International Journal of GEOMATE, Jan. 2019, Vol.16, Issue 53, pp.120-126
Geotec., Const. Mat. & Env., DOI: https://doi.org/10.21660/2019.53.96020
ISSN: 2186-2982 (Print), 2186-2990 (Online), Japan

NET RAINFALL MODELING BASED ON THE LAND COVER FOR ANALYSING THE LOW FLOW DISCHARGE

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ABSTRACT: This research intends to investigate the land cover change and to obtain the canopy interception in the Lesti sub-watershed, and to produce the rainfall-discharge modeling as the function of the net rainfall factor. The Lesti sub-watershed is selected because it has the basic physical condition and the Automatic Water Level Recorder (AWLR) data for carrying out the calibration. The methodology consists of identifying the land cover based on the Normalized Difference Vegetation Index (NDVI) classification, carrying out the field study to obtain the canopy interception, using the net-rainfall modeling as the input on the rainfall-discharge modeling of F.J. Mock. The net rainfall modeling which is designed in this research is as the correlation between the rainfall which is dropped and the canopy interception. The result shows that the use of net-rainfall on the rainfall-discharge modeling of F.J. Mock can increase the accuracy of generated discharge which is strongly influenced by the proportional of land classification

Keywords: Canopy interception, Net rainfall modeling, Rainfall-discharge modeling, F.J. Mock model

1. INTRODUCTION

In designing of irrigation network, water supply as well as the other design which uses the potency of surface water, the hydrological study about dependable discharge as well as design flood is as the basic design of the further detail design. The error and inaccuracies in the water balance analysis will be strongly influenced the reliability of the water resources. It means mainly for the construction design of surface water taking without a reservoir. For example weir and free intake which the reliability is very dependent on the current low flow

The limitation of data series in the river has stimulated many experts to develop the empirical equation of water balance for estimating the river flow from the available rainfall data by using the watershed characteristic as the variable which one of them is the F.J. Mock model. The F.J. Mock model uses the input of monthly rainfall and 4 physical parameters that are soil storage (SS), soil moisture capacity (SMC), infiltration coefficient (I), and groundwater coefficient (k). The F.J. Mock model is widely used by the field practitioners due to the practical and familiar consideration among the owner of the work. However, in many applications, the F.J. Mock model often produces the less satisfactory result if it is compared with the recorded flow data, especially for the low flow. Of course, this matter has strongly influenced the reliability of water availability from the water intake system or the surface water resources usage.

Interception is defined as the amount of rainfall which is captured by the vegetation canopy and then it is evaporated again to the atmosphere through the evaporation or the sublimation. The rainfall interception is one of the important components in determining the water production and the surface flow in the catchment area [1]. If the rainfall has been more than the canopy storage capacity, so the rainfall surplus will become as the through fall and or flowing through the stem flow which potentially becomes as the surface run-off [2]. The amount of rainfall which is intercepted by the vegetation is varied and depend on the type of leaf, canopy form, wind velocity, solar radiation, temperature, and humidity. The difference of vegetation type will influence the difference of canopy structure and architecture, and it will influence the behavior of vegetation interception to the rainfall [3]-[4].

There are many types of research which show the scale of interception, through fall, and stem fall that is happened in the forest [5]-[11] as well as in the monoculture forest vegetation [12]-[18]. Generally, the average of forest vegetation interception is in the range of 10 to 30%. However, in some cases, the value of vegetation interception like bamboo forest can reach 70% of rainfall [19], the interception is inversely proportional with the rainfall intensity. If the rainfall intensity is low, the interception is high enough and it is decreasing for the high rainfall.

This study intends to produce the net rainfall modeling based on the land cover as the correction of the net rainfall input on the rainfall-discharge modeling of F.J. Mock and it is hoped to obtain the more accurate result mainly on the dry season or low rainfall.

