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WATERSHED SHAPE USING SIMODAS: A CASE STUDY OF SABU ISLAND, NTT

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ABSTRACT

The objective of this research was to know the influence of watershed to the flood's hydrograph using SIMODAS. Case study was in Sabu Island, Nusa Tenggara Timur, Indonesia. SIMODAS was a soft ware that could be used to determine watershed shape, to describe drainage network, and to produce hydrograph stream flow. Result was used: 1) to predict watershed shape, 2) to inform on the planning of building flood control, and 3) to give any consideration in the way to prevent or decrease flood.

Keywords: watershed shape, hydrograph, SIMODAS

INTRODUCTION

The insufficient knowledge of the nature of long-term variations in river regime and the impossibility of their long-term prediction in designing various facilities, results in the use probabilistic estimates, based on the laws of mathematical statistics and mathematical modeling (Kalinin and Trufimov, 2011). However, the samples should be representative: adequately represent the features of the total populations. This is the particular importance as far as the available observational series in the hydrological gage network have different duration and not coinciding boundaries.

The optimal combination of flood protection options is determined flood damages and construction cost of flood control options along the river (Oztekon, 2011). The needed design flood values for decided options especially when the lengths of recorded data are short may require usage of various statistical distributions. These distributions enable us to predict values having return periods greater than the lengths of the recorded series (Oztekin, 2011). Therefore, choice of the distribution most suitable to the recorded sample series is important from these aspects.

The Primary objective of frequency analysis is to relate the magnitude of extreme events to their frequency of occurrence through the use of probability distributions (Hassanzadeh et al., 2011) The preciseness of hydrologic frequency analysis depends on the type of statistical distributions and parameter estimation techniques. A lot of models have been developed to describe the distribution of hydrological data. Likewise, there are several methods of parameter estimation, among which the most popular are the methods of maximum likelihood, moment and probability weighted moments (Hassanzadeh et al, 2011).

Watershed is a topographic land area that is bounded by the spines of mountain accommodated and stored water then connected to the rain towards the sea through the main river (Asdak, 2002). One output of the systems is the flood discharge of the river basin. One of the factors that affect the river flood discharge is catchment area or the shape of watershed. Information about river flood discharge would provide more useful results when presented in the form of hydrographs. However, estimation of maximum floods on a watershed can be analyzed if the flood discharge on each form of watershed and its influence on the flood hydrograph are known. Such information can also be used to design the building of flood prevention.

The purpose of this study was to determine the flood discharge at the various forms of watersheds, the effect of different forms of watersheds against flood hydrograph, and the effect of other watershed characteristics in addition to the flood hydrograph shape watershed.

CONTEXT AND REVIEW OF LITERATURE

This research was conducted from September 2008 until June 2009 at the Engineering Laboratory of Natural Resources and Environment, Department of Agricultural Engineering, Faculty of Agricultural Technology, UB, Malang. Equipment and materials used in this research were as follow:

- Equipment: PC *(Personal Computer)*
- Material: contour maps, map of catchment boundaries, river network map of P. Sabu, and data of rainfall
- Software used in this research was ArcView 3.3 ESRI as GIS *software,* Microsoft Visual Basic 6.0 and SIMODAS Software

METHOD

The method used in this study was analysis of spatial and flood hydrographs. The study used three different locations in the catchment area of the island of Sabu, NTT Watershed, namely Daieko DAS, Ladeke DAS, and DAS Raikore Location of this study was as Figure 1. Sabu Island was an island belonging to the territory of Kupang, East Nusa Tenggara Province (NTT) Territorial boundaries Sabu Island were: northern bordering by the Sea Savu / Sabu, the Southern by Indian Ocean, the eastern by Rote Island, and the western by the Raijua island.

Figure 1 Location of Study

FINDINGS AND DISCUSSION

Each watershed of this study was included some of sub-watersheds. The characteristics of watersheds in this study were described as Table 1 below.

