Effects of Land Cover, Evapotranspiration, and Rainfall on Total Runoff in the Gumbasa River Basin, Central Sulawesi, Indonesia

I Wayan Sutapa [1], Saiful Darman[2], Djayani Nurdin[3], Fathurrahman[4]
[1]Department of Civil Engineering, Faculty of Engineering, University of Tadulako, Palu
[2,4]Department of Agriculture, Faculty of Agriculture, University of Tadulako, Palu
[3]Department Economy, Faculty of Economy, University of Tadulako, Palu
Email: [1]wsutapa@yahoo.com, [2]saifuldarman@yahoo.co.id, [3]djayani.nurdin@gmail.com, [4]fathurrahmanshahib@ymail.com

***Abstract* - Land use patterns in various forms and ways will have an impact on the environment. Indications of a decrease in the carrying capacity of the environment in a region can be seen from various disasters that occur such as floods, landslides, and droughts. Therefore, changes in land use from non-built land to build land will stimulate the amount of runoff water. This study aims to determine the effect of changes in land use, evapotranspiration, and rain on total runoff. This research was carried out in the Gumbasa Watershed. Data is needed in the form of primary data (soil characteristics) and secondary data (rain, climatology, a map of the earth and a map of land use). The rainfall data used are Bora, Palolo, Wuasa, Kulawi and Bangga Bawah stations with observations for 14 years (2002-2015). Climatology data was used by Bora Station with observations for 14 years (2002-2015). The analysis was carried out namely: regional rainfall, evapotranspiration, MockWyn-UB model and linear regression. The linear line equation obtained: $Y = 97.325 - 0.747X_1 + 0.697 X_2 + 0.442 X_4 + 0.447 X_5$. This equation has been tested statistically and fulfilled the linear regression requirements. Based on the above equation, it can be said that: 1). Forest land is an excluded variable so that it is not in the equation. 2). The smaller the evapotranspiration and the greater the rainfall and the area of mixed gardens and open land, the greater the runoff, and vice versa.**

Keywords - Gumbasa Watershed, MockWyn-UB Model, Linear Regression

I. INTRODUCTION

The phenomenon of climate change is a very serious challenge facing the world. Climate change is increasingly evident and affects various aspects of life, whether individual or domestic, even to the global development sector. On the other hand, it is increasingly recognized that accelerating the occurrence of climate change begins with human decisions and behavior which then accumulate massively and change the weather elements, especially the temperature that causes the phenomenon of global warming.

Edi Nurrohcman (2018) [1] stated that the hydrological cycle is the rotation of water that never stops from the atmosphere to the earth and returns to the atmosphere through condensation, precipitation, evaporation, and transpiration. The hydrological system is a series of soil type elements, land use, topography and interrelated slope lengths between one component and the other components so as to form a mutually influencing unit towards the balance of the water system. Changes in the hydrological cycle are changes in behavior and function of surface water, namely decreasing the base flow and increasing surface flow which causes an imbalance in water management and the occurrence of flooding and inundation in the downstream area

Indonesia is one of the developing countries that is carrying out development in various sectors. As is known so far, development provides many benefits, especially the provision of employment for the community, but in addition, the development also requires environmental sacrifices such as changes in land use, from the original green space to high-rise buildings or settlements, agriculture, and industry. Changes in land use that have the greatest influence on increasing the value of surface runoff coefficients that have an impact on increasing discharge are the use of forest areas into other uses such as agriculture, settlements, and industry. Industrial activities, livestock, agriculture and settlements along the river flow (river banks) produce various wastes, both solid and liquid, into the river. This condition occurs even worse when the river reaches large cities in Indonesia.

Fuad Halim (2014) [2] suggests that watersheds are natural ecosystems that are bounded by ridges. Rainwater that falls in the area will flow to rivers which eventually lead to the sea or to the lake. In the Watershed, two regions are known, namely the water supply area (upstream) and the water receiving area (downstream area). These two regions are interconnected and affect the watershed ecosystem units. The function of the Watershed is as a catchment area, water storage, and distribution water.

