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The Performance of Equalization Model of Water Allocation Inter Irrigation Areas in River System

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Abstract. In Indonesia, water is public goods so it is necessary to control water allocation. Inequity of water allocation between water users is expanding largely, including irrigation as the largest user, while the density of headworks in the river are getting higher. Considering that water is limited, the practice of irrigation water allocation needs to be refined, from the traditional equity to volumetric equity. MEQAA (*Model Equalisasi Alokasi Air*/Equalization Model of Water Allocation) plays a role in determining water sharing between headworks in order to meet the maximum-equal K-factor in river. MEQAA-Generic is a calculation machine with: analog-deterministic dynamic model; network equation according to mass balance and linear optimization; independent-based system; sustainability-efficiency-equity constraints; Ms. Excel-VBA. The inputs are: scheme system, local inflow, and irrigation demand. The outputs are: K-factor, release and ecosystem quote. The model performance is identified by comparing the output to the class of K-factor based on treatment of water distribution. The model test is performed in an uncontrolled and complicated system in Kukusan Tanggek watershed with 24 headworks in Lombok river basin. As long as it is adequate for water sharing, MEQAA-G can always produce maximum-equal K-factor. The output model is used to operation control.

1 Introduction

System is a collective work between components for a particular purpose [3]. Since every main structure node of water withdrawal (headwork/HW) in the river is hydraulic-gravity connected as a system unit, therefore one integrated management is needed [32]. Water withdrawal must be based on a proportional, efficient, and equitable water allocation plans [13], considering in Indonesia water is public goods, and limited.

Practically, water allocation is not based on system, and disoriented, resulting in inequity [22]. Water allocation gap occurs mostly in water deficit areas, resulting in conflicts [12], [25], and [27]. In [26], competition case between water users in South Bali were caused by irrigation water deficit which makes it a complicated task. Regarding to domination of irrigation (usage rate over 90%) [7], this sector needs to be controlled. This effort is aligned with the emphasis of equity in water allocation by IWRM (Integrated Water Resources management) [29].

To create equity, a proportional water sharing is needed [8], [9], [12], and [25]. In [11], proportional equalization is an equal K-factor (release demand ratio) between same users. Also, K-factor method in Indonesia has been known in irrigation operations since the Dutch era. K-factor indicates volumetric reliability in system [16], which is Release Demand Ratio (RDR) [5], [4], [11], and [30].

Inequity due to the failure of water sharing will trigger conflict, even threaten food security [18]. Inequity also hit the ecosystem. For ecosystems, rules are required and must be taken as other water demands in the calculation [17]. The rule of ecosystem allotment is regulated in Government Regulation RI No. 38 Year 2011 regarding River, 95% probability of water availability and 5 % of water availability (Directorate General of Water Resources RI, Irrigation Planning Criteria or KP-02-revised edition, 2013: 28).

Water allocation control between nodes (headwork) in the complex river systems should be supported by models, such as Decision Support System (DSS) [11]. However, DSS produces many alternatives, other than optimal solutions, that professionals are required to make decisions [3]. From a series of DSS models in Table 1, upon local models it can be concluded as follows: i) limited ability in rigid systems, ii) does not consider ecosystems, and iii) does not produce water release according to volumetric equity. Besides, upon import models, it can be summarized that: i) priority oriented (with penalty), thus not suitable in Indonesia, and ii) integrated hydrology/water quality model.

Alternative model is expected to work multisystem. The output of the model has to fulfill the triangle constraints of sustainability-efficiency-equity [22] or SEE.

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Table 1. Recapitulation of water allocation model

No	Model/Origin/ Year	Programming Language	Orientation/ Function	Integrated Analysis	Type/Scale/ Type of Nodes	Result	Negotiaton
1	HLD/ LOMBOK RB/ England Expert/ 1991	Fortran	Equality / crop production, real time	Hydrology	Specific, scheme (interdependent), Limited nodes, Diversion & reservoir	Release, Unequal K-factor	Yes
2	MS EXCEL MODEL/ Indonesia/ 1998 & 2006	Lotus123 and Excel-VBA	Equality, real time	No	Specific, simple scheme, Very limited nodes, Diversion	Release, Unequal K-factor	Yes
3	PAA/ Indonesia/ 2010	Excel	Equality, real time	Irrigation water demand	Specific, simple scheme, Very limited nodes, Diversion	Water balance, Operation rule "adjusted"	Yes
4	WRMM/ Canada/ 1981	Visual Basic	Priority, planning	Hydrology	Generic, watershed, Diversion & reservoir	Water balance	Yes
5	RIBASIM/ Delft-Belanda/ 1985	Fortran	Priority, planning	Hydrology & water quality	Generic, watershed, Limited nodes, Diversion & reservoir	Water balance	Yes
6	REALM/ Australia/ 1980th	Fortran	Priority, planning	Hydrology & water quality	Generic, system scheme, Nodes >>>, Diversion & reservoir	Water balance	Yes
7	WRAP/ Texas-USACE/ 1980th	Fortran	Priority, planning	Hydrology & water quality	Generic, watershed, Nodes >>>, Diversion & reservoir	Water balance	Yes
8	WEAP/ SEI-Swedia/ 2000th	Javascript	Priority, planning	Hydrology & water quality	Generic, watershed, Diversion & reservoir	Water balance	Yes
9	MIKE BASIN/ DHI-Denmark/ 2008	Link with Excel-Visual Basic	Priority, equally deficit, and crop stress. Planning	Hydrology, groundwater, & water quality	Generic, watershed, Diversion & reservoir	Water balance	Yes

If water is public goods, then "equal for equity" will be accomplished by MEQAA-G. The target of the model is maximum-equal K-factor which is to allocate water proportionally, efficiently, and equally between HW in the system. In the beginning, this model was called MEQAA-E (Embryo), a conceptual model with a linear simulation-optimization based on mass balance equation.

