3/s				0.893	1.785	1.693	1.601	1.601	1.601	1.087	0.573	1.017	1.461	1.358	1.255	1.255	1.255	0.925	0.595	0.298	-	-	-	-	-	-	-
			Total of need	mil m3				1.157	2.468	2.048	1.937	2.075	2.214	1.409	0.743	1.318	2.019	1.760	1.627	1.627	1.735	1.199	0.823	0.386	-	-	-	-	-	-	-

The extensification in the Rumbia extension irrigation area of 5,000 ha has been analyzed accurately for applying the Stochastic Dynamic Programming in the optimization of the Batutegi Reservoir by the real-time half-monthly discharge inflow and reservoir effective storage discretization of 660 million m^3 with the storage gradation unit of 0.05% (that is per 0.33 million m^3), Ni = 2,000, NJ max = 2,290, and upper limit = 12.

3.2. Parameter of Optimization Model by Using SDP in Batutegi Reservoir

Table 7 presents the data of the SDP parameter in the Batutegi reservoir.

3.3. Constraint, Minimum Limitation, and Maximum Release

The minimum limit is taken from the balance of Alt-C cropping pattern manipulation in normal conditions. However, the upper limit is taken from the cropping pattern extensification in the Rumbia extension irrigation area (5,000 ha).

3.4. Distribution of Inflow

Data of reservoir inflow is used from 2002 until 2017; the half-monthly period is used for the input to the Stochastic Dynamic Programming (SDP). The distribution of inflow is presented in Fig. 3.

3.5 Expected Value

The analysis of the expected value, harvest income of the rest cropping pattern of 2018, and cropping pattern of 2019 (paddy III, paddy I, and paddy II) are described below.

By combining the balance based on the water balance and statistical data of GKG price from January until December 2019, it can be calculated the harvest income of paddy in the form of Milled Dry Grain (GKG) from the Alt-C cropping pattern manipulation and the optimization result of Batutegi reservoir by using Stochastic Dynamic Programming (SDP), there is obtained the comparison of harvest income between Alt-C cropping pattern manipulation and Alt-C cropping pattern manipulation plus SDP. The hydropower production and the second crop harvest result are not calculated.

The area of the Sekampung irrigation area is 55,373 ha. The harvest production minimum is 5 ton/ha, and the maximum is 5.8 ton/ha GKG in the Tanggamus Regency. In this research, the average GKG productivity is 5.5 ton/ha. The price of GKG is customized by the fluctuated price per month for one year (January-December 2019); the maximum is in February 2019 (Rp. 5,951.96 per kg).

The result of the analysis using SDP is obtained as follows: the optimal value is 170.38 on the S1192 by maximizing the Jan I value from S0 to S2000 in the SDP optimization of the Batutegi reservoir. However, the water needed in Fider I and Fider II intake with the watershed between Batutegi Dam and Argoguruh Weir also contributes to discharge. Based on the water balance, the discharge analysis is carried out in Way Sekampung River, where the Argoguruh weir is located upstream. The water price (water contribution) per half a month is analyzed and determined from the harvest result and the GKG (Milled Dry Grain) price per month during the harvest time. The result is presented in Table 8.

The above result shows that the Alt-C cropping pattern manipulation using Stochastic Dynamic Programming (SDP) is the most profitable with the highest income of Rp 3,879,363,000,000.00. Table 9 presents the income analysis of Alt-1 (existing) CP, Alt-C manipulation, and SDP. Table 10 presents the data for the income analysis curve of Alt-I (existing) CP, Alt-C manipulation, and Alt-C manipulation by SDP. The curve comparison between the Alt-1 existing cropping pattern (the existing result of RAAT 2018–2019), the Alt-C cropping pattern manipulation by using simulation, and the Alt-C cropping pattern manipulation by using SDP, is presented in Fig. 4. The result shows that the Alt-C cropping pattern manipulation using SDP is more profitable than the other two cropping patterns above. Table 9 presents the income analysis of Alt-1 (existing) CP, Alt-C manipulation, and SDP. Table 10 presents the data for the income analysis curve of Alt-I (existing) CP, Alt-C manipulation, and Alt-C manipulation by SDP.

