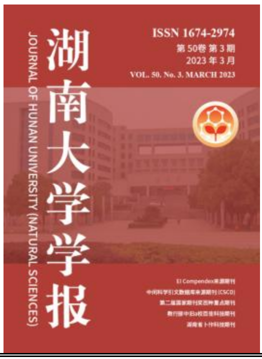

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Assessment of Water Distribution for the Effectiveness of Water Allocation Modeling

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Abstract: This research intends to conduct the assessment of water distributing performance for supporting the performance index assessment of water allocation modeling. The main aim is intending to solve the conflict of water interest, so there is necessary to be carried out the water allocation so water user society will get the water regarding to their right fairly, efficiently, and sustainably. Along with the increasing of population number and the social and economy conditions of society, there will all be increasing water demand for various uses. However, the quality tends to decrease because it has potency to increase the local conflict becoming a conflict between the regency and city that is unwanted. The water preparation and allocation are activities in operating the water resource infrastructure, whose aim is to optimize the usage of water resource infrastructure. This research was conducted in the watersheds of Manjuto, Slagan, Dikit, Teraman, Muar, Padang Guci, Bangkenang, Manna, Kelam, Nasal, and Luas. The methodology consists of collecting data on each watershed that are water availability and water demand; then, water balance and distribution (allocation) are analyzed. The result of water allocation analysis shows the water availability due to the dependable discharge as the reference such as Q_{80} or discharge with the probability of 80%; still several watersheds experience the water deficit in fulfilling the irrigation water requirement, household-city-industry (RKI), plantation, fishery, husbandry, and river flow maintenance needs. A new research is needed for the index assessment of water allocation in the watersheds that experience the water deficit to obtain the plan value of water demand fulfilling allocation in the water deficit condition, whether non-critical, lightly critical, moderately critical, and heavily critical.

Keywords: water availability, water demand, water balance, water allocation.

水资源分配模型有效性评估

摘要：本研究拟进行配水性能评价，以支持配水模型的性能指标评价。其主要目的是为了解决水资源利益冲突，因此有必要进行水资源分配，使用水社会公平、高效、可持续地获得属于他们权利的水资源。随着人口数量的增加和社会经济条件的提高，各种用途的用水需求量都将增加。然而，质量往往会下降，因为它有可能增加当地冲突，成为摄政与城市之间不受欢迎的冲突。备水配水是水资源基础设施的运营活动，其目的是优化水资源基础设施的使用。这项研究是在长寿和、斯拉甘、迪基特、特拉曼、麻坡、巴东古兹、邦克囊、吗哪、

凯拉姆、鼻音和卢阿斯的流域进行的。该方法包括收集每个流域的可用水量和需水量数据；然后，分析水平衡和分布（分配）。水量分配分析结果显示，以可靠排放为参考，如问 80 或 80%概率排放的可用水量；仍有几个流域在满足灌溉用水需求、家庭-城市-工业(RKI)、种植业、渔业、畜牧业和河流流量维护需求方面出现缺水。需要对缺水流域的水量分配指标评估进行新的研究，以获得非临界、轻度临界、中度临界和重度临界缺水条件下的需水满足分配计划值 .

关键词：水的可用性、水的需求、水的平衡、水的分配。

1. Introduction

Water resource management is an effort to plan, conduct, monitor, and evaluate the implementation of water resource conservation [1, 2] and usage and control of water damage. It is needed in a watershed for the continuity of water demand fulfilling. The human activity in a watershed will be very influenced to the pattern of water resource management in the watershed [3, 4].

The pattern of water resource management is as a basic scheme in the management of water resources. It will be affected by the condition of water allocation and water balance in a watershed to determine the policy of water resource management as a strategic way in management [5]. The plan of water resource management is the overall and integrated design result that is needed for implementing water resource management [6]. The plan of water resource management will determine the work program of water management to obtain an illustration related to the watershed condition problems, water balance, and water allocation in the watershed for the usage and handling in the water resource conservation, usage, and control of water damage in the watershed.

Water availability and allocation are the indicators of the operation of water resource infrastructure [7], which includes the regulation, allocating, and supplying water and water resources [8, 9] for optimizing the water resource infrastructure. However, the water resources balance in the context of water resource management intends to use the water resources continuously, mainly for fulfilling the basic need of human life fairly.

Along with the increasing population number and the condition of society and economy, there will be increasing water demand for several uses [10]. However, the quality tends to decrease because it has potency to increase the local conflict becoming a conflict between the regency and city that is unwanted. To handle the conflict of water, it is needed to allocate the water so that society will obtain the water according to their right fairly, efficiently, and sustainably [11, 12]. Considering water an economic commodity must retain the social functions of society and the environment, such as maintaining the environment balance [13, 14], life continuity of flora and fauna, preventing the intrusion of salt water, and functions that are esthetic and healthy for humans. The water division between downstream and upstream and between the sectors of water user is necessary to be allocated so there is obtained the fair, and the optimal and continuous benefit [15].

2. Materials and Method

2.1. Research Allocation

The research location is a watershed in the Sumatera island river area (WS). The river area (WS) selected is the WS that has had the schematic of water allocation in the Plan Document of Water Resources Management that has been remained by the Minister of General Work and Public Housing (PUPR). Every river area will be analyzed in terms of conditions of watersheds due to the condition of deficit and surplus water allocating. From several WSs, we selected those distributed on the Sumatera Island. This research is carried out in the river area (WS) presented in Table 1.

