

Analysis of water demands for freshwater aquaculture ponds in Krueng Aceh watershed, Aceh Province, Indonesia

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Abstract. The growing business of freshwater aquaculture ponds in Krueng Aceh watershed, Aceh Province Indonesia led to the increase of water demand for it and suppress water supply for other sectors. The purpose of this study was to identify the potential of water availability in Krueng Aceh watershed and to analyze the amount of water demand for freshwater aquaculture ponds based on pond area, as well as to analyze the water critical index in Krueng Aceh watershed. The method used was hydrology analysis approach and standard of water demand which is used by the National Standardization Agency of Indonesia. The results showed that the potential of surface water available in Krueng Aceh watershed reached 700,193,659 m³, and during the period 1994-2014 freshwater aquaculture ponds increased to 65 ha with a water demand of 248,091 m³/ha/year. The critical water index was 6.84% which is categorized as not critical for water, thus water demand for freshwater aquaculture pond in Krueng Aceh watershed can still be met from the surface runoff.

Key Words: fishpond, freshwater fish, pond water discharge, pond water volume, water availability.

Introduction. The potential for construction and development of freshwater aquaculture sector in Aceh Province, Indonesia, is highly prospective geographically and topographically with various aquatic resources such as rivers, lakes, reservoirs, and swamps. However, it has not been optimally utilized and managed well (Muchlisin 2012; 2013). Freshwater aquaculture systems that are principally small, non-commercial and family-based, are now expanding rapidly with production for trading nationally, regionally and internationally (Subasinghe et al 2009; Fakoya et al 2009). The development of freshwater aquaculture ponds requires a large supply of fresh water, either from groundwater or surface water (Sharma et al 2013). The current availability of fresh water consumption is decreasing due to increasing population and its demand for water in the domestic, agriculture, aquaculture, livestock and industrial sectors (Muis et al 2016) particularly in Krueng Aceh watershed.

The Krueng Aceh watershed has an important function for harvesting rainwater as well as for storing and flowing water with quantity, quality, and continuity for the community and water users in the downstream area. Water sources for the demands of freshwater aquaculture ponds in Krueng Aceh watershed are obtained through the Krueng Aceh irrigation system, Krueng Jreue irrigation, Keuliling reservoir and the Krueng Aceh river basin. Cultivation of freshwater aquaculture requires a certain volume of water that is able to irrigate and overflow the entire area of the culture pond so that the development and improvement of freshwater aquaculture production can continue. The objectives of this study were to (1) identify the potential of water availability in Krueng Aceh watershed, (2) analyze the amount of water demand for freshwater aquaculture ponds based on pond area, and (3) analyze the capacity of the Krueng Aceh watershed to meet the water demand for ponds.

Material and Method. This study was conducted from January to July 2016 in Krueng Aceh watershed, Aceh Province, Indonesia, which is bordered by the Strait of Malacca to the north, Aceh Jaya district to the south, the Indonesian Ocean to the west, and Pidie district to the east. The total area of this research site was 197,903.62 ha. It is geographically located at positions 5°03'41"-5°38'10"N and 95°11'41"-95°49'46"E (Figure 1).