Table 7 Data of SDP parameter in the Batutegi reservoir (Own study)

Unit Gradation	0.3300	[million m³]																							
Month		Jan		Feb		Mar		Apr		May		Jun		Jul		Aug		Sep		Oct		Nov		Dec	
sub-month		I	II	I	II	I	II	I	II	I	II	I	II	I	II	I	II	I	II	I	II	I	II	I	II
Ranking of Periode		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Wtr unit price	[Rp/m³]	######	3013.69	3039.22	3039.22	2887.07	2887.07	2665.99	2665.99	2705.30	2705.30	2736.96	2736.96	2749.21	2749.21	######	2769.12	2819.16	2819.16	2613.91	######	2888.69	2888.69	2990.21	2990.21
Fixed disch	[ltr/s]	1,282.0	1,282.0	1,282.0	1,282.0	1,282.0	1,282.0	1,282.0	1,282.0	1,282.0	1,282.0	1,282.0	1,282.0	1,282.0	1,282.0	1,282.0	1,282.0	1,282.0	1,282.0	1,282.0	1,282.0	1,282.0	1,282.0	1,282.0	1,282.0
n day		15	16	15	13	15	16	15	15	15	16	15	15	15	16	15	16	15	15	15	16	15	15	15	16
Fixed disch	[million m³]	1.661	1.772	1.661	1.440	1.661	1.772	1.661	1.661	1.661	1.772	1.661	1.661	1.661	1.772	1.661	1.772	1.661	1.661	1.661	1.772	1.661	1.661	1.661	1.772
S_end Min.	[No.Grad.]	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	40	40
Release Min.	[juta m³]	0.000	0.000	0.000	0.000	0.000	3.347	16.489	28.256	49.372	54.553	39.973	30.543	49.500	64.751	53.962	45.232	34.340	27.648	18.977	7.704	0.000	0.000	20.741	3.995
Release Min. [riil]	[juta m³]	1.661	1.772	1.661	1.440	1.661	3.347	16.489	28.256	49.372	54.553	39.973	30.543	49.500	64.751	53.962	45.232	34.340	27.648	18.977	7.704	1.661	1.661	20.741	3.995
		5.346	11.405	9.465	8.951	9.590	13.577	23.001	31.690	55.463	63.885	48.105	38.060	57.017	72.769	59.503	49.033	36.122	27.648	18.977	7.704	0.000	0.000	20.741	3.995
Xj (outflow) Min.	[No.Grad.]	6	6	6	5	6	11	50	86	150	166	122	93	150	197	164	138	105	84	58	24	6	6	63	13
J (outflow) Max.	[No.Grad.]	12	30	24	24	25	32	21	12	20	29	25	24	24	25	18	12	6	3	3	3	3	3	3	3

Month		Jan		Feb		Mar		Apr		May		Jun	
sub-month		I	II	I	II	I	II	I	II	I	II	I	II
Ranking of Period		1	2	3	4	5	6	7	8	9	10	11	12
Water unit price	[Rp/m³]	3014	3014	3039	3039	2887	2887	2666	2666	2705	2705	2737	2737
Fixed discharge	[ltr/s]	1,282	1,282	1,282	1,282	1,282	1,282	1,282	1,282	1,282	1,282	1,282	1,282
n days		15	16	15	13	15	16	15	15	15	16	15	15
Fixed discharge	[million m³]	1.661	1.772	1.661	1.440	1.661	1.772	1.661	1.661	1.661	1.772	1.661	1.661
S_end Min.	No.Grad	10	10	10	10	10	10	10	10	10	10	10	10
Release Min.	[million m³]	0.000	0.000	0.000	0.000	0.000	3.347	16.489	28.256	49.372	54.553	39.973	30.543
Release Min. [riil]	[million m³]	1.661	1.772	1.661	1.440	1.661	3.347	16.489	28.256	49.372	54.553	39.973	30.543
		5.346	11.405	9.465	8.951	9.590	13.577	23.001	31.690	55.463	63.885	48.105	38.060
Xj (outflow) Min.	No.Grad	6	6	6	5	6	11	50	86	150	166	122	93
J (outflow) Max.	No.Grad	12	30	24	24	25	32	21	12	20	29	25	24