2. MATERIALS AND METHODS

The upstream Lesti sub-watershed is located on the south longest of 8°02'50''- 8°12'10'' and on the east longest of 112° 42'58''-112°56'21'', .

and administratively is located in the Malang Regency. The location is selected due to the basic physical condition and the availability of Automatic Water Level Recorder (AWLR) data for calibration. The delineation of the research area uses the Digital Elevation Model (DEM) map with the downstream boundary is in the AWLR of Tawangrejeni-Sumbermanjing Wetan District. Map of location is as in the Fig.1

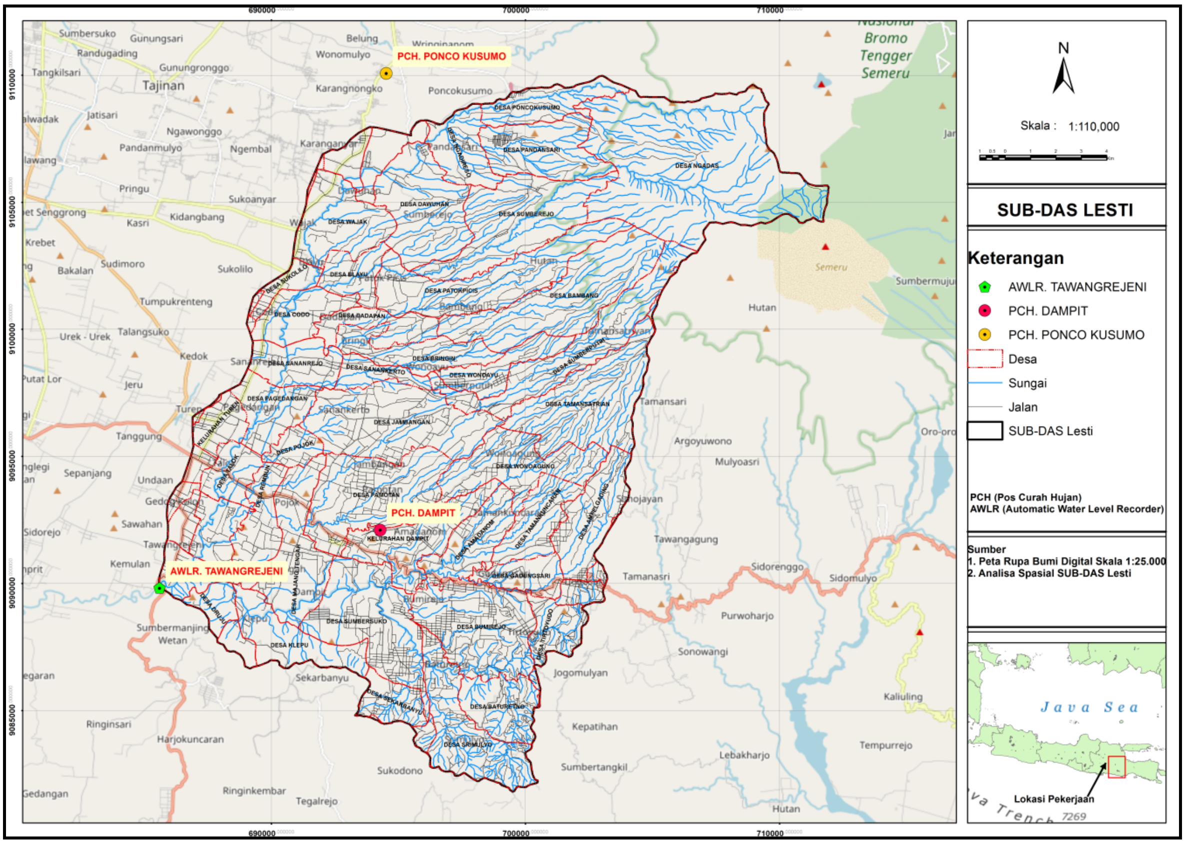

Fig. 1 Map of Lesti sub-watershed. Malang Regency

There are 2 rainfall stations in the Lesti sub-watershed that are Dampit and Poncokusumo. The area of Lesti sub-watershed is 395.28 km^2. The net rainfall modeling which is designed in this research is as the correlation between the rainfall which is dropped and the canopy interception. The difference between the rainfall and the canopy interception is as the net rainfall and it becomes as the rainfall input correction on the rainfall-discharge modeling of F.J. Mock (1973). The density level of the canopy is identified by Normalized Differences Vegetation Index (NDVI). The significant area change of NDVI of a watershed is understood as the land use change of the watershed.