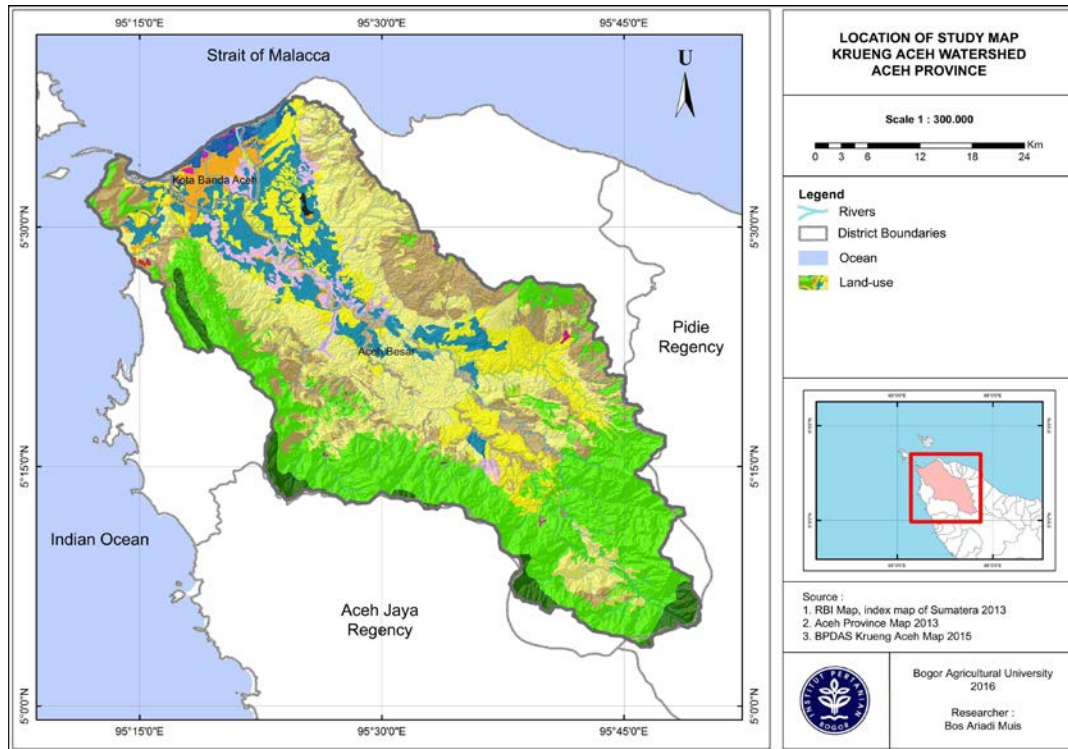


Figure 1. Location of study in Krueng Aceh watershed, Aceh Province, Indonesia.

Materials used in this study were the digital administrative map of Aceh Province with 1:100.000 scale, data of freshwater aquaculture ponds area in 1994-2004, data of rainfall from seven rain observation stations (Meteorology Climatology and Geophysics Agency (BMKG), Sultan Iskandar Muda Airport, BMKG Mata Ie, BMKG Indrapuri, Montasik Station, Jantho Station, Seulumum Station, Saree Station), data of Krueng Aceh river discharge in the period of 1994-2014 from River Basin Organization Sumatera I in Kampung Darang station.

Analysis of water availability of Krueng Aceh watershed. Analysis of water availability aimed to determine the amount of water availability in Krueng Aceh watershed. The water availability from rainwater is calculated to determine the average annual rainwater volume flowed to the hydrological system in Krueng Aceh watershed. To determine the average rainwater volume of the area, mapping of the influenced area from each rain observation station was carried out using ArGIS 10.2 software, then rainfall data from 7 main observation stations in Krueng Aceh watershed area were calculated using polygon Thiessen method (Arsyad 2010), the equation used is as follows:

$$C = A_i / \Sigma A$$

$$P = (A_1P_1 + A_2P_2 + \dots + A_nP_n) / \Sigma A$$

Where:

C = Thiessen coefficient

A_i = influenced area of observation station *i* (ha)

- P = average rainfall of the area (mm)
 A1, A2, An = polygon area of rain observation station (ha)
 P1, P2, Pn = rainfall of each station (mm)
 ΣA = area of Krueng Aceh watershed (ha)

The rain flowing to the Krueng Aceh watershed will turn into a river flow. The river flow was measured using AWLR (Automatic Water Level Recorder) from the observation station of Kampung Darang River basin, River Basin Organization Sumatera Region I of Banda Aceh City. Subsequently, the measured discharge data were used to calculate the water availability in Krueng Aceh watershed by using the method of planning month basis (Limantara 2010).

Data analysis of water demands for aquaculture ponds. The water demands for aquaculture ponds calculated was only for the additional water of the ponds, not the water from the initial condition. The calculation method used was the method from the National Standardization Agency No.19-6728.1-2002, while the water demand for pond additional water was 7 mm/day/ha (BSN 2002). The study of FIDP (Frontiers Investment and Development Partners) and IWRD (Integrated Water Resources Development) reported that the depth of freshwater ponds was 70 cm with the water demand of 35-40 mm/day/ha which was utilized for filling, flowing, rinsing or adding, so the water is not immediately thrown away but flowed to other ponds. The equation used is as follows:

$$Q_p = 365 \text{ days} \times (Q_f / 1000) \times A_{fp} \times 1000$$

Where:

- Q_p = water demand for aquaculture pond (m³/year)
 Q_f = water demand for additional water (7 mm/day/ha)
 A_{fp} = total pond area of aquaculture (ha)