Month		Jul		Aug		Sep		Oct		Nov		Dec	
sub-month		I	II	I	II	I	II	I	II	I	II	I	II
Ranking of Period		13	14	15	16	17	18	19	20	21	22	23	24
Water unit price	[Rp/m³]	2749	2749	2769	2769	2819	2819	2614	2614	2889	2889	2990	2990
Fixed discharge	[ltr/s]	1,282	1,282	1,282	1,282	1,282	1,282	1,282	1,282	1,282	1,282	1,282	1,282
n days		15	16	15	16	15	15	15	16	15	15	15	16
Fixed discharge	[million m³]	1.661	1.772	1.661	1.772	1.661	1.661	1.661	1.772	1.661	1.661	1.661	1.772
S_end Min.	No.Grad	10	10	10	10	10	10	10	10	10	10	40	40
Release Min.	[million m³]	49.500	64.751	53.962	45.232	34.340	27.648	18.977	7.704	0.000	0.000	20.741	3.995
Release Min. [riil]	[million m³]	49.500	64.751	53.962	45.232	34.340	27.648	18.977	7.704	1.661	1.661	20.741	3.995
		57.017	72.769	59.503	49.033	36.122	27.648	18.977	7.704	0.000	0.000	20.741	3.995
Xj (outflow) Min.	No.Grad	150	197	164	138	105	84	58	24	6	6	63	13
J (outflow) Max.	No.Grad	24	25	18	12	6	3	3	3	3	3	3	3

Note: Water contribution is rounded up to Rupiah.

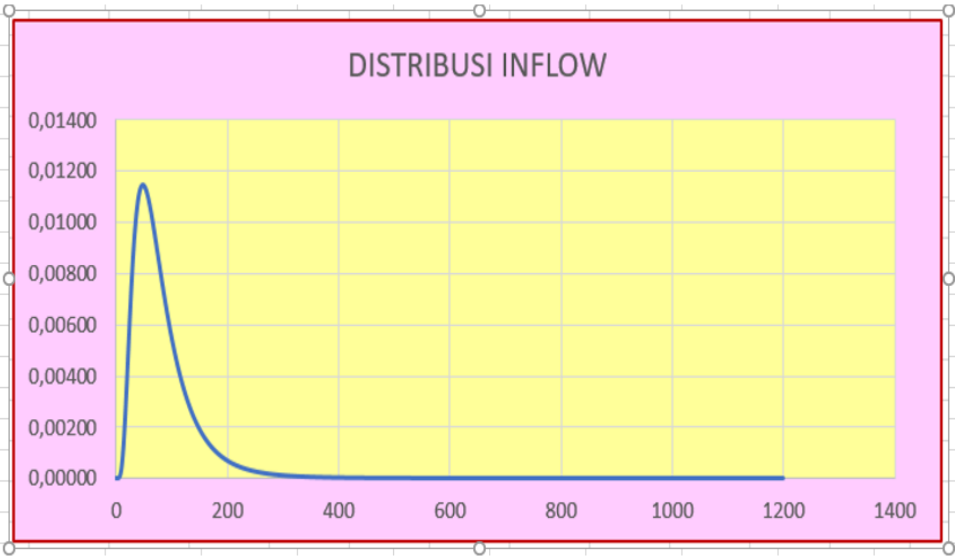

Fig. 3 Log-normal distribution of Batutegi reservoir data inflow

Table 8 The comparison between income additional EV of the existing cropping pattern, Alt-C cropping pattern manipulation, and Alt-C cropping pattern manipulation as the result of SDP (Own study)

			Harvest income (EV) 2019					
No	Period of 2019	Unit Million Rp.	Existing cropping pattern Simulation result of RAAT Cropping pattern 2018-2019		Man. Alt.-C cropping pattern (Intensification)		Man. Alt.-C cropping pattern Intensification result + (SDP - Ektensification)	
			EV	Cumulative EV	EV	Cumulative EV	EV	Cumulative EV
1	2	3	4	5	6	7	8	9
1	January	million Rp.	112,165	112,165	112,165	112,165	112,165	112,165
2	February	million Rp.	251,705	363,870	582,533	694,698	582,533	694,698
3	March	million Rp.	94,317	458,187	94,317	789,015	94,317	789,015
4	April	million Rp.	290,218	748,406	-	789,015	-	789,015
5	May	million Rp.	701,868	1,450,274	701,868	1,490,884	733,410	1,522,425
6	June	million Rp.	-	1,450,274	297,975	1,788,858	297,975	1,820,400
7	July	million Rp.	627,299	2,077,573	627,299	2,416,158	627,299	2,447,699
8	August	million Rp.	301,436	2,379,009	-	2,416,158	-	2,447,699
9	September	million Rp.	731,501	3,110,510	731,501	3,147,659	764,375	3,212,074
10	October	million Rp.	-	3,110,510	-	3,147,659	-	3,212,074
11	November	million Rp.	667,290	3,777,800	667,290	3,814,949	667,290	3,879,363
12	December	million Rp.	-	3,777,800	-	3,814,949	-	3,879,363