The analysis of this study is as follow: 1) To identify the land cover and NDVI classification of the Lesti sub-watershed based on the interpretation series of Citra Landsat TM; 2) To evaluate the correlation between the land use and NDVI on the watershed; 3) To carry out the field research about the canopy interception on the Lesti sub-watershed; 4) To formulate the net rainfall modelling for the Lesti sub-watershed; 5) To use the net rainfall modelling as the rainfall input correction on the rainfall-discharge modelling of F.J. Mock (1973) and to carry out the calibration due to the observed discharge of Tawangrejeni AWLR (200-2012); and 6) To validate the F.J. Mock model correction on the same sub-watershed for the different year that is from 2013 to 2017.

2.1. NDVI map

The density map of canopy cover on the Lesti sub-watershed is made series on 2001, 2003, 2005, 2007, 2009, and 2011 due to the Citra Landsat 7 based and on 2013, 2015, and 2015 due to the Citra Landsat TM 8 based. The 2-year interval in making the NDVI map is represented enough for showing the land use change which is quite significant. The classification of NDVI on the Lesti sub-watershed consists of 3 categories as follow: the rare canopy density (j): the value of NDVI (j) < 0.32; the moderate canopy density (s): the value of NDVI (s): 0.32 ≤ (s) < 0.42; and the crowded canopy density (r): the value of NDVI ≥ 0.42.

2.2. Correlation Between Land Use and NDVI Map

Wibowo *et.al.* [20] have researched the identification of land using on the Lesti sub-watershed by using the citra Aster and have produced the land use map by guided classification. Then, this map will be paired with the NDVI map on the same year for evaluating the correlation between the land use map and the NDVI map.

2.3. Land Cover Change

Vegetation index is as the Citra transformation method with spectra data based for evaluating the level of canopy density. The principal of Normalized Difference Vegetation Index (NDVI) is by measuring the level of greenish plants, the greenish plants on the Citra Landsat is correlated with the level of vegetation canopy density, and to detect the greenish level on the Citra Landsat which is correlated with the content of leaf chlorophyll. However, the good channel to use is the infra-red and red channel. Therefore, in the formula of NDVI, it is used both of the channels. The formula for analyzing NDVI is as follow [21]:

$$NDVI = \frac{IR - R}{IR + R} \quad (1)$$

Where:
IR= the value of infra-red canal reflectance (canal-4)
R= reflection value 0f red canal (canal-3)

The result of Citra satellite classification for land use and NDVI is paired with the soil type map. Then, the association matrix is made as in Table 1.

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Table 1. Association matrix

No.	Classification of Land use map	score	Classification of NDVI value
1	Rice field, residence, and shrubs	1	(j) < 0.32
2	Plantation, dry field, and moor	2	0.32 ≤ (s) < 0.42
3	Forest	3	(r) ≥ 0.42

The value of land use is obtained from the scoring result based on the scoring criteria as follow: a) score 3: forest (forest area), classified as area-III; b) score 2: plantation, shrubs, classified as area-II; c) score 1: residence, industry, rice field and vacant land, waters, classified as area-I. To facilitate the interpretation about the relation between two variables is used the criteria as follow: 0: no correlation between two variables; 0-0.25: very weak correlation; 0.25-0.5: enough correlation; 0.5-0.75: strong correlation; 0.75-0.99: very strong correlation; 1: perfect correlation [22]. However, to know there is happened the difference or change of NDVI or not and the land use is from the Citra Landsat series or not, is carried out the t-test paired sample.

