CENGKLIK RESERVOIR PERFORMANCE AND ITS ROLE FOR DROUGHT MITIGATION

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ABSTRACT

Water availability problem is encountered by Cengklik Reservoir due to drought disaster in the current year. It causes irrigation water crisis over 850 hectares crop field which of 350 hectares were not cultivated. The risk that must be faced by farmers is decrease in potential productivity, losses about more than 2.5 billion. Therefore, it needs technical solution to reduce this drought disaster risk. To obtain an alternative solution against water availability problem for drought disaster mitigation, this research used optimization of reservoir standard operating simulation. It applies field area of rice or *Palawija* at the second and/or the third cultivation season as decision variable, maximum productivity value as objective function, irrigation water demand as parameter depending on specified alternative crop pattern and schedule, and several constraints comprising 100% of reservoir reliability, all field is irrigated at the first and second season in which maximum non-irrigated crop field at the third cultivation season are 300 hectares. The tool used to conduct optimization was Microsoft Excel software. The result showed that crop pattern considered as an alternative solution against water availability problem in Cengklik reservoir is paddy-paddy-maize at the early of November II, cultivated over 433 hectares and 1524 hectares. Risk reduction reached 9.33% in term of reservoir reliability, 23.61% in term of irrigated area, and 27.29% in term of vulnerability towards water availability crisis.

Keywords: water availability, water requirement, and reservoir operation.

1 INTRODUCTION

Cengklik Reservoir as one of reservoirs used for food production control in Boyolali Regency has been dealt with water availability problem induced to drought disaster. Drought which has occurred for the last ten years hinders irrigating land area of 462 hectares located in downstream of division structure BCi 12 over 9 villages in 2 sub-districts. The Solopos Newspaper published on 4 April 2009 stated that 850 ha over 5 villages could not be irrigated. It caused about field area of 350 ha being neglected, while the rest which was cultivated used groundwater pumping system since no water supply from Cengklik Reservoir. The encountered risk is approximately 2.5 billion rupiahs of loss of potential productivity.

The aim of the research was to find out solution regarding to water availability problem by applying technical procedure of reservoir management so that entire Cengklik Irrigation area can be irrigated on Crop Field I and Crop Field II, and minimalize the non-irrigated area on Crop Field III.

2 STANDARD OPERATING RULE

Setiawan (2007) revealed that water release management on the multipurpose reservoir can be conducted by using standard operating rule, as seen in Figure 1.

$$R(t) = S(t) + I(t) - E(t) - DS \tag{1}$$

if $S(t) + I(t) - E(t) - DS \leq R_T$

$$R(t) = R_T \tag{2}$$

if $R_T < S(t) + I(t) - E(t) - DS \leq R_T + Kw - DS$

$$R(t) = S(t) + I(t) - E(t) - Kw \tag{3}$$

if $S(t) + I(t) - E(t) > R_T + Kw$

$$R(t) = 0 \tag{4}$$

if $S(t) + I(t) - E(t) \leq DS$

where R_T is target volume of water release (m^3), $R(t)$ is water release volume at t time (m^3), $S(t)$ is reservoir storage at t time (m^3), $I(t)$ is inflow volume at t time (m^3), $E(t)$ is water losses due to evaporation on the reservoir at t time (m^3), DS is minimum storage of reservoir (m^3), and Kw is reservoir capacity (m^3).

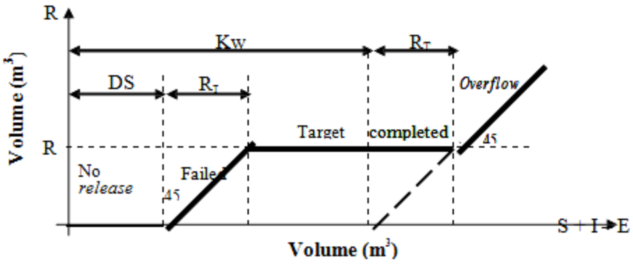

Figure 1. Standard Operating Rule.