Land use patterns in various forms and ways will have an impact on the environment. Indications of a decrease in the carrying capacity of the environment in a region can be seen from various disasters that occur such as floods, landslides, and droughts. The occurrence of flooding is basically triggered by two main things, namely (1) the less land that functions as water absorption. (2) land subsidence due to groundwater exploitation and physical development that exceeds carrying capacity [3]. Therefore changes in land use from non-built land to built land will stimulate the amount of runaway water [4].

Wahyunto (2004) [5] suggested that the impact of changes in land use from green space to built-up areas would affect the ability of water absorption by the land, and the quality of water along the watershed to cause flooding.

II. LITERATURE STUDY

A. *Rainfall Watershed*

The rain that occurs in an area called regional rainfall is calculated by the Polygon Thiessen equation [6-18]:

$$R = \frac{A_1.R_1 + A_2.R_2 + ... + A_x.R_x}{A_1 + A_2 + ... + A_x} \quad (1)$$

B. *Evapotranspiration*

Potential evapotranspiration is calculated using the equation of Penman Montieth [6,15-17,19-24]:

$$ETo = \frac{\Delta(Rn - G) + \rho a.cp \frac{(es - ea)}{ra}}{\Delta + \gamma(1 + \frac{rs}{ra})} \quad (2)$$

C. *Model MockWyn-UB*

Total river water runoff is calculated by the MockWyn-UB equation model [6, 22, 24], which is the sum of the base flow with direct runoff.

Base Flow (BF) = I + ΔVn (3)

Direct Run Off (DR) = WS – I (4)

Total Runoff (TRO) = BF+ DR (5)

D. *Model Regression*

To get the constant and correlation coefficient value of land use, evapotranspiration, rain and total runoff, multiple regression equations are used, namely:

$$Y = a + b X_1 + c X_2 + d X_3 + e X_4 + f X_5 \quad (6)$$

Where:

a = Constant

b-f = Coefficient value for each variable

Y = Total runoff, mm / year

X_1 = Evapotranspiration, mm / year

X_2 = Annual rainfall, mm / year

X_3 = Forest area, Ha

X_4 = Mixed garden area, Ha

X_5 = Open land area, Ha

III. METHODOLOGY

A. Location of Research

The research location is located in the Gumbasa River Basin (Sigi Regency and Poso District, Central Sulawesi Province, Indonesia). Geographically located at 01^0 01'- 01^0 21' South Latitude and $119^0$56'- $120^0$19' East Longitude. Research locations can be seen in the following map:

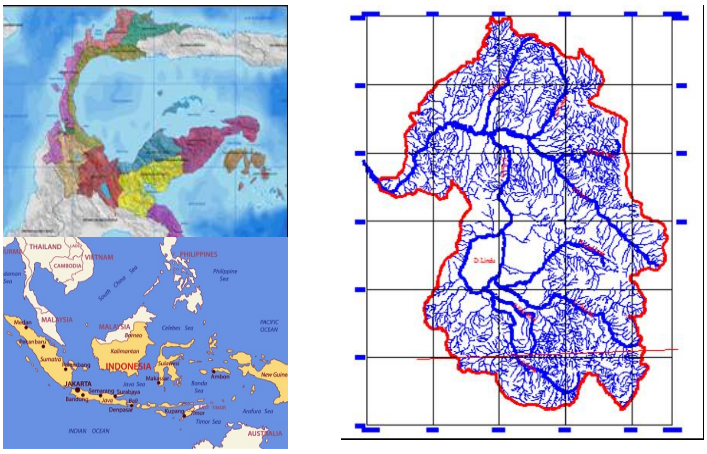

Fig. 1. Location of Reseach [6]

B. Stage of Research

The stages of research can be explained as follows:

1. Data collection

   The data used in this study are primary data (soil characteristics in the form of open land vegetation, mixed gardens, and forests) and secondary (rainfall data, climatological data, maps of the earth and maps of land use). The rainfall data used are Bora, Palolo, Wuasa, Kulawi and Bangga Bawah stations with observations for 14 years (2002-2015). Climatology data was used by Bora Station with observations for 14 years (2002-2015). All data were obtained from the Office of the Sulawesi III River Regional Office, Central Sulawesi, Indonesia. The map of the earth was obtained from the Office of the National Survey and Mapping Coordination Agency (Bakosurtanal) in 1991. The vegetation of land cover was obtained from the Government of Sigi Regency, Central Sulawesi Province, Indonesia in 2015 as well as modifications from satellite image data to obtain 2002, 2005, 2008 land use data and 2012. The data are presented in Table I.

