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Analysis Potency of Water Availability and Water Demand in Krueng Aceh Watershed

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Abstract

Excess water during the rainy season and shortage during the dry season require proper management of water resources. The diminishing water availability of Krueng Aceh irrigation that impact on the insufficiency of water supply to irrigate the rice fields in Krueng Aceh led to harvest failure of rice crop. Along with the population growth, demand for water continues to increase. However, water availability for consumption purpose decreases. Thus, analysis potency of water availability and water demand of Krueng Aceh watershed is required. Method used in this research was direct observation. Results of the study showed that water availability in Krueng Aceh watershed in 2014 amounted to 700 million m^3 and water consumption demand equaled to 47.9 million m^3, resulted in water surplus of 652 million m^3. To accommodate the excess water, building of dams, reservoirs and ponds is needed. Moreover, irrigation and drainage channels are important to be developed to optimize the rice field irrigation system. The Indonesian Drinking Water Company (PDAM) should improve the condition of piping facilities to avoid water wasted during distribution to the customer.

Keywords: water supply; water demand; water resources; domestic water; watershed krueng aceh.

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1. Introduction

Demand of ground water and surface water use continues to increase in order to meet the world's demand of freshwater [1, 2]. Moreover, around 60% of surface water are used for agricultural irrigation and household needs [3, 4]. The water supply in Indonesia around 700 billion m^3/year [5], but 90 million people still lack clean water [6]. Diminishing water supply of Krueng Aceh irrigation and Krueng Jreue irrigation impacted on harvest failure for 1 345 hectares of rice crops in 2010 which increased to 1 436 hectares in 2011 [7]. Along with the rate of population growth and increasing economic development of communities in the Krueng Aceh watershed, therefore water demand increases and causes conflicts between water consumers in the upstream and downstream will be happen. Hence, analysis potency of water availability and water demand in order to investigate the amount of water available in Krueng Aceh watershed and water demand supply for various activities, such as domestic use, agriculture, aquaculture and livestock, is needed.

2. Material and Methods

The study was conducted from January to December 2015. The research location was in Krueng Aceh watershed, ($5^0$03′41′′-$5^0$38′10′′N and $95^0$11′41′′-$95^0$49′46′′E) with an area of 197903.62 hectares in Aceh Province (Figure 1).

Materials used in this study were the digital administrative map of Aceh Province, topographical and land use maps. The required data were 1994-2004 data of rainfall from seven rain observation stations, Krueng Aceh River discharge from Automatic Water Level Recorder of Kampung Darang Station, population, rice area coverage, number of freshwater pond and also number of cattle obtained from the Statistic Agency (BPS) [8,9]. Moreover, ArcGIS 10.2 and Microsoft Office 2010 software were used for mapping and data analysis, respectively.

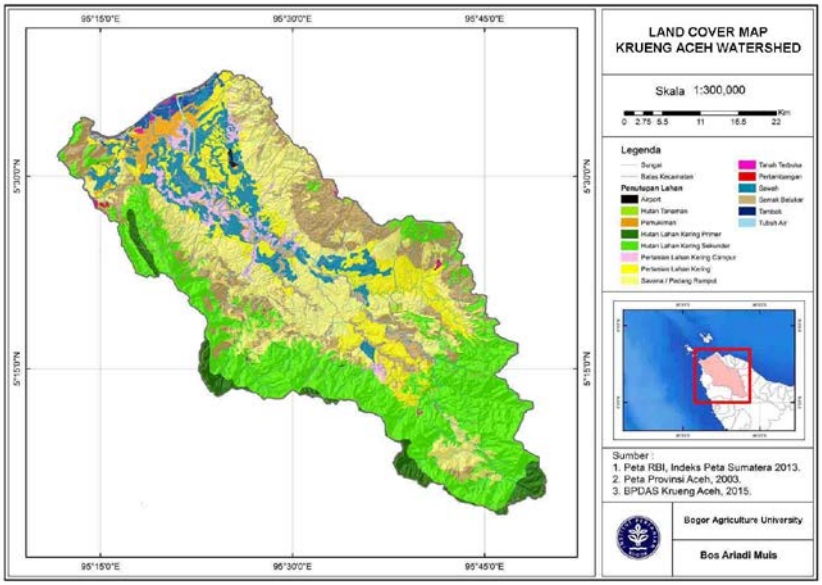

Figure 1: Location of study in Krueng Aceh watershed

2.1. Water Availability Analysis

Influenced region of seven rainfall observation stations first mapped by ArcGIS software, then the rainfall data of each station was calculated using Thiessen Polygon method to obtain the average rainfall within the region. Furthermore data of Krueng Aceh river discharge for 20 years were calculated to determine the maximum and minimum discharge and monthly average discharge of Krueng Aceh watershed.

