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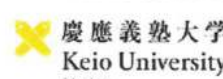Directur of Pascasarjana, University of Mataram

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Analysis of water condition in Dodokan watershed, Lombok, Indonesia

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Abstract. Watershed of Dodokan in Lombok, Indonesia, is one of the strategic watersheds on the island of Lombok, and is a priority for rehabilitation of forest and land. This paper aims to analyse ecological water conditions in Dodokan watershed, Lombok, Indonesia, and recommends policy for improving the ecological conditions of the watershed. The results of this analysis are expected to be useful in implementing policies and programs to improve the ecological condition of this watershed, as well as to provide greater benefits for the communities around or related to this watershed. The watershed analysis focuses on five aspects, including flow regime coefficient, annual flow coefficient, sediment load, flood, and water use index. The results of the analysis show that the ecological condition of water management in the Dodokan watershed is poor, and can threaten the continuity of water resources in the Dodokan watershed. Therefore, rehabilitation activities are urgently needed.

1. Introduction

The concept of watersheds has been put forward by many experts. Several definitions of the watershed state that it generally contains the meaning of watershed: (1) as a land area that is topographically bounded by mountain ridges; (2) has a function to drain, accommodate, store water, sediment, and dissolved materials and discharge them through a single outlet; and (3) includes various resources that provide goods and services for the community and maintain ecosystem functions [5]. In Government Regulation Number 37 of 2012 concerning Watershed Management, a watershed is defined as an area of land that is an integral part of a river and its tributaries, which functions to accommodate, store and drain water originating from rainfall to lakes or the sea independently. natural, where the land boundary is a topographical separator and the sea boundary to a water area that is still affected by land activities. The watershed is a system that has a role as a landscape system, an ecological system, and a water system [7], and consists of biophysical, social, and economic factors [2].

As a system, the role of the watershed is very important in several aspects. The processes that occur in the watershed consist of biophysical, hydrological, and socio-economic which are complexly interrelated. Biophysical and hydrological processes in a watershed are natural processes as part of a hydrological cycle, called water cycle. Meanwhile, community socio-economic activities are a form of human intervention on natural watershed systems, such as urban development, construction of water structures, as well as the development of protected areas and cultivation areas. This is inseparable from the increasing demands on natural resources (water, land, and forests) which are triggered by increased population pressure on land which has an impact on changes in the carrying capacity of the watershed [3].

The condition of the carrying capacity of the watershed can change if land is used without control and does not pay attention to soil and water conservation principles. This in turn resulted in increased erosion and sedimentation, decreased vegetation cover, and accelerated land degradation. The result of this change not only has a real impact on biophysics such as an increase in the area of critical land, a decrease in quantity, quality, and continuity of water flow but also impacts socio-economically. It also causes a decrease in the ability of the community to cultivate their land, and causes decreased community welfare [3]. Therefore, watersheds need to be managed appropriately and timely.

Watershed management is an action that aims to create awareness, capacity, and active participation of relevant institutions and communities in better watershed management. This is to realize land conditions to become productive by increasing capacity of the watershed in a sustainable manner; to realize the optimal quantity, quality, and sustainability of water availability according to space and time; and to improve the welfare of the community [3].

The issuance of Government Regulation Number 37 of 2012 concerning Watershed Management is the legal basis for the implementation of watershed management to coordinate, integrate, synchronize and synergize watershed management to increase the carrying capacity of the watershed. Watershed management is carried out through planning, implementation, community participation and empowerment, funding, monitoring and evaluation, guidance and supervision, and utilization of watershed management information systems [4].

Monitoring activities in watershed management are very important to determine whether the objectives of watershed management carried out through watershed management activities have been achieved, and can then be used as feedback for future improvement in watershed management planning. Monitoring of various indicators of watershed management which includes components of biophysical, hydrological, socio-economic, building investment and spatial use of watershed areas is an effort to collect and collect data and information needed for the purpose of evaluating watershed management. Monitoring of the watershed management indicators is carried out periodically at least every 5 years. The results of the evaluation of watershed management are a description of the carrying capacity of the watershed [3]. This paper aims to analyse ecological water conditions in Dodokan watershed, Lombok, Indonesia, and recommends policy for improving the ecological conditions of the watershed. The results of this analysis are expected to be useful in implementing policies and programs to improve the condition of this watershed, as well as to provide greater benefits for the communities around or related to this watershed.