Table 1 Location of the research river area (WS) (Own study)

No.	Name of watershed	Name of WS	Province
1	DAS Manjuto	WS Teramang	Bengkulu
2	DAS Selagan	Muar	
3	DAS Air Dikit		
4	DAS Teramang		
5	DAS Muar		
6	DAS Manna	WS Nasal Padang	
7	DAS Bengkenang	Guci	
8	DAS Padang Guci		
9	DAS Kelam		
10	DAS Nasal		
11	DAS Luas		

2.2. Analysis of Water Availability

The dependable discharge is mentioned as the available discharge for certain needs (such as irrigation, hydro-power, drinking water, etc.) along year with the failure risk calculated. There are some methods for determining the dependable discharge; each method has the specific characteristic itself. The selection of method that is suitable generally is based on the consideration of the available data, the type of interest, and experience. The methods for analyzing the dependable discharge are [16]: flow characteristic method, basic year, basic month, and $Q_{minimum\ mean}$. According to Sosrodarsono [16], the terminology of discharge is expressed as follows: 1) Moderate water discharge (affluent) is discharge that is exceeded by the discharge in an amount of 95 days in a year (the possibility of reliability is 26.02%); 2) Normal water discharge is discharge that is exceeded by the discharge in an amount of 185 days in a year (the possibility of reliability is 50.68%); 3) Low water discharge is discharge that is exceeded by the discharge in amount of 275 days in a year (the possibility of reliability is 75.34%); 4) Dry water discharge is discharge that is exceeded by the discharge in amount of 355 days in a year (the possibility of reliability is 97.30%).

2.3. Analysis of Water Demand

Water demand in a watershed basically can be classified as follows: water drinking need and urban activity (MPI), water demand for industry (IND), water demand for river maintenance, water demand for fishery, and water demand for husbandry.

2.4. Research Method

Preparation of research parameter: in this stage is intended to prepare the parameters that will be used in the next analysis. The following parameters will be used: the characteristics of catchment area, to inventory the water resource infrastructure data, the water usage data, legal aspect of water allocation, and conduct spatial analysis of water availability and demand.

3. Results and Discussion

The analysis of water allocation and availability has been carried out in 11 watersheds that are the watersheds of Majuanto, Slagan, Dikit, Teramang, Muar, Padang Guci, Bangkenang, Manna, Kelam, Nasal, and Luas.

3.1. Water Allocation and Availability in the Manjuto Watershed

Water allocation and availability in the Manjuto watershed are presented in Fig. 2.