Table 9 Income analysis of Alt-1 (existing) CP, Alt-C manipulation, and SDP (Own study)

No	Discription	Optimization Stage I	Optimization Stage II	Condition of Reservoir Storage		Q Run off	Harvest incom	Profit (EV)	Percentage	Note
No	Alternative Cropping Patterns	Early Intensification Bekri & Rumbia Planting (Million Rp)	Extensifikasion. Early Planting. DI Rumbia Ext. (Area) HA	Volume of Batutergi reserv End of Des.19	Minimum	Bendung Argoguruh Des. 18 - Des 19 Million m3	Man.Alt.C-CP, SDP 1 year CP Million Rp	Profit Income from Optimization Million Rp./Year	%	Vol Wdk C > Existing
1	Alt. 1 (Existing)	Midio Des. 2018		172.56	107.55	232.16	3,777,800	-		Existing
2	Manipulation Alt- C	Initial Okt. 2018		268.74	203.74	270.54	3,814,949	37,149	0.983	Man - C to Exist.
3	Manipulation Alt-C +SDP		Initial Oct. 2018	251.88	187.03	260.85	3,879,363	64,415	1.688	SDP to Man-C
Additional Area		-	1,082.420							
Man C, difference, of Vol. Millio		37,149	-	96.18	96.19	38.38	37,149			
SDP, difference of Vol. Million F		-	64,415	79.32	79.48	28.69	64,415	101,564	2.688	SDP to Existing.

Table 10 Data for income analysis curve of Alt-I (existing) CP, Alt-C manipulation, and Alt-C manipulation by SDP

Cropping pattern	**January**	**February**	**March**	**April**	**May**	**June**
Existing	112.165	363.870	458.187	748.406	1.450.274	1.450.274
Manipulation- C	112.165	694.698	789.015	789.015	1.490.884	1.788.858
SDP	112.165	694.698	789.015	789.015	1.522.425	1.820.400
Cropping pattern	**July**	**August**	**September**	**October**	**November**	**December**
Existing	2,077.573	2,379.009	3,110.510	3,110.510	3,777.800	3,777.800
Manipulation- C	2,416.158	2,416.158	3,147.659	3,147.659	3,814.949	3,814.949
SDP	2,447.699	2,447.699	3,212.074	3,212.074	3,879.363	3,879.363

