The water availability effectiveness in weirs

S Permana*, G J Johari, D Yogaswara and E Walujodjati

Department of Civil Engineering, Sekolah Tinggi Teknologi Garut, Jalan Mayor Syamsu I, Garut 44151, Indonesia

*sulwanpermana@sttgarut.ac.id

Abstract. The Availability of water for irrigation is critical in the sustainability of crops. One of the primary water sources to maintain and even increase yields is the river. Mount Galunggung has many sources of water. Cibanjaran River is one of the rivers that originate on Galunggung mountain used to flood an area of 595 ha of rice fields. At present, the river has undergone silting due to sand mining activities next to the weir. The purpose of this study is to determine the effectiveness of the available discharges in the river in meeting the needs of the rice fields that are due to river sedimentation. Available data processing methods are used to analyze the availability and needs of water. Planting plan in November, water requirements in the rice fields are 1.5 lt/sec/ha. The available discharge is not able to meet the needs of 595 ha of rice fields. River sedimentation due to sand mining upstream affects the availability of water because a lot of water overflows above the spillway so that it cannot be utilized. The use of a group system and scheduling water supply provides the right solution in the distribution of water.

1. Introduction

Indonesia has a lot of rivers and is a lifeblood for people's lives, so it is often used by the community for their daily needs. Some river benefits that are often used are for irrigation, hydroelectric power generation, raw water supply, fisheries, transportation, and tourism. Rivers are grooves or natural and/or artificial water containers in the form of water drainage networks and water in them, ranging from upstream to estuary, with bounded right and left by border lines (Republic of Indonesia's Government Regulation No. 38 of 2011 concerning Rivers).

Rivers, especially in Sumatra, Kalimantan and other islands in Indonesia have a function to support the economy of the community. So that the existence of the river is often used by the community as a means of transportation, distribution of goods and basic commodities, plantation products, mining, trade, and also industrial products.

Indonesia is an agrarian country, and most of its inhabitants make a living as farmers. As an Indonesian agrarian country that has abundant natural resources, besides that Indonesia is also in a strategic position and also lies in the tropics so that many trees that grow rapidly and have high rainfall. Gemah Ripah Loh Jinawi is often associated with Indonesia. Nowadays it has developed amidst the flow of modernization, many agricultural areas, hills that are shifting functions so that it is difficult to find stretches of rice fields and hills in urban areas even to the countryside.

Indonesia has abundant natural resources; this natural wealth is capital in carrying out activities to increase human resources and infrastructure development in all fields. Based on data from the 2018 Central Bureau of Statistics, the area of paddy fields in 2015 was above 8 million ha, the 2015 rice harvest area was above 14 million ha, and 2015 rice production was above 75 million tons.
Reduced agricultural land is caused by the development of the city. With the increase in population, it will result in the need for a place to live so that land needs to be made for living. Since there is high population along the river basin, it will become a major contribution toward the rate of surface runoff and discharge into the river and the risk of flood [1]. As a consequence of these housing needs, many agricultural lands, especially productive paddy fields and unproductive ones, have changed their functions into settlements and have an impact on reducing crop yields each year. In addition to productive land, there are also many hilly areas that are dug up to make settlements, businesses, and others. The aim was to project the future land use in accordance with the historical changes and planned urban development [2]. With the increasing number of land use changes resulting in reduced water catchment areas and also changes in temperature that are getting hotter.

With a large population of around 265 million, food and infrastructure needs will continue to increase. In 2018 Indonesia imports rice to meet needs and increase rice stocks which have decreased. Production of lowland rice in West Java Province from 2013 to 2015 has decreased (Central Java Provincial Statistics Agency, 2018). One area in West Java Province that contributed to the harvest of paddy rice was the Cibanjaran Irrigation Area which irrigated an area of 595 ha of rice fields. The source of the Cibanjaran river comes from Mount Galunggung, Tasikmalaya Regency. This irrigation area is the responsibility of the West Java Provincial Government because the paddy fields irrigated into the Tasikmalaya Regency and Tasikmalaya Regency areas.