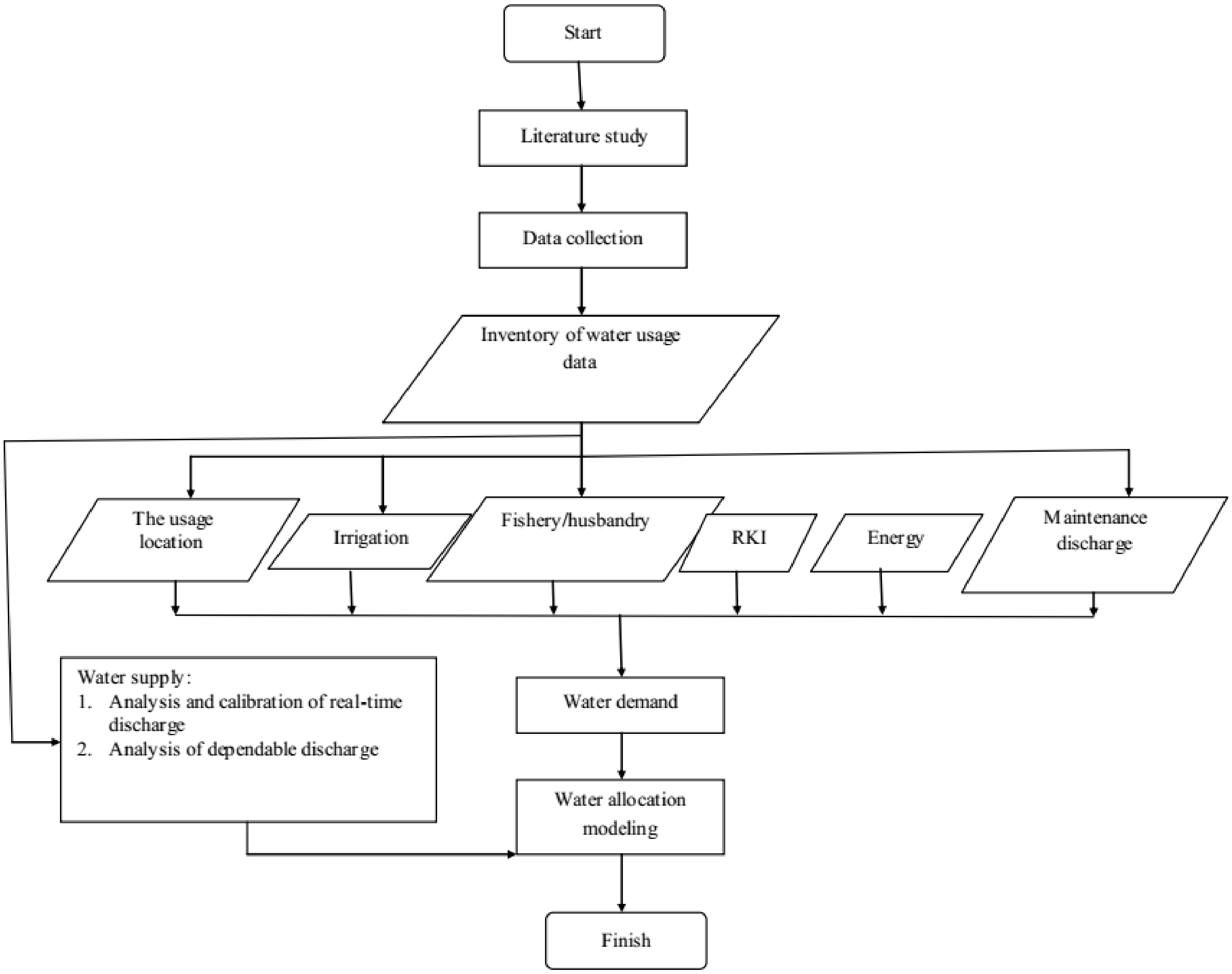

Fig. 1 Flowchart of the study

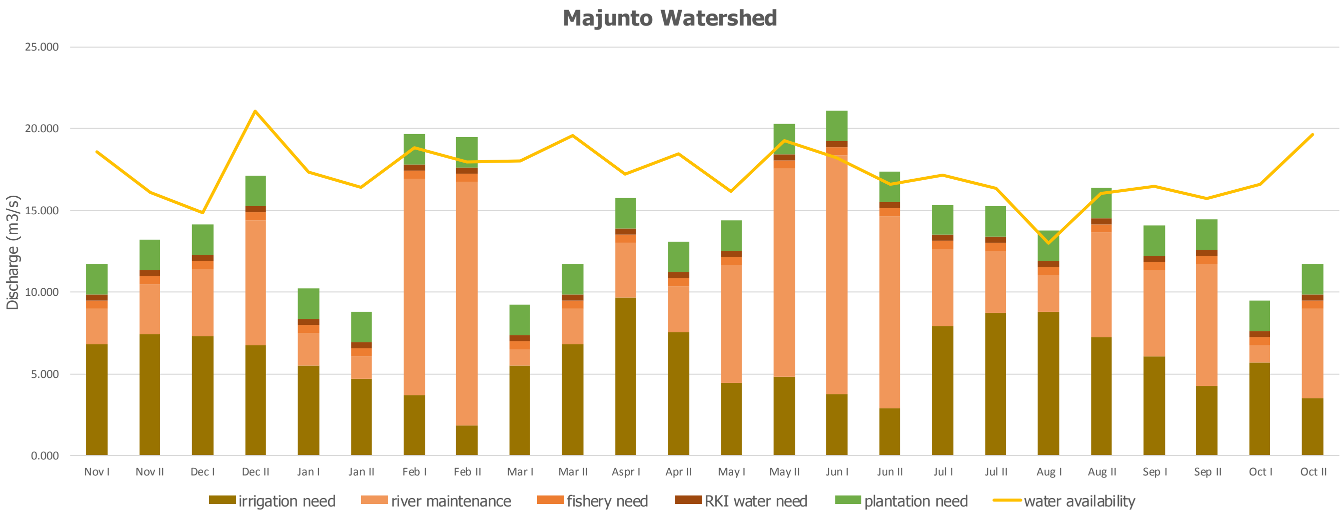

Fig. 2 Plan curve of water balance in the Manjuto watershed (Own study)

The information on water availability in the Manjuto watershed is obtained from the analysis of dependable discharge at every water intake point using dependable discharge with a probability of 80%. The maximum discharge of 21.07 m^3/s happens in period-1 December; the minimum discharge of 13.00 m^3/s happens in period-1 August; the mean discharge is 17.31 m^3/s.

We analyzed irrigation water demand due to the cropping pattern of paddy-paddy-second crop with the cropping periods as follows: CP-1 paddy (November-February), CP-2 paddy (March-June), and CP-3 second crop (July-October). Maximum irrigation water demand in period-1 April is 9.641 m^3/s. Water demand in the Manjuto watershed is analyzed for household-urban-industry (RKI), plantation, fishery, and husbandry. The total of all sectors' water demand is 3.592 m^3/s.

Based on the analysis result and water allocation in the Manjuto watershed, it can be concluded that the water availability due to the 80% dependable discharge is still deficit in fulfilling the irrigation water demand, household-industry (RKI), plantation, fishery, husbandry, and river maintenance needs. In November, period-2 December, January, March, April, period-1 May, July, September, and October, the water surplus happens. However, in period-1 December, February, period-2 May, June, and August, water deficit happens.

3.2. Water Allocation and Availability in the Slagan Watershed

Water allocation and availability in the Slagan watershed are presented in Fig. 3.

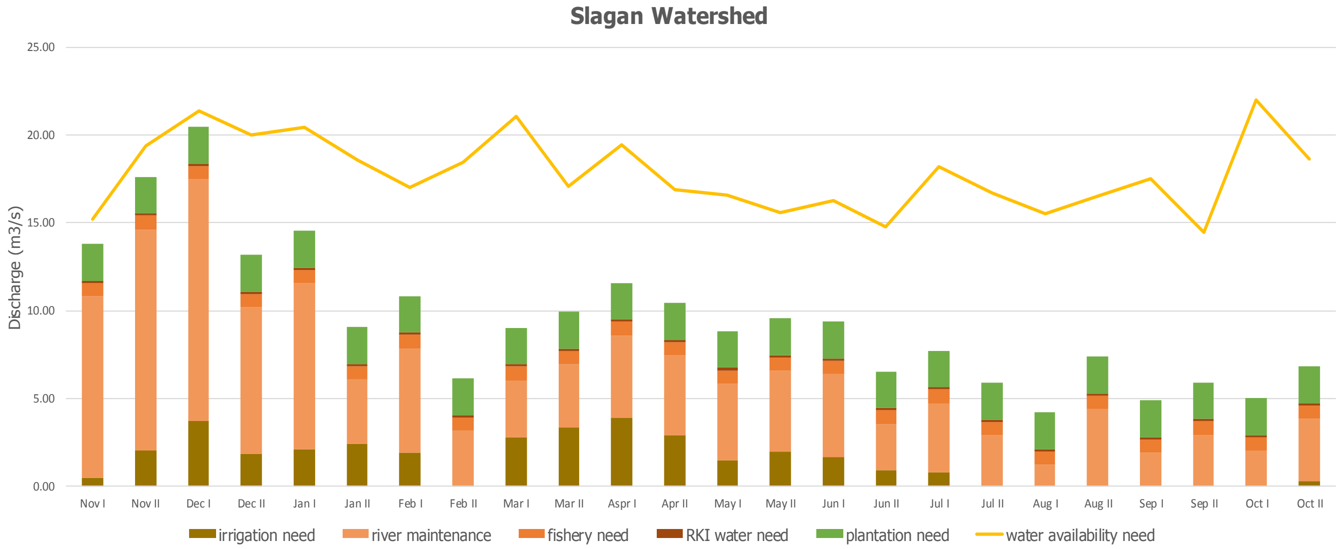

Fig. 3 Plan curve of water balance in the Slagan watershed (Own study)

