International Journal of Latest Engineering Research and Applications (IJLERA) ISSN: 2455-7137

Volume – 04, Issue – 04, April 2019, PP – 11-26

Comparison of Rules for Reservoir Operation Patterns Based on Needs, Based on Storage (Genetic Algorithms) for Tanju Reservoir Optimization

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Abstract: The drought (water crisis) in several reservoirs that have been built, arises due to the ineffectiveness of the reservoir operation pattern and the need for water is not linear (linear) with the water availability (inflow). There are several rules that are used as the basis of reservoir operation patterns, namely the rules of operation based on needs and based on storage, limitations in existing operating patterns (needs), generally occur in cases of reservoirs that have no large water availability and fluctuating characteristics of the inflow, consequently the reservoirs frequently go through emptiness and decreased needs, as an example of a reservoir that needs to be optimized is the Tanju Reservoir in Dompu District. The formulation of the problem in this study is to conduct simulation and compare the results of the pattern of reservoir operations with rules based on needs, based on storage and optimization of genetic algorithms. The purpose and benefits of making simulations and comparing the best value of reservoir operation patterns with certain rules with certain inflow conditions is to provide alternative release guidelines so that the fulfillment of Tanju Reservoir needs is more optimal. The method applied in the reservoir operation pattern is the rules based on needs, based on storage and based on optimized storage with genetic algorithms for inflow conditions of wet discharge (Q_{20}), normal discharge (Q_{50}) and dry discharge (Q_{80}). From the calculation of the best value for wet discharge conditions (Q_{20}) is a rule based on needs, normal discharge (Q_{50}), is a rule based on needs and dry discharge (Q_{80}) is a rule based on the storage optimized with genetic algorithms.

Kata kunci: drought reservoir, Simulation of Reservoir Operation Pattern, Rules based on Needs, Rules based on Storage, Optimization of Genetic Algorithms.

Preface

The increasing development of national water resources will result in sustainable and effective management efforts. One of the many water resources infrastructures that are currently built is dams or reservoirs. Looking at some places, problems arise which disturb the performance of the reservoir, one of which is the drought of the reservoir. This problem is something that is often experienced due to the ineffectiveness of the operation pattern of a reservoir. In addition, the increasing demand for water, even uncontrolled, also adds to the frequent occurrence of water vacancies in reservoirs, and this is because water needs are not linear with the availability of water (inflow).

There are a number of rules that are used as the basis of the reservoir operation pattern in addition to using simple operating rules (requirements) also based on reservoir storage (Soetopo, 2010: 25). Generally, the current reservoir operation pattern utilizes simple operating rules (needs), limitations in existing operating patterns (needs) generally occur in the case of reservoirs that do not have large water availability and fluctuating characteristics of the inflow, consequently, reservoirs often experience vacuity and decreased fulfillment of needs, so that it has a significant effect on the pattern of reservoir operations.

With the existence of several issues and problems above, an alternative and best value comparison is needed with several structured, careful and accurate rules, resulting in an optimal pattern of reservoir operations. One example of a reservoir that needs to be optimized with the characteristic problem described above is the Tanju Reservoir in Dompu District.

The formulation of the problem in this study is to simulate operational patterns based on needs, based on storage, optimization of genetic algorithms and compare the results of the simulation pattern of operations with indicators of the level of fulfillment of needs in the Tanju Dam.

The purpose and benefit of this research is to simulate and compare the best value of reservoir operation patterns with several rules with certain inflow conditions so as to provide an alternative guide to meet the needs of the Tanju Reservoir to be more optimal.

Methodology

Research Sites

One area in Dompu Regency that has considerable potential to be developed is the Rababaka Complex, where geographically the area is located between 118^0 14 '- 118^0 27' East Longitude and 8^0 28 '- 8^0 36' South Latitude.

This study will only specifically discuss the Tanju Reservoir, which is one of the locations for the development of Rababaka Complex, the location of research and the framework of the Rababaka irrigation development system Complex can be seen in Figure 1 and 2 below:

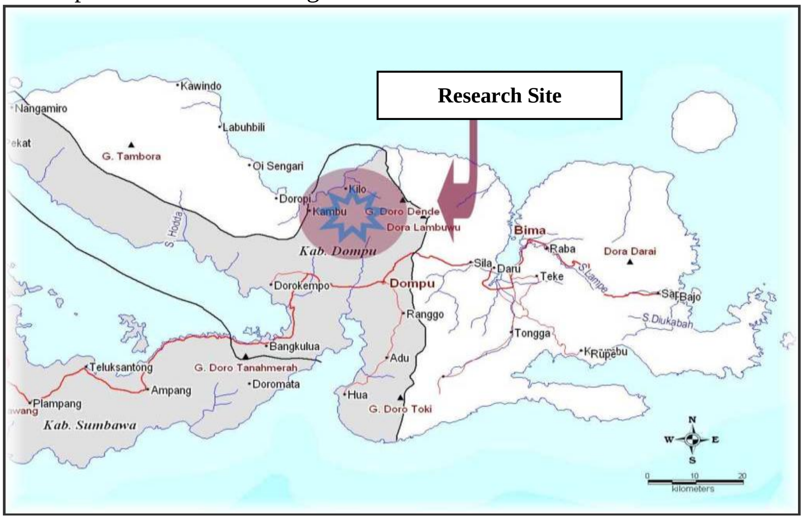

Figure 1. Research Site
Source: Nusa Tenggara River Region I, (2008)

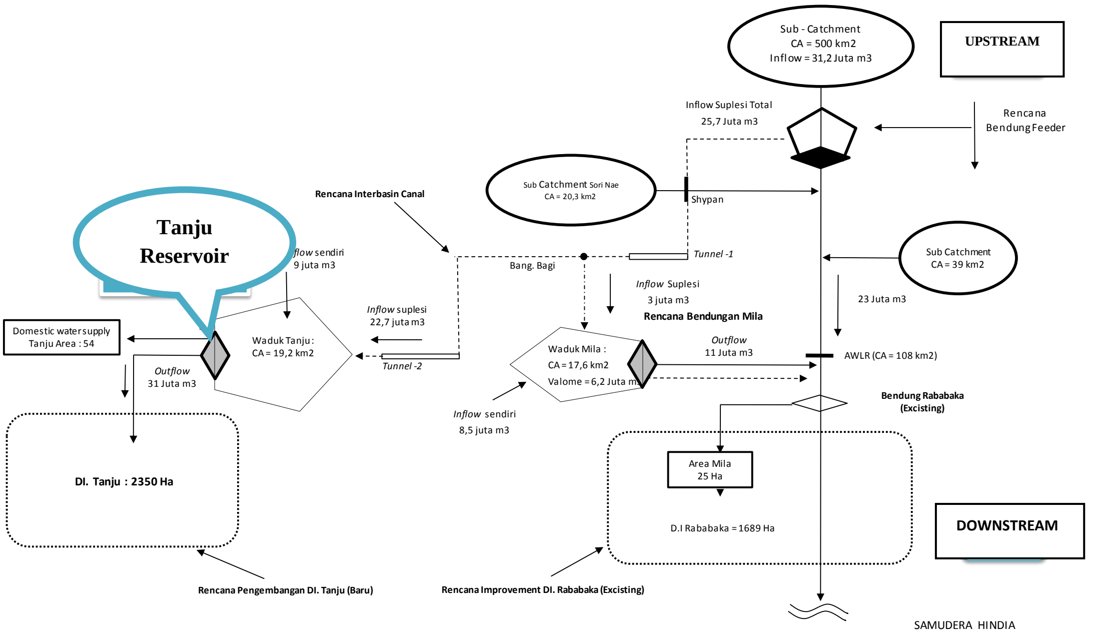

Figure 2. Scheme of Rababaka Complex irrigation development system
Source: Nusa Tenggara River Region I, (2008)

Data Collection

The data used is secondary data, including:

1. Data on Tanju Reservoir Inflow
2. Data on the Characteristics of the Tanju Reservoir
3. Water loss data (evaporation and seepage) of the Tanju Reservoir
4. Data on irrigation and basic water needs of the Tanju Reservoir

Data Processing

Broadly speaking, the work steps in this study are as follows:

1. Simulation of Reservoir Operation Pattern Based on Needs
   After mainstay debit data, water loss data, reservoir characteristics data, and water demand data are known, then, reservoir simulation is carried out based on needs.
2. Simulation of Reservoir Operation Pattern Based on Storage
   After mainstay debit data, water loss data, reservoir characteristics data, and water demand data are known, then reservoir simulation is carried out based on the storage.
3. Simulation of Tanju Reservoir Operation Pattern with Genetic Algorithm Model
   This stage is a process of release optimization based on storage with genetic algorithm method, based on the formulation of parameters of the objective function and applied predetermined function. From the results of optimization using the genetic algorithm method will produce optimal release based on reservoir storage for irrigation and basic water purposes. The stages in the genetic algorithm method are as follows:

   - **Population Initialization**
     Population Initialization aims at generating an initial population of chromosomes stochastically from parameters. This chromosome population is the first generations whose number and value are determined based on parameters and have a predetermined limit value.
   - **Selection**
     From the results of the first generation a selection was made to get a population with a ranking of the work values on each chromosome. The top population will be chosen to get the next generation.
   - **Crossover (Interbreeding)**
     The crossover process aims to improve the quality of chromosomes. The crossover process is interbreeding from previous chromosome selection results. Hence, the chromosome population is regained based on the results of the crossover. The population of the chromosomes produced by this crossover has better performance values than the chromosomes before.
   - **Clarification**
     Clarification is the determination of when the crossover process stops. The cessation of a series of processes from this genetic algorithm is carried out if the crossover process produces a homogeneous population. Due to the continuation of the iteration, there is less improvement in the crossover process between a pair of chromosomes. The conclusion is to stop when one type of chromosome has been dominated. This top ranking will be used as an optimized outflow debit.
4. Comparison of results of Reservoir Operation Patterns Based on Needs, Based on storage and optimized with Genetic Algorithms. The result of each rule is compared and the best value (optimal) will emerge with the criteria for meeting needs.

Results and Discussion

In calculating the reservoir pattern operation rules based on needs, rules based on storage and genetic algorithm rules set behavior as follows:

1. Performed under conditions of wet debit (Q20), normal debit (Q50), dry debit (Q80).
2. The reservoir operation is based on the balance between the inflow and outflow, considering the loss of reservoir water.
3. The initial simulation is carried out when the reservoir is in full condition.
4. Early planting is done in November 2nd period.

Simulation of Tanju Reservoir Operation Pattern Based on Needs

The calculation results of the reservoir operation pattern are based on the following requirements

International Journal of Latest Engineering Research and Applications (IJLERA) ISSN: 2455-7137

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Table 1. Simulation of reservoir operations based on wet debit requirements (Q_{20})

Area of irrigation	=	**2350**	Ha
Effective reservoir storage	=	17.000.000	m^2
Dead storage reservoir	=	1.370.000	m^3
Total storage:	=	18.370.000	m^3
Total storage elevation	=	120,0	m
Low water elevation	=	111,5	m