TABLE 1. Data on Gumbasa Watershed Land Use

Year	Forest (Ha)	Mix Garden (Ha)	Open Field (Ha)	TOTAL (Ha)
2002	1022.76	79.83	126.84	1229.43
2005	1013.2	96.07	120.16	1229.43
2008	974.97	97.99	156.47	1229.43
2012	965.41	110.41	153.61	1229.43
2015	955.85	113.28	160.3	1229.43

2. Rainfall Area

   Rainfall areas are analyzed by the Thiessen equation, where the area of influence of each rain station can be explained as follows: Kulawi Station (0.27); Palolo Station (0.30); Bora Station (0.06); Bangga Bawah Station (0.20) and Wuasa Station (0.17). The input is in the form of monthly rainfall every year from each rainfall station.

3. Evapotranspiration

   Evapotranspiration is calculated by the Penman Montieth equation, where the input is in the form of monthly climatology data (air humidity, air temperature, solar radiation time and wind speed) while the output is in the form of monthly evapotranspiration data.

4. Land Use

   The input of the MockWyn-UB model is in the form of land use every year, while the available data is insufficient. Therefore, a regression analysis was conducted based on existing land use data so that land use data were obtained as follows:

TABLE II. Land Use Results of Regression

Year	Forest (Ha)	Mix Garden (Ha)	Open Field (Ha)	TOTAL (Ha)
2002	1022.76	79.83	126.84	1229.43
2003	1004.58	86.27	138.58	1229.43
2004	986.42	88.73	154.28	1229.43
2005	1013.20	96.07	120.16	1229.43
2006	950.10	93.65	185.69	1229.43
2007	931.93	96.10	201.39	1229.43
2008	974.97	97.99	156.47	1229.43
2009	895.61	101.02	232.80	1229.43
2010	877.45	103.48	248.50	1229.43
2011	859.29	105.93	264.21	1229.43
2012	965.41	110.41	153.61	1229.43
2013	822.97	110.85	295.61	1229.43
2014	804.81	113.31	311.32	1229.43
2015	955.85	113.28	160.30	1229.43

5. Total Run-Off

Total river water runoff was analyzed by the MockWyn-UB model. Data input in the form of monthly rainfall data, monthly evapotranspiration, and land area based on vegetation land cover. The output is a monthly total runoff (TRO) every year.

IV. RESULT AND DISCUSSION

A. *Model MockWyn-UB*

Based on the MockWyn-UB model, the total runoff per month (mm/month) and total annual runoff (mm/year) are as follows:

TABLE III. Recapitulation of Results of Calculation of MockWyn-UB Model

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
2002	21.42	11.29	69.56	91.50	52.84	98.28	34.14	23.90	36.90	16.18	42.86	37.41	536.27
2003	15.43	45.06	01.46	26.28	54.54	32.29	45.76	87.96	79.85	27.33	95.56	137.90	949.43
2004	09.04	48.40	41.68	90.24	63.69	37.17	53.95	22.66	15.86	11.10	15.17	7.08	516.04
2005	4.96	7.60	15.59	46.65	39.71	61.71	32.66	22.27	15.59	59.97	88.16	29.62	524.50
2006	43.16	19.21	17.76	70.37	32.23	52.71	25.43	39.31	29.38	14.14	9.90	63.16	416.76
2007	33.47	99.43	81.44	04.80	28.48	59.36	82.40	65.05	87.66	84.57	14.85	127.90	1269.41
2008	50.02	35.01	92.86	59.05	08.04	69.74	47.89	59.50	32.45	52.77	48.80	98.04	1454.19
2009	51.88	37.23	62.10	48.63	26.76	18.40	31.05	27.91	34.81	58.25	77.07	42.85	516.94
2010	28.37	24.52	52.68	42.58	78.98	91.79	00.77	18.23	81.07	50.77	30.02	56.67	756.45
2011	41.10	64.08	42.06	50.40	39.86	18.91	24.87	56.32	58.37	21.63	93.39	38.40	549.40
2012	21.88	63.55	21.42	26.89	35.31	43.79	50.81	48.14	20.99	34.95	94.67	121.86	784.25
2013	51.05	74.26	49.36	50.13	88.46	88.86	96.96	63.20	93.69	99.12	18.66	133.98	1407.73
2014	57.08	38.09	53.39	31.68	05.06	62.88	29.38	50.87	21.12	14.78	47.86	66.70	578.89
2015	22.23	24.34	12.84	05.64	61.61	55.08	25.09	17.56	12.29	36.99	79.83	23.59	477.10