The information on water availability in the Slagan watershed is obtained from the analysis of dependable discharge at every water in-take point using dependable discharge with a probability of 80%. The maximum discharge is 22.01 m^3/s, in period-1 October; the minimum discharge is 14.45 m^3/s, in period-2 September; the mean discharge is 17.82 m^3/s.

We analyzed irrigation water demand due to the cropping pattern of paddy-paddy-second crop with the cropping periods as follows: CP-1 paddy (November-

February), CP-2 paddy (March-June), and CP-3 second crop (July-October). Maximum irrigation water demand in period-1 April is 3.73 m^3/s. Water demand in the Slagan watershed is analyzed for household-urban-industry (RKI), plantation, fishery, and husbandry. The total of all sectors' water demand is 3.08 m^3/s.

Based on the analysis result and water allocation in the Slagan watershed, it can be concluded that the water availability due to the 80% dependable discharge can fulfill the irrigation water demand, household-industry (RKI), plantation, fishery, husbandry, and river maintenance needs.

3.3. Water Allocation and Availability in the Dikit Watershed

Water allocation and availability in the Dikit watershed are presented in Fig. 4.

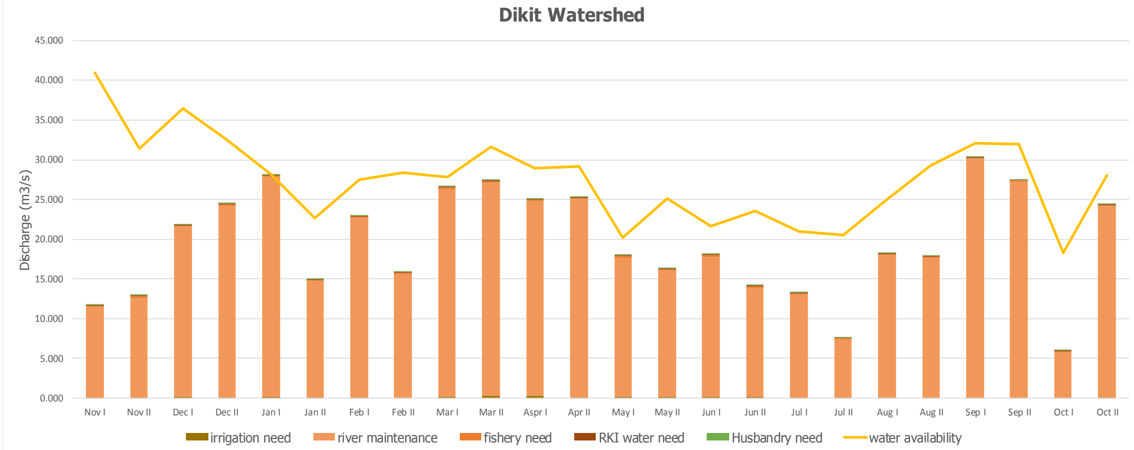

Fig. 4 Plan curve of water balance in the Dikit watershed (Own study)

The information on water availability in the Dikit watershed is obtained from the analysis of dependable discharge at every water in-take point using dependable discharge with a probability of 80%. The maximum discharge is 40.98 m^3/s, in period-1 November; the minimum discharge is 18.26 m^3/s, in period-1 October; the mean discharge is 27.08 m^3/s.

We analyzed irrigation water demand due to the cropping pattern of paddy-paddy-second crop with the cropping periods as follows: CP-1 paddy (November-February), CP-2 paddy (March-June), and CP-3 second crop (July-October). Maximum irrigation water demand in period-1 April is 0.245 m^3/s. Water demand in the Dikit watershed is analyzed for household-urban-industry (RKI), plantation, fishery, and husbandry. The total of all sectors' water demand is 0.294 m^3/s.

Based on the analysis result and water allocation in the Dikit watershed, it can be concluded that the water availability due to the 80% dependable discharge is deficit in fulfilling the irrigation water demand, household-industry (RKI), plantation, fishery, husbandry, and river maintenance needs. On January 1 and in February, the water deficit happens.

3.4. Water Allocation and Availability in the Teramang Watershed

Water allocation and availability in the Teramang watershed are presented in Fig. 5.