No	Month	Period	Total	*S* initial	Initial Elevation	*A*	*Inflow*		Water Needs				Losing Water				*Outflow*	*Total Needs*	*Outfow*	*I - O*	*(S +(I - O - E - R))*	*Spill out*	*S* final	*S* final	Final Elevation
									Irrigation			Raw Water	Evaporation		Seepage										
			(day)	(milions m^3)	(m)	(ha)	(m^3/sc)	(mil m^3)	(lt/sc/ha)	(m^3/sc)	(mil m^3)	(mil m^3)	(mm/day)	(mil m^3)	(m^3/day)	(mil m^3)	%	(mil m^3)	(mil m^3)	(mil m^3)	(mil m^3)	(mil m^3)	(mil m^3)	%	(m)
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
				17,00																			**17,00**	**100,00**	
1	Nop	2	15	**17,00**	120,00	296,30	1,29	1,67	0,31	0,73	0,94	0,07	6,26	0,28	0,01	0,00	100,00	***1,01***	***1,01***	0,65	17,37	0,37	17,00	100,00	120,00
2	Des	1	15	17,00	120,00	296,30	3,53	4,57	0,86	2,02	2,62	0,07	4,87	0,22	0,01	0,00	100,00	***2,69***	***2,69***	1,89	18,67	1,67	17,00	100,00	120,00
3		2	15	17,00	120,00	296,30	4,41	5,71	1,15	2,70	3,50	0,08	4,87	0,22	0,01	0,00	100,00	***3,58***	***3,58***	2,13	18,92	1,92	17,00	100,00	120,00
4	Jan	1	15	17,00	120,00	296,30	1,38	1,79	1,41	3,31	4,29	0,07	4,63	0,21	0,01	0,00	100,00	***4,36***	***4,36***	-2,57	14,22	0,00	14,22	83,65	118,94
5		2	15	14,22	118,94	266,85	1,92	2,49	1,20	2,82	3,65	0,08	4,63	0,19	0,01	0,00	100,00	***3,73***	***3,73***	-1,24	12,80	0,00	12,80	75,29	118,39
6	Feb	1	15	12,80	118,39	251,79	2,21	2,86	1,08	2,54	3,29	0,07	4,65	0,18	0,01	0,00	100,00	***3,36***	***3,36***	-0,50	12,12	0,00	12,12	71,31	118,14
7		2	15	12,12	118,14	244,61	2,02	2,61	1,24	2,91	3,78	0,08	4,65	0,17	0,01	0,00	100,00	***3,85***	***3,85***	-1,24	10,71	0,00	10,71	63,02	117,60
8	Mar	1	15	10,71	117,60	229,69	2,98	3,86	1,03	2,42	3,14	0,07	4,98	0,17	0,01	0,00	100,00	***3,21***	***3,21***	0,65	11,19	0,00	11,19	65,84	117,78
9		2	15	11,19	117,78	234,76	3,64	4,72	0,74	1,74	2,25	0,08	4,98	0,18	0,01	0,00	100,00	***2,33***	***2,33***	2,39	13,40	0,00	13,40	78,85	118,63
10	Apr	1	15	13,40	118,63	258,20	3,58	4,63	0,35	0,82	1,07	0,07	5,37	0,21	0,01	0,00	100,00	***1,14***	***1,14***	3,50	16,69	0,00	16,69	98,20	119,88
11		2	15	16,69	119,88	293,06	2,18	2,82	0,24	0,56	0,73	0,08	5,37	0,24	0,01	0,00	100,00	***0,81***	***0,81***	2,02	18,47	1,47	17,00	100,00	120,00
12	Mei	1	15	17,00	120,00	296,30	1,50	1,94	0,30	0,71	0,91	0,07	5,20	0,23	0,01	0,00	100,00	***0,98***	***0,98***	0,95	17,72	0,72	17,00	100,00	120,00
13		2	15	17,00	120,00	296,30	1,46	1,90	0,45	1,06	1,37	0,08	5,20	0,23	0,01	0,00	100,00	***1,45***	***1,45***	0,45	17,22	0,22	17,00	100,00	120,00
14	Jun	1	15	17,00	120,00	296,30	1,27	1,64	0,50	1,18	1,52	0,07	5,17	0,23	0,01	0,00	100,00	***1,59***	***1,59***	0,05	16,82	0,00	16,82	98,95	119,93
15		2	15	16,82	119,93	294,40	1,16	1,51	0,55	1,29	1,68	0,08	5,17	0,23	0,01	0,00	100,00	***1,75***	***1,75***	-0,24	16,35	0,00	16,35	96,18	119,75
16	Jul	1	15	16,35	119,75	289,42	1,08	1,40	0,49	1,15	1,49	0,07	5,82	0,25	0,01	0,00	100,00	***1,56***	***1,56***	-0,16	15,94	0,00	15,94	93,75	119,59
17		2	15	15,94	119,59	285,03	1,05	1,36	0,33	0,78	1,01	0,08	5,82	0,25	0,01	0,00	100,00	***1,08***	***1,08***	0,28	15,97	0,00	15,97	93,92	119,60
18	Agu	1	15	15,97	119,60	285,35	0,97	1,26	0,27	0,63	0,82	0,07	6,37	0,27	0,01	0,00	100,00	***0,89***	***0,89***	0,37	16,06	0,00	16,06	94,48	119,64
19		2	15	16,06	119,64	286,35	0,97	1,26	0,35	0,82	1,07	0,08	6,37	0,27	0,01	0,00	100,00	***1,14***	***1,14***	0,12	15,91	0,00	15,91	93,58	119,58
20	Sep	1	15	15,91	119,58	284,74	0,78	1,01	0,53	1,25	1,61	0,07	6,64	0,28	0,01	0,00	100,00	***1,68***	***1,68***	-0,68	14,95	0,00	14,95	87,92	119,22
21		2	15	14,95	119,22	274,54	0,77	0,99	0,30	0,71	0,91	0,08	6,64	0,27	0,01	0,00	100,00	***0,99***	***0,99***	0,00	14,68	0,00	14,68	86,34	119,11
22	Okto	1	15	14,68	119,11	271,69	0,78	1,01	0,20	0,47	0,61	0,07	7,68	0,31	0,01	0,00	100,00	***0,68***	***0,68***	0,33	14,70	0,00	14,70	86,45	119,12
23		2	15	14,70	119,12	271,89	1,21	1,57	0,00	0,00	0,00	0,08	7,68	0,31	0,01	0,00	100,00	***0,08***	***0,08***	1,50	15,88	0,00	15,88	93,41	119,57
24	Nov	1	15	15,88	119,57	284,43	1,33	1,72	0,00	0,00	0,00	0,07	6,26	0,27	0,01	0,00	100,00	***0,07***	***0,07***	1,65	17,27	0,27	**17,00**	**100,00**	120,00

Source: Analysis of 2019

Table 2. Simulation of reservoir operations based on normal debit requirements (Q_{50})

Area of irrigation	=	**2350**	Ha
Effective reservoir storage	=	17.000.000	m^2
Dead storage reservoir	=	1.370.000	m^3
Total storage:	=	18.370.000	m^3
Total storage elevation	=	120,0	m
The elevation of low water table	=	111,5	m

No	Month	Period	Total	*S* initial	Initial Elevation	*A*	*Inflow*		Water Needs				Losing Water				*Outflow*	*Total Needs*	*Outfow*	*I - O*	*(S +(I - O - E - R))*	*Spill out*	*S* final	*S* final	Final Elevation
									Irrigation			Raw Water	Evaporation		Seepage										
			(day)	(milions m^3)	(m)	(ha)	(m^3/sc)	(mil m^3)	(lt/sc/ha)	(m^3/sc)	(mil m^3)	(mil m^3)	(mm/day)	(mil m^3)	(m^3/day)	(mil m^3)	%	(mil m^3)	(mil m^3)	(mil m^3)	(mil m^3)	(mil m^3)	(mil m^3)	%	(m)
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
				17,00																			**17,00**	**100,00**	
1	Nop	2	15	**17,00**	119,48	281,77	0,86	1,12	0,31	0,73	0,94	0,07	6,26	0,26	0,01	0,00	100,00	***1,01***	***1,01***	0,11	16,84	0,00	16,84	99,07	119,42
2	Des	1	15	16,84	119,42	280,10	0,97	1,26	0,86	2,02	2,62	0,07	4,87	0,20	0,01	0,00	100,00	***2,69***	***2,69***	-1,43	15,21	0,00	15,21	89,47	118,79
3		2	15	15,21	118,79	262,80	1,08	1,40	1,15	2,70	3,50	0,08	4,87	0,19	0,01	0,00	100,00	***3,58***	***3,58***	-2,18	12,84	0,00	12,84	75,54	117,89
4	Jan	1	15	12,84	117,89	237,72	1,35	1,75	1,41	3,31	4,29	0,07	4,63	0,17	0,01	0,00	100,00	***4,36***	***4,36***	-2,61	10,06	0,00	10,06	59,20	116,58
5		2	15	10,06	116,58	201,60	1,72	2,23	1,20	2,82	3,65	0,08	4,63	0,14	0,01	0,00	100,00	***3,73***	***3,73***	-1,50	8,42	0,00	8,42	49,54	115,73
6	Feb	1	15	8,42	115,73	177,97	2,76	3,58	1,08	2,54	3,29	0,07	4,65	0,12	0,01	0,00	100,00	***3,36***	***3,36***	0,22	8,52	0,00	8,52	50,11	115,78
7		2	15	8,52	115,78	179,37	2,29	2,97	1,24	2,91	3,78	0,08	4,65	0,13	0,01	0,00	100,00	***3,85***	***3,85***	-0,88	7,51	0,00	7,51	44,20	115,26
8	Mar	1	15	7,51	115,26	164,91	1,82	2,36	1,03	2,42	3,14	0,07	4,98	0,12	0,01	0,00	100,00	***3,21***	***3,21***	-0,85	6,54	0,00	6,54	38,47	114,70
9		2	15	6,54	114,70	152,44	2,33	3,02	0,74	1,74	2,25	0,08	4,98	0,11	0,01	0,00	100,00	***2,33***	***2,33***	0,70	7,12	0,00	7,12	41,90	115,05
10	Apr	1	15	7,12	115,05	159,28	1,64	2,12	0,35	0,82	1,07	0,07	5,37	0,13	0,01	0,00	100,00	***1,14***	***1,14***	0,99	7,98	0,00	7,98	46,96	115,50
11		2	15	7,98	115,50	171,65	1,24	1,61	0,24	0,56	0,73	0,08	5,37	0,14	0,01	0,00	100,00	***0,81***	***0,81***	0,81	8,65	0,00	8,65	50,89	115,85
12	Mei	1	15	8,65	115,85	181,26	0,97	1,26	0,30	0,71	0,91	0,07	5,20	0,14	0,01	0,00	100,00	***0,98***	***0,98***	0,27	8,78	0,00	8,78	51,67	115,92
13		2	15	8,78	115,92	183,17	0,93	1,20	0,45	1,06	1,37	0,08	5,20	0,14	0,01	0,00	100,00	***1,45***	***1,45***	-0,24	8,40	0,00	8,40	49,40	115,72
14	Jun	1	15	8,40	115,72	177,63	0,85	1,11	0,50	1,18	1,52	0,07	5,17	0,14	0,01	0,00	100,00	***1,59***	***1,59***	-0,49	7,78	0,00	7,78	45,74	115,39
15		2	15	7,78	115,39	168,67	0,81	1,04	0,55	1,29	1,68	0,08	5,17	0,13	0,01	0,00	100,00	***1,75***	***1,75***	-0,71	6,94	0,00	6,94	40,81	114,95
16	Jul	1	15	6,94	114,95	156,89	0,76	0,98	0,49	1,15	1,49	0,07	5,82	0,14	0,01	0,00	100,00	***1,56***	***1,56***	-0,58	6,22	0,00	6,22	36,59	114,50
17		2	15	6,22	114,50	148,85	0,79	1,02	0,33	0,78	1,01	0,08	5,82	0,13	0,01	0,00	100,00	***1,08***	***1,08***	-0,06	6,03	0,00	6,03	35,49	114,39
18	Agu	1	15	6,03	114,39	146,77	0,69	0,90	0,27	0,63	0,82	0,07	6,37	0,14	0,01	0,00	100,00	***0,89***	***0,89***	0,01	5,90	0,00	5,90	34,70	114,31
19		2	15	5,90	114,31	145,26	0,66	0,86	0,35	0,82	1,07	0,08	6,37	0,14	0,01	0,00	100,00	***1,14***	***1,14***	-0,28	5,48	0,00	5,48	32,24	114,05
20	Sep	1	15	5,48	114,05	140,57	0,60	0,78	0,53	1,25	1,61	0,07	6,64	0,14	0,01	0,00	100,00	***1,68***	***1,68***	-0,90	4,44	0,00	4,44	26,10	113,40
21		2	15	4,44	113,40	128,91	0,58	0,75	0,30	0,71	0,91	0,08	6,64	0,13	0,01	0,00	100,00	***0,99***	***0,99***	-0,24	4,07	0,00	4,07	23,97	113,18
22	Okto	1	15	4,07	113,18	124,85	0,59	0,76	0,20	0,47	0,61	0,07	7,68	0,14	0,01	0,00	100,00	***0,68***	***0,68***	0,08	4,01	0,00	4,01	23,61	113,14
23		2	15	4,01	113,14	124,18	0,70	0,91	0,00	0,00	0,00	0,08	7,68	0,14	0,01	0,00	100,00	***0,08***	***0,08***	0,84	4,71	0,00	4,71	27,70	113,57
24	Nov	1	15	4,71	113,57	131,96	0,71	0,92	0,00	0,00	0,00	0,07	6,26	0,12	0,01	0,00	100,00	***0,07***	***0,07***	0,85	5,44	0,00	**5,44**	**31,99**	114,02

Source: Analysis of 2019

Table 3. Simulation of reservoir operations based on dry debit requirements (Q_{80})

Area of irrigation	=	**2350**	Ha
Effective reservoir storage	=	17.000.000	m^2
Dead storage reservoir	=	1.370.000	m^3
Total storage:	=	18.370.000	m^3
Total storage elevation	=	120,0	m
The elevation of low water table	=	111,5	m