The optimization concepts of MEQAA-E [5] is: i) to control the utilization of local inflow [23], ii) based on node in independent system [14] and [2], and iii) refers to the principle of mass balance [30] and [9]. Based on the concepts, linear network equation (NE) can be formed according to the system configuration. [5] continued, MEQAA-E's experiment used system scheme and hypothetical data, with NE being arranged manually, resulting in: i) max-equal K-factor between same users (irrigation), ii) SEE constraints are fulfilled, and iii) policy rules about K-factor gap between wet-dry system can be applied.

MEQAA-E's ability is limited and prone to human errors if it applied in various independent system states. The current research is the development of MEQAA-E to MEQAA-G (Generic). Generic model applies multisystem [20] and [30]. The principle of K-factor equalization of MEQAA-G follows MEQAA-E. The difference is MEQAA-G automatically builds up a specific model according to system scheme on Excel sheet.

Since MEQAA-E/G is conceptual, the validity of the model is determined based on the theory and assumptions used to construct the model structure [3]. With input variability in the form of system scheme, and also inflow and demand value, it is expected that every specific model formed by MEQAA-G in specific system can produce the optimal output.

As long as water can be allocated based on gravity flow water system, MEQAA-G will produce max-equal K-factor or equal K-factor class. Output model is used to control water allocation proportionally, efficiently, and equally between HW of same users (irrigation) in the river system.

2 Study Area

Lombok River Basin (RB) in Fig. 2 (4.738 km^2, 3.5 million populations, rainy season Nov-Mar, dry season Apr-Oct, normal rain 1189-1505 mm) with irrigation as the dominant user (94%) with system capacity in Table 2. High Level Diversion (HLD) suppletion canal was built in the 1980s to distribute water from the wet watershed in the west Lombok to dry watershed in the middle-east-south with 92 nodes in 6 watersheds interconnection for 60.000 ha of irrigation areas (Kartabrata & Marjanto, 1994: 40). And today, in HLD interconnection with 398 nodes in 12 watersheds for more than 97.000 ha [33].

Meanwhile, Kukusan Tanggek watershed is a dependent system (185 km^2, density of 1 node/5 km^2, 30 units of weir, 1 unit of small reservoir (local name is embung), 6446 ha of irrigation areas, 2 units of 30 lt/s of water domestic).

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Table 2. Capacity of water resources system in Lombok RB.

No	Item	Unit	Independent	Interdependent
1	Total watersheds	unit	40	12
2	Total area of effective watersheds	km^2	1.152	1.454
3	Total nodes: - Weir - Small reservoir (embung) - Reservoir - Diversion in HLD canal	unit	145 118 27 -	371 308 60 3 60
4	Node density	unit/ km^2	0.13	0.26
5	Total irrigation area	ha	26.221	97.037

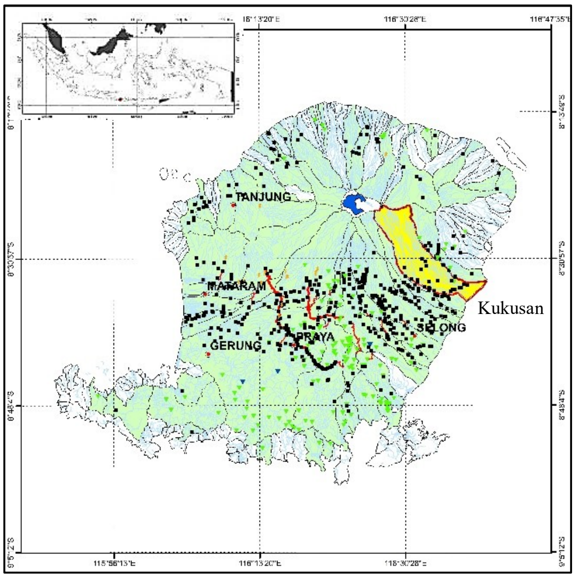


Fig. 2. Distribution of instream irrigation-headwork in Lombok RB and research site

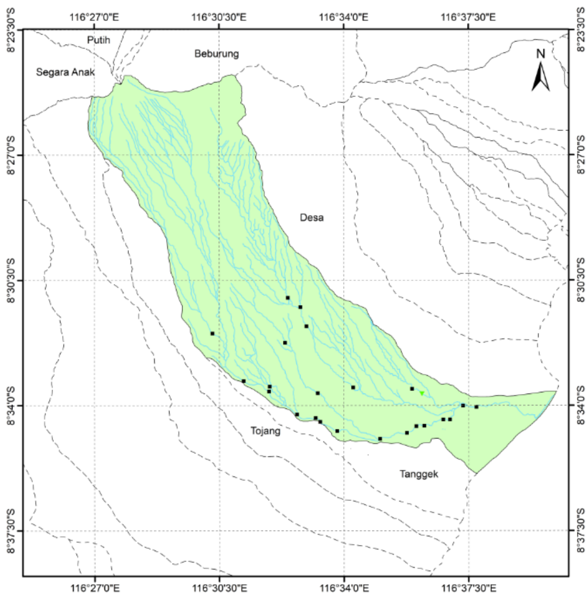


Fig. 3. Kukusan Tanggek watershed

The deficit of irrigation water in Lombok RB is caused by continuity and uneven distribution of water potential [21]. National rice granary areas, such as Lampung, Sulawesi Selatan, Bali and Lombok are experiencing high water vulnerability [10]. Based on the survey of water distribution in irrigation areas in Lombok RB (March IV and May I 2016, crop pattern: paddy (P) and paddy-soybean (P-S), in 114 nodes in 14 main rivers), there are: i) inequity in dry watershed, and ii) K-factor in the upstream is K1/K2, while in the downstream is deficit. The gap is in sync with [27], that in Lombok RB there are 386 conflict cases/year between water users, and drag the government as one of its actors. The gap occurs in Kukusan Tanggek as shows in Table 3.