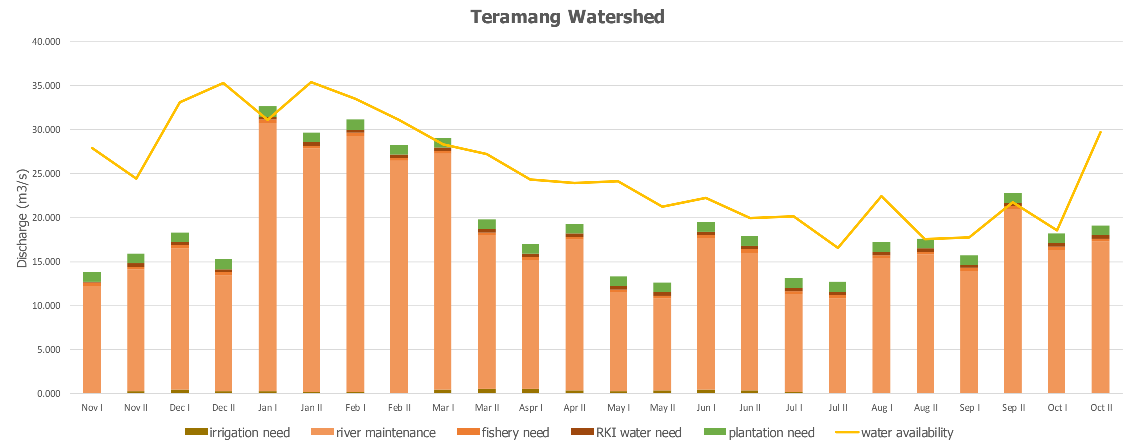

Fig. 5 Plan curve of water balance in the Teramang watershed (Own study)

The information on water availability in the Teramang watershed is obtained from the analysis of dependable discharge at every water in-take point using dependable discharge with a probability of 80%. The maximum discharge is 35.29 m^3/s, in period-2 December; the minimum discharge is 16.53 m^3/s, in period-2 July; the mean discharge is 25.32 m^3/s.

We analyzed irrigation water demand due to the cropping pattern of paddy-paddy-second crop with the cropping periods as follows: CP-1 paddy (November-February), CP-2 paddy (March-June), and CP-3 second crop (July-October). Maximum irrigation water demand on period-1 April is 9.641 m^3/s. Water demand in the Teramang watershed is analyzed for household-urban-industry (RKI), plantation, fishery, and husbandry. The total of all sectors' water demand is 1.557 m^3/s.

Based on the analysis result and water allocation in the Teramang watershed, it can be concluded that the water availability due to the 80% dependable discharge is still deficit in fulfilling the irrigation water demand, household-industry (RKI), plantation, fishery, husbandry, and river maintenance needs. In November, December, period-2 January, February, period-2 March, April, period-1 May, June, July, period-1 August, and period-1 September, the water surplus happens. However, in period-1 January, February, period-1 March, June, period-2 August, and period-2 September, water deficit happens.

3.5. Water Allocation and Availability in the Muar Watershed

Water allocation and availability in the Muar watershed are presented in Fig. 6.

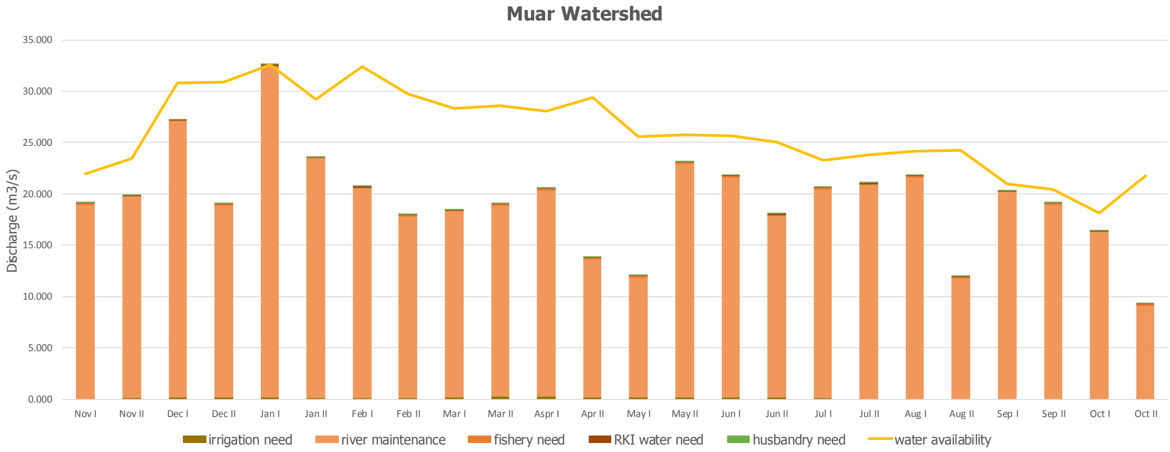

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Fig. 6 Plan curve of water balance in the Muar watershed (Own study)

The information on water availability in the Muar watershed is obtained from the analysis of dependable discharge at every water in-take point using dependable discharge with a probability of 80%. The maximum discharge is 42.80 m^3/s, in period-1 January; the minimum discharge is 18.14 m^3/s, in period-1 October; the mean discharge is 26.44 m^3/s.

We analyzed irrigation water demand due to the cropping pattern of paddy-paddy-second crop with the cropping periods as follows: CP-1 paddy (November-February), CP-2 paddy (March-June), and CP-3 second crop (July-October). Maximum irrigation water demand in period-1 April is 0.303 m^3/s. Water demand in the Muar watershed is analyzed for household-urban-industry (RKI), plantation, fishery, and husbandry. The total of all sectors' water demand is 0.253 m^3/s.

Based on the analysis result and water allocation in the Muar watershed, it can be concluded that the water availability due to the 80% dependable discharge can fulfill the irrigation water demand, household industry (RKI), plantation, fishery, husbandry, and river maintenance needs.

3.6. Water Allocation and Availability in the Padang Suci Watershed

Water allocation and availability in the Padang Suci watershed are presented in Fig. 7.