No	Month	Period	Total	*S* initial	Initial Elevation	*A*	*Inflow*		Water Needs				Losing Water				*Outflow*	*Total Needs*	*Outfow*	*I - O*	*(S +(I - O - E - R))*	*Spill out*	*S* final	*S* final	Final Elevation
									Irrigation			Raw Water	Evaporation		Seepage										
			(day)	(milions m^3)	(m)	(ha)	(m^3/sc)	(mil m^3)	(lt/sc/ha)	(m^3/sc)	(mil m^3)	(mil m^3)	(mm/day)	(mil m^3)	(m^3/day)	(mil m^3)	%	(mil m^3)	(mil m^3)	(mil m^3)	(mil m^3)	(mil m^3)	(mil m^3)	%	(m)
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
				17,00																			17,00	100,00	
1	Nop	2	15	17,00	120,00	296,30	0,57	0,74	0,31	0,73	0,94	0,07	6,26	0,28	0,01	0,00	100,00	1,01	1,01	-0,27	16,45	0,00	16,45	96,78	119,79
2	Des	1	15	16,45	119,79	290,49	0,85	1,10	0,86	2,02	2,62	0,07	4,87	0,21	0,01	0,00	100,00	2,69	2,69	-1,59	14,65	0,00	14,65	86,19	119,10
3		2	15	14,65	119,10	271,42	0,68	0,89	1,15	2,70	3,50	0,08	4,87	0,20	0,01	0,00	100,00	3,58	3,58	-2,69	11,76	0,00	11,76	69,18	118,00
4	Jan	1	15	11,76	118,00	240,79	0,55	0,71	1,41	3,31	4,29	0,07	4,63	0,17	0,01	0,00	100,00	4,36	4,36	-3,66	7,94	0,00	7,94	46,68	116,19
5		2	15	7,94	116,19	190,69	0,66	0,86	1,20	2,82	3,65	0,08	4,63	0,13	0,01	0,00	100,00	3,73	3,73	-2,87	4,93	0,00	4,93	29,01	114,55
6	Feb	1	15	4,93	114,55	149,76	0,78	1,01	1,08	2,54	3,29	0,07	4,65	0,10	0,01	0,00	100,00	3,36	3,36	-2,35	2,48	0,00	2,48	14,56	113,03
7		2	15	2,48	113,03	122,29	0,69	0,89	1,24	2,91	3,78	0,08	4,65	0,09	0,01	0,00	100,00	3,85	3,37	-2,48	0,00	0,00	0,00	0,00	111,50
8	Mar	1	15	0,00	111,50	94,60	1,16	1,50	1,03	2,42	3,14	0,07	4,98	0,07	0,01	0,00	100,00	3,21	1,50	0,00	0,00	0,00	0,00	0,00	111,50
9		2	15	0,00	111,50	94,60	1,45	1,88	0,74	1,74	2,25	0,08	4,98	0,07	0,01	0,00	100,00	2,33	1,88	0,00	0,00	0,00	0,00	0,00	111,50
10	Apr	1	15	0,00	111,50	94,60	0,86	1,12	0,35	0,82	1,07	0,07	5,37	0,08	0,01	0,00	100,00	1,14	1,12	0,00	0,00	0,00	0,00	0,00	111,50
11		2	15	0,00	111,50	94,60	0,83	1,07	0,24	0,56	0,73	0,08	5,37	0,08	0,01	0,00	100,00	0,81	0,81	0,27	0,19	0,00	0,19	1,11	111,62
12	Mei	1	15	0,19	111,62	96,72	0,67	0,86	0,30	0,71	0,91	0,07	5,20	0,08	0,01	0,00	100,00	0,98	0,98	-0,12	0,00	0,00	0,00	0,00	111,50
13		2	15	0,00	111,50	94,60	0,67	0,86	0,45	1,06	1,37	0,08	5,20	0,07	0,01	0,00	100,00	1,45	0,86	0,00	0,00	0,00	0,00	0,00	111,50
14	Jun	1	15	0,00	111,50	94,60	0,59	0,76	0,50	1,18	1,52	0,07	5,17	0,07	0,01	0,00	100,00	1,59	0,76	0,00	0,00	0,00	0,00	0,00	111,50
15		2	15	0,00	111,50	94,60	0,54	0,70	0,55	1,29	1,68	0,08	5,17	0,07	0,01	0,00	100,00	1,75	0,70	0,00	0,00	0,00	0,00	0,00	111,50
16	Jul	1	15	0,00	111,50	94,60	0,50	0,65	0,49	1,15	1,49	0,07	5,82	0,08	0,01	0,00	100,00	1,56	0,65	0,00	0,00	0,00	0,00	0,00	111,50
17		2	15	0,00	111,50	94,60	0,51	0,66	0,33	0,78	1,01	0,08	5,82	0,08	0,01	0,00	100,00	1,08	0,66	0,00	0,00	0,00	0,00	0,00	111,50
18	Agu	1	15	0,00	111,50	94,60	0,49	0,63	0,27	0,63	0,82	0,07	6,37	0,09	0,01	0,00	100,00	0,89	0,63	0,00	0,00	0,00	0,00	0,00	111,50
19		2	15	0,00	111,50	94,60	0,52	0,67	0,35	0,82	1,07	0,08	6,37	0,09	0,01	0,00	100,00	1,14	0,67	0,00	0,00	0,00	0,00	0,00	111,50
20	Sep	1	15	0,00	111,50	94,60	0,49	0,63	0,53	1,25	1,61	0,07	6,64	0,09	0,01	0,00	100,00	1,68	0,63	0,00	0,00	0,00	0,00	0,00	111,50
21		2	15	0,00	111,50	94,60	0,48	0,62	0,30	0,71	0,91	0,08	6,64	0,09	0,01	0,00	100,00	0,99	0,62	0,00	0,00	0,00	0,00	0,00	111,50
22	Okto	1	15	0,00	111,50	94,60	0,48	0,62	0,20	0,47	0,61	0,07	7,68	0,11	0,01	0,00	100,00	0,68	0,62	0,00	0,00	0,00	0,00	0,00	111,50
23		2	15	0,00	111,50	94,60	0,44	0,57	0,00	0,00	0,00	0,08	7,68	0,11	0,01	0,00	100,00	0,08	0,08	0,49	0,38	0,00	0,38	2,24	111,74
24	Nov	1	15	0,38	111,74	98,87	0,43	0,56	0,00	0,00	0,00	0,07	6,26	0,09	0,01	0,00	100,00	0,07	0,07	0,49	0,77	0,00	0,77	4,56	111,98

Source: Analysis of 2019

Simulation of Tanju Reservoir Operation Pattern Based on Storage

The results of the calculation of the reservoir operating pattern are based on the conditions of wet debit, normal debit and dry debit as follows:

Table 4. Simulation of reservoir operations based on wet debitreservoir (Q_{20})

Area of irrigation	=	**2350**	Ha
Effective reservoir storage	=	17.000.000	m^2
Dead storage reservoir	=	1.370.000	m^3
Total storage:	=	18.370.000	m^3
Total storage elevation	=	120,0	m
Low water elevation	=	111,5	m

No	Month	Period	Total	*S* initial	Initial Elevation	*A*	*Inflow*		Water Needs				Losing Water				*Outflow*	*Total Needs*	*Outfow*	*I - O*	*(S +(I - O - E - R))*	*Spill out*	*S* final	*S* final	Final Elevation
									Irrigation			Raw Water	Evaporation		Seepage										
			(day)	(milions m^3)	(m)	(ha)	(m^3/sc)	(mil m^3)	(lt/sc/ha)	(m^3/sc)	(mil m^3)	(mil m^3)	(mm/day)	(mil m^3)	(m^3/day)	(mil m^3)	%	(mil m^3)	(mil m^3)	(mil m^3)	(mil m^3)	(mil m^3)	(mil m^3)	%	(m)
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
				17,00																			**17,00**	**100,00**	
1	Nop	2	15	**17,00**	120,00	296,30	1,29	1,67	0,31	0,73	0,94	0,07	6,26	0,28	0,01	0,00	100,00	***1,01***	***1,01***	0,65	17,37	0,37	17,00	100,00	120,00
2	Des	1	15	17,00	120,00	296,30	3,53	4,57	0,86	2,02	2,62	0,07	4,87	0,22	0,01	0,00	100,00	***2,69***	***2,69***	1,89	18,67	1,67	17,00	100,00	120,00
3		2	15	17,00	120,00	296,30	4,41	5,71	1,15	2,70	3,50	0,08	4,87	0,22	0,01	0,00	100,00	***3,58***	***3,58***	2,13	18,92	1,92	17,00	100,00	120,00
4	Jan	1	15	17,00	120,00	296,30	1,38	1,79	1,41	3,31	4,29	0,07	4,63	0,21	0,01	0,00	100,00	***4,36***	***4,36***	-2,57	14,22	0,00	14,22	83,65	118,94
5		2	15	14,22	118,94	266,85	1,92	2,49	1,20	2,82	3,65	0,08	4,63	0,19	0,01	0,00	100,00	***3,73***	***3,73***	-1,24	12,80	0,00	12,80	75,29	118,39
6	Feb	1	15	12,80	118,39	251,79	2,21	2,86	1,08	2,54	3,29	0,07	4,65	0,18	0,01	0,00	90,00	***3,36***	***3,02***	-0,17	12,46	0,00	12,46	73,28	118,26
7		2	15	12,46	118,26	248,17	2,02	2,61	1,24	2,91	3,78	0,08	4,65	0,17	0,01	0,00	90,00	***3,85***	***3,47***	-0,85	11,43	0,00	11,43	67,25	117,87
8	Mar	1	15	11,43	117,87	237,31	2,98	3,86	1,03	2,42	3,14	0,07	4,98	0,18	0,01	0,00	90,00	***3,21***	***2,89***	0,97	12,23	0,00	12,23	71,92	118,18
9		2	15	12,23	118,18	245,71	3,64	4,72	0,74	1,74	2,25	0,08	4,98	0,18	0,01	0,00	90,00	***2,33***	***2,10***	2,62	14,66	0,00	14,66	86,25	119,11
10	Apr	1	15	14,66	119,11	271,53	3,58	4,63	0,35	0,82	1,07	0,07	5,37	0,22	0,01	0,00	100,00	***1,14***	***1,14***	3,50	17,94	0,94	17,00	100,00	120,00
11		2	15	17,00	120,00	296,30	2,18	2,82	0,24	0,56	0,73	0,08	5,37	0,24	0,01	0,00	100,00	***0,81***	***0,81***	2,02	18,78	1,78	17,00	100,00	120,00
12	Mei	1	15	17,00	120,00	296,30	1,50	1,94	0,30	0,71	0,91	0,07	5,20	0,23	0,01	0,00	100,00	***0,98***	***0,98***	0,95	17,72	0,72	17,00	100,00	120,00
13		2	15	17,00	120,00	296,30	1,46	1,90	0,45	1,06	1,37	0,08	5,20	0,23	0,01	0,00	100,00	***1,45***	***1,45***	0,45	17,22	0,22	17,00	100,00	120,00
14	Jun	1	15	17,00	120,00	296,30	1,27	1,64	0,50	1,18	1,52	0,07	5,17	0,23	0,01	0,00	100,00	***1,59***	***1,59***	0,05	16,82	0,00	16,82	98,95	119,93
15		2	15	16,82	119,93	294,40	1,16	1,51	0,55	1,29	1,68	0,08	5,17	0,23	0,01	0,00	100,00	***1,75***	***1,75***	-0,24	16,35	0,00	16,35	96,18	119,75
16	Jul	1	15	16,35	119,75	289,42	1,08	1,40	0,49	1,15	1,49	0,07	5,82	0,25	0,01	0,00	100,00	***1,56***	***1,56***	-0,16	15,94	0,00	15,94	93,75	119,59
17		2	15	15,94	119,59	285,03	1,05	1,36	0,33	0,78	1,01	0,08	5,82	0,25	0,01	0,00	100,00	***1,08***	***1,08***	0,28	15,97	0,00	15,97	93,92	119,60
18	Agu	1	15	15,97	119,60	285,35	0,97	1,26	0,27	0,63	0,82	0,07	6,37	0,27	0,01	0,00	100,00	***0,89***	***0,89***	0,37	16,06	0,00	16,06	94,48	119,64
19		2	15	16,06	119,64	286,35	0,97	1,26	0,35	0,82	1,07	0,08	6,37	0,27	0,01	0,00	100,00	***1,14***	***1,14***	0,12	15,91	0,00	15,91	93,58	119,58
20	Sep	1	15	15,91	119,58	284,74	0,78	1,01	0,53	1,25	1,61	0,07	6,64	0,28	0,01	0,00	100,00	***1,68***	***1,68***	-0,68	14,95	0,00	14,95	87,92	119,22
21		2	15	14,95	119,22	274,54	0,77	0,99	0,30	0,71	0,91	0,08	6,64	0,27	0,01	0,00	100,00	***0,99***	***0,99***	0,00	14,68	0,00	14,68	86,34	119,11
22	Okto	1	15	14,68	119,11	271,69	0,78	1,01	0,20	0,47	0,61	0,07	7,68	0,31	0,01	0,00	100,00	***0,68***	***0,68***	0,33	14,70	0,00	14,70	86,45	119,12
23		2	15	14,70	119,12	271,89	1,21	1,57	0,00	0,00	0,00	0,08	7,68	0,31	0,01	0,00	100,00	***0,08***	***0,08***	1,50	15,88	0,00	15,88	93,41	119,57
24	Nov	1	15	15,88	119,57	284,43	1,33	1,72	0,00	0,00	0,00	0,07	6,26	0,27	0,01	0,00	100,00	***0,07***	***0,07***	1,65	17,27	0,27	**17,00**	**100,00**	120,00