2.2. Water Demand Analysis

There were four sectors of water demand analyzed in this study, namely (1) domestic sector, where water was purposed for household use which calculation was based on the number of population and using domestic water demand [10] that were 130 liter per person per day (Table 1), (2) water demand of irrigation was calculated based on the rice field area and extensive rainfed rice field area that use water from irrigation channels with pumping system. Later, the value was multiplied by standard water demand of rice in the study area [11] that equaled to 1.88 m^3/sec/ha then it was multiplied by 240 days for two planting seasons in a year (3) water demand of aquaculture sector was calculated based on pond area and standard water demand for flushing [12] that was 7 mm/day/hectare and (4) water need for livestock which calculation was based on the type and number of livestock. The value then was multiplied by the standard livestock water consumption [12] (Table 2). The result of the water demand calculation of four sectors then summed to determine the total of water demand in Krueng Aceh watershed.

Table 1: Standard water demand of domestic

Category	Type of city	Population (person)	Water demand (liter/person/day)
I	Metropolis	> 1.000.000	190
II	Big City	500.000 - 1.000.000	170
III	Town	100.000 - 500.000	130
IV	Small town	20.000 - 100.000	100
V	Village	< 20.000	80

Table 2: Standard water demand of livestock

Type of livestock	Water demand (liter/head/day)
Cattle/Buffalo/Horse	40
Goat/Sheep	5
Poultry	0.6

2.3. Water Balance of Krueng Aceh Watershed

Water balance of Krueng Aceh watershed was applied to investigate water supply condition regarding its

function to meet water demand for users of Krueng Aceh watershed, whether it was water shortage or water deficit. Water balance was calculated using the formula:

$$Q_{Supply} - Q_{Demand} = \Delta S$$

where Q_{Supply} is the total discharge availability (m^3/year), Q_{Demand} is the total discharge demand (m^3/year), and ΔS is the change of water quantity (m^3/year).

3. Result and Discussion

3.1. Water Availability in Krueng Aceh Watershed

Results of rainfall analysis in Krueng Aceh watershed region over a period of 20 years showed the rainfall value was 1 589.97 mm/year with an average of 132.50 mm/year. Krueng Aceh watershed is categorized as tropical region with two seasons, the dry season which occurs between January and June, and the rainy season from July to December. Thus, the rainfall level in December was high, reached 383.24 mm and consequently affected the amount of maximum discharge value in Krueng Aceh River that amounted to 90.70 m^3/sec (Figure 2).

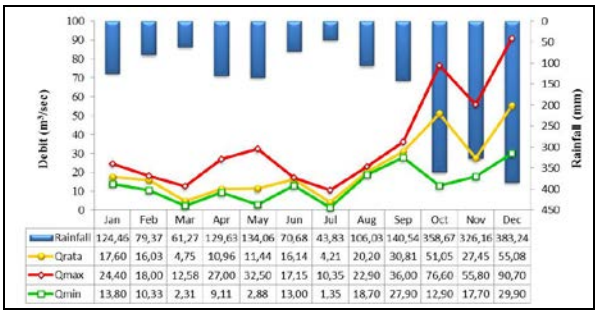

Figure 2: Relationship between rainfall and monthly average discharge in Krueng Aceh watershed in 2014

Calculation results of discharge showed that the availability of surface water in Krueng Aceh watershed reached 700 193 659 m^3 in 2014 with average discharge of 22.14 m^3/sec, maximum discharge of 55.08 m^3/sec and minimum discharge of 4.21 m^3/sec (Table 3). Total water volume in Krueng Aceh River available during the dry season that was April, reached 4 million m^3, and the amount of rain water being stored was 256 million m^3. In addition the total volume of potential water wasted not utilized by public amounted to 251 million m^3 which flowed directly through the sea (Figure 3).