Table 3. Cass of K-factor in the main river of Kukusan Tanggek

Headwork	Irrigation Area (ha)	Crop Start	Crop Pattern	Crop Area (ha)	Class of K-Factor	
					Mar IV	May I
B Meloang	168	Sep II	P-S	162	K1	K2
B Madang 1	138	Sep II	P-S	130	K1	K2
B Madang 2	46	Sep II	P	46	K1	K2
B Bagek Nyake	189	Okt II	P-S	172	K2	K2
B Mamben	477	Okt II	P-S	453	K2	K2
B Kukusan	1117	Okt II	P-S	1055	K2	K2
B Jowet	100	Okt II	P-S	96	K2	K2
B Tegaron	202	Okt II	P-S	192	K2	K2
B Reban Aji	129	Okt II	P-S	124	K3	K2
B Kerumut	58	Okt II	P	58	K3	K2
B Sukamulia	513	Okt II	P-S	480	K3	K3
B Batu Yang	532	Okt I	P-S	517	K2	K2

3 Method

3.1 Equalization Method

Water distribution between HWs need to be controlled, considering that water is limited and unequal. Gravitationally, water in the upstream is allocated to the downstream due to their own needs so K-factor gap does not happen, surely with emphasis on SEE constraints. K-factor could not be measured, therefore K-factor class which is analogized based on water distribution pattern in irrigation area is used. Practically, K-factor class is influnced by the adequacy of water supply and affects the inter-block rotation within the irrigation areas.

Table 4. Optimization constraint within MEQAA-G

	Sustainability	Efficiency	Equity
Indicator	- According to the demands and priority. - Ecosystem. - Both are fulfilled from time to time.	- Water release does not exceed the water demand. - Minimum water sharing is as much as the ecosystem allotment.	Equal K-factor between the same users after the fulfillment of domestic and ecosystem needs.
Goal	To maximize water release proportionally, equally between the same users (max-equal K-factor)		

K-factor class in Table 5 was inspired by [1], [4], [28] and Minesterial Regulation PU-PERA No. 12/PRT/M/2015). This K-factor's class classification considers inflow fluctuations, weir/diversion dominance, operational intensity, and error measuring tool.

Table 5. K-factor class of irrigation

Class	Range of K-Factor (%)	Water Deficit	Operational Categories	Interlude of Water Distribution
K1*	100	-	Continuously	-
K1	80 - 99	Very low	Continuously (limited)	-
K2	60 - 79	Low	Rotation (low)	Short
K3	40 - 59	Medium	Rotation (medium)	Medium
K4	20 - 39	High	Rotation (high)	Long
E	< 20	Very high	Emergency	Withered crop is prioritized

3.2. Model Structure

The purpose of water allocation is to distribute water optimally between nodes in the system [9]. For that purpose, MEQAA-G was built with characteristics of: i) as a "calculating machine" of water allocation with a max-equal K-factor, after drinking water and ecosystem are fulfilled [23], dan ii) using the technique of "tracking" system scheme to create NE. MEQAA-G is supported by Excel-VBA, because it is popular/practical for non-professional programmers and its code format is relative simple to run such a great program [28].

Solutions on water resources system are often using optimization [9], [23], [24] and [30], such as linear programming (LP). In [9], [15], [20] and [30], optimation/simulation model is used to attain system operation decisions. In [24] both combinations produce an optimal solution, although it contains many variables. Concluded by [30], optimal/nearly optimal value is obtained from execution of ad hoc model with iteration. Iteration requires a set up initial value [9], which is K-factor draft 100%-0 with step 0,1 – 1% [5].

The principle of mass balance [9], [30], [31] in every HW is: with the number on the right-hand side.

$$I - O = \Delta V \qquad (1)$$

With inflow (I) includes local inflow (QL) and water sharing (QS) from upstream, outflow (O) includes release (QR) and water sharing (QS) to downstream, and ΔV= a change in volume. It is assumed that the loss of water (LL) between HWs mutually negates with return flow (RF) from irrigation area. The loss value is hard to quantify therefore it is often ignored [30].

MEQAA-G with its purpose of maximizing water distribution is:

$$\max Z = \sum_{i=1}^{n} K_i . QD_i \qquad (2)$$

If every HW is weir/diversion, then ΔV=0 [30]. Based on formula 1 and 2, NE is arranged based on independent system. NE follows domino effect flow [30] and [2]. The simple structure of NE as shown in Figure 3 combines 5 functions of constraint, such as:

- mass balance: $QL_i + QS_{i-1} - QR_i - QS_i = 0$ (3)
- water availability: $0 \leq QR_i \leq (QL_i + QS_{i+1} - QE_i)$ (4)
- ecosystem sustainability: $QS_i \geq QE_i$ with

  $QE = 0.05\ QA$ (5)
- efficiency: $0 \leq QR_i \leq QD_i$ which can substituted into

  $0 \leq K_i \leq 1$ or $QR_i = K_i . QD_i$ [5] (6)
- equity from upstream to downstream of HW:

  $K_i - K_{i+1} = 0$ [5] (7)