B. *Statistic Analysis*

Statistical analysis uses the variables in Table IV below:

TABLE IV. Total Runoff Data, Land Use, Evapotranspiration and Rainfall

Year	Total Runoff, TRO (mm/year), (Y)	Evapotranspiration ETo (mm/year), X1	Rainfall, R (mm/year), X2	Forest (Ha) (X3)	Mix Garden (Ha) (X4)	Open Field (Ha) (X5)
2002	536.27	1330.30	1878.73	1022.76	79.83	126.84
2003	949.43	1090.83	2335.31	1004.58	86.27	138.58
2004	516.04	1332.30	1616.6	986.42	88.73	154.28
2005	524.50	1276.62	2035.98	1013.20	96.07	120.16
2006	416.76	1297.20	1722.07	950.10	93.65	185.69
2007	1269.41	1035.54	2653.81	931.93	96.10	201.39
2008	1454.19	696.09	2339.13	974.97	97.99	156.47
2009	516.94	959.18	1476.25	895.61	101.02	232.80
2010	756.45	1231.69	2162.49	877.45	103.48	248.50
2011	549.40	1186.35	1874.8	859.29	105.93	264.21
2012	784.25	1420.09	2359.54	965.41	110.41	153.61
2013	1407.73	1378.98	2989.57	822.97	110.85	295.61
2014	578.89	1435.82	1840.74	804.81	113.31	311.32
2015	477.10	1239.79	1639.97	955.85	113.28	160.30

With the help of SPSS 16.0 software the following results are obtained:

a. Model Summary

TABLE V. Model Summary

Model	R	R Square	Adjusted R Square	Std. An error of the Estimate	Durbin-Watson
1	.965[a]	.931	.901	113.64009	
2	.965[b]	.931	.911	107.88530	
3	.961[c]	.924	.911	107.98218	2.179

a. Predictors: (Constant), Open field, Rainfall, Evapotranspiration, Mix Garden

b. Predictors: (Constant), Open field, Rainfall, Evapotranspiration

c. Predictors: (Constant), Rainfall, Evapotranspiration

d. Dependent Variable: TRO

To find out the good equation obtained can be known from the reflected coefficient. The closer to 100%, the better the equation will be. The coefficient of determination is shown in the adjusted R square column, which is equal to 91.1%, meaning that the equation obtained is able to predict total runoff by 91.1%, while the remaining 8.9% is obtained from other variables not examined.

The independence requirement is that the independent variable has a strong correlation with the residue that can be known by looking at the value of Durbin-Watson (DW). Independence requirements are met if the DW value is close to two. In the model summary, the DW value is 2.179 meaning that the independence requirements are met

b. Output Coefficient

In the output coefficient (Table VI) information is obtained about variables related to total runoff, the equations obtained as well as testing the requirements for multicollinearity. Multicollinearity requirements can be tested with collinearity statistics. The tolerance value that approaches 1 indicates the absence of multicollinearity between independent variables.

TABLE VI. Output Coefficient

Model		Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	t	Sig.	Collinearity Statistics Tolerance	Collinearity Statistics VIF
1	(Constant)	97.325	376.516		.258	.802		
	Rainfall	.697	.074	.832	9.362	.000	.965	1.036
	Evapotranspiration	-.747	.160	-.421	-4.683	.001	.942	1.062
	Mix Garden	.442	3.898	.013	.113	.912	.596	1.677
	Open field	.447	.641	.079	.698	.503	.601	1.665
2	(Constant)	128.867	240.646		.536	.604		
	Rainfall	.698	.071	.832	9.886	.000	.968	1.033
	Evapotranspiration	-.745	.150	-.420	-4.962	.001	.959	1.043
	Open field	.491	.486	.086	1.010	.336	.941	1.062
3	(Constant)	165.815	238.061		.697	.501		
	Rainfall	.709	.070	.846	10.184	.000	.996	1.004
	Evapotranspiration	-.716	.147	-.403	-4.854	.001	.996	1.004

a. Dependent Variable: TRO

c. Excluded variables

In the excluded variables (Table VII), it is found that the variable coefficient of forest land is very large (8.951E2) but has a tolerance value of almost zero (2.782E-9) so that the total runoff equation is ignored.