As depicted by Figure 1, it can be explained that basically, simulation is carried out by setting trial and error value of target release (R_T) such that optimum parameter in water utilization can be obtained. Simulation of reservoir storage can be calculated by following equation.

$$S_{t+1} = S_t + I_t - E_t - O_t \quad (5)$$

$$0 \leq S_t \leq Kw$$

where t is total of discrete time (24 period in 15 days), S_{t+1} is reservoir storage at t time (m^3), S_t is reservoir storage at the end of time (m^3), I_t is inflow volume at t time (m^3), E_t is water losses due to evaporation on reservoir at t time (m^3), O_t is release/outflow volume at t time (m^3), and Kw is reservoir capacity (m^3).

In order to achieve optimum value, degree of reliability is determined as follows:

$$R = \frac{n}{N} x100\% \quad (6)$$

where R is degree of reliability (%), n is number of failed reservoir operation within half-monthly period, N is data length in half month.

Optimization is a process of activity to gain the best result which is conducted repetitively and mutually influence. The best result is indicated by the minimum or maximum value.

3 STEP OF ANALYSIS

The used data was rainfall and climatology data, irrigation network scheme, crop pattern, crop implementation, water irrigation supply, measured release discharge, and storage volume of the reservoir. There were three steps of analysis comprising water availability analysis, water irrigation demand, and water balance analysis. Water irrigation demand analysis is based on evapotranspiration yielded from climatology data analysis, combined with crop pattern, schedule, and irrigation efficiency. From the result of water availability and water demand analysis, served irrigation area can be determined whether it has been in accordance with the existing design. If the result do not fit the requirement, crop pattern and schedule will be modified. Simulation was done many times until whole area on Crop Field I and Crop Field II was served, the non-irrigated area on Crop Field III decreased which was not more than 300 ha, and gaining the maximum production result.

4 RESULTS

4.1 Characteristic of Cengklik Reservoir

The reservoir characteristic that shows the relationship among the elevation, storage capacity and inundated area is presented in Figure 2.