QD = irrigation demand, QE= ecosystem allocation

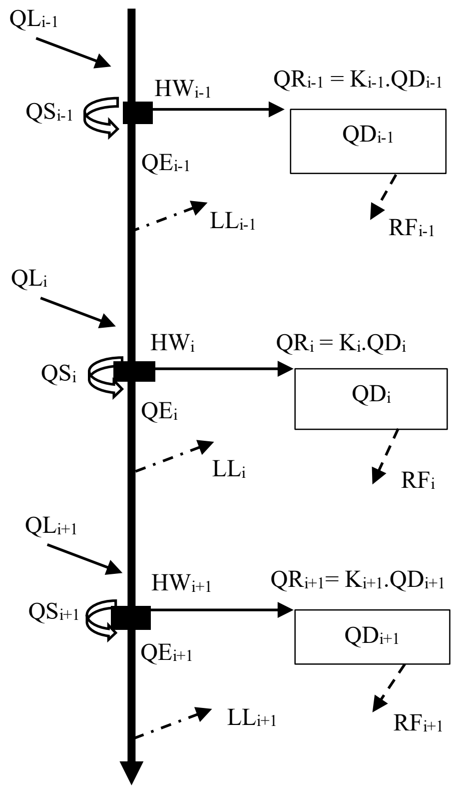


Fig. 3. Network flow sketch in system segment with weir

As for reservoir (ΔV≠ 0), volume calculation is applied [30], [6] and [31]:

$$V_{end} = V_{beg} + V_{inlfow} - V_{release} - WL \qquad (8)$$

With $0 \leq V_{end} \leq V_{eff}$, V_{eff} = effective volume and WL = water loss because of evaporation and seepage. Since in Kukusan Tanggek system there is Embung Senang, therefore reservoir rule curve is required as constraint adjusment factor [31]. Operational volume limit is:

$$VRC = V_{beg} * RCC \text{ on condition that } V_{end} \geq VRC \qquad (9)$$

Regarding to formula 8, rule curve coeficient ($0 \leq RCC \leq 1$) is spesific in every reservoir. This coefficient is based on inflow-demand, reservoir capacity and operating policy. In this study, the equation of RCC line is assumed to follow functional equation of Batujai reservoir.

For more practical [33], WL ($=0.01.V_{beg}$) is assumed to be 1% of the beginning volume of Batujai Reservoir

(V_{eff} = 18.000.000 m^3, with evaporation of 4-6 mm/day and seepage of 0.08 – 0.70 lt/s).

NE's development applies the numbering of streams and juctions respectively such as main river 100, and tributary 200, 300 and so on, while for junction number is {(tributary number: 100) – 1} (Figure 5). The output of model performance test will prove that the field conditions is uncontrolled, which means existing K-factor class is unequal between upstream and downstream.

In MEQAA-G, there is about 1000 lines of syntax code, including: i) tracking (including NE) and ii) equalization. Trial of the code uses hypothetical data, including river scheme, inflow, dan demand.

4 Results and Discussion

4.1. System scheme tracking

In Figure 5, there are: i) 24 HWs with B code for 23 weirs/diversions and EM code for 1 small reservoir, ii) number 100 in the main river, then number 200 – 500 in every branch river, and iii) junction number 1 at tributary 200, 2 at 300, etc.

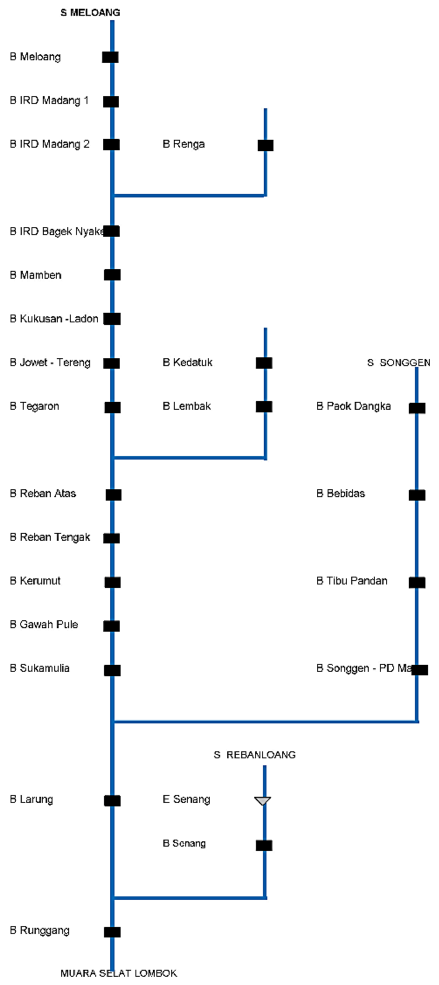


Fig. 5. Node codes of HW and junction in Kukusan Tanggek system scheme

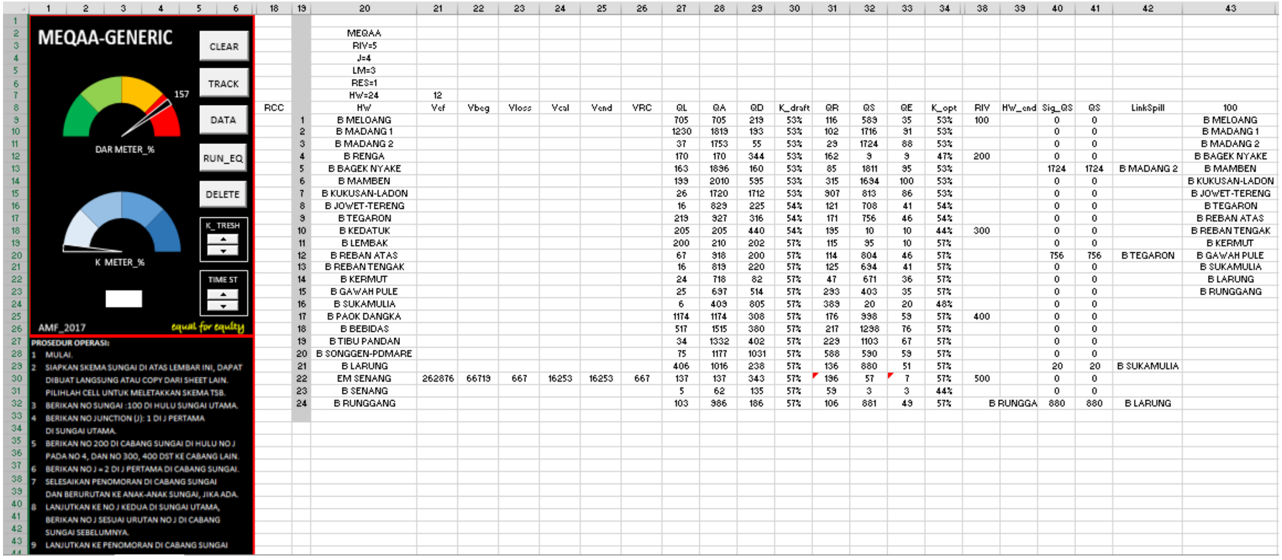
4.2 River group and network equation structure