Analysis of water critical index. The phenomenon of water crisis was caused by decreasing of water production in watershed influenced by rainfall pattern due to the global warming effect, which is characterized by the occurrence of degradation of water resources and the existence of a conflict of interest between water user sectors. The critical of water can be measured by the water critical index that is the ratio between the use and availability of water. The higher the water critical index value indicated the more concerning the availability of water in a region. The classification of water critical index values is shown in Table 1 and calculated using the following equation:

$$WCI = (W_d / W_s) \times 100 \%$$

Where:

- WCI = water critical index (%)
 Wd = total of water demand (m³)
 Ws = total of water availability (m³)

Table 1

The classification of the water critical index value in Krueng Aceh watershed in 2014

No.	Water critical index (%)	Classification
1	< 50	Not critical
2	50-75	Quite critical
3	75-100	Critical
4	>100	Very critical

Source: MFRID 2001.

Results and Discussion

Water availability in Krueng Aceh watershed. The result of rainfall analysis in Krueng Aceh watershed for 20 years from 1994-2014 is 2,767.73 mm/year with an average of 131.80 mm/month. The highest rainfall has occurred in December of 383.24 mm while the lowest rainfall reached 4.13 mm in July (Figure 2).

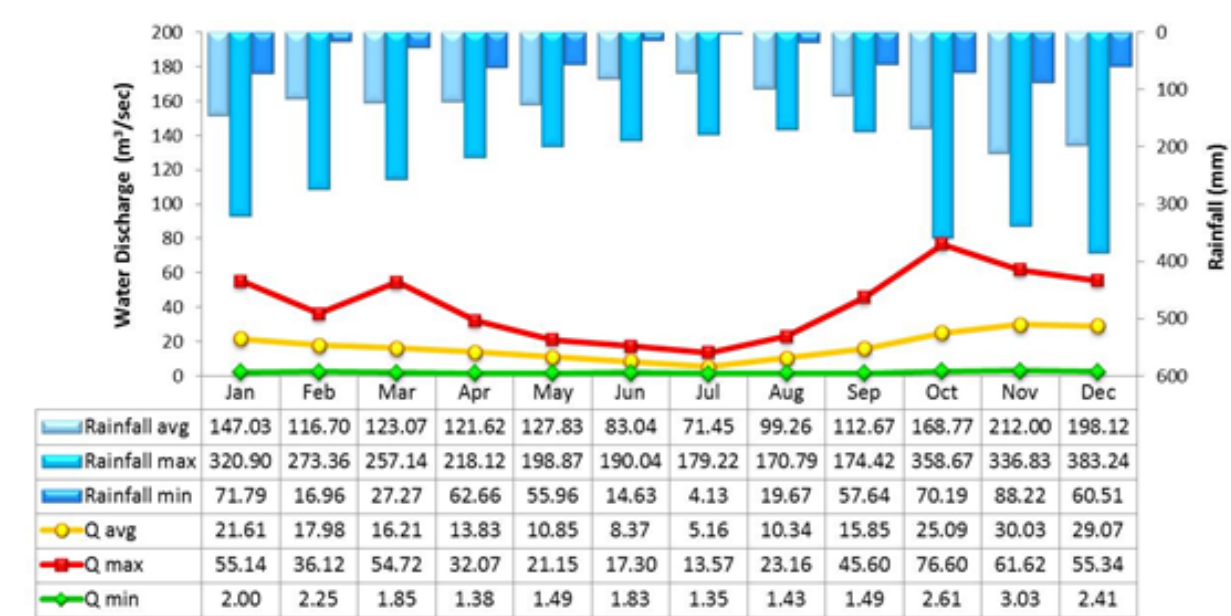


Figure 2. Rainfall and discharge of the Krueng Aceh river 1994-2014.

The rain falling on the soil surface will be infiltrated and flow to be a surface runoff. Runoff generated from the Krueng Aceh watershed were monitored and measured using the AWLR tool to produce a graph of the relationship of water level and time. The river discharge data from the measurement is one of the most important hydrological data in planning and designing the development of aquaculture ponds to meet sustainable water demands.