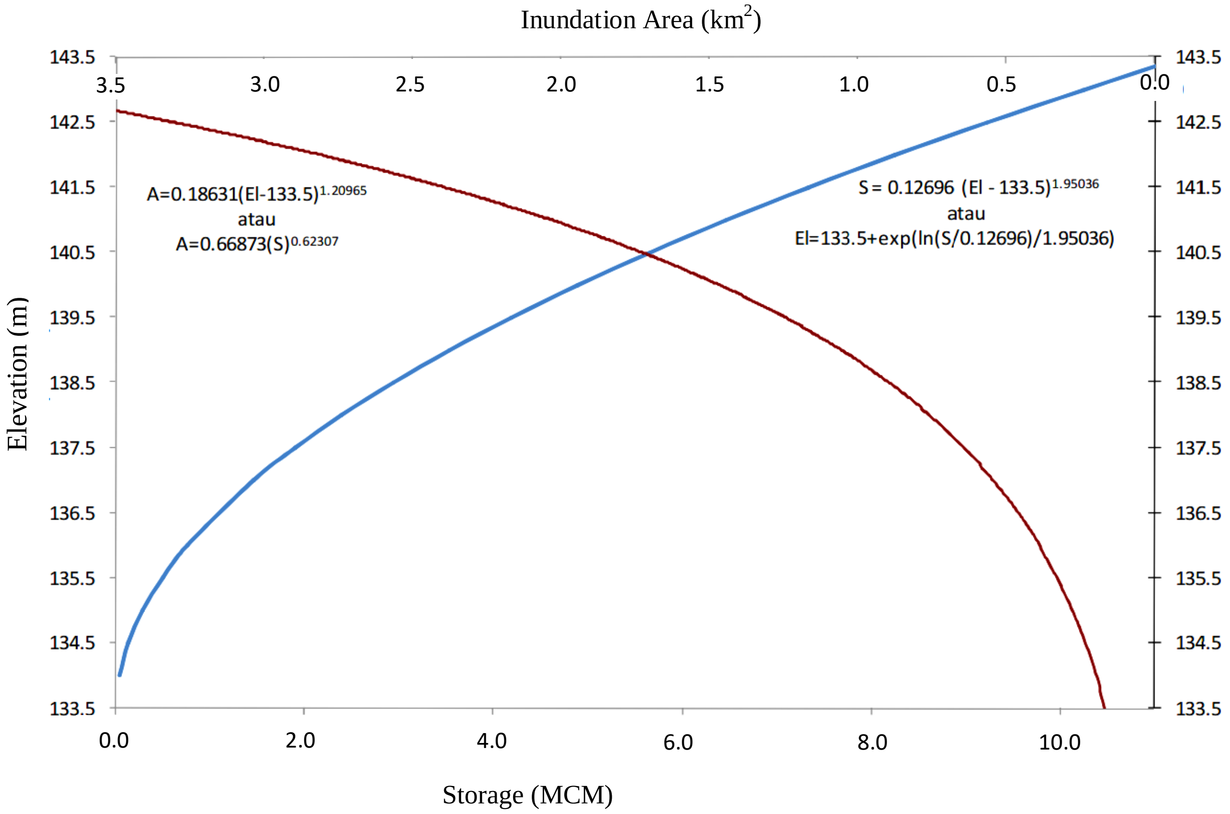

Figure 2. Characteristic of Cengklik reservoir.

4.2 Water Availability on Cengklik Reservoir

Water availability depends on the amount of inflow to the reservoir. Inflow volume is calculated based on water balance analysis. Mean inflow of half-monthly period is shown in Figure 3.

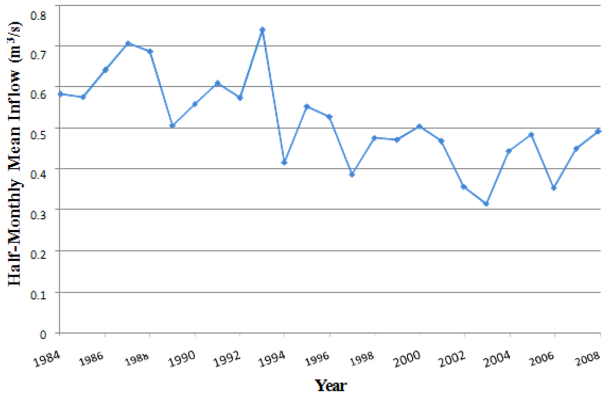

Figure 3.Half-monthly mean inflow.

Figure 3 described that crisis of water availability in Cengklik Reservoir has been occurred since 1994 indicated by declining mean inflow drastically from 0.75 m^3/s in 1993 to 0.4 m^3/s in 1994. In 1997, half-monthly mean inflow was less than 0.4 m^3/s, it caused about crop field area of 462 ha located at downstream of division structure Bci 12 was non-irrigated within 1998-1999. On the following years, half-monthly mean inflow has never reached 0.5 m^3/s (equivalent to 15.5 MCM/year), whereas it used to be surpassed in 1997.

4.3 Water Irrigation Demand

Data which was used to determine potential evaporation (*Eto*) consists of climatology data including maximum and minimum temperature, relative humidity, wind acceleration, solar radiation, and astronomy data containing elevation and location of climatology station. The results of potential evaporation analyzed using Penman Monteith method was provided in Table 1. Percolation parameter in crop field area is based on Directorate General of Irrigation (1986) which is 2 mm/day.

Effective rainfall is defined as depth of rainfall which was consumed by plants to substitute water losses due to evapotranspiration, percolation, and so on. It was calculated using mean algebra method since rainfall station surrounding the observation area is well-distributed. Effective rainfall on half-monthly period is shown in Figure 4.

Variation of water demand in cultivating paddy field is shown in Figure 5. Water demand analysis for *Palawija* was somewhat similar with the analysis of paddy field, yet for *Palawija*, it used 15 days T, and 50 mm S. Water demand variation in *Palawija* case is shown in Figure 6.

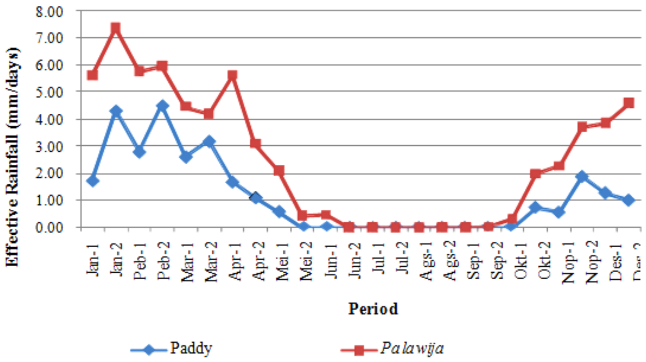

Figure 4. Effective rainfall in Cengklik Irrigation Area for paddy and *Palawija*.