Source: Analysis of 2019

Table 5. Simulation of reservoir operations based on normal debit reservoir (Q_{50})

Area of irrigation	=	**2350**	Ha
Effective reservoir storage	=	17.000.000	m^2
Dead storage reservoir	=	1.370.000	m^3
Total storage:	=	18.370.000	m^3
Total storage elevation	=	120,0	m
The elevation of low water tab	=	111,5	m

No	Month	Period	Total	*S* initial	Initial Elevation	*A*	*Inflow*		Water Needs				Losing Water				*Outflow*	*Total Needs*	*Outfow*	*I - O*	*(S +(I - O - E - R))*	*Spill out*	*S* final	*S* final	Final Elevation
									Irrigation			Raw Water	Evaporation		Seepage										
			(day)	(milions m^3)	(m)	(ha)	(m^3/sc)	(mil m^3)	(lt/sc/ha)	(m^3/sc)	(mil m^3)	(mil m^3)	(mm/day)	(mil m^3)	(m^3/day)	(mil m^3)	%	(mil m^3)	(mil m^3)	(mil m^3)	(mil m^3)	(mil m^3)	(mil m^3)	%	(m)
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
				17,00																			**17,00**	**100,00**	
1	Nop	2	15	**17,00**	119,48	281,77	0,86	1,12	0,31	0,73	0,94	0,07	6,26	0,26	0,01	0,00	100,00	***1,01***	***1,01***	0,11	16,84	0,00	16,84	99,07	119,42
2	Des	1	15	16,84	119,42	280,10	0,97	1,26	0,86	2,02	2,62	0,07	4,87	0,20	0,01	0,00	100,00	***2,69***	***2,69***	-1,43	15,21	0,00	15,21	89,47	118,79
3		2	15	15,21	118,79	262,80	1,08	1,40	1,15	2,70	3,50	0,08	4,87	0,19	0,01	0,00	100,00	***3,58***	***3,58***	-2,18	12,84	0,00	12,84	75,54	117,89
4	Jan	1	15	12,84	117,89	237,72	1,35	1,75	1,41	3,31	4,29	0,07	4,63	0,17	0,01	0,00	90,00	***4,36***	***3,93***	-2,18	10,50	0,00	10,50	61,77	116,81
5		2	15	10,50	116,81	207,88	1,72	2,23	1,20	2,82	3,65	0,08	4,63	0,14	0,01	0,00	90,00	***3,73***	***3,36***	-1,13	9,23	0,00	9,23	54,28	116,15
6	Feb	1	15	9,23	116,15	189,56	2,76	3,58	1,08	2,54	3,29	0,07	4,65	0,13	0,01	0,00	75,00	***3,36***	***2,52***	1,06	10,16	0,00	10,16	59,74	116,63
7		2	15	10,16	116,63	202,92	2,29	2,97	1,24	2,91	3,78	0,08	4,65	0,14	0,01	0,00	75,00	***3,85***	***2,89***	0,08	10,10	0,00	10,10	59,40	116,60
8	Mar	1	15	10,10	116,60	202,07	1,82	2,36	1,03	2,42	3,14	0,07	4,98	0,15	0,01	0,00	75,00	***3,21***	***2,41***	-0,05	9,90	0,00	9,90	58,22	116,50
9		2	15	9,90	116,50	199,20	2,33	3,02	0,74	1,74	2,25	0,08	4,98	0,15	0,01	0,00	75,00	***2,33***	***1,75***	1,28	11,03	0,00	11,03	64,87	117,08
10	Apr	1	15	11,03	117,08	215,45	1,64	2,12	0,35	0,82	1,07	0,07	5,37	0,17	0,01	0,00	90,00	***1,14***	***1,02***	1,10	11,96	0,00	11,96	70,32	117,55
11		2	15	11,96	117,55	228,33	1,24	1,61	0,24	0,56	0,73	0,08	5,37	0,18	0,01	0,00	90,00	***0,81***	***0,73***	0,89	12,66	0,00	12,66	74,46	117,82
12	Mei	1	15	12,66	117,82	235,78	0,97	1,26	0,30	0,71	0,91	0,07	5,20	0,18	0,01	0,00	90,00	***0,98***	***0,89***	0,37	12,85	0,00	12,85	75,57	117,89
13		2	15	12,85	117,89	237,78	0,93	1,20	0,45	1,06	1,37	0,08	5,20	0,19	0,01	0,00	90,00	***1,45***	***1,30***	-0,10	12,56	0,00	12,56	73,90	117,78
14	Jun	1	15	12,56	117,78	234,77	0,85	1,11	0,50	1,18	1,52	0,07	5,17	0,18	0,01	0,00	90,00	***1,59***	***1,43***	-0,33	12,06	0,00	12,06	70,92	117,59
15		2	15	12,06	117,59	229,39	0,81	1,04	0,55	1,29	1,68	0,08	5,17	0,18	0,01	0,00	90,00	***1,75***	***1,58***	-0,53	11,35	0,00	11,35	66,75	117,25
16	Jul	1	15	11,35	117,25	220,05	0,76	0,98	0,49	1,15	1,49	0,07	5,82	0,19	0,01	0,00	90,00	***1,56***	***1,41***	-0,43	10,73	0,00	10,73	63,11	116,93
17		2	15	10,73	116,93	211,16	0,79	1,02	0,33	0,78	1,01	0,08	5,82	0,18	0,01	0,00	90,00	***1,08***	***0,97***	0,05	10,60	0,00	10,60	62,33	116,86
18	Agu	1	15	10,60	116,86	209,26	0,69	0,90	0,27	0,63	0,82	0,07	6,37	0,20	0,01	0,00	90,00	***0,89***	***0,80***	0,10	10,49	0,00	10,49	61,72	116,80
19		2	15	10,49	116,80	207,75	0,66	0,86	0,35	0,82	1,07	0,08	6,37	0,20	0,01	0,00	90,00	***1,14***	***1,03***	-0,17	10,13	0,00	10,13	59,57	116,61
20	Sep	1	15	10,13	116,61	202,50	0,60	0,78	0,53	1,25	1,61	0,07	6,64	0,20	0,01	0,00	75,00	***1,68***	***1,26***	-0,48	9,44	0,00	9,44	55,55	116,26
21		2	15	9,44	116,26	192,67	0,58	0,75	0,30	0,71	0,91	0,08	6,64	0,19	0,01	0,00	75,00	***0,99***	***0,74***	0,01	9,26	0,00	9,26	54,50	116,17
22	Okto	1	15	9,26	116,17	190,09	0,59	0,76	0,20	0,47	0,61	0,07	7,68	0,22	0,01	0,00	75,00	***0,68***	***0,51***	0,25	9,30	0,00	9,30	54,70	116,18
23		2	15	9,30	116,18	190,59	0,70	0,91	0,00	0,00	0,00	0,08	7,68	0,22	0,01	0,00	75,00	***0,08***	***0,06***	0,86	9,94	0,00	9,94	58,45	116,52
24	Nov	1	15	9,94	116,52	199,76	0,71	0,92	0,00	0,00	0,00	0,07	6,26	0,19	0,01	0,00	75,00	***0,07***	***0,05***	0,87	10,62	0,00	**10,62**	**62,47**	116,87

Source: Analysis of 2019

Table 6 Simulation of reservoir operations based on dry debitreservoir (Q_{80})

Area of irrigation	=	**2350**	Ha
Effective reservoir storage	=	17.000.000	m^2
Dead storage reservoir	=	1.370.000	m^3
Total storage:	=	18.370.000	m^3
Total storage elevation	=	120,0	m
The elevation of low water tab	=	111,5	m

No	Month	Period	Total	*S* initial	Initial Elevation	*A*	*Inflow*		Water Needs				Losing Water				*Outflow*	*Total Needs*	*Outfow*	*I - O*	*(S +(I - O - E - R))*	*Spill out*	*S* final	*S* final	Final Elevation
									Irrigation			Raw Water	Evaporation		Seepage										
			(day)	(milions m^3)	(m)	(ha)	(m^3/sc)	(mil m^3)	(lt/sc/ha)	(m^3/sc)	(mil m^3)	(mil m^3)	(mm/day)	(mil m^3)	(m^3/day)	(mil m^3)	%	(mil m^3)	(mil m^3)	(mil m^3)	(mil m^3)	(mil m^3)	(mil m^3)	%	(m)
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
				17,00																			**17,00**	**100,00**	
1	Nop	2	15	17,00	120,00	296,30	0,57	0,74	0,31	0,73	0,94	0,07	6,26	0,28	0,01	0,00	100,00	1,01	1,01	-0,27	16,45	0,00	16,45	96,78	119,79
2	Des	1	15	16,45	119,79	290,49	0,85	1,10	0,86	2,02	2,62	0,07	4,87	0,21	0,01	0,00	100,00	2,69	2,69	-1,59	14,65	0,00	14,65	86,19	119,10
3		2	15	14,65	119,10	271,42	0,68	0,89	1,15	2,70	3,50	0,08	4,87	0,20	0,01	0,00	100,00	3,58	3,58	-2,69	11,76	0,00	11,76	69,18	118,00
4	Jan	1	15	11,76	118,00	240,79	0,55	0,71	1,41	3,31	4,29	0,07	4,63	0,17	0,01	0,00	90,00	4,36	3,93	-3,22	8,37	0,00	8,37	49,25	116,42
5		2	15	8,37	116,42	196,97	0,66	0,86	1,20	2,82	3,65	0,08	4,63	0,14	0,01	0,00	75,00	3,73	2,80	-1,94	6,30	0,00	6,30	37,03	115,34
6	Feb	1	15	6,30	115,34	167,09	0,78	1,01	1,08	2,54	3,29	0,07	4,65	0,12	0,01	0,00	40,00	3,36	1,34	-0,34	5,84	0,00	5,84	34,37	115,10
7		2	15	5,84	115,10	160,58	0,69	0,89	1,24	2,91	3,78	0,08	4,65	0,11	0,01	0,00	40,00	3,85	1,54	-0,65	5,08	0,00	5,08	29,91	114,65
8	Mar	1	15	5,08	114,65	151,48	1,16	1,50	1,03	2,42	3,14	0,07	4,98	0,11	0,01	0,00	40,00	3,21	1,28	0,22	5,19	0,00	5,19	30,53	114,72
9		2	15	5,19	114,72	152,66	1,45	1,88	0,74	1,74	2,25	0,08	4,98	0,11	0,01	0,00	40,00	2,33	0,93	0,94	6,02	0,00	6,02	35,42	115,19
10	Apr	1	15	6,02	115,19	163,14	0,86	1,12	0,35	0,82	1,07	0,07	5,37	0,13	0,01	0,00	40,00	1,14	0,45	0,66	6,55	0,00	6,55	38,54	115,47
11		2	15	6,55	115,47	170,78	0,83	1,07	0,24	0,56	0,73	0,08	5,37	0,14	0,01	0,00	40,00	0,81	0,32	0,75	7,16	0,00	7,16	42,14	115,79
12	Mei	1	15	7,16	115,79	179,58	0,67	0,86	0,30	0,71	0,91	0,07	5,20	0,14	0,01	0,00	75,00	0,98	0,74	0,13	7,15	0,00	7,15	42,05	115,78
13		2	15	7,15	115,78	179,37	0,67	0,86	0,45	1,06	1,37	0,08	5,20	0,14	0,01	0,00	75,00	1,45	1,08	-0,22	6,79	0,00	6,79	39,93	115,59
14	Jun	1	15	6,79	115,59	174,17	0,59	0,76	0,50	1,18	1,52	0,07	5,17	0,14	0,01	0,00	40,00	1,59	0,64	0,12	6,77	0,00	6,77	39,85	115,58
15		2	15	6,77	115,58	173,98	0,54	0,70	0,55	1,29	1,68	0,08	5,17	0,13	0,01	0,00	40,00	1,75	0,70	0,00	6,64	0,00	6,64	39,05	115,51
16	Jul	1	15	6,64	115,51	172,01	0,50	0,65	0,49	1,15	1,49	0,07	5,82	0,15	0,01	0,00	40,00	1,56	0,62	0,02	6,51	0,00	6,51	38,30	115,45
17		2	15	6,51	115,45	170,18	0,51	0,66	0,33	0,78	1,01	0,08	5,82	0,15	0,01	0,00	40,00	1,08	0,43	0,23	6,59	0,00	6,59	38,78	115,49
18	Agu	1	15	6,59	115,49	171,37	0,49	0,63	0,27	0,63	0,82	0,07	6,37	0,16	0,01	0,00	40,00	0,89	0,36	0,28	6,71	0,00	6,71	39,45	115,55
19		2	15	6,71	115,55	173,01	0,52	0,67	0,35	0,82	1,07	0,08	6,37	0,17	0,01	0,00	40,00	1,14	0,46	0,21	6,75	0,00	6,75	39,73	115,57
20	Sep	1	15	6,75	115,57	173,69	0,49	0,63	0,53	1,25	1,61	0,07	6,64	0,17	0,01	0,00	40,00	1,68	0,67	-0,04	6,54	0,00	6,54	38,47	115,46
21		2	15	6,54	115,46	170,59	0,48	0,62	0,30	0,71	0,91	0,08	6,64	0,17	0,01	0,00	40,00	0,99	0,40	0,23	6,60	0,00	6,60	38,80	115,49
22	Okto	1	15	6,60	115,49	171,40	0,48	0,62	0,20	0,47	0,61	0,07	7,68	0,20	0,01	0,00	40,00	0,68	0,27	0,35	6,75	0,00	6,75	39,70	115,57
23		2	15	6,75	115,57	173,60	0,44	0,57	0,00	0,00	0,00	0,08	7,68	0,20	0,01	0,00	40,00	0,08	0,03	0,54	7,08	0,00	7,08	41,67	115,75
24	Nov	1	15	7,08	115,75	178,43	0,43	0,56	0,00	0,00	0,00	0,07	6,26	0,17	0,01	0,00	75,00	0,07	0,05	0,50	7,42	0,00	7,42	43,65	115,92

