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WATER ALLOCATION OPTIMIZATION FOR COMBINED USERS OF ENERGY GENERATION AND IRRIGATION DEMAND AT THE UPSTREAM BRANTAS RIVER REACH USING MIXED INTEGER LINEAR PROGRAMMING METHOD

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Presentation outlines

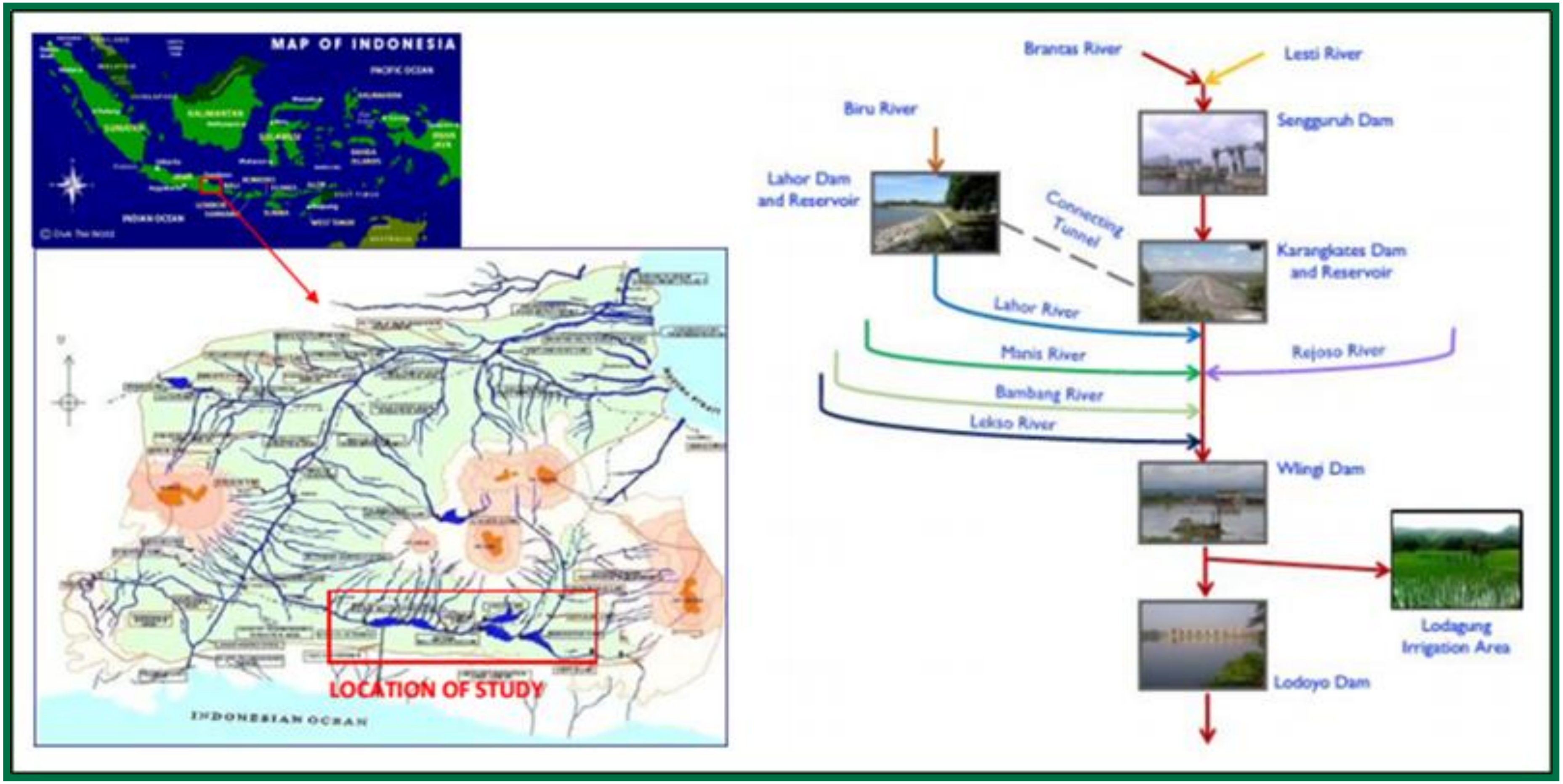
1. Background
2. Location
3. Formulation
4. Result
5. Conclusion

Background

As a major river in East Java Indonesia, Brantas River become an important water source in the basin area of 12.000 km2 with 320 km length originated at Sumber Brantas Villaga to Surabaya, the capital city of East Java Province. Several large dams have been constructed in purpose of water conservation and flood control. The river supplies irrigation as well as municipal, industrial and domestic water, including water power generator produce electricity energy.