Table 1 Results of watershed characteristics

Watershed	R_B	R_L	R_A	D	Lo	Area (km2)	Length of main river (m)
Daieko	5	1.046	5.031	2.211	0.226	8.501533	4627.924
Daieko 2	6	1.629	5.971	1.59	0.314	10.58851	5863.069
Ladeke	10.25	4.608	16.587	1.966	0.254	8.564623	3113.478
Ladeke 2	12	6.399	22.746	1.948	0.257	12.97595	3652.036
Ladeke 3	7.2	1.657	8.733	1.538	0.325	10.31123	2215.713
Ladeke 4	11.5	5.685	22.143	2.096	0.239	19.25934	4997.173
Raikore	7	1.555	4.379	1.777	0.344	8.460305	5305.907
Raikore 2	6.83	1.743	5.943	1.982	0.317	11.14883	5593.719
Raikore 3	9	2.714	11.245	1.574	0.318	10.51605	3350.745

In addition to the characteristics in Table 2, the form of watershed was one of the factors that influenced the occurrence of flood discharge and hydrograph shape. In this study, it also had a watershed that was used in different forms, among others could be seen in Figure 7 as follow:

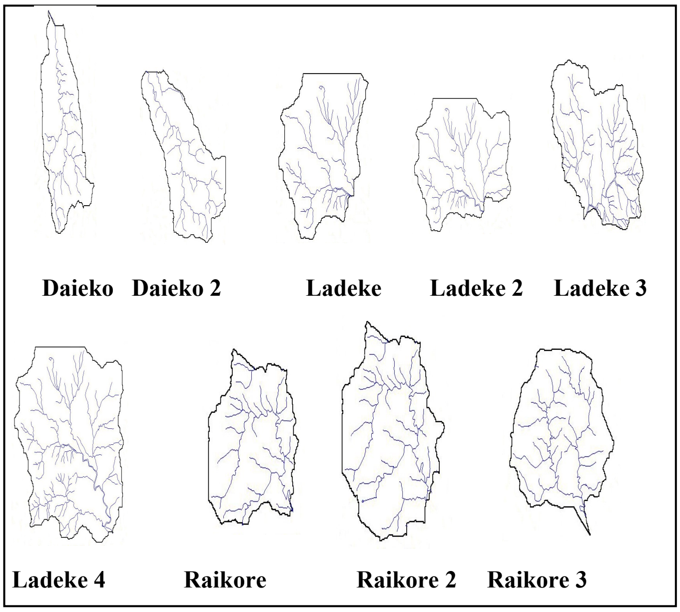

Figure 7 Shapes of watershed

Watershed Flood Hydrograph Analysis

Flood Hydrograph analysis of watershed with CN 50

Curve Number (CN) was a number that indicated the state of land use in an area. CN 50 showed the state of land use was still large forested. Large flood peak discharge in each watershed on the hydrograph could be seen in Table 3 below:

Table 3. The Flood Hydrograph watershed with CN 50

watershed	**CN 50**	
	Q peak (m^3/s)	Time to peak (minute)
Daieko	1.06	460-470
Daieko 2	1.03	500-510
Ladeke	1.28	410-420
Ladeke 2	1.22	430
Ladeke 3	0.958	420-430
Ladeke 4	1.12	480-490
Raikore	0.957	500-510
Raikore 2	0.93	490-500
Raikore 3	1.14	460-470

Hydrograph results in Table 3 showed that the highest flood peak discharge values at the watershed Ladeke was equal to 1:28 m^3 / second with a time to peak 420-480 minutes and the lowest was 410-420 minutes Raikore second watershed was equal 0.93 with a time to peak 490-500 min.

Flood Hydrograph Analysis watershed with CN 70

In the rain flow simulation using *the Curve Number* 70, it was assumed that 50% of land was remains forested and 50% had already been in the form of settlement. Large flood peak discharge in each watershed in the hydrograph could be seen in Table 4 below:

Table 4 The Flood Hydrograph watershed with CN 70

Watershed	CN 70	
	Q peak (m^3/s)	Time to peak (minute)
Daieko	16.068	220
Daieko 2	15.999	230
Ladeke	17.889	200
Ladeke 2	17.448	200
Ladeke 3	14.054	200
Ladeke 4	16.752	220
Raikore	15.376	230
Raikore 2	15.139	230
Raikore 3	16.43	220

Table 4 showed that the highest flood discharge in the watershed Ladeke was the same as in the simulation with the CN 50. Values of flood peak discharge on the flow simulation of watershed Ladeke with CN 70 was 17 889 m ^{3} / second with a time of 200 minutes. Flood peak time on the CN 70 was faster than the CN 50. This was due to the CN 70, it was assumed to be 50% of forest land and 50% residential. The lowest flood peak discharge in the watershed Ladeke was 3 14 054 m ^{3} / sec with flood peak time was 200 minutes.