The current condition of the Cibanjaran river has been silenced due to sedimentation due to sand mining activities next to the weir. The investigation of fluvial bed materials The investigation of fluvial bed materials permits an identification of dominant sediment type in a particular river [3]. Based on the results of the field survey, almost half the width of the weir was covered by deposits resulting from sand excavation. The degree of flow complexity is intensified by erosion and sedimentation processes [4]. Therefore, it will greatly affect the availability of water needed to irrigate rice fields. The downstream area of the Cibanjaran irrigation network has a connecting road between Mangkubumi District and Indihang District of Tasikmalaya City; this will have an impact on the conversion of productive paddy fields into settlements. The purpose of this study was to determine the effectiveness of the discharge in the weir in irrigating an area of 595 ha of rice fields and giving input to decision makers in handling sand mining activities on the upstream of the weir. The results of this study can help in structuring the excavation of sand in the Cibanjaran river upstream.

2. Method

Definition of watersheds according to Government Regulation of the Republic of Indonesia No. 38 of 2011 concerning rivers is a land area which is an integral part of the river and its tributaries, which function to collect, store and drain water originating from natural rainfall to the sea, where the boundary on land is a topographic separator and a boundary at the sea to the waters which are still affected by land activities.

Galunggung Mountain is a legendary mountain in West Java Province. This mountain has an altitude of 2168 m above sea level and erupted in 1982. During this time exploitation of the use of Galunggung sand was considered to be of quality for building materials and road construction.

Mount Galunggung is the upstream of the Cibanjaran river; this river empties into the Cikunir river. The area of the Cikunir river with upstream rivers originating from Mount Galunggung with an altitude of approximately 2168 m above average sea level. The river flows into urban areas that divide several sub-districts, namely Sukaratu District (Tasikmalaya Regency), the boundary between Singaparna Subdistrict, Tasikmalaya Regency and Mangkubumi District, Tasikmalaya City, and Kawalu District (Tasikmalaya City), the Ciloseh River empties into the Ciwulan River which is widely used by the community especially for irrigation.

Usually, the use of the methodology used is adjusted to the conditions of the river flow in Indonesia in order to get the appropriate results. The water balance model for river flows in Indonesia was introduced by Dr. F.J. Mock in 1973. This model is used to calculate the monthly discharge from average monthly rainfall data, evapotranspiration, and hydrological characteristics of watersheds, such as soil
moisture and groundwater storage, and vegetation characteristics. This model is used if there are no discharge measurements directly in the field. The discharge that occurs in the Cibanjaran dam area is calculated based on observations of the water level next to the weir. The discharge data calculated in this study for 12 years starting from 2006 to 2017.

Flood discharge usually occurs in a short time, while small discharge occurs over a long period of time. Flooding and extreme droughts resulted in many causalities in the aspects of anthropology, hydrology and economics [5]. Water loss due to evaporation in flood discharge can usually be ignored, whereas in small discharge because it occurs for a long time, the evaporation process must be taken into account [6]. At the location of this study, the evapotranspiration process was taken into account in calculating the discharge. ET₀ is the evapotranspiration rate from a reference surface, not short of water. The reference surface is a hypothetical grass surface with specific characteristic [7].

The study was conducted in the Cibanjaran irrigation area; the water for irrigating this irrigation area was supplied from the Cibanjaran river with a flow area of 10 km². Figure 1 shows the Cibanjaran river and the Cibanjaran primary channel. Because in the upper reaches of the weir there are many activities carried out by the community, especially sand mining, which has an impact on silting the river. The environmental conditions, such as the increasing urbanization and the occurrence of natural hazards like flood and landslides may affect the homogeneity and the continuity of rainfall data [8]. Floods are one of the primary climate related disasters, and within the context of climate change [9]. Cibanjaran irrigation area is located in Sukaratu District, Tasikmalaya Regency, this river empties into the Cikunir river. This irrigation area consists of the Cibanjaran trunk channel and one Warung Sabelah secondary channel which irrigates an area of 233 ha. Secondary data collection is mainstay discharge, water balance, cropping pattern, and network scheme. Secondary data was obtained from the Regional Technical Implementation Unit for the Management of Water Resources in the Ciwulan-Cilaki River Region. Primary data is obtained from direct field surveys by observing river conditions around the weir.