The analysis of the Krueng Aceh River discharge data during the period 1994-2014 presented in Figure 2 showed the maximum discharge value (Q_{max}) that reached 76.60 m³/sec in October, and minimum discharge (Q_{min}) of 1.35 m³/sec in July. The results of the calculation of 90% mainstay discharge suggested that to meet the water demand of continuous aquatic pond, the discharge of water should be available with Q_{min} of 3.03 m³/sec. This indicated that in the dry season, Krueng Aceh watershed is no longer able to provide water to meet the water demand of freshwater aquaculture ponds from the surface runoff. The availability of surface water in Krueng Aceh watershed in 2014 showed that the amount of water available amounted 700,193,659 m³. The largest water supply available in December reached 147,519,360 m³ with Q_{max} of 55.08 m³/sec while the lowest water availability in July was 11,282,438 m³ with Q_{min} of 4.21 m³/sec, with more details in Table 2.

Water demands of freshwater aquaculture ponds. The Krueng Aceh watershed has a flat, bumpy and hilly physiology areas, which is very potential for the development of freshwater aquaculture. Freshwater aquaculture can be a major driver of economic growth in Aceh province when marine fisheries are overfishing. The water source of freshwater aquaculture pond in Krueng Aceh watershed was obtained from Krueng Aceh irrigation channel and Krueng Jreue irrigation that is a technical irrigation with adjustable and measured discharge rate. Krueng Aceh irrigation was built to irrigate a rice field area of 7,200 ha, and also supplies water to the Krueng Jreue irrigation scheme with a covered area of 800 ha through aquaduct in Indrapuri sub-District, Aceh Besar District.

The result of the analysis of the development of freshwater aquaculture in Aceh Besar district showed that the total culture pond area currently continues to increase with increasing production number, it might be caused by the availability of continuous water supply and the people's desire to increase the source of economic income as well as the support from local government in programming the development of intensive freshwater aquaculture with commodity of goldfish (*Carassius auratus*), Nile tilapia (*Oreochromis niloticus*), giant gourami (*Osphronemus goramy*) and Philippine catfish (*Clarias batrachus*). Support from technical implementing service unit of Jantho fish seed center as a provider of freshwater fish seeds to the farmers ensured the community's effort in the field of aquaculture to increase freshwater fish production in Aceh Besar District.

Data from BPS (2015a) showed that the development of freshwater aquaculture ponds in Aceh Besar district has reached 78.86% for the last 20 years, from 20.10 ha in 1994, expanded to 95.10 ha in 2014. While in Banda Aceh City, the development of the land area of freshwater aquaculture pond tended to decrease by 83.33%, from an area of 12 ha in 1994 and reduced to 2 ha in 2014 (BPS 2015b). The reduction of aquaculture pond area is might be caused by land conversion into residential area and expansion of urban public facility development in Banda Aceh City. The graph of the development of the freshwater aquaculture pond in Krueng Aceh watershed is shown in Figure 3.

Table 2

Water availability in Krueng Aceh watershed in 2014

No.	Month	Discharge average (m ³ /sec)	Water availability (m ³ /month)
1	January	17.60	47 139 840
2	February	16.03	38 783 813
3	March	4.75	12 735 053
4	April	10.96	28 413 337
5	May	11.44	30 633 754
6	June	16.14	41 836 531
7	July	4.21	11 282 438
8	August	20.20	54 095 040
9	September	30.81	79 868 160
10	October	51.05	136 723 392
11	November	27.45	71 162 942
12	December	55.08	147 519 360
Total		22.14	700 193 659

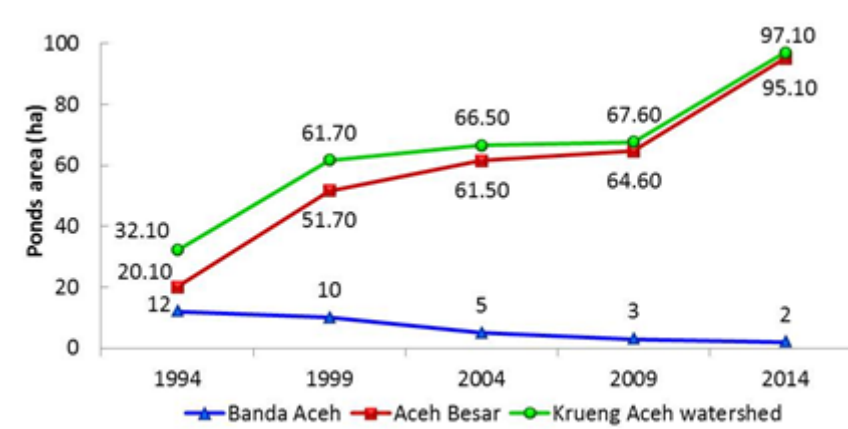


Figure 3. The development of freshwater aquaculture area in Krueng Aceh watershed 1994-2014.