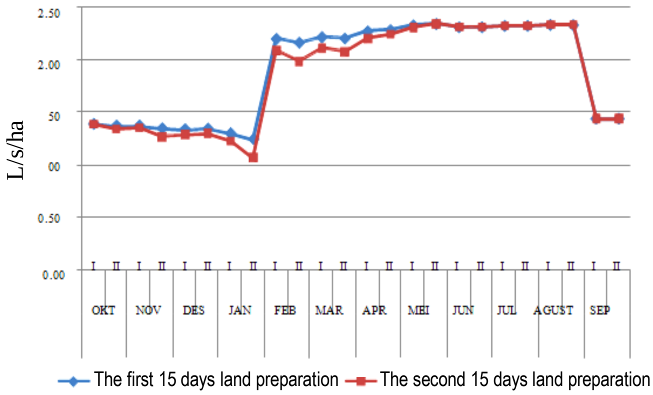

Figure 5. Water demand variation for land preparation of paddy.

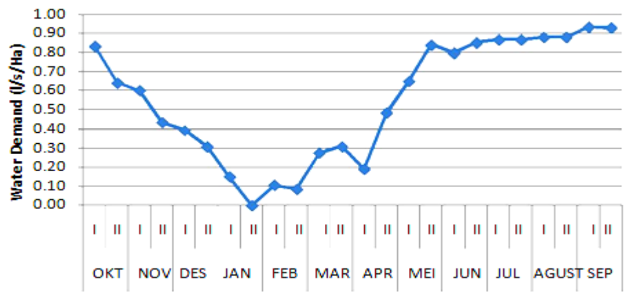

Figure 6. Water demand variation for land preparation of *Palawija*.

Table 1. Potential evaporation

	Latitude		7.5180	LS				Altitude		137.762 m		
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
ET fao	3.32	3.07	3.24	3.76	4.24	3.83	4.00	4.13	4.65	4.03	3.99	3.73

Table 2. Water demand for paddy (mm)

Period (every 2 weeks)	Kc	Month	OCT I	OCT II	NOV I	NOV II	DES I	DES II	JAN I	JAN II	FEB I	FEB II	MAR I	MAR II	APR I	APR II	MAY I	MAY II	JUN I	JUN II	JUL I	JUL II	AGT I	AGT II	SEP I	SEP II
		Eo	4.43	4.43	4.39	4.39	4.10	4.10	4.43	4.43	4.39	4.39	4.10	4.10	4.14	4.14	4.67	4.67	4.21	4.21	4.40	4.40	4.54	4.54	5.11	5.11
1	1.20	Etc = Kc x Eo	5.32	5.32	5.27	5.27	4.92	4.92	5.32	5.32	5.27	5.27	4.92	4.92	4.97	4.97	5.60	5.60	5.05	5.05	5.28	5.28	5.45	5.45	6.13	6.13
2	1.27		5.63	5.63	5.58	5.58	5.21	5.21	5.63	5.63	5.58	5.58	5.21	5.21	5.26	5.26	5.93	5.93	5.35	5.35	5.58	5.58	5.76	5.76	6.49	6.49
3	1.33		5.90	5.90	5.84	5.84	5.45	5.45	5.90	5.90	5.84	5.84	5.45	5.45	5.50	5.50	6.21	6.21	5.60	5.60	5.85	5.85	6.04	6.04	6.80	6.80
4	1.30		5.76	5.76	5.71	5.71	5.33	5.33	5.76	5.76	5.71	5.71	5.33	5.33	5.38	5.38	6.07	6.07	5.47	5.47	5.72	5.72	5.90	5.90	6.65	6.65
5	1.15		5.10	5.10	5.05	5.05	4.72	4.72	5.10	5.10	5.05	5.05	4.72	4.72	4.76	4.76	5.37	5.37	4.84	4.84	5.06	5.06	5.22	5.22	5.88	5.88
6	0.00		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.14	4.14	4.67	4.67	4.21	4.21	4.40	4.40	4.54	4.54	5.11	5.11

Table 3. Water demand for maize (mm)