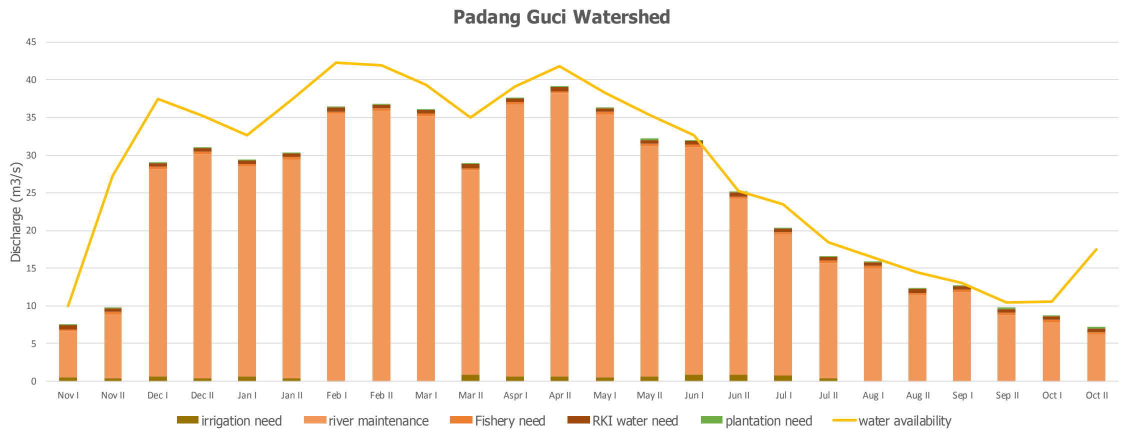

Fig. 7 Plan curve of water balance in the Padang Guci watershed (Own study)

The information on water availability in the Padang Guci watershed is obtained from the analysis of dependable discharge at every water in-take point using dependable discharge with a probability of 80%. The maximum discharge is 42.30 m^3/s, in period-2 February; the minimum discharge is 10.00 m^3/s, in period-1 November; the mean discharge is 28.14 m^3/s.

We analyzed irrigation water demand due to the cropping pattern of paddy-paddy-second crop with the cropping periods as follows: CP-1 paddy (November-February), CP-2 paddy (March-June), and CP-3 second crop (July-October). The maximum irrigation water demand in period-2 June is 0.925 m^3/s. Water demand in the Padang Guci watershed is analyzed for household-urban-industry (RKI), plantation, fishery, and husbandry. The total of all sectors' water demand is 0.0973 m^3/s.

Based on the analysis result and water allocation in the Padang Guci watershed, it can be concluded that the water availability due to the 80% dependable discharge can fulfill irrigation water demand, household-industry (RKI), plantation, fishery, husbandry, and river maintenance needs.

3.7. Water Allocation and Availability in the Bengkenang Watershed

Water allocation and availability in the Bengkenang watershed are presented in Fig. 8.

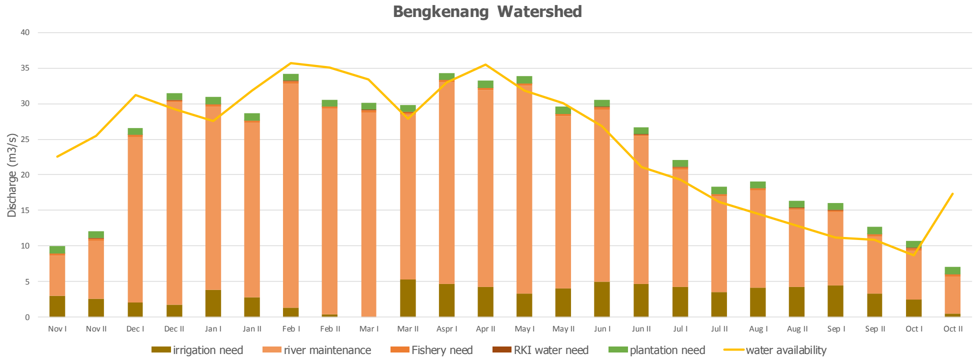

Fig. 8 Plan curve of water balance in the Bengkenang watershed (Own study)

The information on water availability in the Bengkenang watershed is obtained from the analysis of dependable discharge at every water in-take point using dependable discharge with a probability of 80%. The maximum discharge is 35.70 m^3/s, in period-2 February; the minimum discharge is 8.7 m^3/s, in period-2 October; the mean discharge is 24.55 m^3/s.

We analyzed irrigation water demand due to the cropping pattern of paddy-paddy-second crop with the cropping periods as follows: CP-1 paddy (November-February), CP-2 paddy (March-June), and CP-3 second crop (July-October). Maximum irrigation water demand in period-1 March is 5.29 m^3/s. Water demand in the Bengkenang watershed is analyzed for household-urban-industry (RKI), plantation, fishery, and husbandry. The total of all sectors' water demand is 1.329 m^3/s.

Based on the analysis result and water allocation in the Bengkenang watershed, it can be concluded that the water availability due to the 80% dependable discharge is still deficit in fulfilling the irrigation water demand, household-industry (RKI), plantation, fishery, husbandry, and river maintenance. In November, period-1 December, period-2 January, February, period-1 March, period-2 April, period-2 May, and period-2 October, the water surplus happens. However, in period-1 December, period-1 January, period-2 March, period-1 April, period-1 May, June, July, August, September, and period-1 October, water deficit happens.

3.8. Water Allocation and Availability in the Manna Watershed

Water allocation and availability in the Manna watershed are presented in Fig. 9.