Flood Hydrograph Analysis watershed with CN 90

In this simulation, the flow of rain with the CN 90 was assumed as land especially in the form of settlement. Urban land use that was considering or not to the environmental balance aspects such as the provision of water catchment areas, would affect water flow patterns in the event of rain. Fewer recharge area, causing rain falling most of the land surface would become surface runoff *(runoff).* Large flood peak discharge in each watershed in the hydrograph could be seen in Table 5 below:

Table 5 Flood Hydrograph Results watershed with CN 90

	CN 90	
	Q peak (m^3/s)	Time to peak (minute)
I watershed	61.46	150
Daleko 2	60.55	150
Ladeke	67.63	140
Ladeke 2	66.19	140
Ladeke 3	53.75	140
Ladeke 4	63.39	150
Raikore	58.57	150
Raikore 2	57.94	150
Raikore 3	62.76	150

Table 5 showed the the highest flood peak discharge was the same as in the watershed Ladeke rain flow simulation with CN 50 and CN 70. Values of flood peak discharge on the flow simulation of watershed Ladeke with CN in 1990 was calculated as 67.63 m ^{3} / second with a time of 140 minutes. When the flood peak on the CN 1990 was much faster than the CN 50 and CN 70, this was due to the CN 90, it was assumed that most of the land was in the form of settlement (densely populated) so that water flow rate was not detained and the majority of rainwater became runoff. Lowest flood peak discharge value in the simulation with the CN 1990 was a watershed Ladeke 3. Large flood peak discharge in the watershed Ladeke 3 was 53.75 m ^{3} / second with a time of 140 minutes.

Relationship analysis of watershed characteristics with Flood Hydrograph

In statistical science, the term had the meaning of relationship of quantitative correlation between two variables measured on ordinal or interval scale [5]. While correlation analysis was a form of analysis (statistics), which showed the strength of the relationship between two variables, the coefficient of determination indicated how far the error in estimating the magnitude *of y* could be reduced by using information held by the variable *x*. Regression model was said to be better if the amount of R ^{2} close to 1.

Correlation between peak flood discharge watershed characteristics could be seen in Figure 11 to 17 below.

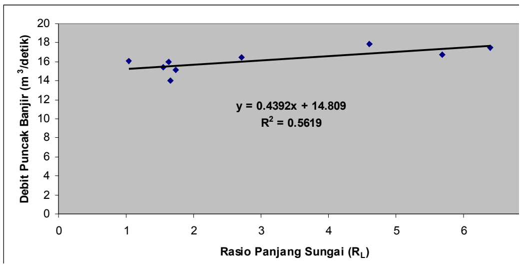

Figure 11 Graph Flood peak discharge relations with River Length Ratio (R $_L$)

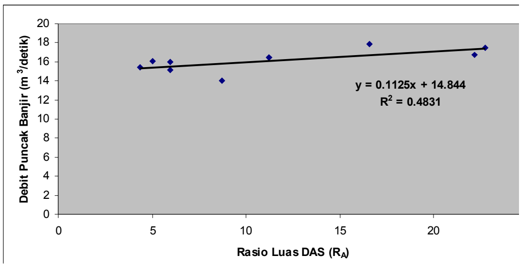

Figure 12 Graph Flood peak discharge relationship with the ratio of watershed area ratio (R $_A$)

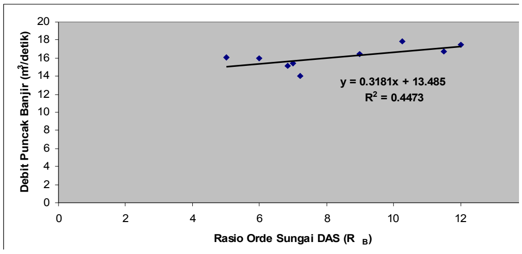

Figure 13 Graph Flood peak discharge relationship with the Order of Comparative Ratios River watershed (of R $_B$)

