Hydrology Modeling for Hydrograph Analysis in Sayang Watershed East Java, Indonesia

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1. Introduction

Sayang watershed is located at 112°22'09" Eastern Longitude and 07°50'34" Southern Latitude. It flows into Selorejo dam directly (see figure 1). In 1970, early development of Selorejo dam, effective capacity was approximately 54.600.000 m³. Its capacity was decreasing to 38.510.000 m^3 in 2005 (Rijsdijk, 2005). On the other hand, the rainfall runoff is increasing due to residential developments which change the land use from the green area to the pavement area. Therefore, it is important to analyze rainfall runoff due to land use change for dam sustainability. SIMODAS has been known as information system and hydrological models for watershed management. In addition, this system could estimate rainfall runoff due to land use change. However the applicability of this system in Sayang watershed has not been investigated yet. Based on above condition, this research is ongoing research to investigate the land use change effect to the rainfall runoff. However for the first step, this research aims to investigate the applicability of SIMODAS model in Sayang watershed by comparing its hydrograph with common Nakayasu hydrograph. The distinctions and similarities between them will also be discussed.

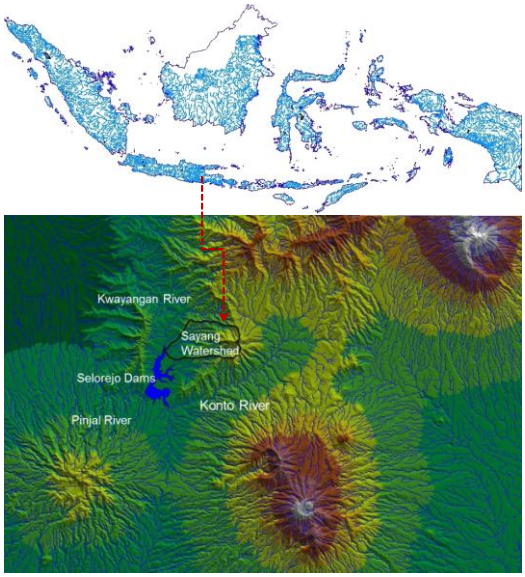

Figure 1. Study Location

2. Concept and Method

The method in this study is a spatial analysis using SIMODAS model that used to estimate the hydrographs at Sayang watershed. Hydrograph is controlled by meteorological factors such as rainfall intensity, rainfall and land cover. SIMODAS is developed base on *kinematic wave concept* with input rainfall (*i*) and loses factor that known as abstraction (*f*).further, abstraction is summation between interception by infiltration, the equation is below:

$$Q_{i+1}^{j+1} = \frac{\left[\frac{\Delta t}{\Delta x} Q_i^{j+1} + \alpha\beta Q_{i+1}^{j}\left(\frac{Q_{i+1}^{j}+Q_i^{j+1}}{2}\right)^{\beta-1} + \Delta x(i-f)_{i+1}^{j+1}\right]}{\left[\frac{\Delta t}{\Delta x} + \alpha\beta\left(\frac{Q_{i+1}^{j}+Q_i^{j+1}}{2}\right)^{\beta-1}\right]} \quad (1) \quad \text{Where,} \quad \alpha = \left[nP^{2/3}/\sqrt{S_0}\right]^{0.6} \quad \text{and} \quad \beta = 0.6 \quad (2)$$

Q is a discharge, *x* is length of flow direction, *n* is Manning Coefficient and *So* is slope factor. For runoff model *P* is equal to *x*. Based on slope, flow direction can determine by equation (3):

$$AALIR = 2^{j-1} \quad ; j = 1 \text{ for } \left\{ \max_{i=1,8} Q(i)\left|\frac{z_x - z_i}{\lambda}\right| \right\} \quad (3)$$

j is eight main directions and calculate from matrix $\begin{bmatrix} 64 & 128 & 1 \\ 32 & x & 2 \\ 16 & 8 & 4 \end{bmatrix}$

The next important parameter is flow accumulation where it is equal to the sum of the flow of surrounding cells (Sutanhaji, 2005).

3. Physically Condition in Sayang Watershed

Land Cover in Sayang watershed is dominated by Pine forest with 58.382% of the watershed area. Based on land use map in 2003(shown in Table 1 and Figure 3), the total area of Sayang watershed is 1209.598 ha. Land cover is an input to determine Curve Number which is used as interception variable.

Table 1. Land Use in Sayang Watershed

No.	Land Use	Area	
		Ha	%
1	Forest	706,184	58,382
2	Residential	17,438	1,442
3	Coffee Plantation	125,190	10,350
4	Rice Field	170,002	14,054
5	Bush	91,981	7,604
6	Dry Farm Field	98,803	8,168
	Total	**1209,598**	**100**

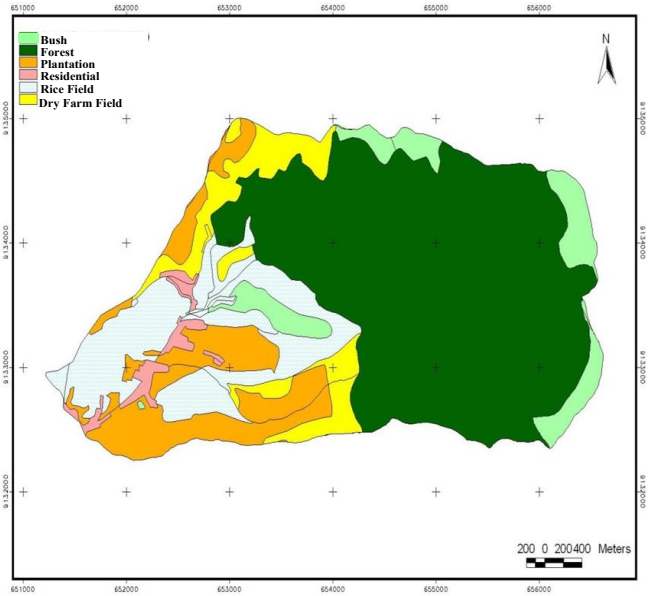

Figure 2. Land Use in Sayang Watershed

Soil types in Sayang watershed consists of 3 types, Andosol, Cambisol and Mediteran. Andosol is the largest area, amount 750.519 ha, Cambisol is the second, amount 400.707 ha and the last is Mediteran amount 58.372 ha. Soil types are inputted to determine infiltration value.