Period (every 2 weeks)	Kc	Month	OCT I	OCT II	NOV I	NOV II	DES I	DES II	JAN I	JAN II	FEB I	FEB II	MAR I	MAR II	APR I	APR II	MAY I	MAY II	JUN I	JUN II	JUL I	JUL II	AGT I	AGT II	SEP I	SEP II
		Eto	4.03	4.03	3.99	3.99	3.73	3.73	3.32	3.32	3.07	3.07	3.24	3.24	3.76	3.76	4.24	4.24	3.83	3.83	4.00	4.00	4.13	4.13	4.65	4.65
1	0.5	Etc = Kc xEo	2.32	2.32	2.30	2.30	2.14	2.14	1.91	1.91	1.76	1.76	1.86	1.86	2.16	2.16	2.44	2.44	2.20	2.20	2.30	2.30	2.37	2.37	2.67	2.67
2	0.5		2.73	2.73	2.71	2.71	2.53	2.53	2.25	2.25	2.08	2.08	2.20	2.20	2.55	2.55	2.88	2.88	2.60	2.60	2.71	2.71	2.80	2.80	3.15	3.15
3	0.9		4.45	4.45	4.41	4.41	4.12	4.12	3.67	3.67	3.39	3.39	3.58	3.58	4.15	4.15	4.69	4.69	4.23	4.23	4.41	4.41	4.56	4.56	5.13	5.13
4	1.0		4.87	4.87	4.82	4.82	4.50	4.50	4.01	4.01	3.71	3.71	3.91	3.91	4.54	4.54	5.13	5.13	4.62	4.62	4.83	4.83	4.98	4.98	5.61	5.61
5	1.0		4.73	4.73	4.68	4.68	4.37	4.37	3.89	3.89	3.60	3.60	3.80	3.80	4.41	4.41	4.98	4.98	4.49	4.49	4.69	4.69	4.84	4.84	5.45	5.45
6	0.9		4.40	4.40	4.36	4.36	4.07	4.07	3.63	3.63	3.35	3.35	3.54	3.54	4.11	4.11	4.64	4.64	4.18	4.18	4.37	4.37	4.51	4.51	5.08	5.08

Table 4. Water irrigation demand

Group	Plant	Water Demand	OCT I	OCT II	NOV I	NOV II	DES I	DES II	JAN I	JAN II	FEB I	FEB II	MAR I	MAR II	OKT I	OKT II	NOV I	NOV II	DES I	DES II	JAN I	JAN II	FEB I	FEB II	MAR I	MAR II	Network Efficiency
								Paddy							Paddy							Paddy/Maize					
I	Paddy	Field	0.810	1.357	1.272	1.143	1.177	1.004	0.691	0.425	0.116	1.084	1.530	0.953	1.164	1.006	0.875	0.543	0.116	1.158	1.779	1.248	1.303	1.118	0.958	0.573	
		Intake	1.249	2.094	1.963	1.764	1.816	1.549	1.066	0.656	0.179	1.771	2.501	1.557	1.903	1.643	1.430	0.888	0.190	2.010	3.089	2.167	2.262	1.940	1.664	0.995	
	Maize	Field	0.236																	0.426	0.568	0.291	0.427	0.553	0.642	0.607	Crop Field I=
		Intake	0.410																	0.740	0.986	0.505	0.741	0.960	1.114	1.053	0,648
								Paddy							Paddy							Paddy/Maize					Crop Field II=
II	Paddy	Field	0.528	0.802	1.361	1.189	1.135	1.190	0.902	0.600	0.425	0.116	1.110	1.494	1.119	1.192	1.110	0.896	0.513	0.116	1.164	1.779	1.269	1.303	1.205	0.958	0,612
		Intake	0.916	1.238	2.101	1.834	1.752	1.836	1.392	0.926	0.655	0.179	1.813	2.441	1.828	1.947	1.814	1.463	0.838	0.190	2.021	3.089	2.202	2.262	2.092	1.664	
	Maize	Field	0.492	0.140																	0.435	0.568	0.300	0.427	0.623	0.638	Crop Field III=
		Intake	0.854	0.243																	0.755	0.986	0.521	0.741	1.082	1.107	0,576

Minimum water demand for *Palawija* was on January. Water demand during May-September was somewhat high since those were in dry season. The estimation result of crop evapotranspiration (*Etc*) in paddy case can be seen at Table 2, while for maize, it is shown in Table 3. Water layer (*Wlr*) change was given 50 mm within 1 ½ months from the first two weeks up to the third after plantation.