2.4. Canopy Interception

Based on the analysis of variance (ANOVA) by using the facility on the Excel 2007 for the rainfall analysis, the value of $F_{calculated}$ is less than F_{table}, it indicates that there is no significant difference on the level of significance of 5%. Therefore, it can be concluded that the rainfall measurement in the study location is suitable enough to be used for analyzing the rainfall interception. Analysis of interception is carried out by using the approach of Volume Balanced Method as follow:

$$I = P - (T + S) \quad (2)$$

Where:
I = canopy interception (mm)
P= gross rainfall (mm)
T= through-fall (mm)
S= stem-flow (mm)

By using the formula as above, the through-fall and stem-fall in the three stations can comply into one data series for the area classification-II and in the two others stations can be compiled for the area classification-III.

2.5. Net Rainfall Modeling

The formula of net rainfall modeling for the area classification-II in the Lesti sub-watershed is as follow

$$Pnetto = P - (-1E07P^2 + 0.059P + 0.260) \quad (3)$$

Where:
P_{netto} = rainfall after interception (mm)
P = recorded rainfall in the rainfall station (mm)
Note: If the rainfall (P) ≤ 3 mm, so P_{netto} = 0.85*P
If the rainfall (P) > 70 mm, so P_{netto} = 0.94*P
The formula of net rainfall modeling for the area classification-III in the Lesti sub-watershed is as follow

$$P_{netto} = P - (-1E07P^2 + 0.199P + 0.16) \quad (4)$$

Where:
P_{netto} = rainfall after interception (mm)
P = recorded rainfall in the rainfall station (mm)
Note: If the rainfall (P) ≤ 3 mm, so P_{netto} = 0.70*P
If the rainfall (P) > 70 mm, so P_{netto} = 0.86*P

3. RESULTS AND DISCUSSION

By using the classification map of NDVI which has been justified. However, the rationalization result is presented as in Table 2.

Table 2. Area rationalization based on the NDVI and land using classification

Taking of CITRA		Density area of NDVI (km^2)				The ratio of land using area			
Year	Source	Rare	Enough	Crowd	Total	Area ratio Classify. I (%)	Area ratio Classic. II (%)	Area ratio Classify. III (%)	Total (%)
2001	Landsat TM 7	166.02	138.35	90.91	395.28	0.42	0.35	0.23	1.00
2003	Landsat TM 7	189.73	122.54	83.01	395.28	0.48	0.31	0.21	1.00
2005	Landsat TM 7	185.78	130.44	79.06	395.28	0.47	0.33	0.20	1.00
2007	Landsat TM 7	201.59	134.40	59.29	395.28	0.51	0.34	0.15	1.00
2009	Landsat TM 7	201.59	138.35	55.34	395.28	0.51	0.35	0.14	1.00
2011	Landsat TM 7	213.45	114.63	67.20	395.28	0.54	0.29	0.17	1.00
2013	Landsat TM 7	209.50	130.44	55.34	395.28	0.53	0.33	0.14	1.00
2015	Landsat TM 7	201.59	142.30	51.39	395.28	0.51	0.36	0.13	1.00
2017	Landsat TM 7	213.45	122.54	59.29	395.28	0.54	0.31	0.15	1.00
		Mean				0.50	0.33	0.17	

The shift of area ratio due to the classification-I: land using for residence, industry, rice field, dry field, and vacant land indicate that the shift is expanding during 16 years that is 12% and for classification-III: forest, the ratio is shifted (narrowed) that is 8%. This result shows that there is land using change in the Lesti sub-watershed. However, for the classification-II: plantation and shrubs, it seems the area ratio does not show the trend that it is moving from 35-39%. The expanding ratio of classification-I usually occupies the shrubs area and less displaced plantation, however, the ratio narrowing of area classification-III is due to the bumming Sengon (Albazia) plantation in the society from 2002 to 2004.