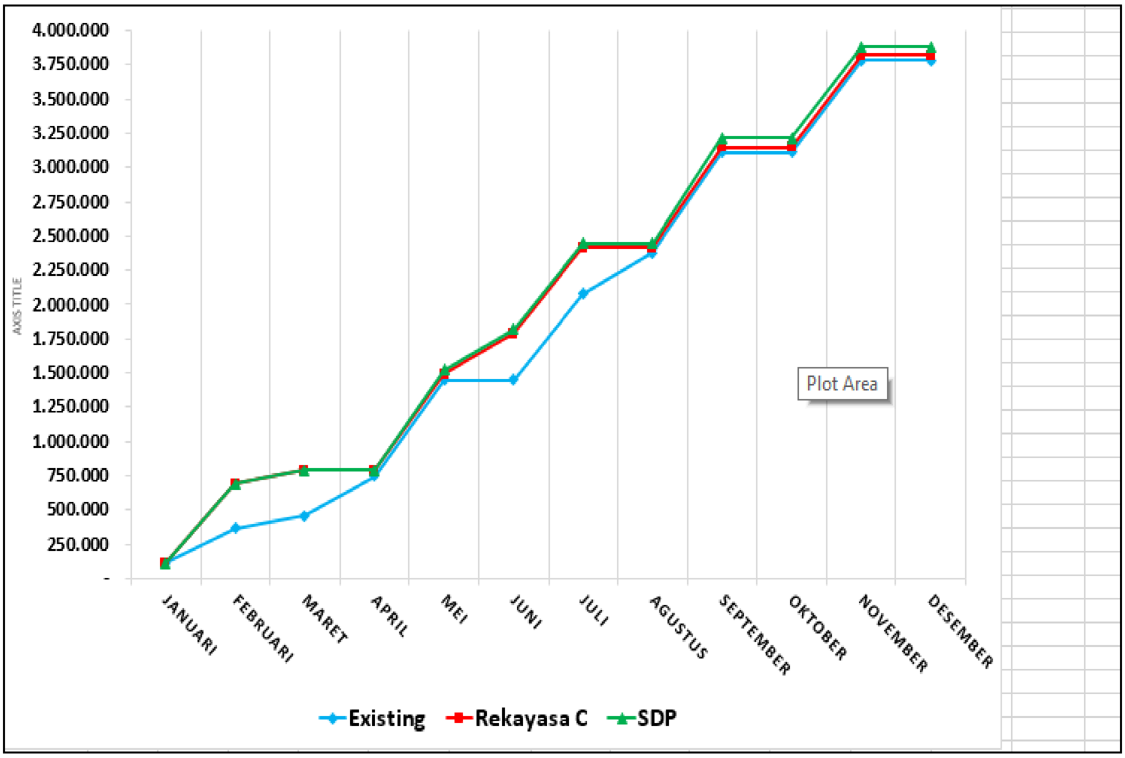

Fig. 4 The curve of GKG harvest income, existing cropping pattern, Alt-C cropping pattern manipulation, Alt-C cropping pattern manipulation by SDP

Due to increased crop intensity, the additional area of Rumba Extension is 1,082 hectares (ha), this showed a volume change in the reservoir at the end of December as presented in Table 11 and Fig. 5.

Table 11 The additional crop area of the Rumbia extension of 1,082 ha and the reservoir volume change

Vol of Batutegi Nov-end. 290

Description	Unit	Sept 1	Sept 2	Oct 1	Oct 2	Nov 1	Nov 2	Dec 1	Dec 2	Jan 1	Jan 2	Feb 1	Feb 2	March 1	March 2	April 1	April 2
		15	15	15	16	15	15	15	16	15	16	15	13	15	16	15	15
Q40% Argoguruh	m^3/s	7.41	10.23	17.53	17.38	20.67	21.93	**38.17**	**70.18**	80.07	122.47	104.74	101.34	109.47	70.26	65.17	33.92
Q60% Argoguruh	m^3/s	5.98	4.52	4.75	7.36	8.68	11.66	16.81	28.58	63.02	82.57	73.69	86.76	66.02	52.42	48.70	30.58
Q40% Batutegi	m^3/s	**8.67**	**6.27**	**6.91**	**5.91**	**10.30**	**11.88**	**16.10**	**20.47**	**20.51**	**24.16**	**27.20**	**32.00**	**26.67**	**29.54**	**27.59**	**25.77**
Water reqm DI.Sekampung 55.373 ha.	l/s	390	2,722	15,761	28,960	31,744	32,201	31,529.72	30,187.81	35,561.73	41,483.69	40,780.21	40,224.18	55,136.41	71,153.59	60,652.58	51,099.81
Water reqm DI.Rumbia Ext.1,082 ha.	l/s	-	-	-	-	-	-	-	-	893	1,785	1,693	1,601	1,601	1,601	1,087	573
Water reqm PDAM Pringsewu	l/s	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200
Water reqm PDAM Metro	l/s	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50
PT. Tirta Kreasi Amrita	l/s	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21
PT. Kirin Miwon	l/s	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11
PDAM Bandar Lampung	l/s	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
River maintenance	l/s	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000
Total of water need	l/s	1,672	4,004	17,043	30,242	33,026	33,483	32,812	31,470	37,736	44,551	43,756	43,108	58,020	74,037	63,022	52,955
Total of water need	m^3/s	1.67	4.00	17.04	30.24	33.03	33.48	32.81	31.47	37.74	44.55	43.76	43.11	58.02	74.04	63.02	52.96
Supply from Batutegi	m^3/s	0.00	0.00	12.29	22.88	24.35	21.82	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.77	0.00	19.04
Volume of Batutegi reservoir	million m^3	301.23	298.13	283.02	266.53	271.79	277.12	310.86	339.16	365.74	399.14	434.40	470.34	504.90	540.51	576.27	585.00
reservoir is run-off/ not	million m^3	-	-	-	-	-	-			-	-	-	-	-	-	-	-
Volume of run-off	million m^3	-	-	-	-	-	-			-	-	-	-	-	-	-	-
Run-off of Argoguruh	m^3/s	4.31	0.51							25.28	38.02	29.94	43.65	8.01			
Run-off of Argoguruh	million m^3	5.58	0.67	-	-	-	-	-	-	32.76	52.56	38.80	49.03	10.37	-	-	-