4.4 Planning and Realization of Crop Pattern in Cengklik Irrigation Area during 2008-2009

Water irrigation demand according to Decision Letter of Boyolali Regent No. 521/569 in 2008 for half-monthly period is given at Table 4 (Agriculture Research and Development Board, 2008), while land area planned to be cultivated is listed on Table 5. Realization of crop pattern which is used water supply from Cengklik Reservoir during 2008-2009 is shown in Table 6. Based on the water availability and crop realization data, *k* factor can be calculated which will be used for water irrigation supply analysis. Water irrigation is ratio between given discharge and total water demand within a period of time.

Table 5. Planned Crop Field (CF) area in Cengklik Irrigation Area during 2008-2009

Group	Area	CF I Paddy	CF II Paddy	CF III Paddy	Maize
I	Irobayan	112	112	100	12
	Cengklik	321	321	270	51
II	Irobayan	272	272	190	82
	Cengklik	1252	1252	471	781
Total		1957	1957	1031	926

Table 6. Realization of crop pattern in Cengklik Irrigation Area as consumer of Cengklik Reservoir during 2008-2009

Group	Area	CF I Paddy	CF II Paddy	Paddy	CF III Maize
I	Irobayan	112	112	100	12
	Cengklik	321	321	270	51
II	Irobayan	272	272	190	82
	Cengklik	790	790	471	319
Total		1495	1495	1031	464

Source: Irrigation Division on DPUPPK of Boyolali Regency and GP3A Tri Mandiri Sejahtera

Based on the interview, farmers applies intermittent water irrigation system with duration time of 2x24 hours/week. It gives *k* factor of 0.805. Water balance in Cengklik Reservoir with intermittent system, *k* is 0.805, and served area according to aforementioned Decision Letter is shown in Figure 7.

Figure 7 shows that if the existing crop pattern is implemented with the crop field area followed Decision Letter of the Regent, it may deal with drought disaster which causes failed in harvesting time. It is indicated by the amount of potential release which is less than target release. It can be found in 4th year thru 10th year on the above graph.

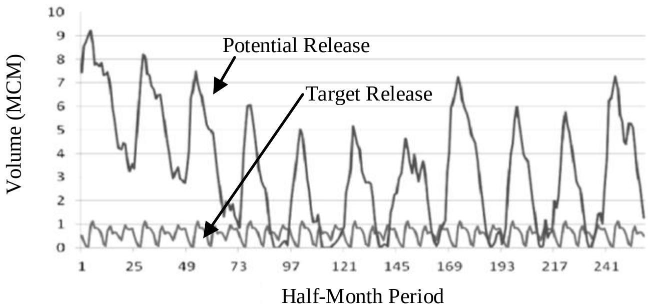

Figure 7. Water balance in Cengklik Reservoir with intermittent system, *k*=0.805, served area = 1,957 ha per Crop Field.

4.5 Optimization

Evaluation towards crop field plan was conducted by applying several alternative patterns in order to reduce the amount of water demand. The following patterns were proposed as alternative patterns:

a) Rain fed paddy– Paddy – Paddy/*Palawija*
b) Paddy – Paddy – Paddy/*Palawija*
c) Paddy – Paddy – *Palawija*
d) Paddy – Paddy/ *Palawija – Palawija*

Kind of *Palawija* used in this study was maize since it only needs small amount of water so that it was considered adaptive for drought disaster mitigation. Water demand of each alternative crop patterns were determined by using different initial time of Crop Field I:

a) October, first half-month
b) October, second half-month
c) November, first half-month
d) November, second half-month

Optimization was carried out by using Microsoft Excel software. To know the feasibility of alternative crop pattern, monthly rainfall and ten daily rainfall should be examined as shown in Table 7 and Table 8. Table 7 shows that the highest rainfall is 165 mm/month occurred on January, so that no wet month indicated in this irrigation area. From Table 8, it can be seen that the third week on January is the right time to conduct plantation in rain fed, yet productivity of paddy become very small because of low rainfall probability at ripening period.