2. Material and Method

The method used in this journal is the scoring method in accordance with the Regulation of the Minister of Forestry of the Republic of Indonesia Number P/61/Menhut-II/2014 of 2014 on water management parameters (Table 1). Data for this were obtained from secondary and primary sources.

Table 1. Criteria for evaluating ecological water condition.

Parameter	Weight	Score	
	%	Minimum	Maximum
1. Flow Regime Coefficient	5	2.5	7.5
2. Annual Flow Coefficient	5	2.5	7.5
3. Sediment Load	4	2	6
4. Flooding	2	1	3
5. Water Use Index	4	2	6

The method used in analyzing the condition of the Dodokan watershed is detailed for each of the parameters of flow regime coefficient, annual flow coefficient, sediment load, flooding, and water use index. Each is described below.

2.1. Flow Regime Coefficient (FRC)

The maximum discharge data were obtained from predictions using the Manning formula and reconstruction of the cross-section of the former flood, while the minimum data was obtained from the results of direct measurements during the dry season. Monitoring of river discharge is carried out to determine the quantity of river flow from time to time, especially the highest (maximum) discharge in the rainy season and the lowest (minimum) discharge in the dry season.

The FRC value is the ratio of Qmax to Qmin, which is the absolute discharge (Q) from SPAS observations or formula calculations. As for areas where during the dry season there is no water in the

river, the FRC value is the ratio of Qmax to Qa. Qmax is the absolute maximum discharge and Qa is the mainstay discharge (Qa = 0.25 x Q monthly average).

A high FRC value indicates that the range of runoff values in the rainy season (floodwater) is large, while in the dry season the flow of water that occurs is very small or indicates drought. Indirectly, this condition indicates that the infiltration capacity of the land in the watershed is less able to hold and store rainwater that falls and a lot of its runoff water continues to enter the river and is wasted into the sea so that the availability of water in the watershed during the dry season is low. The KRA calculation uses the classification of values as shown in Table 2.

Table 2. Values and Classification of Flow Regime Coefficient.

Parameter	Score	Class	Sum
Wet area:	FRC ≤ 20	Very low	0.5
	20 < FRC ≤ 50	Low	0.75
$FRC = \dfrac{Qmax}{Qmin}$	50 < FRC ≤ 80	Medium	1
	80 < FRC ≤ 110	High	1.25
	FRC > 110	Very High	1.5
Dry area:	FRC ≤ 5	Very low	0.5
	5 < FRC ≤ 10	Low	0.75
$FRC = \dfrac{Qmax}{Qa}$	10 < FRC ≤ 15	Medium	1
	15 < FRC ≤ 20	High	1.25
	FRC > 20	Very High	1.5

2.2. Annual Flow Coefficient (AFC)

The Annual Flow Coefficient (AFC) is the ratio between the thickness of the annual flow (Q, mm) and the thickness of the annual rain (P, mm) in the watershed or it can be said how many percent of the rainfall becomes runoff in the watershed. The calculation of AFC uses the value classification as shown in Table 3.

Table 3. Values and Classification of Annual Flow Coefficients.

Parameter	Score	Class	Sum
$AFC = \dfrac{Qyearly}{Pyearly}$	AFC ≤ 0,2	Very low	0.5
	0.2 < AFC ≤ 0.3	Low	0.75
	0.3 < AFC ≤ 0.4	Medium	1
	0.4 < AFC ≤ 0.5	High	1.25
	AFC > 0.5	Very High	1.5

The value in Table 3 is the real annual runoff value (direct runoff, DRO), which is the total runoff value (Q) after deducting the base flow value (BF), or in its equation: DRO = Q – BF. Base flow calculation (BF) for the monthly average daily BF value = the lowest daily average Q value when there is no rain (P = 0). If the base flow value is included in the calculation, the value of the runoff coefficient (C) for the watershed/sub watershed can be more than 1 (>1). This is because even though it is not raining, for example during the dry season, the flow of water in the river is still there, which is a form of base flow. Therefore, in evaluating the "C" value indicator, you must be more careful, namely using the direct runoff value.