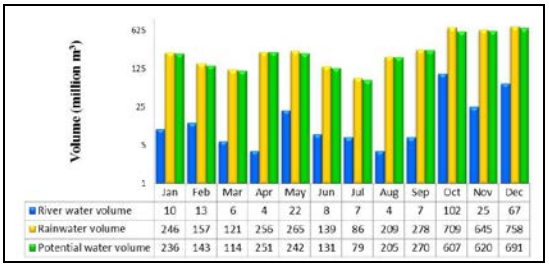

Figure 3: Total volume of potential water wasted not utilized in Krueng Aceh watershed

Table 3: Water availability in Krueng Aceh watershed in 2014

Month	Water discharge (m^3/sec)	Water availability (m^3/month)
January	17.60	47 139 840
February	16.03	38 783 813
March	4.75	12 735 053
April	10.96	28 413 337
May	11.44	30 633 754
June	16.14	41 836 531
July	4.21	11 282 438
August	20.20	54 095 040
September	30.81	79 868 160
October	51.05	136 723 392
November	27.45	71 162 942
December	55.08	147 519 360
Total	22.14	700 193 659

Discharge rate fluctuations of Krueng Aceh River always happen. Result of study [13] stated that in 2003, discharge in sub-watershed of Krueng Aceh, namely Krueng Boga obtained maximum value of 247.6 m^3/sec and minimum value of 11.6 m^3/sec. However, the value decreased in 2008, that the maximum discharge became 45.10 m^3/sec and minimum discharge equaled to 10.80 m^3/sec. Refers to the study result of [11] the discharge of water in Sub Krueng Jreue ranged from 0.24 to 3.22 m^3/sec in 2012. According to [14] conditions of catchment area affected the discharge and water quality. Land cover change from forest to agriculture could reduce the power of absorbing water into the ground thereby increasing the amount of runoff [15]. Krueng Aceh watershed has flat of undulating, hilly and mountainous physiographic. The author in [16] stated that area with undulating and hilly topography should apply soil and water conservation technology to maximize rainwater penetrate into the soil also to minimize runoff. Study of [17,18,19,20,21,22] showed that the land use change might decrease the water catchment areas, affect the the surface water, and impact on water availability in the long run. [23] stated that application of 17% area of total land area to be built into pond (*embung*) could harvest rainwater and surface water up to 100%.

This present study of water availability only examined the surface water source up to the year of 2014 and did not analyze the calculation of 80% dependable discharge for the long run.

3.2. Water Demand of Krueng Aceh Watershed

3.2.1. Water Demand for Domestic Use

Water demand calculated in this study was at household scale, namely the amount of water consumed per person per day for drinking, cleaning, cooking, washing household equipment and other household purposes including garden watering [24]. This study did not examine the age of water users [24], factors of religion and cultural differences [25] as well as the property size owned by the householder [26].

Source of raw water for domestic sector was obtained from Krueng Aceh River by Indonesian Drinking Water Company (PDAM) Tirta Mountala in Aceh Besar Regency and PDAM Tirta Daroy in Banda Aceh to be managed into clean water that will be suitable for consumption. Water production capacity of PDAM Tirta Mountala was 8 359 971 m^3/year with 20 538 consumers [8]. PDAM Titra Daroy produced clean water with capacity of 22 798 173 m^3/year with number of consumer channels equaled to 50 033 [9]. The result of analysis of household water demand in Krueng Aceh watershed based on population in 2014 showed that 651 958 inhabitants. By using the standard calculation for domestic water demand that is 130 liter/person/day, it can be calculated that the water consumption demand for public reached 30 935 407 m^3.

3.2.2. Water Demand for Irrigation Sector

Result of data collecting in rice field located in Krueng Aceh watershed in 2014, there were 32 012 hectares of utilized rice fields, consisted of 20 688 hectares of irrigated rice field and 11 324 hectares of rainfed rice field. Water source to irrigate rice fields was obtained from irrigation channel of Krueng Aceh dam that was able to provide water for 7 450 hectares of irrigated rice fields [27] and irrigation channels of Krueng Jreue dam which was able to irrigate 2 350 hectares of irrigated rice fields. Water for rainfed rice fields was sourced from Keuliling reservoir that was able to irrigate rice fields of 4 790.50 hectares which is planned to be developed as a technical irrigation [28].