Table 7. Monthly rainfall

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Des
$R_{monthly}$	165.0	144.0	144.0	77.5	36.0	0.0	0.0	0.0	0.0	23.0	80.0	104.0

Table 8. Ten daily rainfall

Period	Jan			Feb			Mar			Apr			May			Jun		
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
R_{10days}	35	27	70	44	45	39	40	38	36	31	26	8	9	0	0	0	0	0
Period	Jul			Aug			Sep			Oct			Nov			Des		
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
R_{10days}	0	0	0	0	0	0	0	0	0	0	0	11	2	26	15	18	14	7

Table 9. Recapitulation of the optimization results of crop pattern and schedule

Crop Pattern Alternative	Initial Crop Field I	Area (ha)				Non-irrigated Area (ha)	Production Cost (Rp 000)
Paddy-Paddy Paddy/Maize	October I	Crop Field I	Gol I	Paddy	433	0	68,962,564.00
		Crop Field II	Gol II	Paddy	1,524	0	
			Gol I	Paddy	433	0	
			Gol II	Paddy	1,524	0	
		Crop Field III	Gol I	Paddy	190	52	
				Maize	191		
			Gol II	Paddy	191	1,142	
				Maize	191		
	October II	Crop Field I	Gol I	Paddy	433	0	69,237,018.40
			Gol II	Paddy	1,524	0	
		Crop Field II	Gol I	Paddy	433	0	
			Gol II	Paddy	1,524	0	
		Crop Field III	Gol I	Paddy	196	40	
				Maize	197		
			Gol II	Paddy	197	1.13	
				Maize	197		
	November I	Crop Field I	Gol I	Paddy	433	0	69,801,318.40
			Gol II	Paddy	1,524	0	
		Crop Field II	Gol I	Paddy	433	0	
			Gol II	Paddy	1,524	0	
		Crop Field III	Gol I	Paddy	209	15	
				Maize	209		
			Gol II	Paddy	209	1,106	
				Maize	209		
	November II	Crop Field I	Gol I	Paddy	433	0	71,493,787.20
			Gol II	Paddy	1,524	0	
		Crop Field II	Gol I	Paddy	433	0	
			Gol II	Paddy	1,524	0	
		Crop Field III	Gol I	Paddy	216	1	
				Maize	216		
			Gol II	Paddy	276	972	
				Maize	276		
Paddy-Paddy-Maize	October I	Crop Field I	Gol I	Paddy	433	0	69,463,996.80
			Gol II	Paddy	1,524	0	
		Crop Field II	Gol I	Paddy	433	0	
			Gol II	Paddy	1,524	0	
		Crop Field III	Gol I	Maize	433	724	
				Maize	800		

Table 9. Recapitulation of the optimization results of crop pattern and schedule (continued)

Crop Pattern Alternative	Initial Crop Crop Field I	Area (Ha)				Non-irrigated Area (ha)	Production Cost (Rp 000)
Paddy-Paddy-Maize	October II	Crop Field I	Gol I	Paddy	433	0	70,316,716.80
			Gol II	Paddy	1,524	0	
		Crop Field II	Gol I	Paddy	433	0	
			Gol II	Paddy	1,524	0	
		Crop Field III	Gol I	Maize	433	610	
				Maize	914		
	November I	Crop Field I	Gol I	Paddy	433	0	72,141,836.80
			Gol II	Paddy	1,524	0	
		Crop Field II	Gol I	Paddy	433	0	
			Gol II	Paddy	1,524	0	
		Crop Field III	Gol I	Maize	433	366	
				Maize	1,158		
	November II	Crop Field I	Gol I	Paddy	433	0	74,879,516.80
			Gol II	Paddy	1,524	0	
		Crop Field II	Gol I	Paddy	433	0	
			Gol II	Paddy	1,524	0	
		Crop Field III	Gol I	Maize	433	0	
				Maize	1,524		
Paddy-Paddy/Maize-Maize	October I	Crop Field I	Gol I	Paddy	433	0	66,952,752.80
			Gol II	Paddy	1,524	0	
		Crop Field II	Gol I	Paddy	258	0	
				Maize	175	0	
			Gol II	Paddy	804	0	
				Maize	720		
		Crop Field III	Gol I	Maize	433	0	
			Gol II	Maize	1,411	113	
	October II	Crop Field I	Gol I	Paddy	433	0	71,287,832.00
			Gol II	Paddy	1,524	0	
		Crop Field II	Gol I	Paddy	433	0	
				Maize	0	0	
			Gol II	Paddy	1,07	0	
				Maize	454		
		Crop Field III	Gol I	Maize	433	0	
			Gol II	Maize	1,524	0	
	November I	Crop Field I	Gol I	Paddy	433	0	72,925,450.40
			Gol II	Paddy	1,524	0	
		Crop Field II	Gol I	Paddy	433	0	
				Maize	0	0	
			Gol II	Paddy	1,277	0	
				Maize	247		
		Crop Field III	Gol I	Maize	433	0	
			Gol II	Maize	1,524	0	