TABLE 7. Excluded variables

Model		Beta In	t	Sig.	Partial Correlation	Collinearity Statistics Tolerance	Collinearity Statistics VIF	Collinearity Statistics Minimum Tolerance
1	Forest	8.951E2[a]	.519	.618	.180	2.782E-9	3.595E8	2.782E-9
2	Forest	-.086[b]	-.113	.912	-.038	.013	75.964	.013
	Mix Garden	.013[b]	.113	.912	.038	.596	1.677	.596
3	Forest	-.087[c]	-1.018	.333	-.306	.935	1.070	.935
	Mix Garden	.060[c]	.685	.509	.212	.935	1.070	.935
	Opened field	.086[c]	1.010	.336	.304	.941	1.062	.941

a. Predictors in the Model: (Constant), Open field, Rainfall, vapotranspiration, Mix Garden

b. Predictors in the Model: (Constant), Open field, Rainfall, Evapotranspiration

c. Predictors in the Model: (Constant), Rainfall, Evapotranspiration

d. Dependent Variable TRO

d. Output Residual Statistics

In the Residual Statistics output (Table VIII), information about the residual requirement can be obtained as zero.

Based on Table VIII, the mean of the residue is equal to zero, meaning that the residue does not play a role in the equation obtained.

TABLE VIII. Output Residual Statistics

	Minimum	Maximum	Mean	Std. Deviation	N
Predicted Value	359.0840	1.3270E3	7.6695E2	347.25378	14
Std. Predicted Value	-1.175	1.613	.000	1.000	14
Standard Error of Predicted Value	29.890	81.851	47.421	16.404	14
Adjusted Predicted Value	325.1434	1.3205E3	7.4755E2	323.68074	14
Residual	-1.71935E2	1.56956E2	.00000	99.32916	14
Std. Residual	-1.592	1.454	.000	.920	14
Stud. Residual	-1.660	1.806	.072	1.080	14
Deleted Residual	-1.86960E2	2.99043E2	1.94057E1	142.99702	14
Stud. Deleted Residual	-1.829	2.054	.103	1.158	14
Mahal. Distance	.067	6.541	1.857	2.029	14
Cook's Distance	.000	1.469	.191	.407	14
Centered Leverage Value	.005	.503	.143	.156	14

a. Dependent Variable: TRO

e. Output Histogram

At the histogram output (Figure 2), normality conditions can be known, namely, the residue is normally distributed. Figure 2 shows that the residual has a normal distribution

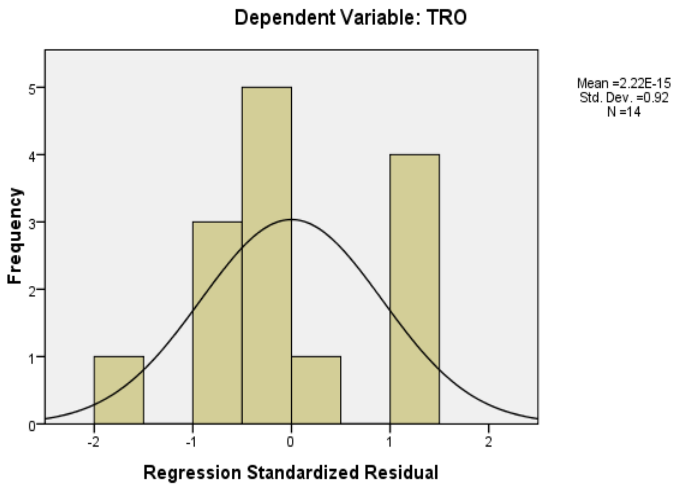

Fig. 2. Histogram Total Runoff

f. Scatter Output Linearity Plots

In the scatter plot output (Figure 3), linearity requirements can be known. Based on Figure 3 it appears that linearity requirements are met, meaning that the correlation between the dependent variables and free variables is linear.