Source: Analysis of 2019

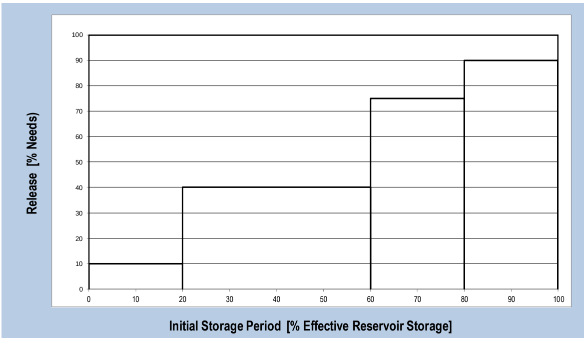

Figure 3. Tanju Reservoir operating pattern guidelines for wet debit, normal debit and dry debit based on simple storage (maximum release)

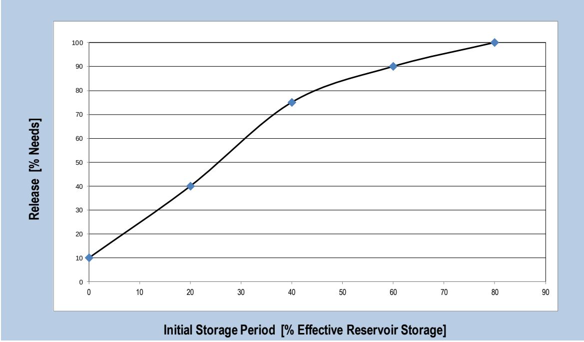

Figure 4. Tanju Reservoir operating pattern guidelines for wet debit, normal debit and dry debit based on simple storage (interpolation equation)

Simulation of Reservoir Operating Patterns Based on Genetic Algorithms

In calculating the reservoir operation pattern based on the genetic algorithm the behavior is determined as follows:

1. Release using rules based on storage
2. Performed under conditions of wet debit (Q_{20}), normal debit (Q_{50}), dry debit (Q_{80})
3. The reservoir operation is based on the balance between the inflow and outflow, considering the loss of reservoir water
4. The initial simulation is carried out when the reservoir is in full condition.
5. Early planting is carried out in November 2nd period
6. Removable optimized with genetic algorithms
7. The genetic algorithm program is a search engine for binary values (0 to 1) to produce the best value in a predetermined function and constraint
8. The goal / fitness parameter is the minimum value of fulfillment of needs in one period
9. Constraints / constraints are random numbers (0-1) and reservoir release intervals of 5%
10. The process of genetic algorithms is initialization, crossover and selection
11. Process of optimizing genetic algorithms using Ms. Program. Excel-VBA.
12. In the initialization process, a population of several chromosomes (removable alternatives) is generated as follows:
    - Number of generations: 16
    - Iteration
      Initial iteration: 50
      Advanced iterations: 10
    - Random range: 0.3000 - 0.0005

Calculation Steps of Reservoir Operation Simulation Based on Wet Debit Genetic Algorithm (Q20), Normal Debit (Q50), Dry Debit (Q80)

The steps taken in this calculation are as follows:

1. Determine the total reservoir volume =18,370,000 million m^3
2. Determine the volume of dead storage reservoir= 1,370,000 million m^3
3. Determine the active storage volume of the reservoir =17,000,000 million m^3
4. Determine the peak elevation of the total reservoir storage = 120 m
5. Determine the elevation dead storage reservoir= 111.5 m
6. Failure of simulation reservoir operation is set at dead storage volume= 1,370,000million m^3
7. Generating initial population (initialization)

International Journal of Latest Engineering Research and Applications (IJLERA) ISSN: 2455-7137

Volume – 04, Issue – 04, April 2019, PP – 11-26

Table 7 Initial population generation results from the wet debit initialization process (Q_{20})

Performance/Purpose
(fulfillment of needs in every period)

Population
(a collective rules of release *outflow*based on storage)

Chromosome
(Alternative Solution /Alternativerelease rules*outflow*/Decision Variable)

Gene/Variable
(One Release Rule, Based on the certain storage condition, wwith Interval 5%)

No	1	2	3	4	5		6
Performance	84,83	81,86	77,14	76,99	76,86		78,87
Storage (%)	Release (%)						
0,00	4,58	10,23	5,58	8,18	1,99	-	7,64
5,00	13,36	12,25	8,47	16,34	7,46	-	14,85
10,00	16,90	18,81	15,70	21,02	16,39	-	22,53
15,00	27,19	27,62	18,42	24,84	23,33	-	26,26
20,00	35,48	36,29	27,16	29,26	28,05	-	30,49
25,00	44,16	38,85	35,21	31,82	30,93	-	38,36
30,00	49,11	44,54	42,71	42,70	31,21	-	42,17
35,00	56,17	52,77	46,82	46,20	40,00	-	48,83
40,00	63,49	59,99	50,18	53,46	48,35	-	56,66
45,00	69,21	66,17	57,23	57,30	49,60	-	61,04
50,00	73,82	71,05	59,05	61,56	56,23	-	69,55
55,00	80,68	76,55	63,68	63,38	64,00	-	76,12
60,00	84,83	81,86	68,19	70,01	68,90	-	84,34
65,00	84,83	82,11	77,14	76,99	76,86	-	85,03
70,00	85,58	83,83	77,24	77,03	76,87	-	85,38
75,00	86,00	85,97	79,05	80,76	77,91	-	85,61
80,00	86,08	87,98	82,41	83,69	82,09	-	91,10
85,00	[illegible]	92,48	86,01	84,66	87,43	-	91,36
90,00	90,63	95,82	91,60	90,00	89,35	-	95,03
95,00	92,23	98,07	98,10	95,49	96,36	-	99,57
100,00	100,00	[illegible]	100,00	100,00	100,00		100,00

Source: Analysis of 2019

8. After the 16 alternative release (chromosome) was built in the first generations of the generating result from the initialization process, the crossover process is done.
   Example of calculating a new variable / gene resulting from a cross between two variables from both derivative generation chromosomes (removable rules based on storage conditions (0% -100%), giving new variables as follows:

Table 8 Calculation of initial generation crossover wet debit (Q_{20})

Chromosome 1	Chromosome 2	Random Number	Join Chromosome
0,666059	0,861825	0,0776	0,846626
0,678905	0,725605	0,1624	0,718018
0,773654	0,586191	0,1304	0,610637
0,920703	0,582414	0,2772	0,676179
0,855779	0,567360	0,5069	0,713553
0,625030	0,421837	0,3198	0,486809
0,745864	0,409443	0,1560	0,461925
0,890221	0,371879	0,6951	0,732169
0,539690	0,728825	0,5753	0,620017
0,615285	0,656378	0,5112	0,635369
0,624940	0,579388	0,4614	0,600404
0,687724	0,805492	0,5856	0,736530
0,861693	0,330666	0,2300	0,452779
0,451218	0,068819	0,7518	0,356319
0,030232	0,152074	0,3216	0,112892
0,003056	0,661027	0,1137	0,586218
0,310292	0,298769	0,5755	0,305400
0,291272	0,214915	0,4346	0,248103
0,740588	0,320838	0,4378	0,504592
0,735729	0,179319	0,4979	0,456339
0,547242	0,147928	0,8112	0,471842

Source: Analysis of 2019

Table 9 Population rules for inter-generational combination reservoir release in the crossover process in the initial generation of wet debit (Q_{20})

No	1	2	3	4	5	6	7		8
Performance	84,07	83,55	84,52	83,12	86,92	85,75	82,48		82,56
Storage (%)	Release (%)								
0,00	8,05	5,76	5,94	2,53	6,57	3,12	2,21	-	6,51
5,00	16,28	12,67	14,56	11,28	12,17	11,54	9,79	-	15,14
10,00	21,54	16,94	18,50	17,99	17,05	18,18	14,34	-	22,29
15,00	31,01	23,81	28,40	27,86	26,20	27,26	23,15	-	30,90
20,00	39,50	33,18	34,54	34,00	34,40	34,26	30,74	-	37,64
25,00	43,80	42,84	41,72	38,81	43,00	42,77	38,80	-	45,79
30,00	48,80	48,89	50,97	39,75	52,47	47,44	42,94	-	51,18
35,00	56,13	54,30	54,63	47,96	60,56	55,07	51,79	-	58,99
40,00	63,41	62,03	62,02	57,37	68,16	63,89	59,31	-	65,88
45,00	69,33	69,12	67,54	63,67	75,24	69,34	64,93	-	71,60
50,00	74,01	73,13	72,11	70,26	79,51	78,22	70,46	-	76,24
55,00	79,50	78,82	78,09	78,43	86,92	85,75	76,26	-	81,35
60,00	84,07	83,55	84,52	83,12	90,11	90,23	82,48	-	85,37
65,00	84,18	84,40	84,71	83,44	90,27	90,29	82,62	-	85,46
70,00	85,01	84,78	85,32	83,93	91,00	90,72	83,38	-	86,10
75,00	85,85	85,49	86,07	84,84	91,50	91,06	83,84	-	86,38
80,00	86,22	86,31	86,81	85,88	92,99	92,54	83,91	-	86,56
85,00	88,56	89,36	87,90	89,28	95,23	94,08	86,47	-	87,54
90,00	91,01	93,10	91,51	91,76	96,66	97,69	91,35	-	93,32
95,00	92,69	97,43	93,53	95,08	98,23	99,33	93,34	-	94,62
100,00	100,00	100,00	100,00	100,00	100,00	100,00	100,00	-	100,00

Source: Analysis of 2019

So the 120 removable alternatives (chromosomes) are the result of crosses made between removable alternatives (chromosomes) from the generation of the first generation of the initialization process.