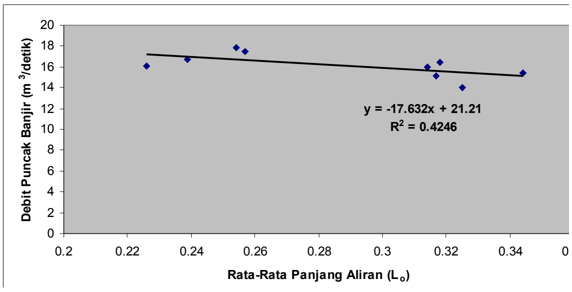

Figure 14 Graph Debit Relationship with Peak Flood Flow Average length (L $_o$)

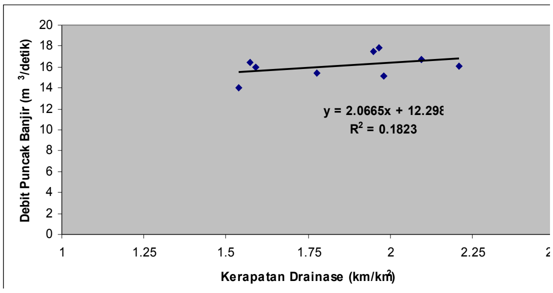

Figure 15 Graph Relations Flood peak discharge with drainage density

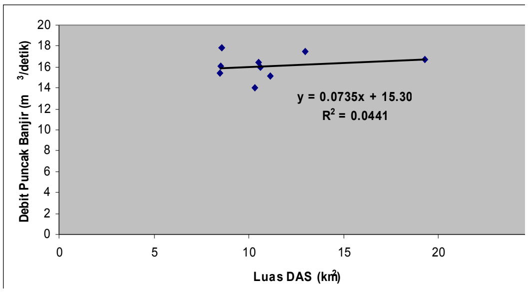

Figure 16 Graph of flood peak discharge relations with watershed area

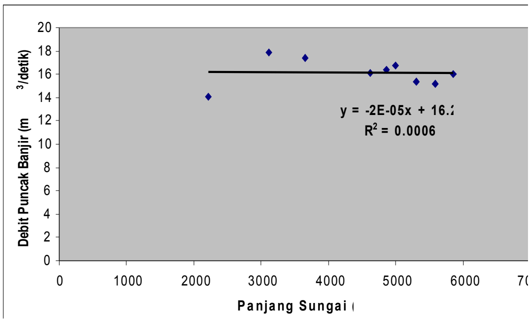

Figure 17 Graph Debit Related with the Long River Flood Peak

Correlation graph in Figure 11 to Figure 17 showed that the R ^{2} value was the highest flood peak discharge on the relationship with R $_L$ by 0.5619. Relatively strong positive correlation also occurred in the flood peak discharge relationship with R $_A$ and flood peak discharge relationship with R $_B$ respectively of 0.4831 and 0.4473. Flood peak discharge related with drainage density was relatively weak because it only had a value of R ^{2} of 0.1823. Otherwise very weak correlation occurred in flood peak discharge relations watershed area that was equal to 0.0441.

Flood peak discharge related with the river length that was equal to 0.0006. With R ^{2} values of 0.0006 which indicates that the greater the length of the river and very little affect the increase in flood peak discharge or it could be said that the flood peak discharge with a length of the river there is no correlation.

Results from the correlation graphs were not in accordance with data obtained from the simulation hydrograph. This could be as high or low values of flood peak discharge in a watershed is influenced by many factors of watershed characteristics that was occured simultaneously instead of just one characteristic factor.