There were two planting seasons in Krueng Aceh watershed, those were *gadu* rice planting season (May to August) and *rendengan* rice planting season (November to February). Moreover, cropping pattern applied was *gadu-bera-rendengan rice-bera* with one planting season required 120 calendar days. The analysis result on irrigated rice area suggested that irrigation of rice fields area of 32 012 hectares needed water equaled to 14 443 814 m^3. According to [8], Aceh Besar Regency experienced fluctuations in rice production during the period of 2009-2014 in which the supply of irrigation water from Krueng Aceh and Krueng Jreue were not sufficient due to global climate change (Figure 4). The authors in [29] added an opinion that global climate change impacted on disruption of irrigation water supply in increasing rice production.

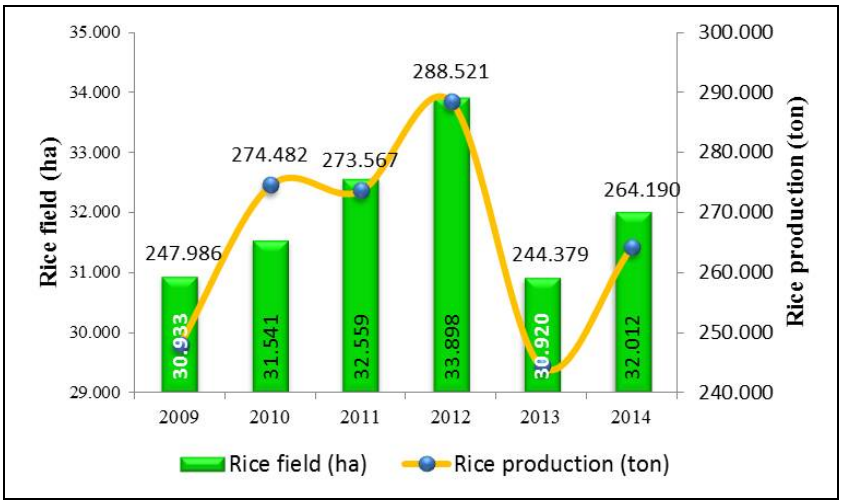

Figure 4: Fluctuation of rice production due to irrigation water availability

3.2.3. Water Demand for Aquaculture Sector

Aquaculture sector requires sustainable water availability as large amount of water is needed to fill the ponds to create a suitable place for freshwater fish growth. Water is used for activities, such as first time water-filling, water addition, and water exchange. The water demand for freshwater aquaculture was calculated based on the width of pond area located in Krueng Aceh watershed then was multiplied by the standard of water requirements for pond flushing was 7 mm/day/ hectare.

Result of analysis showed that total area of 1 396.10 hectares were utilized for freshwater aquaculture in Krueng Aceh watershed in 2014, consisted of 745.10 hectares in Aceh Besar District and 651 hectares in Banda Aceh City. It was calculated that 3 567 036 m^3 of water was needed to meet the water demand for pond area. Availability of sustainable water greatly affected the value of freshwater aquaculture production in Krueng Aceh watershed. From data [8,9] obtained in 2014, freshwater aquaculture production reached 423.5 tons and 430.76 tons in Aceh Besar Regency and Banda Aceh City, respectively (Figure 5).

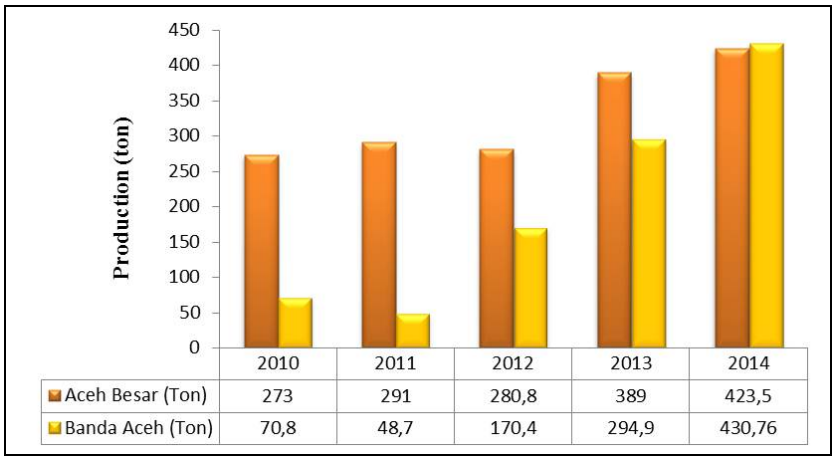

Figure 5: Effect of water availability on the increase of aquaculture production value in Krueng Aceh watershed