The objective of this research is to optimize the use of available water in river in order to gain the maximum benefit that obtained from power generators and irrigation water supply in the upper reach of Brantas River. Trade off solution may be obtained by using mixed integer linear programming approach.

Location (1)


MAP OF INDONESIA
LOCATION OF STUDY
INDONESIAN OCEAN
Brantas River
Lesti River
Biru River
Sengguruh Dam
Lahor Dam
and Reservoir
Connecting Tunnel
Karangkates Dam
and Reservoir
Lahor River
Manis River
Rejoso River
Bambang River
Lekso River
Wlingi Dam
Lodagung
Irrigation Area
Lodoyo Dam

Location (2)

No.	Name of Dam	Location	Function
1.	Sengguruh	Village of Sengguruh, Kepanjen, 24 km south of Malang.	Elevtricity power generator 2x14.5 MW, control sediment entering Karangkates.
2.	Karangkates-Lahor	Village of Karangkates, Sumber-pucung, Malang. Lahor is 1.5 km north of Karangkates.	Flood control, irrigation, municipal and industry water supply, electricity power generator 3x35 MW.
3.	Wlingi	Village of Jegu, Kutojayan, Blitar.	Flood Control, sediment control, flood control and electricity power generator 2x27 MW
4.	Lodoyo	7 km downstream of Wlingi Dam.	Electricity power generator 1x4.5 MW and sediment control from Wlingi Dam.

Formulation (1)

Mixed Integer Linear Programming (MILP)

Max Revenue $Z = \Sigma\, bt_i.T_{ik} + \Sigma\, ba_j.A_{jk}$, i = 1 (Sengguruh), 2 (Karangkates), 3 (Wlingi), 4 (Lodoyo)
j = 1 (Rice crop), 2 (Corn crop)
k = 1 (Rainy season), 2 (1st Dry season), 3 (2nd Dry season)

Subject to:

Power generator:	$p_{ik}.T_{ik}$	$\leq P_{ik}$	, i = 1 to 4, k = 1 to 3
Farm area:	$\Sigma\, A_{jk}$	$\leq A_{total}$	, j = 1 to 2, k = 1 to 3
Water balance:	$qt_1.T_{1k}$	$\leq Q_{1k}$	, k = 1 to 3
	$qt_2.T_{2k} - V_k + V_{k+1} + S_k$	$= Q_{2k}$	, k = 1 to 3
	$qt_3.T_{3k} + \Sigma\, qa_{jk}.A_{jk} - S_k$	$\leq Q_{3k}$	, j = 1 to 2, k = 1 to 3
	$qt_4.T_{4k} + \Sigma\, qa_{jk}.A_{jk} - S_k$	$\leq Q_{4k}$	, j = 1 to 2, k = 1 to 3
Reservoir at Karangkates:	V_1	$= V_{initial}$	
	V_k	$\leq V_{capacity}$	, k = 2 to 3
Non negativity	T_{ik}	≥ 0 and Integer	
	A_{jk}, V_k, S_k	≥ 0 and Real	

Where:

- T_{ik} : Number of turbine at i-Dam and k-Season
- A_{jk} : Area of irrigation for j-Crop and k-Season (Ha)
- V_k : Volume of water at Karangkates reservoir in k-Season (m^3), except V_1 = initial volume at first season
- S_k : Spill out discharge at Karangkates reservoir in k-Season (m^3)
- bt_i : Unit benefit of turbine at i-Dam (Rupiah/Turbine)
- ba_j : Unit benefit of j-Crop (Rupiah/Ha)
- p_{ik} : Unit power production (Megawatt)
- qt_i : Unit discharge for turbine operation (m^3/season/turbine)
- qa_{jk} : Unit discharge for irrigation (m^3/season/Ha)

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Formulation (2)

Software Application:
The calculation of integer linear programming using QM for Windows (POMQMv3).