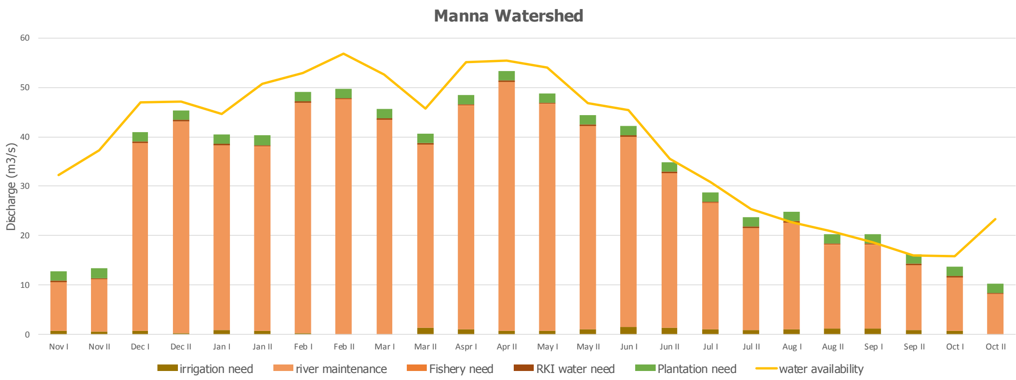

Fig. 9 Plan curve of water balance in the Manna watershed (Own study)

The information on water availability in the Manna watershed is obtained from the analysis of dependable discharge at every water in-take point using dependable discharge with a probability of 80%. The maximum discharge is 55.5 m^3/s, in period-2 April; the minimum discharge is 16.00 m^3/s, in period-2 September; the mean discharge is 38.90 m^3/s.

We analyzed irrigation water demand due to the cropping pattern of paddy-paddy-second crop with the cropping periods as follows: CP-1 paddy (November-February), CP-2 paddy (March-June), and CP-3 second crop (July-October). The maximum irrigation water demand in period-1 June is 51.45 m^3/s. Water demand in the Manna watershed is analyzed for household-urban-industry (RKI), plantation, fishery, and husbandry. The total of all sectors' water demand is 2.979 m^3/s.

Based on the analysis result and water allocation in the Manna watershed, it can be concluded that the water availability due to the 80% dependable discharge is still deficit in fulfilling the irrigation water demand, household-industry (RKI), plantation, fishery, husbandry, and river maintenance. In November, December, January, February, March, April, May, June, July, period-2 August, and October, the water surplus happens. However, in period-2 August and September, water deficit happens.

3.9. Water Allocation and Availability in the Kelam Watershed

Water allocation and availability in the Kelam watershed are presented in Fig. 10.

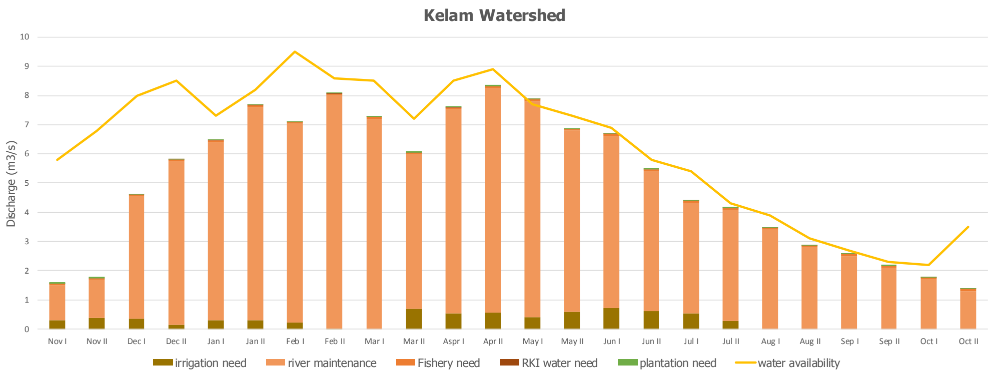

Fig. 10 Plan curve of water balance in the Kelam watershed (Own study)

The information on water availability in the Kelam watershed is obtained from the analysis of dependable discharge at every water in-take point using dependable discharge with a probability of 80%. The maximum discharge is 9.5 m^3/s, in period-1 February; the minimum discharge is 2.2 m^3/s, in period-1 October; the mean discharge is 6.29 m^3/s.

We analyzed irrigation water demand due to the cropping pattern of paddy-paddy-second crop with the cropping periods as follows: CP-1 paddy (November-February), CP-2 paddy (March-June), and CP-3 second crop (July-October). The maximum irrigation water demand in period-1 June is 0.730 m^3/s. Water demand in the Kelam watershed is analyzed for household-urban-industry (RKI), plantation, fishery, and husbandry. The total of all sectors' water demand is 0.400 m^3/s.

Based on the analysis result and water allocation in the Kelam watershed, it can be concluded that the water availability due to the 80% dependable discharge is still deficit in fulfilling the irrigation water demand, household-industry (RKI), plantation, fishery, husbandry, and river maintenance. In period-1 May and February, water deficit happens.

3.10. Water Allocation and Availability in the Nasal Watershed

Water allocation and availability in the Nasal watershed are presented in Fig. 11.

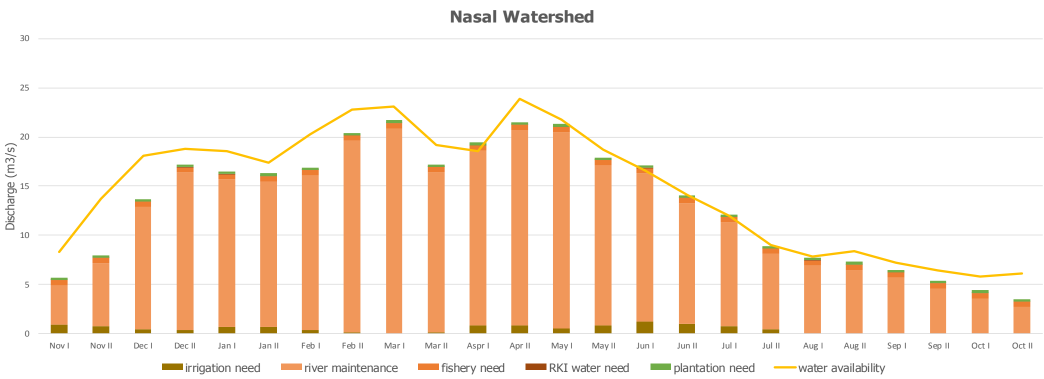

Fig. 11 Plan curve of water balance in the Nasal watershed (Own study)

The information on water availability in the Nasal watershed is obtained from the analysis of dependable discharge at every water in-take point using dependable discharge with a probability of 80%. The maximum discharge is 23.9 m^3/s, in period-2 April; the minimum discharge is 5.8 m^3/s, in period-1 October; the mean discharge is 14.86 m^3/s.