Based on system scheme track (Figure 5), the model automatically produces river grouping (Table 6). In this case, there are 5 river groups with numbers 100-500 (Table 6). NE structure is on the Excel sheet (Table 7), generally described that: i) NE translates the mass balance principles and optimation that detailed into 3 to 10 equations to form computational equations in every HW, ii) If a HW has demand =0, then link of gap will go towards HW in the downstream, and iii) there is no link of gap in the most downstream HW, due to the estuary.

Table 6. River grouping

43	48	53	58	63
RIV_100	RIV_200	RIV_300	RIV_400	RIV_500
B MELOANG	B RENGA	B KEDATUK	B PAOK DANGKA	EM SENANG
B MADANG 1	B BAGEK NYAKE	B LEMBAK	B BEBIDAS	B SENANG
B MADANG 2	B MAMBEN	B REBAN ATAS	B TIBU PANDAN	B RUNGGANG
B BAGEK NYAKE	B KUKUSAN-LADON	B REBAN TENGAK	B SONGGEN-PDMARE	
B MAMBEN	B JOWET-TERENG	B KERMUT	B LARUNG	
B KUKUSAN-LADON	B TEGARON	B GAWAH PULE	B RUNGGANG	
B JOWET-TERENG	B REBAN ATAS	B SUKAMULIA		
B TEGARON	B REBAN TENGAK	B LARUNG		
B REBAN ATAS	B KERMUT	B RUNGGANG		
B REBAN TENGAK	B GAWAH PULE			
B KERMUT	B SUKAMULIA			
B GAWAH PULE	B LARUNG			
B SUKAMULIA	B RUNGGANG			
B LARUNG				
B RUNGGANG				

Table 7. Some specific MEQAA-G worksheeet format in Kukusan Tanggek system



MEQAA
RIV=5
J=4
LM=3
RES=1
HW=24 12

RCC		HW	Vef	Vbeg	Vloss	Vcal	Vend	VRC	QL	QA	QD	K_draft	QR	QS	QE	K_opt	RIV	HW_end	Sig_QS	QS	LinkSpill	100
	1	B MELOANG							705	705	219	53%	116	589	35	53%	100		0	0		B MELOANG
	2	B MADANG 1							1230	1819	193	53%	102	1716	91	53%			0	0		B MADANG 1
	3	B MADANG 2							37	1753	55	53%	29	1724	88	53%			0	0		B MADANG 2
	4	B RENGA							170	170	344	53%	162	9	9	47%	200		0	0		B BAGEK NYAKE
	5	B BAGEK NYAKE							163	1896	160	53%	85	1811	95	53%			1724	1724	B MADANG 2	B MAMBEN
	6	B MAMBEN							199	2010	595	53%	315	1694	100	53%			0	0		B KUKUSAN-LADON
	7	B KUKUSAN-LADON							26	1720	1712	53%	907	813	86	53%			0	0		B JOWET-TERENG
	8	B JOWET-TERENG							16	829	225	54%	121	708	41	54%			0	0		B TEGARON
	9	B TEGARON							219	927	316	54%	171	756	46	54%			0	0		B REBAN ATAS
	10	B KEDATUK							205	205	440	54%	195	10	10	44%	300		0	0		B REBAN TENGAK
	11	B LEMBAK							200	210	202	57%	115	95	10	57%			0	0		B KERMUT
	12	B REBAN ATAS							67	918	200	57%	114	804	46	57%			756	756	B TEGARON	B GAWAH PULE
	13	B REBAN TENGAK							16	819	220	57%	125	694	41	57%			0	0		B SUKAMULIA
	14	B KERMUT							24	718	82	57%	47	671	36	57%			0	0		B LARUNG
	15	B GAWAH PULE							25	697	514	57%	293	403	35	57%			0	0		B RUNGGANG
	16	B SUKAMULIA							6	409	805	57%	389	20	20	48%			0	0		
	17	B PAOK DANGKA							1174	1174	308	57%	176	998	59	57%	400		0	0		
	18	B BEBIDAS							517	1515	380	57%	217	1298	76	57%			0	0		
	19	B TIBU PANDAN							34	1332	402	57%	229	1103	67	57%			0	0		
	20	B SONGGEN-PDMARE							75	1177	1031	57%	588	590	59	57%			0	0		
	21	B LARUNG							406	1016	238	57%	136	880	51	57%			20	20	B SUKAMULIA	
	22	EM SENANG	262876	66719	667	16253	16253	667	137	137	343	57%	196	57	7	57%	500		0	0		
	23	B SENANG							5	62	135	57%	59	3	3	44%			0	0		
	24	B RUNGGANG							103	986	186	57%	106	881	49	57%		B RUNGGA	880	880	B LARUNG	