3.2.4. Water Demand for Livestock Sector

The livestock sector also needs water for drinking purposes. Livestock animal analysed in this study were cattle, buffalo, horse, goat, sheep, chicken and duck. The animals were formerly grouped according to the standard water demand of livestock consumption (Table 2). There were three groups formed due to the amount of water consumed. The first group contained 116 616 livestock required 40 liter/day/head of water, the second group consisted of 145 827 animals consumed 5 liter/day/head of water, and the last livestock group needed 0.6 liter/day/head of water which was amounted to 1 398 899 animals. Based on the analysis of total water demand for livestock consumption in Krueng Aceh watershed, it was concluded that water for livestock consumption reached 2 275 087 m^3 (Table 4).

3.3. Water Balance of Krueng Aceh Watershed

Water balance of Krueng Aceh watershed was calculated based on approach of surface water availability and its

demand. Water availability is influenced by rainfall frequency, thus it affects the river flow rate. Based on calculation of total water demand, Krueng Aceh watershed needed water amounted to 51221344 m^3/year (Table 5). Therefore, the availability of surface water which amounted to 700 193 659 m^3 resulted in a surplus in surface water of 648 972 315 m^3 (Figure 6).

Table 4: Water demand for livestock consumption in Krueng Aceh watershed in 2014

District	Livestock (head)			Water demand (m^3/year)
	Σ Cattle/Buffalo/Horse	Σ Goat/Sheep	Σ Poultry	
Aceh Besar	114 580	140 150	1 352 859	2 224 918
Banda Aceh	2 036	5 677	46 040	50 169
Total	116 616	145 827	1 398 899	2 275 087

Source : Data analysis result [8, 9]

Table 5: Total water demand of Krueng Aceh watershed in 2014

District	Total water demand (m^3/year)				Total (m^3/year)
	Domestic	Agriculture	Fisheries	Livestock	
Aceh Besar	18 250 124	14 359 440	242 981	2 224 918	35 077 462
Banda Aceh	12 685 283	84 374	5 110	50 169	12 824 936
Total	30 935 407	14 443 814	248 091	2 275 087	47 902 399

Source : Data analysis result [8, 9]

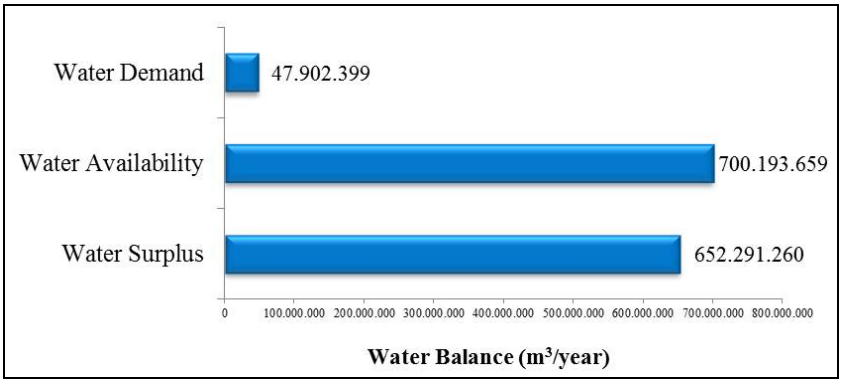

Figure 6: Water balance of Krueng Aceh watershed in 2014

4. Conclusion

The result of this study showed that the availability of Krueng Aceh watershed was still sufficient to be used for domestic use, watering irrigated rice field, filling freshwater aquaculture and meeting the water demand for livestock consumption.

Water use is expected to increase during the growth population rate and the various water needs, so it is needed a management strategy of integrated water resource potential, and also the water conservation without disturb the balance of nature in the Krueng Aceh watershed.

Additional facilities such as dams and reservoirs in Krueng Aceh watershed were needed to accommodate the excess water during the rainy season to be used in the dry season. Moreover, development of irrigation channels of Krueng Aceh and Krueng Jreue as well as drainage channels of Keuliling reservoir is need to be improved. To optimize the water service for public, PDAM has to improve pipeline management system in order to prevent water wasted during water distribution to customers.

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