The next step is estimate water irrigation demand for alternative 2, 3, and 4 at the early of Crop Field I which is used as one of optimization parameter. Required components to conduct simulation are as follows:

a) Decision variables: crop field area at each group in Crop Field II and/or Crop Field III in which paddy or maize will be cultivated, and it is denoted by the initial name of each group, for instance Jg3I represents crop field area which is planned to cultivate maize at Crop Field III group I,
b) Objective function: maximizing productivity on Crop Field II and/or Crop Field III, for productivity of paddy and maize which are 5,830 kg GKP; 3,400 kg JPK; and price of the product per kg Rp 2,640.00 and Rp 2,200.00, respectively.
c) Constraint: several limitation which should be followed in determining decision variable, comprises several criteria, such as crop field area should be in positive in which maximum value is total area of each groups, 433 ha and 1,524 ha,

reliability of reservoir or 100% of probability is succeed, and total non-irrigated area on Crop Field I and Crop Field II is 0 Ha, while maximum Crop Field III is 300 ha.

Recapitulation of the optimization results for each alternative combinations is provided in Table 9. It shows that Paddy-Paddy-Paddy/Maize crop pattern which has been applied to mitigate drought disaster is not relevant with the current condition since there is 975-1200 ha non-irrigated area at Crop Field III. The most optimum design is shown by crop pattern of Paddy-Paddy-Maize at Crop Field I on November II in which whole field area can be irrigated and has the higher productivity, Rp 74,879,516,800.00.

4.6 Drought Disaster Mitigation

The effect of mitigation effort which is gained by several modification of crop pattern and schedule is presented at Table 10.

Table 10. Drought disaster mitigation by modifying crop pattern and schedule

Parameter			Risk Level (%)		Risk mitigation (%)
Reliability (%)	Before modification	90.67	Before modification	9.33	9.33
	After modification	100.00	After modification	0.00	
Supplied area with 100% of reliability (ha/year)	Before modification	4,485	Before modification	23.61	23.61
	After modification	5,871	After modification	0.00	
Annual volume of dam (MCM)	Before water crisis	18.80	Before modification	27.29	27.29
	After water crisis	13.67	After modification	0.00	

5 CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

There are some conclusions can be summarized as follows:

a) Water irrigation supply in Cengklik Reservoir applies intermittent system with allocation of water 2x24 hours/weeks/terraces, *k* = 0.805
b) Reservoir operation simulated based on Regent's Agreement Letter No. 521/569 in 2008 using Paddy-Paddy-Paddy/Maize crop pattern yields irrelevant result with the current condition since about 975 - 1200 ha area is non-irrigated for achieving 200% reliability at Crop Field III.
c) Paddy-Paddy-Maize at Crop Field I on November II provides the most optimum result for drought disaster mitigation. Productivity value per year reaches Rp 74,879,516,800.00.
d) Risk mitigation has been achieved through modification of crop pattern and schedule is approximately 9.33% in term of reservoir reliability, 23.61% in term of irrigated area, and 27.29% in term of vulnerability.

5.2 Recommendations

Some recommendations necessary to consider for the further research are as follows:

a) Regent's Agreement Letter about crop pattern and design is necessary to re-evaluate in order to make more adaptive to overcome the risk of drought disaster.
b) Paddy-Paddy-Maize applied at Crop Field I, November II is considered to be alternative solution against the lack of water availability in Cengklik Reservoir
c) Sedimentation on Cenglik Reservoir should be controlled.
d) Irrigation network served by Cenglik Reservoir should be maintained regularly to avoid decent of network efficacy.

6 REFERENCES

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