Along with the increase of freshwater aquaculture ponds in Aceh Besar district, the number of fish production also increased to 2.78% from 2010 to 2012, moreover, the training and development of freshwater aquaculture from local government increased the number of production to 33.70% or 423.50 tons in 2014 (BPS 2015a). The number of freshwater fish produced in Banda Aceh city generally increased to 83.56% during the period 2010-2014, from 70.80 tons to 430.76 tons (BPS 2015b), however, in 2011 the production of freshwater aquaculture decreased by 48.70 tons. This is because the rainfall area in Krueng Aceh watershed is only 1,602.37 mm, thus the water discharge can not meet all the water demand of pond in the area of Banda Aceh City which is located in the downstream area of the Krueng Aceh watershed.

The factor of increasing production in Banda Aceh City is not in line with the decrease of the total land area because the farmer applies intensification method starting from the technical aspect of freshwater aquaculture up to water management so that the implementation is more efficient with the optimal yield. Subasinghe et al (2009) stated that the key to cultivation development is intensification in the production and modification of its integrated practice system. The freshwater aquaculture commodities cultivated in Banda Aceh city area are *O. niloticus*, *C. macropomum* and *C. batrachus*. The more details of the increasing number of freshwater aquaculture production in Krueng Aceh watershed is shown in Figure 4.



Figure 4. Number of freshwater fish production in Krueng Aceh watershed 2010-2014.

The freshwater aquaculture ponds require a sustainable water supply to overflow the pond in large number and to create a suitable habitat for freshwater fish growth. This water demand is needed at the initial water filling, addition, and change of pond water. The results of water demand analysis for freshwater aquaculture ponds in Krueng Aceh watershed tended to increase, in 1994 the area of freshwater aquaculture pond was 32.10 ha with the demand of water supply of 82,016 m³/ha, and an increase of 51.73% In 2004 to 66.50 ha with water demand of 169,908 m³/ha. Along with the development of aquaculture pond area which had reached 97.10 ha in 2014, then the demand for water supply had increased to 248,091 m³/ha. It showed that for the last 20 years in Krueng Aceh watershed the water demands increased to 66.94%. The development of ponds area and water demand in Krueng Aceh watershed is shown in Table 3.

Table 3
The water demand of aquaculture ponds in Krueng Aceh watershed 1994-2014

Year	Aquaculture pond area (ha)		Total area of pond (ha)	Total of water demand (m ³ /ha/year)
	Banda Aceh	Aceh Besar		
1994	12	20.10	32.10	82 016
1999	10	51.70	61.70	157 644
2004	5	61.50	66.50	169 908
2009	3	64.60	67.60	172 718
2014	2	95.10	97.10	248 091

Based on the results of water availability and water demand analysis for freshwater aquaculture ponds in Krueng Aceh watershed, Sari et al (2012) stated that the appropriate water discharge for freshwater aquaculture pond was 10-15 L/sec/ha, while the minimum discharge of water was 20 m³/sec/ha, however, the ideal condition was 27-55 m³/sec/ha (Khairuddin & Munir 2012). Based on the results of this study and based on the calculation of the average monthly discharge to 2014 of 22.14 m³/sec, as well as based on the water critical index of finding results by Muis et al (2016), it was determined that from 5 sectors of activity in Krueng Aceh watershed, it required a water demand of 47,902,399 m³ while the water availability was 700,193,659 m³ so that the water critical index value was 6.84% which then classified not critical. Therefore, water demand for freshwater aquaculture ponds in Krueng Aceh watershed can still be met from the runoff.

Conclusions. The potential of water resources in Krueng Aceh watershed until 2014 is still able to irrigate the freshwater aquaculture area of 97.10 ha with the water demand amounted to 248,091 m³/ha/year which sourced from the river basin and irrigation channels. Freshwater aquaculture will continue to grow, however, the main water source of the pond comes from irrigation channels which is prioritized to irrigate rice fields in the future consequences will be a conflict of interest of water use for the domestic, agriculture, livestock and industry sectors.

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