Effective rainfall is used by the Harza formula, for effective rainfall irrigation the rice plant is taken 70% of the minimum monthly rainfall with a 5 year return period. Dependable flow calculations use the Weibull probability formula by sorting data from large to small and the number of data 12 years. For irrigation purposes, 80% of the minimum river discharge for possible fulfillment is taken while the calculation of water requirements is used 6 alternatives.

Some of the discharge that occur at the end of the watershed are used to irrigate paddy fields while the calculated debits to irrigate this rice field area are based on dependable flow, and some are passed through weirs. The majority of water resources projects are planned, designed, and operated based on the historical prototype of water availability, quality and demand, assuming constant climatic behaviour [10]. Dependable flow is a discharge from a water source (river) that is expected to be tapped with a certain risk of failure. In irrigation that applies in Indonesia, the probability of discharge being fulfilled is 80%.
3. Result and discussion

3.1. Result
The condition of land use in the upstream area is a very important parameter in determining river discharge, in addition to rainfall. The land condition in the Upper Cibanjaran River has sand mining activities carried out by the community; the impact of this activity will lead to reduced water catchment areas. So that a lot of land is eroded when it rains which will eventually enter the river. The area of the Cibanjaran river basin ranges from weir to upstream about 10 km². At present the Cibanjaran river is silting, resulting in overflowing river water during the rainy season. Cibungaran Dam is currently almost half closed as a result of mining activities.

In addition to the mining activities in the upstream area, the Tasikmalaya City Government has also built a connecting road between the Mangkubumi and Indihiang Districts. This connecting road is located downstream of the Cibanjaran irrigation network. With the existence of this road which was built starting in 2003, the condition of the land has begun to change with the presence of sand mining activities downstream of this irrigation network. This condition will have an impact on development activities in the future, especially the construction of settlements that will use agricultural land, especially rice fields in the region so that paddy fields will shrink. Activities in the flood plain and catchment may increase the magnitude of the flood [11]. Watershed management is generally scientifically management of water in the earth it has evolved and passed through several developmental stages [12].

Almost every year the Cibanjaran river is often flooded, flooding occurs due to high rainfall so that infrastructure such as buildings and roads in several villages including Linggajati Village, Sinagar Village, and Gunungsari Village in Sukaratu Subdistrict are damaged. Climate change can several impact on hydrological processes, including an increase in rainfall, particularly during extreme events [13]. In March 2019 the Cibanjaran river was flooded due to heavy rains and caused a puddle of water until the 3-meter long embankment of the Cibanjaran river embankment was broken. The flood from the river brought mud material and plastic waste. Apart from due to heavy rain, flooding was also caused by siltation of the Cibanjaran river due to the excavation of sand in the Sukaratu District. The quality of groundwater depends on the quality of recharged water, atmospheric precipitation, inland surface water, and subsurface geochemical processes [14].

In addition to the condition of the land, another parameter that affects the availability of water on the channel is the network condition. The evaluation of the performance of the irrigation system uses 6 (six) parameters, namely: physical infrastructure, plant productivity, supporting facilities, personnel organizations, documentation, and water-using farmer associations. Based on data obtained in 2014 the condition of irrigation networks with good conditions was 59.41% and heavily damaged 17.05%. With the presence of heavily damaged conditions, it will disrupt the amount of discharge flowing into the rice fields. In 2015 the condition of the network with good conditions was 59.62% in conditions of severe damage was 16.85%. In 2016 the network conditions were still good at 59.64%, and the condition of severe damage was 16.85%. In 2017 good network conditions amounted to 78.80% and were severely damaged at 18.92%. Whereas in 2018 the condition of irrigation networks with good conditions was 81.39% and in conditions of severe damage was 16.33%. From the percentage above, the Government through the Regional Technical Implementation Unit for the Management of Water Resources in the Ciwulan-Cilaki River Region has made efforts to improve the network to improve network performance again.