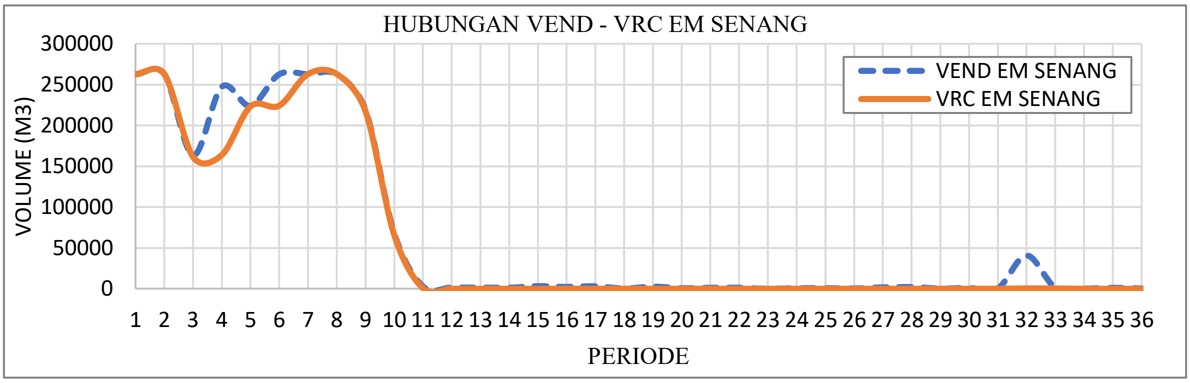


Fig. 5. Vend and VRC of Senang Small Reservoir

4.3 Result and discussion

Based on the input data of QL and QD (Table 8), MEQAA-G output is obtained as shown in Table 9 (K-factor) dan Figure 6a and 6b. It is generally described: i) on trial with hypothetical data and ends with secondary data of 36 periods of inflow and demand, there is ouput model with release that is compatible with max-equal K-factor, ii) K-factor value is strongly influenced by inflow, iii) spillout/water sharing is always the same as or more than the ecosystem rations, iv) water sharing from Senang small reservoir (embung) to Senang Weir can be controlled ($V_{end} \geq$ VRC), and v) if the inflow is high, then the iteration will be fast, and vice versa. In this case, there are about 1.298 – 844.240 iteration (K-factor's step = 0.1%), with total time around 7 minutes.

Table 8. Some local inflow (QL, lt/s) and irrigation demand (QD, lt/s) data

NO	HEADWORK	QL	QD	QL	QD
		JAN I	JAN I	JUL I	JUL I
1	B MELOANG	1057	0	337	99
2	B MADANG 1	1849	0	588	22
3	B MADANG 2	62	0	18	6
4	B RENGA	270	0	82	160
5	B BAGEK NYAKE	267	0	78	103
6	B MAMBEN	332	0	95	402
7	B KUKUSAN-LADON	49	11	13	1146
8	B JOWET-TERENG	31	27	8	172
9	B TEGARON	418	40	105	252
10	B KEDATUK	304	34	98	267
11	B LEMBAK	325	20	95	140
12	B REBAN ATAS	132	25	32	161
13	B REBAN TENGAK	31	30	7	183
14	B KERMUT	48	11	11	68
15	B GAWAH PULE	52	71	12	444
16	B SUKAMULIA	12	84	3	581
17	B PAOK DANGKA	1713	0	561	153
18	B BEBIDAS	746	0	247	193
19	B TIBU PANDAN	50	0	16	236
20	B SONGGEN-PD MARE	125	58	52	736
21	B LARUNG	698	0	283	165
22	EM SENANG	236	0	96	252
23	B SENANG	10	0	4	94
24	B RUNGGANG	194	0	72	134

Table 9 shows some model outputs (8 of 36 periods), referring to equal K-factor in every river group. The flow follows hydraulic link from HW in the upstream to HW in the downstream in each river. Downstream in river 100 will experience more than once equalization, due to its part of many rivers (200 – 500) as shown in Table 6. Under conditions of demand = 0 for the period of Jan I and Oct III (Table 9), it is written "FALSE" which means the HW is not included in the calculation of the K-factor gap (grey colour in Figure 6a). The calculation of gap is forwarded to the downstream HW.

In Figure 5, V_{end} ≥VRC is fulfilled. RCC=100% occurred in Jan 1 (rainy season) that the reservoir was full. Menwhile, in Apr I - Des III (dry season), RCC=1%, the volume reservoir was minimum (≈0).

Table 9. Some MEQAA-G output (K factor)

NO	HEADWORK	1	3	10	12	19	21	28	30
		JAN I	JAN III	APR I	APR III	JUL I	JUL III	OKT I	OKT III
1	B MELOANG	FALSE	100%	88%	53%	37%	55%	14%	14%
2	B MADANG 1	FALSE	100%	88%	53%	37%	55%	14%	FALSE
3	B MADANG 2	FALSE	100%	88%	53%	37%	55%	14%	FALSE
4	B RENGA	FALSE	100%	88%	47%	37%	41%	11%	14%
5	B BAGEK NYAKE	FALSE	100%	88%	53%	37%	55%	14%	14%
6	B MAMBEN	FALSE	100%	88%	53%	37%	55%	14%	14%
7	B KUKUSAN-LADON	100%	100%	88%	53%	37%	55%	14%	14%
8	B JOWET-TERENG	100%	100%	88%	54%	38%	55%	15%	14%
9	B TEGARON	100%	100%	88%	54%	38%	55%	15%	14%
10	B KEDATUK	100%	100%	88%	44%	35%	49%	15%	15%
11	B LEMBAK	100%	100%	89%	54%	38%	55%	15%	15%
12	B REBAN ATAS	100%	100%	89%	54%	38%	55%	15%	15%
13	B REBAN TENGAK	100%	100%	89%	54%	38%	56%	15%	15%
14	B KERMUT	100%	100%	89%	54%	38%	56%	15%	15%
15	B GAWAH PULE	100%	100%	89%	54%	38%	56%	15%	15%
16	B SUKAMULIA	100%	100%	88%	53%	38%	55%	14%	14%
17	B PAOK DANGKA	FALSE	100%	100%	83%	65%	95%	22%	24%
18	B BEBIDAS	FALSE	100%	100%	83%	65%	95%	22%	24%
19	B TIBU PANDAN	FALSE	100%	100%	83%	65%	96%	22%	24%
20	B SONGGEN-PD MARE	100%	100%	100%	82%	64%	95%	21%	23%
21	B LARUNG	FALSE	100%	100%	100%	100%	100%	69%	89%
22	EM SENANG	FALSE	63%	62%	30%	28%	60%	21%	28%
23	B SENANG	FALSE	62%	61%	29%	27%	59%	20%	27%
24	B RUNGGANG	FALSE	100%	100%	100%	100%	100%	68%	89%