Average Rainfall in certain areas can be analyzed by several methods such as algebraic average, Thiessen Polygon and Isohyet method (Brooks, 2002). In this research, we selected Thiessen Polygon method with collected rainfall data from 1998 until 2007. Based on maximum daily rainfall, the highest rainfall happened in 2007, amount 193.10 mm and the lowest happened in 2005. For calibration SIMODAS model purposes, we collected field rainfall data from December 2008 until February 2009.

4. Result and Discussion

Based on Nakayasu method in 10 years return period, the time from early rainfall until flood peak (Tp) is 1.77 hours or 106.523 minute and peak of discharge is 11.578 m^3/sec. In Sayang watershed, we used flow coefficient 0.292 and α value equal 2. We assume that flow in Sayang watershed is ordinary flow. While based on SIMODAS model in 10 years return period, the time from early rainfall until flood peak (Tp) is 1.98 hours or 119 minute and peak of discharge is 12.224 m^3/sec. Therefore, the result of both methods Nakayasu and SIMODAS model has similarities. Result of comparison between Nakayasu method and SIMODAS model is shown in Table 2.

Table 2. Comparison Tp and Qp Value

No.	Q Return Period	Hydrograph			
		SIMODAS		Nakayasu	
		Tp (minute)	Qp (m^3/s)	Tp (minute)	Qp (m^3/s)
1	10 years	119	12.224	106.523	11.578
2	25 years	117	13.078	106.523	12.876
3	50 years	113	14.233	106.523	13.715

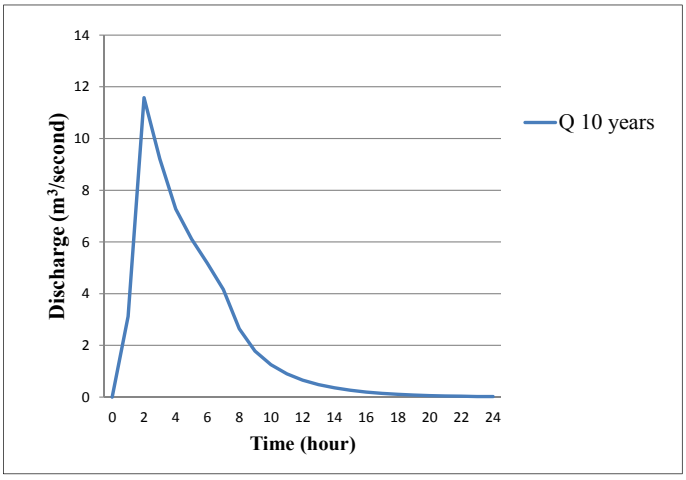

Figure 3. Nakayasu Hydrograph at 10 years return period

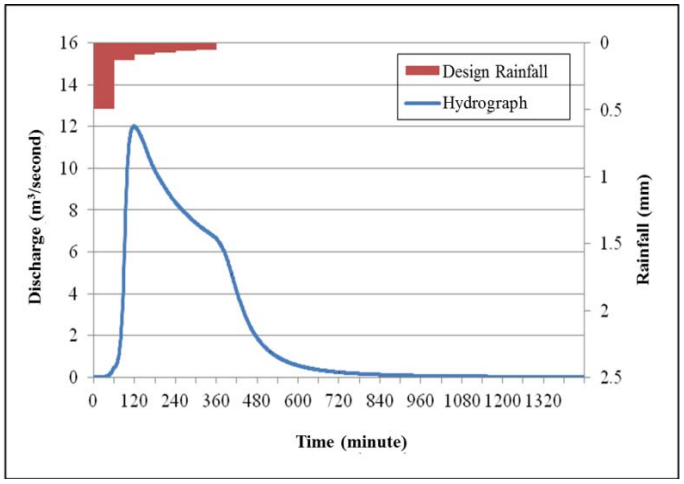

Figure 4. SIMODAS model Hydrograph at 10 years return period

Comparison hydrograph shape from Nakayasu method and SIMODAS model (see Figure 3 and Figure 4) is determined by determination coefficient test, the comparison ratio of the square difference between them. The value of determination coefficient in each hydrograph 10 years return period, 25 years return period and 50 years return period are 0.9079, 0.9419 and 0.9152. All of determination coefficient is close to 1. Therefore, hydrograph from SIMODAS model and hydrograph from Nakayasu method has similarities. But the hydrograph product of SIMODAS is different with the hydrograph Nakayasu method because in the SIMODAS model, rainfall distribution pattern as input for the simulation and generate discharge value per minute while Nakayasu method, the value of rainfall as input and generate discharge value per hour. SIMODAS model is more thorough than the Nakayasu method and it is better than Nakayasu method, if applied in Sayang Watershed because rainfall pattern in this watershed happened in short-time period.

5. Conclusion

This research concludes that comparison hydrograph between SIMODAS and Nakayasu method has similarities. It can be concluded from Tp value and Qp value, both of them has close value and the ratio of determination coefficient R^2 value is close to 1. SIMODAS model is appropriate applied to analyze water management in Sayang watershed because in this area the rainfall pattern usually occurred short-time period.

References

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