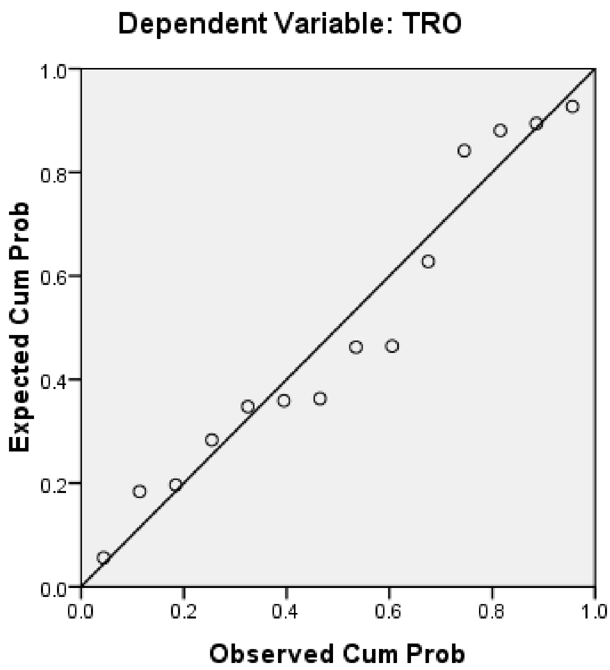

Fig. 3. Scatter Output Linearity Plots

g. Homogeneity Scatter Plot Output

On the scatter plot output homogeneity (Figure 4) shows a homogeneous nature where scatter does not have a certain pattern, meaning that the variant of residual is homogeneous.

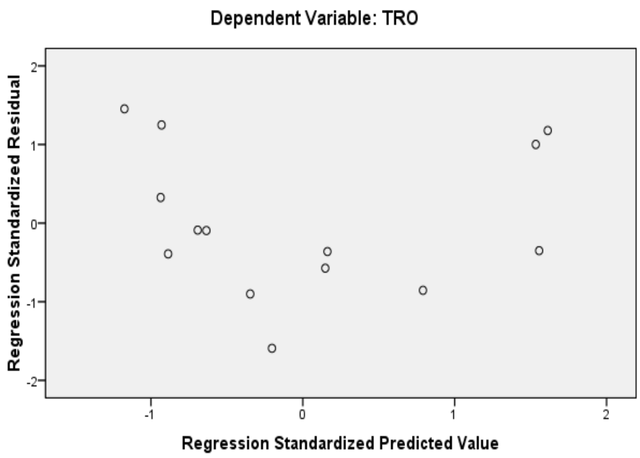

Fig. 4. Homogeneity Scatter Plot Output

h. Statistical Test Recapitulation

Based on the results of the statistical tests above, it can be recapitulated as follows

TABLE IX. Results of Testing Linear Regression Terms

Component	Conditions	Test Result	Conclusion
Independent and dependent variables	The relationship between independent and dependent variables must be linear	Scatter must be around the diagonal line	Qualify
Residue	The residue has a normal distribution	Histograms are normally distributed	Qualify
Residue-Independent variable	The residue does not have a strong correlation with the independent variable	Value DW = 2.179	Qualify
Residue-Independent variable	The variant of the residue is constant	The variant is constant because scatter doesn't have a certain pattern	Qualify
Independent variable	There is no strong correlation between the independent variables	Tolerance value = 1	Qualify

C. *The relationship between Land Use, Evapotranspiration, Rainfall, and Total Runoff*

Based on the results of the statistical analysis with SPSS, the correlation between the total runoff and land use, evapotranspiration and rainfall are:

$$Y=97,325-0.747X_1+0.697X_2+0.442X_4+0.447X_5 \quad (6)$$

From equation (6) some conclusions can be drawn, namely: 1). Forest land (X_3), the variable coefficient is very large but the correlation value is almost zero so it is an excluded variable. 2). Evapotranspiration (X_1) as a deduction, meaning that the greater the evapotranspiration, the lower the total runoff. 3). Rain (X_2) as the increasing variable of total runoff, meaning that the greater the rain, the greater the total runoff. 4). Variables of mixed garden land (X_4) and open land (X_5) as increasing variables, meaning that the wider the mixed garden and open land, the greater the total runoff.