The flow thickness (Q) is obtained from the discharge volume (Q, in units of m^3) from the observations of SPAS in the watershed for one year or the calculation of the formula divided by the area of the watershed (ha or m2) which is then converted to mm. Meanwhile, the annual rainfall thickness (P) is obtained from the results of recordings at the Rain Observer Station (SPH) either with the Automatic Rainfall Recorder (ARR) and or an ombro meter.

2.3. Sediment Load

Sedimentation is the amount of soil material in the form of silt in water by river water flow

originating from the erosion process upstream, which is deposited at a place downstream where the sedimentation speed of the suspension material grains is smaller than the transport speed. From the sedimentation process, only some of the sediment flow material in the river is transported out of the watershed, while the others settle at certain locations in the river during their journey.

Indicators of sedimentation can be seen from the amount of mud in the water transported by river water, or the amount of sediment deposition in water bodies and/or reservoirs. The greater the sediment content carried by the flow, the more unhealthy the watershed condition.

The amount of sediment load in the water flow is expressed in terms of the sedimentation rate (in units of tons or m3 or mm per year). Sediment load (MS) is calculated by direct measurement, using the equation:

$$Qs = k \times Cs \times Q$$

Description:
Qs (ton/day) = debit sediment
k = 0.0864
Cs (mg/l) = sediment load rate
Q (m3/dt) = river water discharge
Qs in ton/day can be converted into ton/ha/year by dividing the value of Qs by the area of the watershed. Furthermore, the value of Qs in tons/ha/yr is converted to Qs in mm/year by multiplying it by the specific gravity (BJ) of the soil to produce a thick value of sedimentary deposits.

In addition, the sediment load can be obtained through the erosion prediction approach, using the formula:

$$SL = A \times SDR$$

Description:
SL = Sediment Load (ton/ha/year)
A = total erosion (ton/ha/year)
SDR = sediment delivery ratio
Total erosion value is determined using the USLE formula, while the sediment delivery ratio (SDR) can be determined using the matrix sediment delivery ratio (SDR).
The Calculation of sediment load used the classification of values as shown in Table 4.

Table 4. Value and Classification of Sediment Load.

Parameter	Score	Class	Sum
Qs = k x Cs x Q	MS ≤ 5	Very low	0.5
MS = A x SDR	5 < MS ≤ 10	Low	0.75
	10 < MS ≤ 15	Medium	1
	15 < MS ≤ 20	High	1.25
	MS > 20	Very High	1.5

2.4. Flooding

Flooding in a general sense is the flow of river water in high quantities, or the flow of water in the river is relatively larger than normal conditions due to rain that falls upstream or in a certain place continuously, so that the water cannot be accommodated by the river. the existing river channel, then the water overflows out and inundates the surrounding area. A Flash flood is a large flood that comes suddenly and rushes to wash away large objects such as wood and so on. Thus, flooding must be seen from the amount of floodwater supply that comes from rainwater that falls and is processed by the catchment area (catchment area), as well as the capacity of the riverbed to drain the water supply. Flood monitoring is carried out to determine the frequency of flood events, both flash floods, and inundation floods. Data is obtained from reports of disaster events or direct observations. The calculation of the frequency of flood events uses the value classification as listed in Table 5.

Table 5. Score and Flood Classification.

Parameter	Score	Class	Sum
Flooding frequency	Nothing	Very low	0.5
	Once on 5 years	Low	0.75
	Once on 2 years	Medium	1
	Once on 1 year	High	1.25
	More than once in a year	Very High	1.5

2.5. Water Usage Index (WUI)

The calculation of the water use index uses the availability of water per capita per year by comparing the amount of water with the total population. Population data were obtained from the Central Statistics Agency for West Lombok and Central Lombok. Water supply (m^3) is calculated directly, namely from the results of observations of the volume of discharge (Q, m^3) and or with a land-use approach. Monitoring of water use is carried out to find out the description of the amount of water demand compared to the quantity of water available in the watershed.