The vegetation in the classification-II is as follow Sengon (Albazia), cane, coffee (*Coffea canephora Pierre*), orang (*citrus*), rubber (*Hevea brasiliensis*), fir (*Cupressus lusitanica*), clove (*Euginia aromatica*), and coffee (*Theobroma cacao*). However, the vegetation in the classification-III is as follows mahogany (*Swietenia mahagoni*), banyan (*Ficus benjamina*), timber tree (*Shorea sp*), almond tree (*Terminalia catappa*).

3.1. Rainfall-discharge Simulation of F.J. Mock

Rainfall-discharge modeling of F.J. Mock (1973) is used for simulating two condition model that is simulation without and with the canopy interception. Simulation is carried out from January 2000 until December 2012. The result of calibration shows that by correcting the rainfall data using the net rainfall modeling on the rainfall-discharge simulation of F.J. Mock in the Lesti sub-watershed produces the better result as presented in Fig. 2, Fig. 3, and Table 3.

The validation of the model is carried out on the same sub-watershed but in the different time that is from 2013 to 2017. The result is satisfying as presented in Figure 3 with the model statistical indicator as presented in Table 3. The validation of the model gives good value for the error volume indicator (VE) that is more than the condition less than 5% but is still under 10%. However, the correlation coefficient for the dry month is 85.2%.

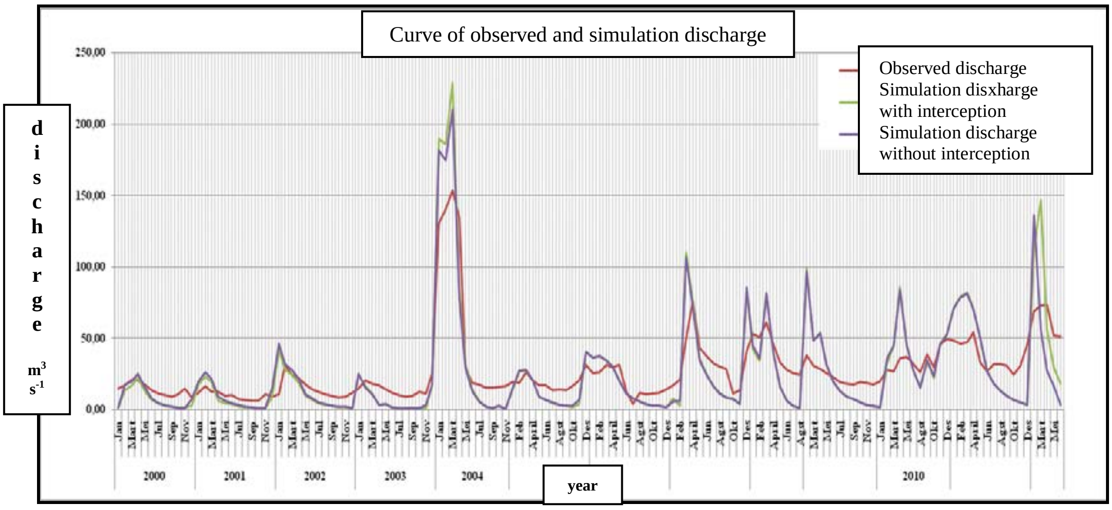

Fig. 2. Rainfall-discharge simulation in the Lesti sub-watershed

Table 3. Model statistical indicator (Validation)

The accuracy of the simulation model			Note
1.	Correlation coefficient of Pearson	83.72%	> 70
2.	Volume error (VE) = [(∑Qo-Qm)/(∑Qo)]* 100%	9.53	> 5
3.	Efficiency coefficient (CE) = [∑(Qo-Qm)^2]/[∑(Qo-Qor)^2]	0.88	≥ 75
4.	Run-off ratio (RI) = ∑Qm/∑Qo	0.90	= 1