Even though the Cibanjaran river in the upstream area has been degraded due to sand mining activities until now the river is still used for irrigation activities especially to irrigate rice fields in Sukaratu Subdistrict, Tasikmalaya Regency covering an area of 260 ha and Tasikmalaya City Mangkubumi District covering 335 ha. The Cibanjaran main canal ends at situ Gede in Mangkubumi District, Tasikmalaya City. Situ Gede with an area of 47 ha in addition to tourism sites as well as the availability of water there is used to irrigate rice fields in the area of Tasikmalaya City.
Plans for planting season 1 (MT 1) began in October with plans for a rice planting area of 558 ha, planting season 2 (MT 2) with rice plants covering 558 ha starting in February, and planting season 3 (MT 3) of rice plants covering an area of 233 ha starts in June, while those not planted cover 37 ha. Realization of planting for MT 1, MT 2 and MT 3 is the same as the planting plan. Figure 2 shows a graph of the water balance and planting intensity. In general, cropping intensity (planting intensity is the area divided by the crop multiplied by 100%) in February to May by 0.52 while between June and September the planting intensity is 1.37%. This shows that the harvest from February to May is lower than the yield from June to September.

![Figure 2](image_url). Water balance chart and plant intensity [15].

Rainfall is an important parameter in determining river discharge. Rainfall information is useful for runoff prediction and hydrograph analysis and their impact on surface water impoundments, floods and groundwater recharge works [16]. In the Cibanjaran river basin, there is no rain station so that the determination of the discharge in the weir is done by direct measurement of river elevation in the upstream of the weir. Calculation of dependable flow starts in October I from 2006 to 2017 for 12 years. Dependable flow is used to determine the availability of water in the river which will be used as a basis in determining the area of rice fields to be irrigated; the dependable flow is calculated every half-monthly.

Water balance is obtained by comparing between irrigation water requirements and water availability for current conditions and future projections. Conjunctive use of surface water and groundwater for irrigation should plays an important role both as a source of recharge to the groundwater and as a cause of discharge by pumping [17]. Water availability is based on 80% dependable flow. While the water demand in the Cibanjaran irrigation area is calculated based on the area of rice fields that will be irrigated. Table 1 shows the relationship between availability, needs, and percentage fulfilled Cibanjaran irrigation area. From the water balance table, it can be seen that in one year the planting season is fulfilled or the percentage is above 100% only in January II and September II. While other months are not fulfilled or the percentage is less than 100%.
Table 1. Water balance [15].

| No | Month | Q Dependable flow (l/sec) | Q Requirement (l/sec) | % Fulfilled |
|----|-------|---------------------------|-----------------------|------------|
| 1  | Oct I | 402                       | 984,69                | 40.83      |
| 2  | Oct II| 408                       | 984,69                | 41.43      |
| 3  | Nov I | 421                       | 621,10                | 67.78      |
| 4  | Nov II| 382                       | 621,10                | 61.50      |
| 5  | Dec I | 434                       | 621,10                | 69.88      |
| 6  | Dec II| 483                       | 621,10                | 77.77      |
| 7  | Jan I | 440                       | 621,10                | 70.84      |
| 8  | Jan II| 479                       | 326,77                | 146.59     |
| 9  | Feb I | 452                       | 898,12                | 50.33      |
| 10 | Feb II| 455                       | 898,12                | 50.66      |
| 11 | Mar I | 442                       | 707,67                | 62.46      |
| 12 | Mar II| 333                       | 707,67                | 47.06      |
| 13 | Apr I | 283                       | 707,67                | 39.99      |
| 14 | Apr II| 264                       | 707,67                | 37.31      |
| 15 | May I | 245                       | 707,67                | 34.62      |
| 16 | May II| 229                       | 707,67                | 32.36      |
| 17 | Jun I | 125                       | 898,12                | 13.92      |
| 18 | Jun II| 117                       | 898,12                | 13.03      |
| 19 | Jul I | 181                       | 707,67                | 25.58      |
| 20 | Jul II| 309                       | 707,67                | 43.66      |
| 21 | Aug I | 364                       | 707,67                | 51.44      |
| 22 | Aug II| 209                       | 707,67                | 29.53      |
| 23 | Sep I | 355                       | 707,67                | 50.16      |
| 24 | Sep II| 356                       | 326,77                | 108.95     |

Figure 3 shows the water balance curve in the Cibanjaran irrigation area, from the water balance curve, it can be seen that the main discharge is not able to meet irrigation water needs, only in January II and September II can the water supply be able to meet water requirements. This is because in that month it has entered the harvest period.