The WUI value of a watershed is said to be good if the amount of water used in the watershed is still less than its potential so that the watershed still produces water that comes out of the watershed for its downstream area, on the contrary, it is said to be bad if the amount of water used is greater than its potential so that the volume of water produced from the watershed for the downstream area is little or no. WUI indicators in watershed management are very important, especially concerning mitigation of annual drought disasters in watersheds.

The calculation of the water use index can be calculated in the following ways:

$$WUI = \frac{Amount\ of\ water\ (Q)}{Population}$$

Description:

Q= River water discharge in m^3/year

Population= Total population in the watershed

WUI calculation uses value classification as shown in Table 6.

Table 6. Score and Classification of Water Use Index.

Parameter	Value	Class	Score
$WUI = \dfrac{Q}{Population}$	WUI > 6,800	Very low	0.5
	5,100 < WUI ≤ 6,800	Low	0.75
	3,400 < WUI ≤ 5,100	Medium	1
	1,700 < WUI ≤ 3,400	High	1.25
	WUI ≤ 1,700	Very High	1.5

3. Results and Discussion

Geographically, the Dodokan watershed is located at 08°35'1.53" - 08°52'48.56" South Latitude and 116°3'21.79"-116°21'45.69" East Longitude (Figure 1). Administratively, the Dodokan watershed is located in the regencies of West Lombok and Central Lombok.

Source: Watershed boundary map (2018, processed)

Figure 1. Dodokan watershed area

Dodokan watershed is categorized as a small watershed with an area of 56,613.65 hectares covering 15 districts consisting of 125 villages. The results and discussion of the analysis of the condition of the Dodokan watershed are as follows:

3.1. Flow Regime
The flow regime for the Dodokan watershed is calculated by comparing the maximum discharge value (Qmax) with the minimum discharge (Qmin). The calculation of the discharge in the Dodokan watershed is carried out using river flow observation data (SPAS) at two locations, namely Petitik in upstream and Karang Makam in downstream.

The flow coefficient calculation data used is 2016 data which is the most complete recording data. The complete calculation results can be seen in Table 7.

Table 7. Values and Scores of Flow Regime Coefficients in the Dodokan Watershed

SPAS Location	Qmax	Qmin	KRA	Score
Petitik	47.3	0.12	22.78	
Karang Makam	56.72	0.01	5.672	1.5

Source: SPAS Field Data (2019, Processed)

The results of the comparison of the maximum and minimum discharge values at the Dodokan watershed outlets obtained a value of 5,672 which was included in the very high category with a score of 1.5 for the calculation of the carrying capacity of the Dodokan watershed.

The results of the calculation of the flow regime in the Dodokan watershed show that the ability of the Dodokan watershed to store rainwater is very lacking [1]. In the rainy season, the water discharge is very large while in the dry season there is a flow of water with a very small discharge so that the continuity of water resources can be said to be lacking. The discharge that occurs has a positive relationship with rainfall, where an increase in rainfall will increase the amount of discharge produced [6].

3.2. Annual Flow Coefficient (AFC)
The annual flow coefficient is the ratio between the annual runoff value and the annual rainfall of a watershed. The AFC calculation for the Dodokan watershed was carried out using the Karang Makam SPAS data analysis as the location closest to the outlet.

The results of the AFC calculation show a value of 0.08. The Annual Flow Coefficient is one of the indicators of watershed health, the magnitude of which depends on the rainfall received by the watershed; The closer to 0 the AFC value is getting better [1]. The AFC value in the Dodokan watershed can be interpreted as good where only 0.08% of the rain becomes surface runoff while the rest goes into the ground as base flow and some are stuck in water structures in the Dodokan watershed, so the role of water structures in the Dodokan watershed is very important. big. The value of 0.08 is in the very low category, with a score of 0.5 for the calculation of the overall carrying capacity of the Dodokan watershed. The data from the calculation of the annual flow coefficient of the Dodokan watershed are presented in Table 8.