Shape Analysis and Watershed Flood Hydrograph

The shape of the flood hydrograph of a watershed was influenced by some watershed properties. One of these properties was the shape of the watershed. Form of a watershed would affect the timing of peak discharge (Tp) and the volume of peak discharge (Qp)

Flood hydrograph of a watershed was influenced by watershed characteristics, one such characteristic was the shape of the watershed. Form of watershed was classified into three types, namely the form of bird feathers, a radial shape, and form parallel. A part form of watershed was a factor that also influenced flood hydrograph is the land use of the watershed. Watershed remains forested land would produce hydrographs that were different from most of the watershed land in the form of settlement. The following were the results of the classification of the shape and the resulting flood hydrograph with different *Curve Number.*

Table 6 Watershed and Flood Hydrograph Shape

Watershed shape	Qp (m^3/s)			Tp (minutes)		
	CN 50	CN 70	CN 90	CN 50	CN 70	CN 90
Bird feather (Daieko)	1.06	16.068	61.46	460.470	220	150
Bird feather (Daieko 2)	1.03	15.999	60.55	500.510	230	150
Radial (Ladeke)	1.28	17.889	67.63	410.420	200	140
Radial (Ladeke 2)	1.22	17.448	66.19	430	200	140
Radial (Ladeke 3)	0.958	14.054	53.75	420.430	200	140
Radial (Ladeke 4)	1.12	16.752	63.39	480.490	220	150
Paralel (Raikore)	0.957	15.376	58.87	500.510	230	150
Paralel (Raikore 2)	0.93	15.139	57.94	490.500	230	150
Paralel (Raikore 3)	1.14	16.43	62.76	460.470	220	150

Table 6 showed that the watershed was relatively insensitive to change in land was a watershed in the form of bird feathers (lengthwise). Watershed with a form of bird feathers tended to have the flood peak discharge is much smaller than the shape of the radial and parallel watershed. Time of the flood peak is also relatively long because the elongated shape. While the watershed of the most sensitive to changes in land or to the watershed was watershed degradation with a radial shape (widened). This was shown from the values of flood peak discharge that it was always great on any changes in the land.

The flood peak was also relatively fast. Watershed with a form like this had a greater potential for flooding. Watersheds with a parallel form of relatively sensitive were to changes in land or watershed degradation. Flood peak discharge value was relatively large, although the timing of the flood peak was relatively longer than the watershed with a radial shape. Watershed with a parallel form also had a great potential for the occurrence of floods.

Results of analysis of flood peak discharge increased at each change of land in each watershed with different shapes showed that watershed experienced the smallest increase in flood peak discharge on any changes in land was the watershed that had a parallel form. Improving the highest flood peak discharge in each watershed land of changes was occured in the form of the radial.

CONCLUSION

1. Watershed Ladeke were most prone to disasters due to flooding than any other watershed flood peak discharge that was always high on every different CN.
2. Watershed shape of bird feathers (lengthwise) produced values of flood peak discharge relatively small with a time of flood peak was relatively long. Performing a broad basin with a river pattern of spread (radial) tended to generate higher flood peak discharge with a fast time. The shape of a parallel watershed tended to produce values of flood peak discharge relatively small with a time of flood peak was relatively long.
3. Watersheds with increased radial shape of flood peak discharge of the highest in the land and each change had a greater potential for flooding. Watershed with a parallel shape of flood peak discharge increased by the smallest one on any changes in the land.

REFERENCES

Kalinin, V.G. and Trufimov, N.A (2011). Esrimating the Nacessary Duration of Observation Period in Studying Water River Runoff. *Journal of Water Resources*, 38(2), p. 149-154

Oztekin, Tekin (2011) Estimation of the Parameters of Wakeby Distribution by a Numerical Least Squares Method and applying it to the Annual Peak Flows of Turkish River. *Journal of Resource Man*age, 25(12): p. 1299-1313

Hassanzadeh, Yousef; Abdi, Amin; Talatahari, Siamak; and Singh, Vijay P (2011) Meta-Heuristic Algorithms for Hydrologic Frequency Analysis. *Journal of Water Resource Manage*, 25: p. 1855-1879

Asdak, C. (2002) *Hidrologi dan Pengelolaan Daerah Aliran Sungai*. Cetakan kedua (revisi). Gadjah Mada University. Yogyakarta

Fowler, J. Dan L. Cohen (1993(*Practical Statistics for Field Biology. 3rd edition*. Jons Wiley and Sons. New York.