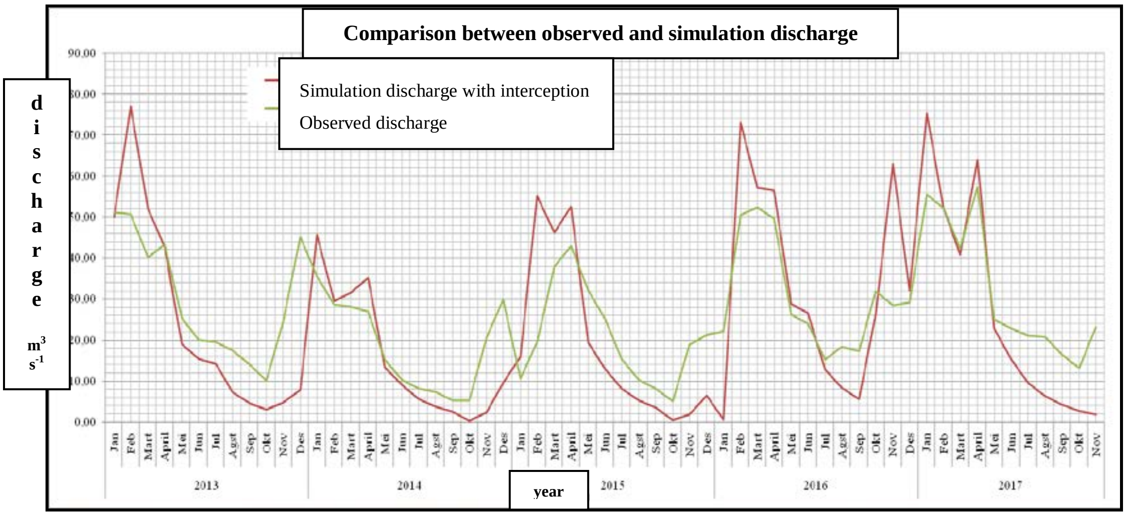

Fig. 3 The curve of observed and simulation discharge (Validation)

The canopy density value (NDVI) is strongly influenced by the vegetation type, age of vegetation, To see the correlation between NDVI and land using classification, it is needed to carry out the guided classification which indicates that if the classification is only based on the NDVI value, it does not illustrate the pattern of land using. However, after it is carried out the guided classification, it is obtained the significant correlation which indicates the happening of land using change in the Lesti sub-watershed for the area classification-I and III. The measurement of canopy interce*ption based on the volume balance to be converted into area interception is suggested to be careful in selecting the vegetation sampling which represented the area interception. The sampling method of stratified random sampling is effective and efficient enough. The interception for area classification-II in the Lesti sub-watershed is between +15% on the rainfall of 3-6 mm and it is gradually decreasing intp +6% for the rainfall of 60-70 mm. However, for the area classification-III, the interception is between +30% for the rainfall of 2-8 mm and +14% for the rainfall of 60-70 mm.

4. CONCLUSIONS

Based on the analysis as above, the conclusion is the canopy density value (NDVI) is strongly influenced by the vegetation type, age of vegetation, However, after it is carried out the guided classification, it is obtained the significant correlation which indicates the happening of land using change in the Lesti sub-watershed for the area classification-I and III. The interception for area classification-II in the Lesti sub-watershed is between +15% on the rainfall of 3-6 mm and it is gradually decreasing into +6% for the rainfall of 60-70 mm. However, for the area classification-III, the interception is between +30% for the rainfall of 2-8 mm and +14% for the rainfall of 60-70 mm. The net rainfall modeling (eq. 3 and 4) is only valid for the Lesti sub-watershed, however, the usage of net rainfall modeling for the other watershed is needed to attend the variability of vegetation and agriculture practice in the watershed.

The usage of net rainfall modeling on the rainfall-discharge modeling of F.J. Mock can increase the accuracy generated a discharge. The increasing of accuracy on the generated discharge is strongly influenced by the proportional area classification. However, the coefficient of F.J. Mock model for Lesti sub-watershed is presented as in Table 3 below:

Table 3. The coefficient of F.J. Mock model for Lesti sub-watershed

Coefficient	F.J. Mock (1973)	Lesti sub-watershed
Infiltration	0.2 – 0.8	0.5
Recession of groundwater	0.4 - 0.7	0.65
Storm run-off	-	5.03
Coefficient of discharge	-	2.55

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