V. CONCLUSION

The equation model resulting from multiple regression analysis between variables of land use, rainfall, and evapotranspiration with total runoff is: $Y= 97,325-0.747\ X_1 +0.697\ X_2+0.442\ X_4+0.447\ X_5$

This equation has been tested statistically and fulfills linear regression requirements such as independent and dependent scatter variables around the diagonal line, histogram normally distributed, mean residue value zero, DW value approaching 2, constant variant scatter residue does not have a certain pattern and variable tolerance value independent approaching one. Based on the above equation, it can be said that: 1). Forest land is an excluded variable so that it is not in the equation. 2). The smaller the evapotranspiration and the greater the rain and the wider the area of mixed garden and open land, the greater the runoff, and vice versa.

ACKNOWLEDGMENT

The author would like to thank the Head of the Technical Management Unit and the staff of the Regional River III Hydrology Center Sulawesi Office in Palu, Central Sulawesi, Indonesia (BWS III) which provided rainfall data and climatology to support this research. Thank you also to the Sigi District Government for providing land use data.

REFERENCES

[1] Edi Nurrohcman, Benny Joy, and Chay Asdak, "Study of the Hydrological System due to Changes in Land Use in the North Bandung area (Case Study West Bandung Regency)", Envirosan J. Vol. 1, No. 1. 2018.
[2] Fuad Halim, "Effect of Relationship between Land Use and Flood Discharge in the Malayang River Basin", Media Engineering J. Vol. 1, No. 4. 2014.
[3] Chapin, F. Stuart, JR and Kaise, Edward J., Urban, and Land Use Planning: Fourth Edition, University of Illionis Press, Chicago. 1995.
[4] Hadi, Sudharto P., Environmental Dimensions of Development Planning, Gadjah Mada University Press, Yogyakarta. 2001.
[5] Wahyunto and Shofiyati, The Idea of Control of Rice Field Conversion in the Context of Increasing National Food Security, Proceedings of the Multifunctional Seminar on Agriculture and Conservation of Land Resources. Bogor. December 13, 2003 . 2004.
[6] A. Solihin Ansari, Sutapa IW. and M. Galib Ishak., "Model Hydrology MockWyn-UB to Analyse Water Availability in Gumbasa Watershed Central Sulawesi Province", Int. Journal of Engineering Research and Application, Vol. 7, No. 1, pp. 94-101. 2017.
[7] CD. Soemarto, Engineering Hydrology, Usaha Nasional, Surabaya, Indonesia. 1985.
[8] Chay Asdak, Hydrology and Watershed Management, 2nd., Gadjah Mada University Press, Yogyakarta, Indonesia. 2002.
[9] Imam Subarkah, Hydrology to Design Water Structure, Idea Dharma, Bandung, Indonesia. 1980.
[10] Nugroho Hadisusanto, Application of Hydrology, 1st. ed., Jogja Mediautama, Malang, Indonesia. 2011.
[11] Ray K. Linsley and Joseph B. Franzini, Water Resources Engineering, 3rd. ed., McGraw Hill, Inc. 1979.
[12] Sri Harto, Application Hydrology, Gadjah Mada University Press, Yogyakarta, Indonesia. 1983.
[13] Suyono Sosrodarsono and Kensaku Takeda, Hydrology for Watering, 4rd. ed., Pradnya Paramita, Jakarta, Indonesia. 1983.