9. Of the 120 removable (chromosome) alternatives resulting from the crossover, 16 of the best removable alternatives were selected based on the function / objective function. The population generation of 16 alternative alternatives (chromosomes) as a result of this selection will be the next generation of generations, where the selection results in the first generation is as follows:

Table 4.10 Population results of improvement (selection) on reproductive generation of derivatives to 1 wet debit (Q_{20})

No	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Performance	87,32	86,92	85,75	85,40	85,39	85,13	85,07	84,87	84,74	84,52	84,47	84,46	84,43	84,39	84,32	84,23
Storage (%)	**Release (%)**															
0,00	8,99	6,57	3,12	8,01	6,60	4,35	4,89	8,93	4,36	5,94	7,90	5,94	7,60	8,77	8,03	4,84
5,00	14,53	12,17	11,54	15,07	15,22	11,52	12,92	15,26	6,89	14,56	11,55	14,23	15,96	15,69	15,52	13,58
10,00	22,05	17,05	18,18	20,70	22,36	19,58	17,71	22,15	14,65	18,50	17,65	20,07	24,08	21,31	21,29	22,42
15,00	26,40	26,20	27,26	24,61	30,97	29,16	27,07	26,38	18,52	28,40	20,29	29,75	28,13	32,05	30,54	26,81
20,00	33,94	34,40	34,26	32,13	37,71	35,39	35,17	34,12	25,34	34,54	28,05	38,02	33,86	35,24	38,45	32,68
25,00	43,83	43,00	42,77	41,19	45,85	43,07	41,89	41,94	36,00	41,72	36,85	45,19	42,13	45,29	46,35	40,79
30,00	52,66	52,47	47,44	50,42	51,23	47,67	49,17	49,29	41,87	50,97	45,67	49,97	46,15	53,60	51,03	46,37
35,00	61,27	60,56	55,07	57,82	59,03	54,61	56,79	56,20	50,45	54,63	53,66	56,75	53,16	61,71	56,91	54,30
40,00	69,11	68,16	63,89	65,07	65,91	60,87	62,96	63,68	60,16	62,02	61,68	61,93	60,40	69,53	64,13	61,06
45,00	77,85	75,24	69,34	73,33	71,62	67,49	68,33	68,30	69,28	67,54	69,77	67,42	65,23	72,70	70,43	67,97
50,00	82,35	79,51	78,22	77,81	76,26	74,83	73,61	75,19	76,41	72,11	78,00	71,81	73,47	77,50	76,30	76,97
55,00	87,32	86,92	85,75	85,40	81,37	81,22	80,05	80,84	84,74	78,09	84,47	80,32	77,25	84,39	84,32	80,37
60,00	89,30	90,11	90,23	87,54	85,39	85,13	85,07	84,87	86,82	84,52	86,89	84,46	84,43	89,76	88,31	84,23
65,00	89,58	90,27	90,29	87,82	85,47	85,32	85,37	85,11	87,15	84,71	87,70	84,51	84,98	89,85	88,37	84,98
70,00	90,12	91,00	90,72	88,88	86,12	85,66	85,73	85,83	87,65	85,32	89,02	85,28	85,48	92,42	89,11	85,38
75,00	90,78	91,50	91,06	90,54	86,40	85,85	85,80	86,43	87,96	86,07	90,19	85,73	85,61	92,84	90,23	85,44
80,00	93,77	92,99	92,54	93,48	86,58	86,81	86,22	86,99	93,99	86,81	93,79	86,20	88,73	93,26	91,01	88,35
85,00	94,63	95,23	94,08	95,66	87,55	88,82	88,49	87,82	95,79	87,90	95,06	88,83	89,25	95,76	93,17	89,22
90,00	97,12	96,66	97,69	97,00	93,33	93,54	90,88	89,76	97,01	91,51	96,22	93,71	94,07	97,73	95,44	96,36
95,00	98,63	98,23	99,33	98,68	94,62	95,40	94,02	94,84	99,03	93,53	98,00	96,06	97,40	98,58	97,12	98,83
100,00	100,00	100,00	100,00	100,00	100,00	100,00	100,00	100,00	100,00	100,00	100,00	100,00	100,00	100,00	100,00	100,00

Source: Analysis of 2019

10. The process (initialization, crossover, selection) is carried out several times to produce a generation that has a homogeneous / uniform / identical performance / purpose function, and the following results of genetic algorithms up to the 11th generation of generations

Table 4.11 Recapitulation of results of optimization iterations of the wet debit with genetic algorithm method (Q_{20})

REKAP HASIL	**No.**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
Early Generation	0	84,83	84,17	83,50	82,48	81,86	81,79	81,64	79,25	79,24	78,89	78,87	78,72	77,14	76,99	76,86	74,54
Derivative Generation	1	87,32	86,92	85,75	85,40	85,39	85,13	85,07	84,87	84,74	84,52	84,47	84,46	84,43	84,39	84,32	84,23
Derivative Generation	2	89,21	88,93	88,80	88,75	88,70	88,56	88,56	88,56	88,54	88,54	88,46	88,35	88,31	88,28	88,24	88,11
Derivative Generation	3	89,21	88,93	88,80	88,75	88,70	88,56	88,56	88,56	88,54	88,54	88,46	88,35	88,31	88,28	88,24	88,11
Derivative Generation	4	89,37	89,27	89,26	89,25	89,24	89,24	89,23	89,22	89,22	89,22	89,21	89,21	89,20	89,19	89,18	89,19
Derivative Generation	5	89,43	89,41	89,41	89,41	89,40	89,39	89,40	89,39	89,39	89,38	89,38	89,38	89,37	89,37	89,37	89,37
Derivative Generation	6	89,51	89,51	89,49	89,49	89,49	89,48	89,48	89,48	89,48	89,48	89,47	89,48	89,47	89,47	89,47	89,47
Derivative Generation	7	89,56	89,55	89,55	89,54	89,55	89,54	89,54	89,55	89,55	89,54	89,54	89,55	89,54	89,54	89,53	89,54
Derivative Generation	8	89,58	89,58	89,57	89,57	89,57	89,57	89,57	89,57	89,57	89,57	89,57	89,57	89,58	89,57	89,57	89,57
Derivative Generation	9	89,60	89,59	89,59	89,59	89,59	89,59	89,59	89,59	89,59	89,59	89,59	89,59	89,59	89,59	89,59	89,59
Derivative Generation	10	89,61	89,61	89,61	89,61	89,60	89,60	89,60	89,60	89,60	89,60	89,60	89,60	89,60	89,60	89,60	89,60
Derivative Generation	11	89,61	89,61	89,61	89,61	89,61	89,61	89,61	89,61	89,61	89,61	89,61	89,61	89,61	89,61	89,61	89,61

Source: Analysis of 2019

Homogen

Based on the results of the objective function and the alternative rules of the homogeneous reservoir release, the release rules for the Tanju Reservoir are determined based on genetic algorithms which are considered the most optimal in the 11th generation of generations.

This process is carried out similar to the normal inflow and dry debit conditions. Where the results of calculation of reservoir operation simulation and release guidelines for reservoir operation patterns are based on genetic algorithms with conditions of wet discharge, normal discharge and dry discharge as follows:

Table 4.12 Simulation of reservoir operations based on the wet debit genetic algorithm (Q_{20})

Area of irrigation	=	**2350**	Ha
Effective reservoir storage	=	17.000.000	m^2
Dead storage reservoir	=	1.370.000	m^3
Total storage:	=	18.370.000	m^3
Total storage elevation	=	120,0	m
The elevation of low water table	=	111,5	m

No	Month	Period	Total	*S* initial	Initial Elevation	*A*	*Inflow*		Water Needs: Irrigation			Water Needs: Raw Water	Losing Water: Evaporation		Losing Water: Seepage		*Outflow*	Total *Needs*	*Outfow*	*I - O*	*(S +(I - O - E - R))*	*Spill out*	*S* final	*S* final	Final Elevation
			(day)	(milions m^3)	(m)	(ha)	(m^3/sc)	(mil m^3)	(lt/sc/ha)	(m^3/sc)	(mil m^3)	(mil m^3)	(mm/day)	(mil m^3)	(m^3/day)	(mil m^3)	%	(mil m^3)	(mil m^3)	(mil m^3)	(mil m^3)	(mil m^3)	(mil m^3)	%	(m)
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
				17,00																			**17,00**	**100,00**	
1	Nop	2	15	**17,00**	120,00	296,30	1,29	1,67	0,31	0,73	0,94	0,07	6,26	0,28	0,01	0,00	100,00	***1,01***	***1,01***	0,65	17,37	**0,37**	**17,00**	100,00	120,00
2	Des	1	15	17,00	120,00	296,30	3,53	4,57	0,86	2,02	2,62	0,07	4,87	0,22	0,01	0,00	100,00	***2,69***	***2,69***	1,89	18,67	1,67	17,00	100,00	120,00
3		2	15	17,00	120,00	296,30	4,41	5,71	1,15	2,70	3,50	0,08	4,87	0,22	0,01	0,00	100,00	***3,58***	***3,58***	2,13	18,92	1,92	17,00	100,00	120,00
4	Jan	1	15	17,00	120,00	296,30	1,38	1,79	1,41	3,31	4,29	0,07	4,63	0,21	0,01	0,00	100,00	***4,36***	***4,36***	-2,57	14,22	0,00	14,22	83,65	118,94
5		2	15	14,22	118,94	266,85	1,92	2,49	1,20	2,82	3,65	0,08	4,63	0,19	0,01	0,00	92,90	***3,73***	***3,46***	-0,97	13,06	0,00	13,06	76,85	118,50
6	Feb	1	15	13,06	118,50	254,60	2,21	2,86	1,08	2,54	3,29	0,07	4,65	0,18	0,01	0,00	92,49	***3,36***	***3,11***	-0,25	12,64	0,00	12,64	74,34	118,33
7		2	15	12,64	118,33	250,07	2,02	2,61	1,24	2,91	3,78	0,08	4,65	0,17	0,01	0,00	92,16	***3,85***	***3,55***	-0,94	11,53	0,00	11,53	67,81	117,91
8	Mar	1	15	11,53	117,91	238,31	2,98	3,86	1,03	2,42	3,14	0,07	4,98	0,18	0,01	0,00	91,68	***3,21***	***2,94***	0,92	12,27	0,00	12,27	72,15	118,19
9		2	15	12,27	118,19	246,14	3,64	4,72	0,74	1,74	2,25	0,08	4,98	0,18	0,01	0,00	92,16	***2,33***	***2,15***	2,57	14,65	0,00	14,65	86,19	119,10
10	Apr	1	15	14,65	119,10	271,42	3,58	4,63	0,35	0,82	1,07	0,07	5,37	0,22	0,01	0,00	93,83	***1,14***	***1,07***	3,57	18,00	1,00	17,00	100,00	120,00
11		2	15	17,00	120,00	296,30	2,18	2,82	0,24	0,56	0,73	0,08	5,37	0,24	0,01	0,00	100,00	***0,81***	***0,81***	2,02	18,78	1,78	17,00	100,00	120,00
12	Mei	1	15	17,00	120,00	296,30	1,50	1,94	0,30	0,71	0,91	0,07	5,20	0,23	0,01	0,00	100,00	***0,98***	***0,98***	0,95	17,72	0,72	17,00	100,00	120,00
13		2	15	17,00	120,00	296,30	1,46	1,90	0,45	1,06	1,37	0,08	5,20	0,23	0,01	0,00	100,00	***1,45***	***1,45***	0,45	17,22	0,22	17,00	100,00	120,00
14	Jun	1	15	17,00	120,00	296,30	1,27	1,64	0,50	1,18	1,52	0,07	5,17	0,23	0,01	0,00	100,00	***1,59***	***1,59***	0,05	16,82	0,00	16,82	98,95	119,93
15		2	15	16,82	119,93	294,40	1,16	1,51	0,55	1,29	1,68	0,08	5,17	0,23	0,01	0,00	98,49	***1,75***	***1,72***	-0,22	16,38	0,00	16,38	96,34	119,76
16	Jul	1	15	16,38	119,76	289,70	1,08	1,40	0,49	1,15	1,49	0,07	5,82	0,25	0,01	0,00	98,49	***1,56***	***1,54***	-0,14	15,99	0,00	15,99	94,04	119,61
17		2	15	15,99	119,61	285,56	1,05	1,36	0,33	0,78	1,01	0,08	5,82	0,25	0,01	0,00	96,82	***1,08***	***1,05***	0,31	16,05	0,00	16,05	94,41	119,64
18	Agu	1	15	16,05	119,64	286,23	0,97	1,26	0,27	0,63	0,82	0,07	6,37	0,27	0,01	0,00	96,82	***0,89***	***0,86***	0,40	16,17	0,00	16,17	95,13	119,68
19		2	15	16,17	119,68	287,53	0,97	1,26	0,35	0,82	1,07	0,08	6,37	0,27	0,01	0,00	98,49	***1,14***	***1,12***	0,14	16,04	0,00	16,04	94,33	119,63
20	Sep	1	15	16,04	119,63	286,09	0,78	1,01	0,53	1,25	1,61	0,07	6,64	0,28	0,01	0,00	96,82	***1,68***	***1,63***	-0,62	15,13	0,00	15,13	88,98	119,28
21		2	15	15,13	119,28	276,45	0,77	0,99	0,30	0,71	0,91	0,08	6,64	0,28	0,01	0,00	93,83	***0,99***	***0,93***	0,07	14,92	0,00	14,92	87,74	119,20
22	Okto	1	15	14,92	119,20	274,22	0,78	1,01	0,20	0,47	0,61	0,07	7,68	0,32	0,01	0,00	93,83	***0,68***	***0,64***	0,37	14,97	0,00	14,97	88,08	119,23
23		2	15	14,97	119,23	274,83	1,21	1,57	0,00	0,00	0,00	0,08	7,68	0,32	0,01	0,00	93,83	***0,08***	***0,07***	1,50	16,16	0,00	16,16	95,05	119,68
24	Nov	1	15	16,16	119,68	287,39	1,33	1,72	0,00	0,00	0,00	0,07	6,26	0,27	0,01	0,00	98,49	***0,07***	***0,07***	1,65	17,54	0,54	17,00	100,00	120,00