Assumptions for boundaries are:
* the total area at Lodagung Irrigation Scheme is 12,499 Ha,
* maximum of reservoir volume at Karangkates Dam is 175,000,000 m3
* maximum number of turbines or power generators:

- Sengguruh Turbines	2 x 14.5 MW
- Karangkates Turbines	3 x 35 MW
- Wlingi Turbines	2 x 27 MW
- Lodoyo Turbines	1 x 4.5 MW

Result of calculation shown for each three seasons:
* rainy season
* 1st dry season and
* 2nd dry seasons

Formulation (3)

Objective 1 Maximizing Both Irrigation and Energy:

$$\text{Max } Z = (377.0496\, T_{S1} + 377.0496\, T_{S2} + 377.0496\, T_{S3} + 377.0496\, T_{K1} + 377.0496\, T_{K2} + 377.0496\, T_{K3} + 377.0496\, T_{W1} + 377.0496\, T_{W2} + 377.0496\, T_{W3} + 377.0496\, T_{L1} + 377.0496\, T_{L2} + 377.0496\, T_{L3} + 19.65\, A_{R1} + 19.65\, A_{R2} + 19.65\, A_{R3} + 8.868\, A_{C1} + 8.868\, A_{C2} + 8.868\, A_{C3}) \times 10^6$$

Subject to Constraints:

$14.5\ TS_1$	≤ 29
$14.5\ TS_2$	≤ 29
$14.5\ TS_3$	≤ 29
$35\ T_{K1}$	≤ 105
$35\ T_{K2}$	≤ 105
$35\ T_{K3}$	≤ 105
$27\ T_{W1}$	≤ 54
$27\ T_{W2}$	≤ 54
$27\ T_{W3}$	≤ 54
$4.5\ T_{L1}$	≤ 4.5
$4.5\ T_{L2}$	≤ 4.5
$4.5\ T_{L3}$	≤ 4.5
$A_{R1} + A_{C1}$	≤ 12499
$A_{R2} + A_{C2}$	≤ 12499
$A_{R3} + A_{C3}$	≤ 12499
$54328.32\ T_{S1}$	$\leq 643.6031 \times 10^6$
$54328.32\ T_{S2}$	$\leq 670.5556 \times 10^6$
$54328.32\ T_{S3}$	$\leq 286.5378 \times 10^6$
$14826.24\ T_{K1} - V_1 + V_2 + S_1$	$= 962.7508 \times 10^6$
$14826.24\ T_{K2} - V_2 + V_3 + S_2$	$= 1002.721 \times 10^6$
$14826.24\ T_{K3} - V_3 + S_3$	$= 458.187 \times 10^6$
$52565.76\ T_{W1} + 123109\ A_{R1} + 76364\ A_{C1} - S_1$	$\leq 1384.319 \times 10^6$
$52565.76\ T_{W2} + 123109\ A_{R2} + 76364\ A_{C2} - S_2$	$\leq 1385.102 \times 10^6$
$52565.76\ T_{W3} + 123109\ A_{R3} + 76364\ A_{C3} - S_3$	$\leq 588.4799 \times 10^6$
$111974.4\ T_{L1} + 123109\ A_{R1} + 76364\ A_{C1} - S_1$	$\leq 1851.886 \times 10^6$
$111974.4\ T_{L2} + 123109\ A_{R2} + 76364\ A_{C2} - S_2$	$\leq 1893.865 \times 10^6$
$111974.4\ T_{L3} + 123109\ A_{R3} + 76364\ A_{C3} - S_3$	$\leq 697.0769 \times 10^6$
V_1	$= 175 \times 10^6$
V_2	$\leq 175 \times 10^6$
V_3	$\leq 175 \times 10^6$
$T_{S1}, T_{S2}, T_{S3}, T_{K1}, T_{K2}, T_{K3}, T_{W1}, T_{W2}, T_{W3}, T_{L1}, T_{L2}, T_{L3}$	≥ 0 and Integer
$A_{R1}, A_{R2}, A_{R3}, A_{C1}, A_{C2}, A_{C3}, V1, V2, V3, S1, S2, S3$	≥ 0 and Real

Formulation (4)

By using the same constraints, the programs also execute for 2 other objectives, that are