[14] Suripin, Sustainable Urban Drainage System, Andi, Yogyakarta, Indonesia. 2004.
[15] Sutapa IW., Moh. Bisri, Rispiningtati, Lily Montarcih, "Effect of Climate Change on Water Availability of Bangga River, Central Sulawesi of Indonesia", J. Basic. Appl. Sci. Res., Vol. 3, No. 2, pp. 1051-1058. 2013.
[16] Sutapa IW., "Study Water Availability of Malino River to Meet the Need of Water Requirement in District Ongka Malino, Central Sulawesi of Indonesia" International Journal Of Engineering and Technology, Vol. 7, No. 3, pp. 1069-1075. 2015a.
[17] Sutapa IW. and Ishak M. Galib, "Application of non-parametric test to detect trend rainfall in Palu Watershed, Central Sulawesi, Indonesia", Int. J. Hydrology Science and Technology, Vol. 6, No. 3, pp. 238-253. 2016.
[18] Heldy Suherman and Arief Firmansyah, "Analysis of the Effect of Changes in Land Use Against Flood Discharge in the Lower Watershed of the Angke River", J. Construction, Vol. 8, No. 2. 2017.
[19] Sutapa IW.," Effect of Climate Change on Recharging Groundwater in Bangga Watershed, Central Sulawesi of Indonesia", Environ. Eng.Res.J. Vol. 22, No. 1, pp.87-94. 2017.
[20] Allen G. Richard, Crop Evapotranspiration-Guidelines for Computing Crop Water Requirement-FAO Irrigation and Drainage Paper No. 56. Rome, Food Agriculture Organization of the United Nation, p.chapter 2. 1998.
[21] Sutapa IW., "Application Model Mann-Kendall and Sen'S (Makesens) for Detecting Climate Change", Infrastructure J.Civil Eng. Univ. Tadulako, Vol. l, No. 4, pp. 31-40. 2014.
[22] Sutapa IW., "Modeling Discharge of Bangga Watershed under Climate Change", Applied Mechanics and Materials J., Vol. 776, pp.133-138. 2015b.
[23] Sutapa IW., "Long-Term Trend Climatology in Sigi, Central Sulawesi province', National Seminar on Civil Engineering Narotama of University, February 28, 2015, Surabaya. pp.267-277. 2015c.
[24] Sutapa IW., "Effect of Climate Change on Recharging Groundwater in Bangga Watershed, Central Sulawesi of Indonesia", Environ. Eng.Res.J. Vol. 22, No. 1, pp.87-94. 2017.

AUTHORS PROFILE

I Wayan Sutapa, Graduation from Water Engineering Brawijaya University, Malang, Indonesia (1990), Master of Engineering in Land and Water Development at IHE Delft the Netherlands (2001) and Doctorate Civil Engineering at the University of Brawijaya, Malang, Indonesia (2013). He worked as irrigation engineering consultancy field for seven years (1990-1997) after it became a Lecturer and Researcher at the Faculty of Engineering, University of Tadulako, Palu, Central Sulawesi until now. He got Professor in the year 2017 at Hydrology Engineering in University of Tadulako, Palu, Indonesia.

Saiful Darman, Graduation from Soil Science, Hasanuddin University, Makassar, Indonesia (1985), Master of Soil Chemistry, Gadjah Mada University, Yogyakarta, Indonesia (1994), and Doctor of Agricultural Sciences, Chemical Soil Fertility at Padjadjaran University, Bandung, Indonesia (2006). He worked as Consultant Environmental Impact Assessment (2007- to present, and Lecturer and Researcher at the Faculty of Agriculture, Tadulako University, Palu, Central Sulawesi. He received a Professor in 2009 in Soil Fertility at Tadulako University, Palu, Central Sulawesi, Indonesia.

Djayani Nurdin is currently an associate professor in the Faculty of Economic Tadulako University Palu Central Sulawesi Indonesia. He completed his Master and Doctor Degree at Airlangga University Surabaya Indonesia. His research interests lie in the area of economic management, ranging from theory to design to implementation. He has collaborated actively with researchers in several other disciplines of economic resources development. He has published several journals in both National or International. He is also currently as a Vice Rector of Students Affair of Tadulako University, Central Sulawesi, Indonesia.

Fathurrahman. Bachelor (1986) and Master (1994) in Agricultural Science of Hasanuddin University, Makassar- Indonesia. Doctor (2002) in Agricultural Science of Padjajaran University, Bandung-Indonesia. A senior lecturer and a researcher at Tadulako University from 1998 until now. Professor (2006) in Plant Physiology and Plant Management at Tadulako University, Indonesia. He has ever as Director of postgraduate at University Tadulako.