Source: Analysis of 2019

Table 4.13 Guidelines for the pattern of operation of the Tanju Reservoir with the wet debit genetic algorithm (Q_{20})

Storage [%]	Q maks [%]
0	**7,21**
5	**14,83**
10	**21,86**
15	**28,08**
20	**35,38**
25	**44,90**
30	**52,48**
35	**60,49**
40	**68,65**
45	**76,28**
50	**82,33**
55	**89,60**
60	**91,57**
65	**91,68**
70	**92,16**
75	**92,49**
80	**92,90**
85	**93,83**
90	**96,82**
95	**98,49**
100	**100,00**

Source: Analysis of 2019

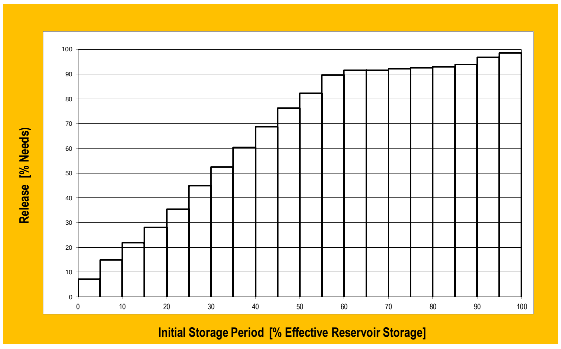

Figure 5 Guidelines for the pattern of operation of the Tanju Reservoir based on the wet debit genetic algorithm (Q_{20})
(Maximum release)

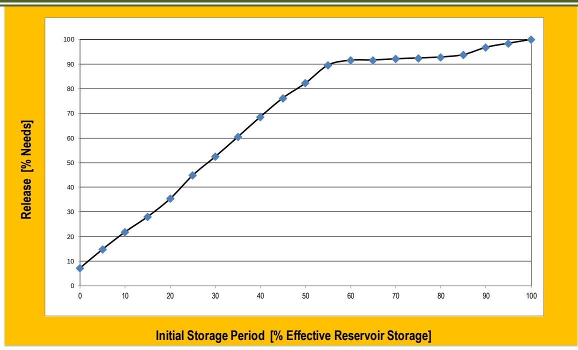

Figure 6 Guidelines for the pattern of operation of the Tanju Reservoir based on the wet discharge genetic algorithm (Q_{20})
(Interpolation equation)

Table 4.14 Simulation of reservoir operations based on the normal debit genetic algorithm (Q_{50})

Area of irrigation	=	**2350**	Ha
Effective reservoir storage	=	17.000.000	m^2
Dead storage reservoir	=	1.370.000	m^3
Total storage:	=	18.370.000	m^3
Total storage elevation	=	120,0	m
The elevation of low water tab	=	111,5	m

No	Month	Period	Total	*S* initial	Initial Elevation	*A*	*Inflow*		Water Needs: Irrigation			Water Needs: Raw Water	Losing Water: Evaporation		Losing Water: Seepage		*Outflow*	Total *Needs*	*Outfow*	*I - O*	*(S +(I - O - E - R))*	*Spill out*	*S* final	*S* final	Final Elevation
			(day)	(milions m^3)	(m)	(ha)	(m^3/sc)	(mil m^3)	(lt/sc/ha)	(m^3/sc)	(mil m^3)	(mil m^3)	(mm/day)	(mil m^3)	(m^3/day)	(mil m^3)	%	(mil m^3)	(mil m^3)	(mil m^3)	(mil m^3)	(mil m^3)	(mil m^3)	%	(m)
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
				17,00																			**17,00**	**100,00**	
1	Nop	2	15	**17,00**	119,48	281,77	0,86	1,12	0,31	0,73	0,94	0,07	6,26	0,26	0,01	0,00	100,00	***1,01***	***1,01***	0,11	16,84	0,00	16,84	99,07	119,42
2	Des	1	15	16,84	119,42	280,10	0,97	1,26	0,86	2,02	2,62	0,07	4,87	0,20	0,01	0,00	93,98	***2,69***	***2,53***	-1,27	15,37	0,00	15,37	90,42	118,85
3		2	15	15,37	118,85	264,52	1,08	1,40	1,15	2,70	3,50	0,08	4,87	0,19	0,01	0,00	89,24	***3,58***	***3,19***	-1,79	13,39	0,00	13,39	78,75	118,10
4	Jan	1	15	13,39	118,10	243,51	1,35	1,75	1,41	3,31	4,29	0,07	4,63	0,17	0,01	0,00	76,18	***4,36***	***3,32***	-1,57	11,65	0,00	11,65	68,50	117,40
5		2	15	11,65	117,40	224,35	1,72	2,23	1,20	2,82	3,65	0,08	4,63	0,16	0,01	0,00	69,50	***3,73***	***2,59***	-0,36	11,13	0,00	11,13	65,44	117,13
6	Feb	1	15	11,13	117,13	216,86	2,76	3,58	1,08	2,54	3,29	0,07	4,65	0,15	0,01	0,00	69,50	***3,36***	***2,33***	1,25	12,22	0,00	12,22	71,88	117,65
7		2	15	12,22	117,65	231,13	2,29	2,97	1,24	2,91	3,78	0,08	4,65	0,16	0,01	0,00	70,96	***3,85***	***2,73***	0,24	12,30	0,00	12,30	72,33	117,68
8	Mar	1	15	12,30	117,68	231,95	1,82	2,36	1,03	2,42	3,14	0,07	4,98	0,17	0,01	0,00	70,96	***3,21***	***2,28***	0,08	12,20	0,00	12,20	71,79	117,64
9		2	15	12,20	117,64	230,97	2,33	3,02	0,74	1,74	2,25	0,08	4,98	0,17	0,01	0,00	70,96	***2,33***	***1,65***	1,37	13,40	0,00	13,40	78,85	118,10
10	Apr	1	15	13,40	118,10	243,68	1,64	2,12	0,35	0,82	1,07	0,07	5,37	0,20	0,01	0,00	76,18	***1,14***	***0,87***	1,26	14,47	0,00	14,47	85,10	118,51
11		2	15	14,47	118,51	254,94	1,24	1,61	0,24	0,56	0,73	0,08	5,37	0,21	0,01	0,00	85,67	***0,81***	***0,69***	0,92	15,18	0,00	15,18	89,31	118,78
12	Mei	1	15	15,18	118,78	262,53	0,97	1,26	0,30	0,71	0,91	0,07	5,20	0,20	0,01	0,00	85,67	***0,98***	***0,84***	0,42	15,39	0,00	15,39	90,55	118,86
13		2	15	15,39	118,86	264,76	0,93	1,20	0,45	1,06	1,37	0,08	5,20	0,21	0,01	0,00	89,24	***1,45***	***1,29***	-0,09	15,10	0,00	15,10	88,83	118,75
14	Jun	1	15	15,10	118,75	261,65	0,85	1,11	0,50	1,18	1,52	0,07	5,17	0,20	0,01	0,00	85,67	***1,59***	***1,36***	-0,26	14,64	0,00	14,64	86,12	118,57
15		2	15	14,64	118,57	256,78	0,81	1,04	0,55	1,29	1,68	0,08	5,17	0,20	0,01	0,00	85,67	***1,75***	***1,50***	-0,46	13,99	0,00	13,99	82,27	118,32
16	Jul	1	15	13,99	118,32	249,84	0,76	0,98	0,49	1,15	1,49	0,07	5,82	0,22	0,01	0,00	77,84	***1,56***	***1,22***	-0,24	13,53	0,00	13,53	79,60	118,15
17		2	15	13,53	118,15	245,04	0,79	1,02	0,33	0,78	1,01	0,08	5,82	0,21	0,01	0,00	76,18	***1,08***	***0,82***	0,20	13,52	0,00	13,52	79,53	118,15
18	Agu	1	15	13,52	118,15	244,90	0,69	0,90	0,27	0,63	0,82	0,07	6,37	0,23	0,01	0,00	76,18	***0,89***	***0,68***	0,22	13,50	0,00	13,50	79,44	118,14
19		2	15	13,50	118,14	244,74	0,66	0,86	0,35	0,82	1,07	0,08	6,37	0,23	0,01	0,00	76,18	***1,14***	***0,87***	-0,01	13,26	0,00	13,26	78,01	118,05
20	Sep	1	15	13,26	118,05	242,17	0,60	0,78	0,53	1,25	1,61	0,07	6,64	0,24	0,01	0,00	76,18	***1,68***	***1,28***	-0,50	12,52	0,00	12,52	73,64	117,76
21		2	15	12,52	117,76	234,30	0,58	0,75	0,30	0,71	0,91	0,08	6,64	0,23	0,01	0,00	70,96	***0,99***	***0,70***	0,05	12,34	0,00	12,34	72,58	117,69
22	Okto	1	15	12,34	117,69	232,38	0,59	0,76	0,20	0,47	0,61	0,07	7,68	0,27	0,01	0,00	70,96	***0,68***	***0,48***	0,28	12,35	0,00	12,35	72,65	117,70
23		2	15	12,35	117,70	232,52	0,70	0,91	0,00	0,00	0,00	0,08	7,68	0,27	0,01	0,00	70,96	***0,08***	***0,05***	0,86	12,94	0,00	12,94	76,14	117,93
24	Nov	1	15	12,94	117,93	238,80	0,71	0,92	0,00	0,00	0,00	0,07	6,26	0,22	0,01	0,00	76,18	***0,07***	***0,05***	0,87	13,59	0,00	13,59	79,93	118,17

Source: Analysis of 2019

Table 4.15 Guidelines for the pattern of operation of the Tanju Reservoir with the normal debit genetic algorithm (Q_{50})

Storage [%]	Q maks [%]
0	**7,72**
5	**13,46**
10	**20,87**
15	**25,68**
20	**35,22**
25	**43,97**
30	**52,97**
35	**60,00**
40	**67,17**
45	**67,22**
50	**68,08**
55	**68,18**
60	**68,81**
65	**69,50**
70	**70,96**
75	**76,18**
80	**77,84**
85	**85,67**
90	**89,24**
95	**93,98**
100	**100,00**

Source: Analysis of 2019

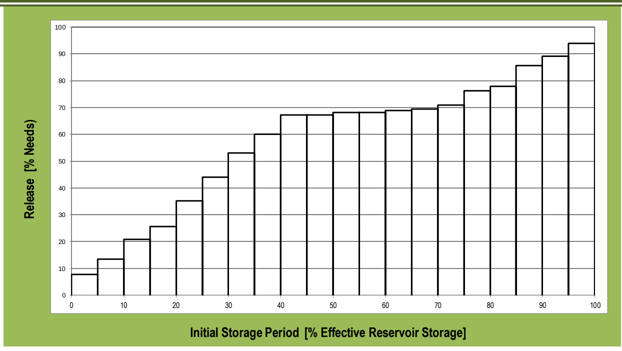

Figure 7 Guidelines for the pattern of operation of the Tanju Reservoir based on a normal debit genetic algorithm (Q_{50})
(Maximum release)

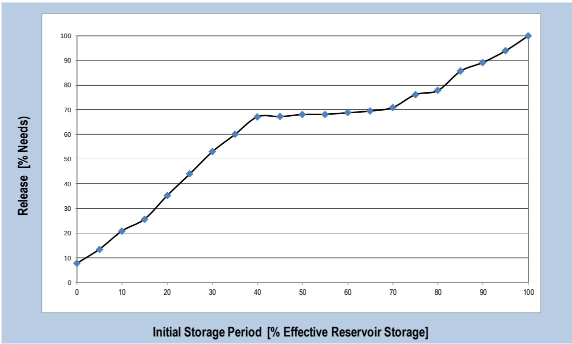

Figure 8 Guidelines for the Tanju Reservoir operating pattern based on the normal debit genetic algorithm (Q_{50})
(Interpolation equation)

Table 4.16 Simulation of reservoir operations based on the dry discharge genetic algorithm (Q_{80})

Luas Daerah Irigasi	=	**2350**	Ha
Tampungan Efektif Waduk	=	17.000.000	m^2
Tampungan Mati Waduk	=	1.370.000	m^3
Tampungan Total Waduk	=	18.370.000	m^3
Elevasi Tampungan Total	=	120,0	m
Elevasi Muka Air Rendah	=	111,5	m