Still in Table 9, in the period of Oct I and Oct II, there is an equal K-factor with a very small value (11-15%) or emergency (E). In this condition, it is difficult for the water to flow along the river and also the operations can be hampered. To overcome this, it is necessary to allocate water between irrigation area in the river segment with specific HW. In this on-off system, water allocation has to be prioritized according to crop age or urgent demand. This effort is made to increase the K-factor into class K4 or K3.

Figure 6a and 6b are the examples of output machine for the period of Jan I and Jul I. The colours will be plotted on the scheme, such as grey (HW with demand = 0), red (K4), yellow (K3), green (K2), light blue (K1) and dark blue (K1*). These colours are suitable with the equalization results as shown in Table 5.

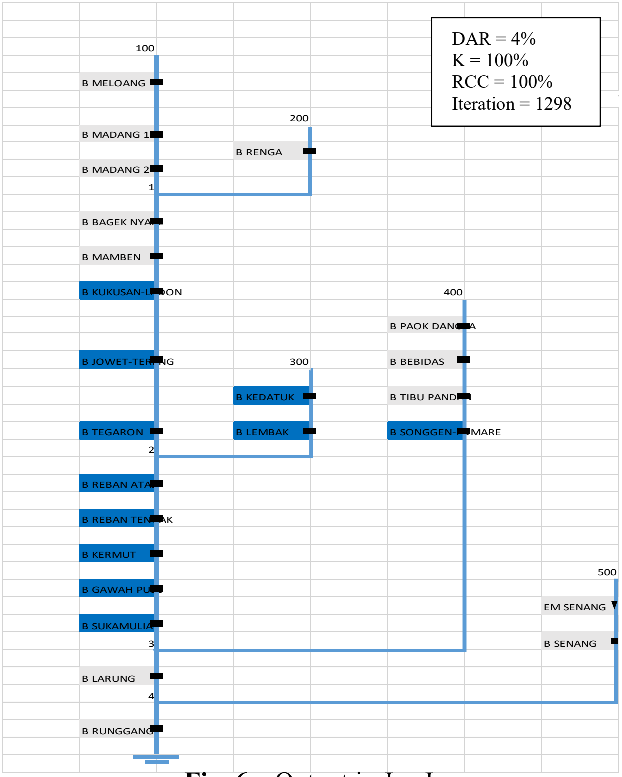


Fig. 6a. Output in Jan I

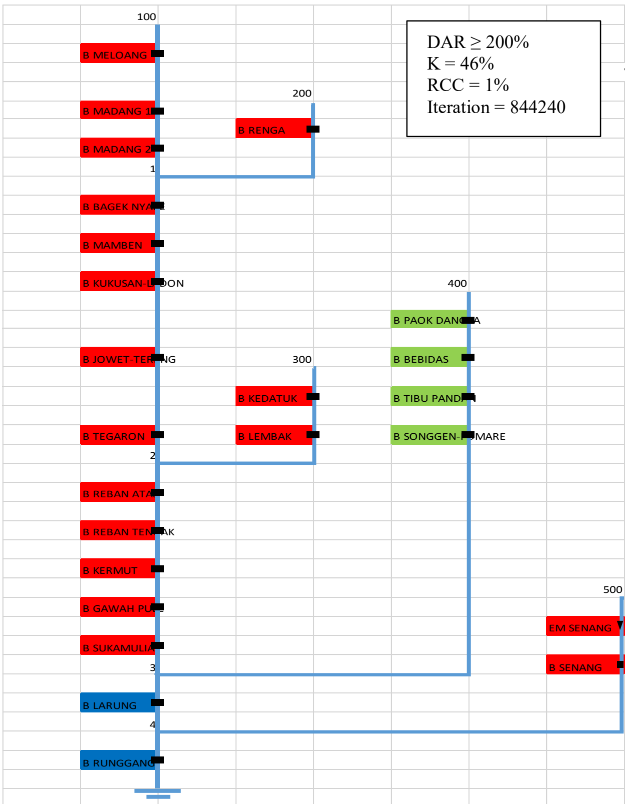


Fig. 6b. Output in Jul I

3 Conclusions and recommendation

Based on the trials in the hypothetical system and Kukusan Tanggek system, it can be concluded and recommended as follows:

1. MEQAA-G simplifies the computation of water allocation in the independent river systems with the final result always meet the max-equal K-factor, and also the ecosystem quota,
2. For the reservoir that produces a result as mentioned above in point a, the water sharing will follow the V_{end} ≥VRC criteria, with RCC value always varying between operating periods. Rule curve is specific that it always be different in every reservoir.
3. MEGAA-G is not influenced by types of data (hypothetical and or secondary data), since it is a conceptual model and also because NE shapes and links are always dynamic following HW configuration in the system,
4. The number of iterations depends on the density/configuration of HW (including reservoir), water balance and K-factor step,
5. MEQAA-G output is very contrastive with on the field reality (Table 3), i.e. from inequal classification of K-factor (reality) become equal.
6. It is necessary to make priority on water allocation (on-off system) if K-factor < 20% (emergency) occurs in some HWs in the system, and
7. MEQAA-G needs to be applied in a more complex independent system with cascade/multi reservoirs or dependent system (2 watersheds) to interdependent systems (more than 2 watersheds) in Lombok RB and another.