We analyzed irrigation water demand due to the cropping pattern of paddy-paddy-second crop with the cropping periods as follows: CP-1 paddy (November-February), CP-2 paddy (March-June), and CP-3 second crop (July-October). The maximum irrigation water demand in period-1 June is 1.206 m^3/s. Water demand in the Nasal watershed is analyzed for household-urban-industry (RKI), plantation, fishery, and husbandry. The total of all sectors' water demand is 1.700 m^3/s.

Based on the analysis result and water allocation in the Nasal watershed, it can be concluded that the water availability due to the 80% dependable discharge is still deficit in fulfilling the irrigation water demand, household-industry (RKI), plantation, fishery, husbandry, and river maintenance. In period-1 April, period-2 June, and period-1 July, water deficit happens.

3.11. Water Allocation and Availability in the Luas Watershed

Water allocation and availability in the Luas watershed are presented in Fig. 12.

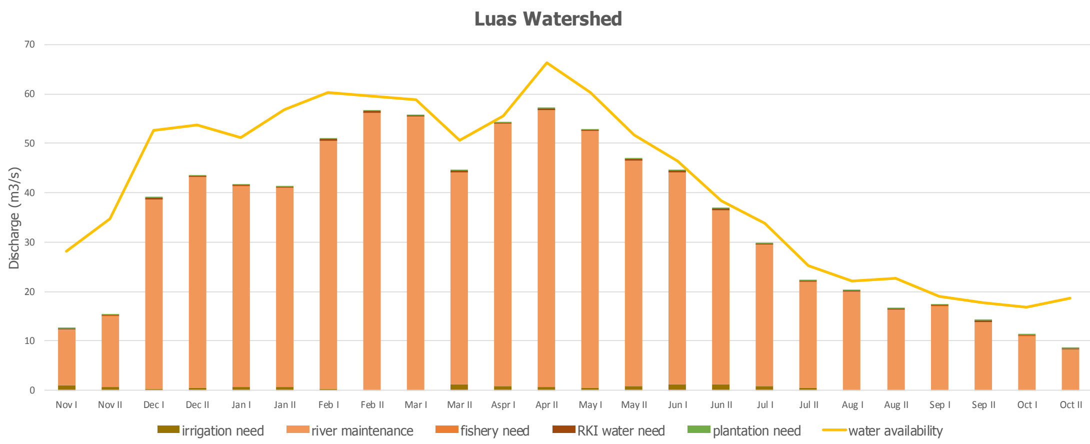

Fig. 12 Plan curve of water balance in the Luas watershed (Own study)

The information on water availability in the Luas watershed is obtained from the analysis of dependable discharge at every water in-take point using dependable discharge with a probability of 80%. The maximum discharge is 66.4 m^3/s, in period-2 April; the minimum discharge is 16.9 m^3/s, in period-1 October; the mean discharge is 41.74 m^3/s.

We analyzed irrigation water demand due to the cropping pattern of paddy-paddy-second crop with the cropping periods as follows: CP-1 paddy (November-February), CP-2 paddy (March-June), and CP-3 second crop (July-October). The maximum irrigation water demand in period-2 June is 1.142 m^3/s. Water demand in the Luas watershed is analyzed for household-urban-industry (RKI), plantation, fishery, and husbandry. The total of all sectors' water demand is 1.274 m^3/s.

Based on the analysis result and water allocation in the Luas watershed, it can be concluded that the water availability due to the 80% dependable discharge can fulfill irrigation water demand, household-industry (RKI), plantation, fishery, husbandry, and river maintenance needs.

4. Conclusion

Water demand in a watershed can be classified as follows: water drinking need and urban activity (MPI), water demand for industry (IND), water demand for river maintenance, water demand for fishery, and water demand for husbandry. The analysis of water allocation and availability has been carried out in 11 watersheds that are the watersheds of Majuanto, Slagan, Dikit, Teramang, Muar, Padang Guci, Bangkenang, Manna, Kelam, Nasal, and Luas.

Based on the analysis result of water allocation as above, water availability by using dependable discharge with a probability of 80%, still several watersheds experience water deficit in fulfilling the irrigation water demand, household-urban-industry (RKI), plantation, husbandry, and river maintenance needs, such as Teramang Muar river area (WS) that consists of Majuanto, Dikit, Teramang, and Nasal watersheds; Padang Guci river area (WS) that consists of Manna, Bengkenang, Kelam, and Nasal watersheds.

The analysis result shows that the watersheds have not been able to fulfill all of the water demand. This is proved through the ratio of 80%-dependable discharge and the projection of water demand. The mitigation of water deficit is a series of efforts to decrease the water deficit through the structural and non-structural measures and increasing society awareness about the importance of water. The mitigation of water deficit is very needed to be carried out as the main starting point of water allocation management. If there is water deficit, policy for addressing the condition is needed.

Due to the water deficit condition, it is necessary to conduct an index assessment of water allocation in the watershed to obtain the plan value of water demand fulfilling allocation. The water allocation faces water deficit in different degrees: non-critical, lightly critical, moderately critical, and heavily critical.

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