Description	Unit	May 1	May 2	June 1	June 2	July 1	July 2	August 1	August 2	Sep 1	Sep 2	Oct 1	Oct 2	Nov 1	Nov 2	Dec 1	Dec 2	TOTAL
		15	16	15	15	15	16	15	16	15	15	15	16	15	15	15	16	
Q40% Argoguruh	m^3/s	41.14	33.69	20.97	14.59	12.55	15.52	12.86	9.13	7.41	10.23	17.53	17.38	20.67	21.93	38.17	70.18	
Q60% Argoguruh	m^3/s	18.08	25.38	17.28	12.04	6.75	6.68	4.22	4.42	5.98	4.52	4.75	7.36	8.68	11.66	16.81	28.58	
Q40% Batutegi	m^3/s	**23.54**	**19.54**	**17.56**	**15.00**	**12.83**	**12.65**	**8.76**	**9.52**	**8.67**	**6.27**	**6.91**	**5.91**	**10.30**	**11.88**	**16.10**	**20.47**	
Water reqm DI.Sekampung 55.373 ha.	l/s	55,371.31	63,477.88	47,507.67	37,282.25	46,624.46	55,199.67	68,093.58	37,337.96	31,176.01	31,795.76	25,029.56	18,366.35	18,811.88	12,478.10	12,163.80	12,163.80	
Water reqm DI.Rumbia Ext.1,082 ha.	l/s	1,017	1,461	1,358	1,255	1,255	1,255	925	595	298	-	-	-	-	-	-		
Water reqm PDAM Pringsewu	l/s	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	
Water reqm PDAM Metro	l/s	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	
PT. Tirta Kreasi Amrita	l/s	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	
PT. Kirin Miwon	l/s	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	
PDAM Bandar Lampung	l/s	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
River maintenance	l/s	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	
Total of water need	l/s	57,670	66,221	50,148	39,819	49,162	57,737	70,301	39,215	32,756	33,078	26,312	19,648	20,094	13,760	13,446	13,446	
Total of water need	m^3/s	57.67	66.22	50.15	39.82	49.16	57.74	70.30	39.22	32.76	33.08	26.31	19.65	20.09	13.76	13.45	13.45	
Supply from Batutegi	m^3/s	16.53	32.53	29.18	25.23	36.61	42.22	57.44	30.09	25.35	22.84	8.79	2.26	0.00	0.00	0.00	0.00	
Volume of Batutegi reservoir	million m^3	594.09	576.12	561.06	547.81	516.99	476.12	413.02	384.59	362.97	341.50	339.07	344.11	357.45	372.86	393.72	422.01	
reservoir is run-off/ not	million m^3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Volume of run-off	million m^3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Run-off of Argoguruh	m^3/s															3.36	15.13	
Run-off of Argoguruh	million m^3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4.36	20.92	215.04