Objective 2 Maximizing Irrigation:

$$\text{Max } Z = (19.65\, A_{R1} + 19.65\, A_{R2} + 19.65\, A_{R3} + 8.868\, A_{C1} + 8.868\, A_{C2} + 8.868\, A_{C3}) \times 10^6$$

Objective 3 Maximizing Energy:

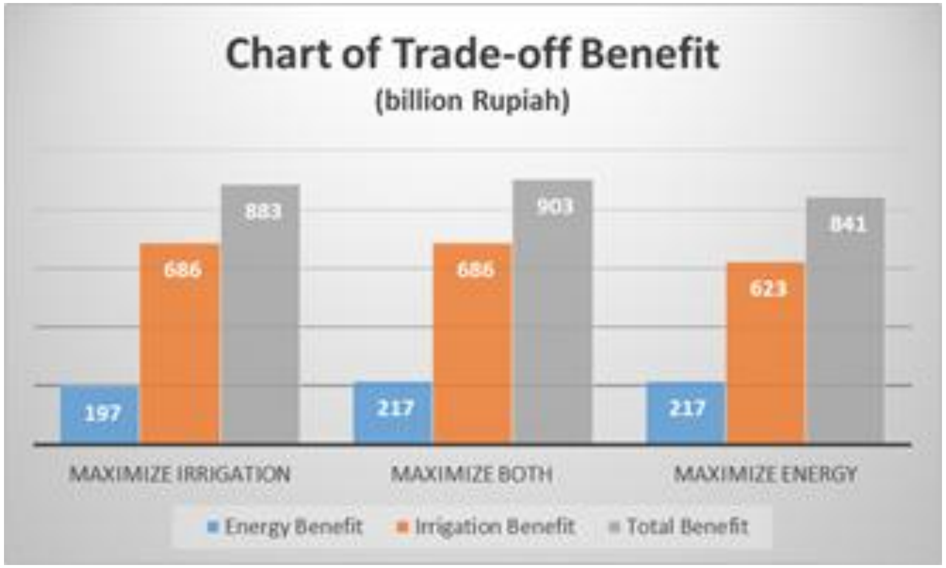
$$\text{Max } Z = (377.0496\, T_{S1} + 377.0496\, T_{S2} + 377.0496\, T_{S3} + 377.0496\, T_{K1} + 377.0496\, T_{K2} + 377.0496\, T_{K3} + 377.0496\, T_{W1} + 377.0496\, T_{W2} + 377.0496\, T_{W3} + 377.0496\, T_{L1} + 377.0496\, T_{L2} + 377.0496\, T_{L3}) \times 10^6$$

Result (1)

Results of Decision Variables (Operational Alternatives)

Operational Alternatives		Unit	Maximize Irrigation at Season			Maximixe Both at Season			Maximize Energy at Season		
			Rainy	1st Dry	2nd Dry	Rainy	1st Dry	2nd Dry	Rainy	1st Dry	2nd Dry
Number of Turbines Operated at											
1	Sengguruh Dam	Unit	2	2	2	2	2	2	2	2	2
2	Karangkates Dam	Unit	3	3	3	3	3	3	3	3	3
3	Wlingi Dam	Unit	2	2	0	2	2	2	2	2	2
4	Lodoyo Dam	Unit	1	1	1	1	1	1	1	1	1
Irrigated Area at Lodagung Scheme											
1	Rice Plant	Ha	12499	12499	9922	12499	12499	9922	12499	12499	1696
2	Corn Crop	Ha	0	0	0	0	0	0	0	0	10530
Condition at Karangkates Reservoir											
1	Volume of Reservoir	Million m^3	175	0	175	175	0	175	175	0	0
2	Spillway Reslease Discharge	Million m^3	1138	828	633	1138	828	633	1138	1002	458

Result (2)



Alternative Strategy	Maximize Irrigation	Maximize Both	Maximize Energy
Energy Benefit	197.385.465.600	217.746.144.000	217.746.144.000
Irrigation Benefit	686.197.650.000	686.178.000.000	623.281.590.000
Total Benefit	**883.583.115.600**	**903.924.144.000**	**841.027.734.000**

(Currency in Rupiah)

Conclusion

The optimizations are done by calculating from three strategies that are maximizing irrigation benefits, maximizing energy benefits, and maximizing both irrigation and energy benefits.

Thank You ....