![Water Balance Curve](image)

Figure 3. Water balance curve.

3.2. Discussion

Until now, sand mining activities carried out by people around the foot of Mount Galunggung and its surroundings in Sukaratu Subdistrict, Tasikmalaya Regency resulted in the silting of the Cibanjaran river as a result of flooding in the rainy season due to high rainfall. The impact of mining activities and the occurrence of heavy rains that fell in the Cibanjaran dam upstream area resulted in damaged school buildings, community settlements and roads in the area. With this activity, the sediment is carried to settle around the weir. In addition to causing flooding, river water also becomes cloudy and is carried into the Cibanjaran main canal and Warung Sabelah secondary channel, thereby reducing the performance of the irrigation network. The degradation of the Cibanjaran river has serious impacts on the condition of the river and the local community as well as the condition of the rice field area.
The condition of the Cibanjaran irrigation area with severe damage from year to year has decreased; this is because the government is very concerned about the condition of the irrigation network. The irrigation area of Cibanjaran irrigates rice fields in Tasikmalaya Regency and Tasikmalaya City so that if the upstream network conditions are less noticed, it will have an impact on the existing network conditions in the downstream area. Cibanjaran irrigation network consists of main buildings, complementary buildings, primary channels, and secondary channels.

Although the condition of the Cibanjaran weir where almost half the width of the weir was covered by mud deposits originating from the upper reaches of the river impacted siltation around the weir until now the weir was still used to irrigate rice fields in the Sukaratu District of Tasikmalaya District and Mangkubumi District in Tasikmalaya City. Because until now 595 ha of rice fields are still planted.

In the Cibanjaran river basin, especially in the upper reaches of the weir, there is no rain gauge because Cibanjaran weir is not far from the foot of Mount Galunggung. Therefore, the measurement of discharge every half monthly in the weir is done by measuring the discharge that overflows over the weir overflow.

Based on the results of measurement of discharge for 12 years, the dependable flow that is not able to irrigate the area of land area of 595 ha. The maximum area of irrigated area is only 77.77%, while the minimum area that can still be drained is around 13.03% because during the peak of the rainy season the river is unable to accommodate the discharge which causes flooding that damages surrounding residential settlements and other infrastructure often used by the community. Change in human mind set and life style with more demand of comfort and to reduce man power needed in farming [18]. Losses felt by the local community besides settlements as well as water overflowing inundated the rice field area. Therefore, the presence of sand mining activities in the upstream dam has a very serious impact on the availability of discharge to irrigate rice fields.

4. Conclusion
The downstream area of the Cibanjaran irrigation network, which is in Cipari Village, Mangkubumi Sub-District, has a connecting road between Mangkubumi District and Indihiang District, Tasikmalaya City. This road was first built in 2003, with the existence of various road constraints inaugurated in 2016. With the existence of the road, there was a significant change in the existence of land, especially the presence of sand mining activities in Mangkubumi Subdistrict and an increase in the number of settlements that displaced the remaining rice fields productive.

Changes in land use, especially the mining activities at the foot of Mount Galunggung, have resulted in half the width of the weir covered with sediments which has an impact on the large amount of discharge flowing in the Cibanjaran river. Dependable flow was calculated based on the Weibull formula with many data 12 years starting from 2006 to 2017. The maximum dependable flow occurred in December at 483 lt/sec, and the smallest dependable flow occurred in June at 117 lt/sec. Water balance in Cibanjaran irrigation area between the availability of water based on mainstay discharge and water requirements in the rice field area is not fully irrigated, the maximum area of rice field irrigated is only 77.77%. Peak needs occur in October, and only 40.83% is fulfilled.

Based on the water balance table, all of the water requirement in the area are not fulfilled, except in January and September the availability of water is above the requirement. As a result of sedimentation in the upstream of the weir as a result of sand mining activities, the effectiveness of water distribution to irrigate the rice field area of 595 ha has decreased. The downstream area of the Cibanjaran irrigation network has also undergone changes as a result of the connecting road between the Mangkubumi and Indihiang Districts. Therefore, to reduce the impact on dependable flow, the government took steps by structuring the excavation area and replanting the excavated land.