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References

1. R. Azuan, AH. Wahyudi, Sobriyah, PKOWDR, *Media Teknik Sipil,* **IX**, 71-75 (2009)
2. D. Dutta, S. Kima, J. Vazea, J. Hughesa, A. Yanga, WASWRM, *21st International Congress on Modelling and Simulation. Australia,* 2040-2046 (2015)
3. Eriyatno, *Ilmu Sistem-Meningkatkan Mutu dan Efektivitas Manajemen*, Jilid I E **IV** (2012)
4. A.M. Fagi, PSDA, *Buletin Iptek Tanaman Pangan*, **2** No 1, (2007)
5. A.M. Farriansyah, G.R. Novelia, B. Husnan, DEMWA, *Prosiding Seminar Internasional HATHI-V*, 722-732 (2016)
6. S.S. Fayaed, A. El-Shafie, O. Jaafar, RSSOT, *Stoch Environ Res Risk Assess*, 27:1751–1772 (2013)
7. M.A. Fulazzaky, CIWRM, *Water*, **6**, 2000-2020 (2014)
8. S.D. Gorantiwar, I.K. Smout, *Performance Assessment Of Irrigation Water Management Of Heterogeneous Irrigation Schemes: 1. A Framework For Evaluation. Irrigation and Drainage Systems*, Loughborough University's Institutional Repository (2005)
9. D. Haro, J. Paredes, A. Solera, J. Andreu, MSOWAPWNFP, *Water Resour Manage,* 26:4059–4071 (2012)
10. W. Hatmoko, IKAI, *Paper Conference*, *Seminar INAICD*, **1** (2014)
11. W. Hatmoko, W. Triweko, D. Yudianto, SPKAA, *Jurnal Teknik Hidraulik Puslitbang SDA*, **3**, 71-86 (2012)
12. G. Irianto, PWS, *Kompas* (2004)
13. M. Kartabrata, W.D. Marjanto, PCMDAA, *Jurnal Informasi Teknik, Ditjen Pengairan-Dep PU*, **14**, (1994)
14. T.J. Kim, R.A. Wurbs, MRRSM, *KSCE Journal of Civil Engineering*, 15(8):1457-1467 (2011)
15. Koch, Grunewald, CMSDRWRMP, *Water Resour Manage*, 23:1403-1422 (2008)
16. Z.W. Kundzewicz, J. Kindler, MCERA, *Modelling and Management of Sustainable Basin-scale Water Resource Systems (Proceedings of a Boulder Symposium, July 1995)*, *IAHS Publ. 231*, 217 – 224 (1995)
17. K.S. Meijer, W.N.M. Krogt van der, E. Beek van, NAIEFR, *Water Resour Manage*, 26:1271–1286 (2012)
18. J.K. Mutiga, S.T. Mavengano, S. Zhongbo, T. Woldai, R. Becht, WAPTMWUC, *Water Resour Manage*, 24:3939–3959 (2010)
19. H. Pawitan, B.I. Setiawan, B. Kartiwa, K. Subagyono, P. Rejekiningrum, MPAPBKL, *Laporan Akhir Penelitian Kerja Sama Kemitraan Penelitian Pertanian dengan Perguruan Tinggi (KKP3T)* (2009)
20. B.J.C. Perera, B. James, M.D.U. Kularathna, REALM, *Journal of Environmental Management*, **77**, 291–300 (2005)
21. D. Rohmat, UKKKSDA, *talk show Hari Air Dunia* (2010)
22. R. Roozbahani, B. Abbasi, S. Schreider, A. Ardakani, MATRWA, *Water Resour Manage*, 28:5447–5463 (2014)
23. R. Roozbahani, B. Abbasi, S. Schreider, OAWCS, *Ann Oper Res*, 229:657–676 (2015)
24. A. Singh, CMMWR, *Hydrogeology Journal*, 23: 1217–1227 (2015)
25. H. Sosiawan, K. Subagyono, Strategi Pembagian Air Secara Proporsional Untuk Keberlanjutan Pemanfaatan Air. Balai Besar Penelitian dan Pengembangan Sumberdaya Lahan Pertanian, *Pengembangan Inovasi Pertanian* 2 (4) (2009)
26. S. Strauß, WC, *Hum Ecol*, 39:69–79 (2011)
27. S. Suryadi, Kekeringan dan Hak Guna Air, *Koran Kompas 09 Agustus* (2006)
28. B. Tongongar, C.E. Kan, J.H. Chen, DFT, *American-Eurasian J. Agric. & Environ. Sci*., **3** (3) (2008)
29. UN Water, World Water Development Report 2015, “Water for a Sustainable World”, *UNESCO* (2015)
30. R.A. Wurbs, Comparative Evaluation of Generalized Reservoir/River System Models, Technical Report No. 282 Texas Water Resources Institute (2005)

31. Y.B. Yazdeli, O.B. Haddad, E.F. Mehdipour, M.A. Mariño, ERSO, *Water Resour Manage*, 28:715–729 (2014)
32. B. Yulistiyanto, B.A. Kironoto, PPSDA, *Media Teknik*, **2** (2008)
33. BWS-NT I, Rencana Alokasi Air Tahunan (RAAT) WS Lombok, *Balai Wilayah Sungai Nusa Tenggara I* (2016)