No	Month	Period	Total	*S* initial	Initial Elevation	*A*	*Inflow*		Water Needs				Losing Water				*Outflow*	Total *Needs*	*Outfow*	*I - O*	*(S +(I - O - E - R))*	*Spill out*	*S* final	*S* final	Final Elevation
									Irrigation			Raw Water	Evaporation		Seepage										
			(day)	(milions m^3)	(m)	(ha)	(m^3/sc)	(mil m^3)	(lt/sc/ha)	(m^3/sc)	(mil m^3)	(mil m^3)	(mm/day)	(mil m^3)	(m^3/day)	(mil m^3)	%	(mil m^3)	(mil m^3)	(mil m^3)	(mil m^3)	(mil m^3)	(mil m^3)	%	(m)
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
				17,00																			**17,00**	**100,00**	
1	Nop	2	15	17,00	120,00	296,30	0,57	0,74	0,31	0,73	0,94	0,07	6,26	0,28	0,01	0,00	100,00	1,01	1,01	-0,27	16,45	0,00	16,45	96,78	119,79
2	Des	1	15	16,45	119,79	290,49	0,85	1,10	0,86	2,02	2,62	0,07	4,87	0,21	0,01	0,00	93,18	2,69	2,51	-1,40	14,84	0,00	14,84	87,27	119,17
3		2	15	14,84	119,17	273,36	0,68	0,89	1,15	2,70	3,50	0,08	4,87	0,20	0,01	0,00	81,19	3,58	2,90	-2,02	12,62	0,00	12,62	74,21	118,32
4	Jan	1	15	12,62	118,32	249,85	0,55	0,71	1,41	3,31	4,29	0,07	4,63	0,17	0,01	0,00	68,05	4,36	2,97	-2,26	10,18	0,00	10,18	59,88	117,35
5		2	15	10,18	117,35	222,96	0,66	0,86	1,20	2,82	3,65	0,08	4,63	0,15	0,01	0,00	62,05	3,73	2,31	-1,46	8,57	0,00	8,57	50,40	116,52
6	Feb	1	15	8,57	116,52	199,77	0,78	1,01	1,08	2,54	3,29	0,07	4,65	0,14	0,01	0,00	57,51	3,36	1,93	-0,92	7,50	0,00	7,50	44,14	115,96
7		2	15	7,50	115,96	184,47	0,69	0,89	1,24	2,91	3,78	0,08	4,65	0,13	0,01	0,00	55,30	3,85	2,13	-1,24	6,14	0,00	6,14	36,12	115,25
8	Mar	1	15	6,14	115,25	164,84	1,16	1,50	1,03	2,42	3,14	0,07	4,98	0,12	0,01	0,00	54,60	3,21	1,75	-0,25	5,77	0,00	5,77	33,92	115,06
9		2	15	5,77	115,06	159,48	1,45	1,88	0,74	1,74	2,25	0,08	4,98	0,12	0,01	0,00	53,87	2,33	1,25	0,62	6,27	0,00	6,27	36,88	115,32
10	Apr	1	15	6,27	115,32	166,71	0,86	1,12	0,35	0,82	1,07	0,07	5,37	0,13	0,01	0,00	54,60	1,14	0,62	0,50	6,63	0,00	6,63	39,01	115,51
11		2	15	6,63	115,51	171,93	0,83	1,07	0,24	0,56	0,73	0,08	5,37	0,14	0,01	0,00	54,60	0,81	0,44	0,63	7,12	0,00	7,12	41,91	115,77
12	Mei	1	15	7,12	115,77	179,02	0,67	0,86	0,30	0,71	0,91	0,07	5,20	0,14	0,01	0,00	55,30	0,98	0,54	0,32	7,30	0,00	7,30	42,97	115,86
13		2	15	7,30	115,86	181,60	0,67	0,86	0,45	1,06	1,37	0,08	5,20	0,14	0,01	0,00	55,30	1,45	0,80	0,06	7,23	0,00	7,23	42,51	115,82
14	Jun	1	15	7,23	115,82	180,48	0,59	0,76	0,50	1,18	1,52	0,07	5,17	0,14	0,01	0,00	55,30	1,59	0,88	-0,12	6,96	0,00	6,96	40,97	115,68
15		2	15	6,96	115,68	176,71	0,54	0,70	0,55	1,29	1,68	0,08	5,17	0,14	0,01	0,00	55,30	1,75	0,97	-0,27	6,56	0,00	6,56	38,58	115,47
16	Jul	1	15	6,56	115,47	170,86	0,50	0,65	0,49	1,15	1,49	0,07	5,82	0,15	0,01	0,00	54,60	1,56	0,85	-0,21	6,20	0,00	6,20	36,49	115,29
17		2	15	6,20	115,29	165,76	0,51	0,66	0,33	0,78	1,01	0,08	5,82	0,14	0,01	0,00	54,60	1,08	0,59	0,07	6,13	0,00	6,13	36,07	115,25
18	Agu	1	15	6,13	115,25	164,74	0,49	0,63	0,27	0,63	0,82	0,07	6,37	0,16	0,01	0,00	54,60	0,89	0,49	0,15	6,12	0,00	6,12	36,02	115,25
19		2	15	6,12	115,25	164,60	0,52	0,67	0,35	0,82	1,07	0,08	6,37	0,16	0,01	0,00	54,60	1,14	0,62	0,05	6,01	0,00	6,01	35,36	115,19
20	Sep	1	15	6,01	115,19	163,00	0,49	0,63	0,53	1,25	1,61	0,07	6,64	0,16	0,01	0,00	54,60	1,68	0,92	-0,29	5,56	0,00	5,56	32,71	114,94
21		2	15	5,56	114,94	156,80	0,48	0,62	0,30	0,71	0,91	0,08	6,64	0,16	0,01	0,00	53,87	0,99	0,53	0,09	5,49	0,00	5,49	32,32	114,90
22	Okto	1	15	5,49	114,90	156,05	0,48	0,62	0,20	0,47	0,61	0,07	7,68	0,18	0,01	0,00	53,87	0,68	0,37	0,26	5,57	0,00	5,57	32,77	114,95
23		2	15	5,57	114,95	156,91	0,44	0,57	0,00	0,00	0,00	0,08	7,68	0,18	0,01	0,00	53,87	0,08	0,04	0,53	5,91	0,00	5,91	34,79	115,14
24	Nov	1	15	5,91	115,14	161,61	0,43	0,56	0,00	0,00	0,00	0,07	6,26	0,15	0,01	0,00	53,87	0,07	0,04	0,52	6,28	0,00	6,28	36,95	115,33

Source: Analysis of 2019

Table 4.17 Guidelines for the pattern of operation of the Tanju Reservoir with the dry discharge genetic algorithm (Q_{80})

Storage [%]	Q maks [%]
0	8,76
5	17,48
10	27,28
15	34,82
20	43,98
25	52,69
30	53,87
35	54,60
40	55,30
45	57,03
50	57,51
55	62,05
60	65,03
65	66,26
70	68,05
75	73,96
80	75,98
85	81,19
90	84,57
95	93,18
100	100,00

Source: Analysis of 2019

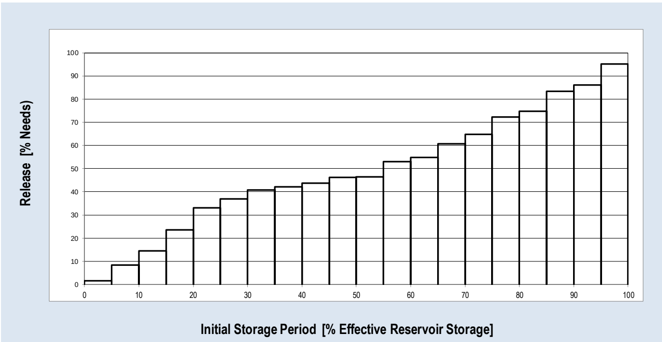

Figure 9 Guidelines for the pattern of operation of the Tanju Reservoir based on the dry debit genetic algorithm (Q_{80})
(Maximum release)

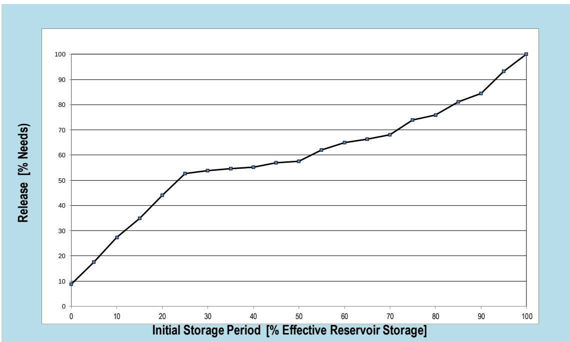

Figure 10 Guidelines for the pattern of operation of the Tanju Reservoir based on the dry debit genetic algorithm (Q_{80})
(Interpolation equation)

Comparison of Results of Reservoir Operation Patterns Based on Needs, Based on Storage and Optimization of Genetic Algorithms

Comparison of the results of the reservoir operation pattern with several inflow rules and conditions as follows:

Table 4.18 Comparison of results of the Tanju Reservoir operating pattern conditions of wet debit (Q_{20})

No	Rules	Result of Needs FullfilmentPlanting Season I (%)			Result of Needs FullfilmentPlanting Season II (%)			Result of Needs FullfilmentPlanting Season III (%)		
		Maximum	Interpolation	Deviation	Maximum	Interpolation	Deviation	Maximum	Interpolation	Deviation
1	Based on Needs	100,00 %	100,00 %	(+) 0,00	100,00 %	100,00 %	0,00	100,00 %	100,00 %	0,00
2	Based on Storage(simple)	90,00 %	92,21 %	(+) 2,21	90,00 %	94,35 %	(+) 4,35	100,00 %	100,00	0,00
3	Based on Genetic Algorithms	91,68 %	91,93 %	(+) 0,25	92,16 %	92,28 %	(+) 0,12	93,83 %	95,14 %	(+) 1,31

Source: Analysis of 2019

Table 4.19 Comparison of results of the Tanju Reservoir operating pattern for normal debit conditions (Q_{50})

No	Rules	Result of Needs Fullfilment MT I (%)			Result of Needs Fullfilment MT II (%)			Result of Needs Fullfilment MT III (%)		
		Maximum	Interpolation	Deviation	Maximum	Interpolation	Deviation	Maximum	Interpolation	Deviation
1	Based on Needs	100,00 %	100,00 %	(+) 0,00	100,00 %	100,00 %	(+) 0,00	100,00 %	100,00 %	(+) 0,00
2	Based on Storage(simple)	75,00 %	82,09 %	(+) 7,09	75,00 %	80,45 %	(+) 5,45	75,00 %	75,95 %	(+) 0,95
3	Based on Genetic Algorithms	69,50 %	69,37 %	(-) 0,13	70,96 %	70,97 %	(+) 0,02	70,96 %	70,94 %	(-) 0,02

Source: Analysis of 2019

Table 4.20 Comparison of results of the Tanju Reservoir operating pattern dry debit conditions (Q_{80})

No	Rules	Result of Needs Fullfilment MT I (%)			Result of Needs Fullfilment MT II (%)			Result of Needs Fullfilment MT III (%)		
		Maximum	Interpolation	Deviation	Maximum	Interpolation	Deviation	Maximum	Interpolation	Deviation
1	Based on Needs	46,81 %	46,81 %	(+) 0,00	39,91 %	39,91 %	(+) 0,00	37,49 %	37,49 %	(+) 0,00
2	Based on Storage(simple)	40,00 %	39,62 %	(-) 0,38	40,00 %	40,92 %	(+) 0,92	40,00 %	45,91 %	(+) 5,91
3	Based on Genetic Algorithms	54,60 %	54,44 %	(-) 0,16	53,87 %	54,13 %	(+) 0,26	53,87 %	53,94 %	(+) 0,06

Source: Analysis of 2019

Conclusion

From the results of the discussion that refers to the formulation of the problem, a number of things can be summarized as follows:

1. The results of the Tanju Reservoir operating pattern based on needs in the conditions of wet and normal debit indicate the fulfillment of needs of 100%, whereas in dry debit conditions (37.49% - 46.81%).
2. The results of the Tanju Reservoir operating pattern are based on storage under wet debit conditions (90% - 100%), normal debit is 75% and dry debit is 40%.
3. The results of the Tanju Reservoir operating pattern based on genetic algorithms show the conditions of wet debit (91.68% - 93.83%), normal debit (69.50% - 70.96%) and dry debit (54.60% - 53 , 87%).
4. Comparison of the results of the Tanju Reservoir operating pattern shows the best value for the condition of wet debit is based on needs, normal debit is based on needs and dry debit is based on genetic algorithms.
5. In this study also added release rules based on simple storage and genetic algorithms with interpolation equations and resulted in an increase in the value of fulfillment of needs.

Suggestion

1. The need for factual trials (rill) in the field to determine the results of the pattern of reservoir operations, especially with rules based on storage and release results with genetic algorithms, for 1 year (24 periods).
2. The need for adequate pc/laptop specifications in the process of running genetic algorithms in the Microsoft Excel program.

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