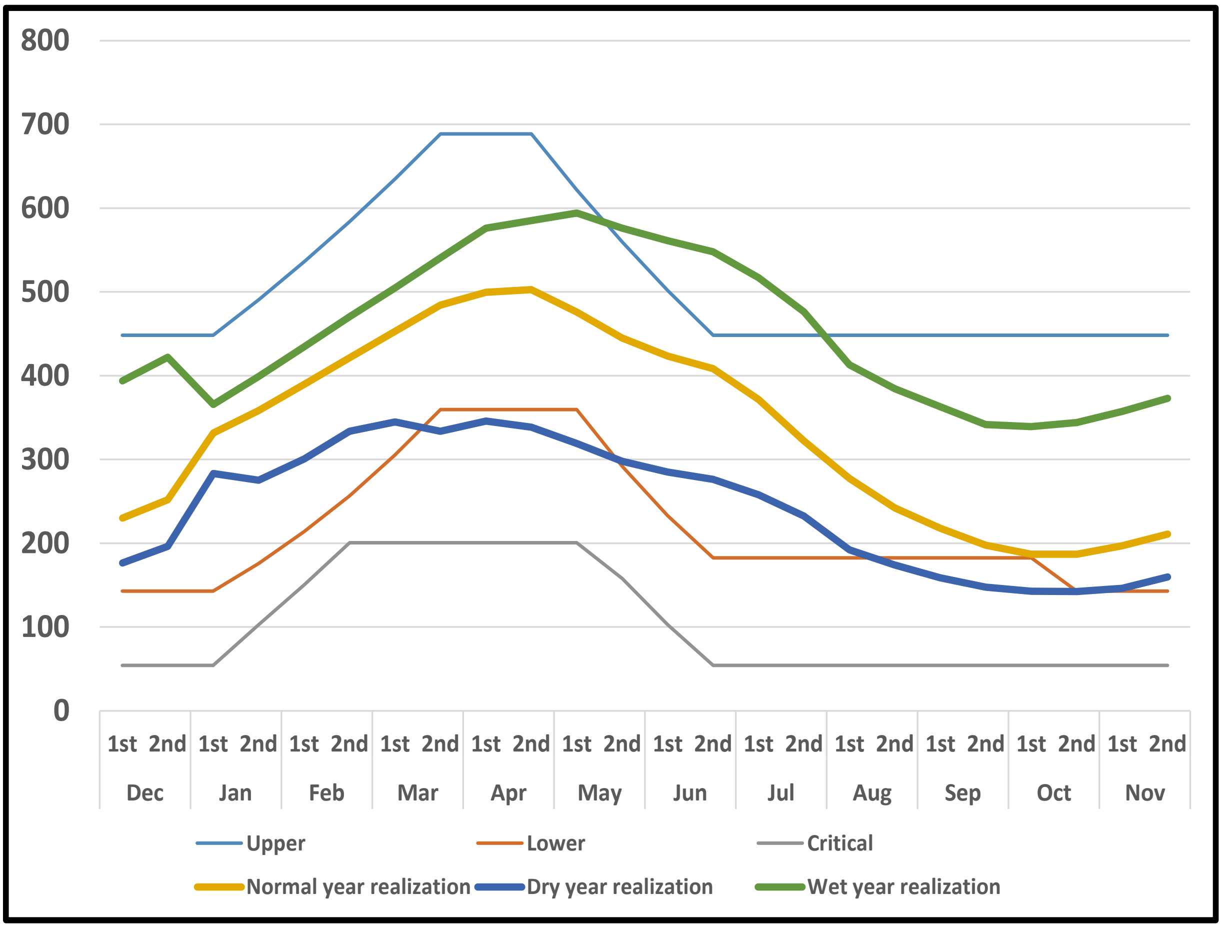

Fig. 5 Scenario of normal, dry, wet year for Alt - C + Rumbia Ext. 1,082 ha

4. Conclusion

Based on the analysis and discussion above, the conclusion is as follows:

1. The Batutegi reservoir operation optimization model was obtained by using Stochastic Dynamic Programming (SDP) for fulfilling the water requirements in the Way Sekampung irrigation area as follows: the intensification was obtained by Alt-C cropping pattern manipulation, and the extensification by applying the optimization model using the Alt-C cropping pattern manipulation by SDP. This obtained an additional crop area (crop intensity) of 1,082.420 ha in Rumbia Extension from the target of 5,000 ha or 21.648%, or the expected value of Rp 64,415,350.00, from the target of Rp 348,347,000,000.00 or 18.491%. As measured from Rumbia Extension, the application of SDP has proven economically more profitable.

2. If measured from the income of Alt-C cropping pattern manipulation, the expected value earned is Rp 3,814,949.00. However, after carrying out the optimization by using SDP, the expected income is Rp 3,879,363,000,000.00, or a profit of Rp 64,415,350,000.00—1.688% increase in one year. The

total profit of one year's cropping pattern in the Batutegi reservoir using the optimization of simulation method and the application of SDP, is Rp 101,564,000,000.00 or 2.688%, as opposed to the existing RAAT cropping pattern that is arranged by Balai Besar Wilayah Sungai (BBWS) Mesuji Sekampung.

3. The application of the SDP method on the reservoir optimization operation, supported by real-time data inflow and the discretization of reservoir storage per 0.05% (relatively small), is effective enough if compared with the simulation system supported by dependable discharge and water balance. Therefore, the reservoir release can produce optimal profit in operating the Batutegi reservoir.

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