Table 8. Dodokan Watershed Annual Flow Coefficient scores

Watershed Average Rainfall (mm)	Rainfall Volume (m^3)	Flow Volume (m^3)	Volume ET+L (m^3)	Flow Coefficient (C)	Score
1,951.8	1,104,989,124.3	85,787,744.4	1,019,201,379.9	0.08	0.5

Sources: Field Data (2019, Processed)

3.3. Sediment Load

Sedimentation is the amount of soil material in the form of silt content in water by river water flow originating from the results of the erosion process upstream, which is deposited at a place downstream where the sedimentation speed of the suspension material grains is smaller than the transport speed. From the sedimentation process, only some of the sediment flow material in the river is transported out of the watershed, while the others settle at certain locations in the river during their journey.

Calculation of sediment load is carried out using the erosion value approach from the results of the calculation of the USLE method multiplied by the value of the sediment conductivity (SDR). The sediment conductivity value of the Dodokan watershed is 56,613.65 Ha (at the outlet which is measured to determine the minimum discharge) of 8.5%. From the calculation results, the sediment load value in the Dodokan watershed is 2.49 tons/ha/year, where this value is included in the very low category with a score of 0.5 for the calculation of the carrying capacity of the watershed. The complete results can be seen in Table 9.

Table 9. Dodokan Watershed Sediment Payload Value and Score

Description	Unit	Sum
Watershed Area	Hectares	56,613.65
Erosion	Ton/hectares/year	29.303
Sediment Delivery Ratio (SDR)	%	8.5
Sediment	Ton/hectares/year	2.49
Score		0.5

Sources: Field Data (2019, Processed)

3.4. Flooding

Flooding in a general sense is the flow of river water in high quantities, or the flow of water in the river is relatively larger than normal conditions due to rain that falls upstream or in a certain place continuously, so that the water cannot be accommodated by the river, the existing river channel, then the water overflows out and inundates the surrounding area.

According to information from the NTB Provincial Disaster Management Agency as well as information from the community downstream, there is 1 flood event every 2 years in the Dodokan watershed area. The flood parameter value in the Dodokan watershed is in the medium category with a score of 1 for the calculation of the carrying capacity of the watershed. Data on flood events in the Dodokan watershed can be seen in Table 10.

Table 10. Frequency and Value of Flood Events in the Dodokan Watershed

Year	Number of occurrence	Flooding	Category	Score
2014	0	None		
2015	1	Runoff Flood		
2016	0	None	Medium	1
2017	0	None		
2018	1	Flooding		

Sources: Data (2019, Processed)

3.5. Water Use Index (WUI)

The Water Use Index (WUI) is a comparison between the water demand and the water supply of a watershed. The calculation of the water use index in the Dodokan watershed is carried out using the method of availability per capita per year, namely by comparing the amount of discharge (Q) in one year with the total population in a watershed.

The amount of water in the Dodokan watershed from data processing in 2019 was 85,787,744.4

m^3 per year with a population of 545,532 people, an WUI value of 157.26 was included in the very bad category with a score of 1.5 (Table 11). This means that the Dodokan watershed is prone to water shortages during the dry season. As such, the life of the surrounding community is threatened in the dry season. Therefore, actions need to be taken to solve this problem, particularly in maintaining the availability of water for any time in the year or among future years.

Table 11. Water Use Index and Dodokan Watershed WUI Score

Amount of Water (m^3)	Total Population (Individu)	WUI	Score
85,787,744.37	545.532	157.26	1.5

Sources: Field Data (2019, Processed)

4. Conclusion

The watershed analysis focuses on five aspects, including flow regime coefficient, annual flow coefficient, sediment load, flood, and water use index. The results of the analysis show that the ecological condition of water management in the Dodokan watershed, Lombok, was poor, indicated by very high flow regime coefficient and very bad water use, all of which can threaten the continuity of water resources in the Dodokan watershed. Therefore, rehabilitation activities for Dodokan watershed are urgently needed.

5. Acknowledgements

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