Acknowledgments
Authors wishing to acknowledge Sekolah Tinggi Teknologi Garut that supports and funds this research publication.
References

[1] Saudi A S M, Juahir H, Azid A, Toriman M E, Kamarudin M K A, Saudi M M, Mustafa A D and Amran M A 2015 Flood risk pattern recognition by using environment technique: A case study in langat river basin J. Teknol. 77 145–52

[2] Bello A-A D, Haniffah M R M, Hashim N B and Anuar K M 2018 Estimation of Hydrological Changes in a Tropical Watershed Using Multi-Temporal Land-Use and Dynamic Modelling J. Teknol. 80 126

[3] Hanna W, Wan M, Aminah S, Nawang B and Porhemmat M 2015 Statistical Characterisation of Grain-Size Distribution in Fluvial Sediment of Kelantan Jurnal Teknologi Full paper Statistical Characterisation of Grain-Size Distribution in Fluvial Sediment of Kelantan Rivers J. Teknol. 3 103–9

[4] Jumain M, Ibrahim Z, Ismail Z, Samsudin M F, Anuar M Z T, Harun S, Makhtar M R and Rahman M S A 2016 Flood flow characteristics and bed load transport in non-vegetated compound straight channels J. Teknol. 78 1–8

[5] Muhammad N S, Akashah A I and Abdullah J 2016 Analysis of Extreme Rainfall Indices in Peninsular Malaysia J. Teknol. 78

[6] Bambang T 2008 Hidrologi terapan Beta Offset, Yogyakarta 59 50

[7] Shamsuddin S A and Amran M J M 2016 Reference evapotranspiration (ETo) in tropical forested areas determined by penman-monteith model in cropwat software J. Teknol. 78 91–7

[8] Lin N J, Aziz S A, Feng H Y, Wayayok A and Kamal M R 2015 Homogeneity analysis of rainfall in Kelantan, Malaysia J. Teknol. 76 1–6

[9] Yoshioka Y, Masumoto T, Maruyama K and Minakawa H 2015 Agricultural water-gate management for operational flood protection in low-lying paddies J. Teknol. 76 37–44

[10] Abdulkareem J H and Sulaiman W N A 2016 Trend Analysis of Precipitation Data in Flood Source Areas of Kelantan River Basin J. Teknol. 78 116

[11] Khalid K, Ali M F, Rahman N F A, Zainuddin M R, Muhamad N S, Den E M and Othman Z 2016 Surface runoff variation assessment using process-based hydrologic model J. Teknol. 78 39–44

[12] Dubey S 2018 A Review of Approach Pattern of Watershed Management in Agroforestry, Climate Change, Social Aspects and Livelihoods Int. J. Sci. Res. 7 169–75

[13] Othman M A, Zakaria N A, Ab. Ghani A, Chang C K and Chan N W 2016 Analysis of Trends of Extreme Rainfall Events Using Mann Kendall Test: a Case Study in Pahang and Kelantan River Basins J. Teknol. 78

[14] Khan D, Ejaz N, Khan T A, Saeed T U and Attaullah H 2015 Sustainable groundwater – A need of sustainable agriculture Int. J. Civ. Eng. 13 305–20

[15] UPTD Pengelolaan Sumber Daya Air WS Ciwulan-Cilaki 2018 Neraca Kebutuhan Air Daerah Irigasi Cihanjaran (sebagai dasar penetapan pola tanam) (Tasikmalaya)

[16] Rahman N A, Yusop Z, Šen Z, Taher S and Kane I L 2017 Mitigation of time series approach on climate change adaptation on rainfall of Wadi Al-Aqiq, Madinah, Saudi Arabia J. Teknol. 79 91–104

[17] Ezrin M H, Aimrun W, Amin M S M and Bejo S K 2016 Development of real time soil nutrient mapping system in paddy field J. Teknol. 78 125–31

[18] Alam I, James R A, Padmanabhan V and Sunny A 2018 a Low Cost Automated Irrigation System With Soil Moisture Sensor Int. Res. J. 5 4146–8