Hydrologic Input-Output Model of Mt. Isarog Watersheds

Asia Pacific Journal of Multidisciplinary Research
Vol. 7 No.4, 27-35
November 2019 Part II
P-ISSN 2350-7756
E-ISSN 2350-8442
CHED Recognized Journal
ASEAN Citation Index
Excellence in Research for Australia Accredited Journal

Raymundo V. Romero[1], Fe B. Romero[2], Nelson V. Romero[3], Marijane A. Iglesia[4], Moriel L. Prado[5], Alicia Pempena[6]
[1,3,4,5,6]College of Engineering and Technology, Partido State University
[2]College of Education, Partido State University
munding25@yahoo.com.ph[1], fe.romero@yahoo.com[2], nelson_romero27@yahoo.com[3], marijaneatole@yahoo.com[4], moyellapril80@yahoo.com[5], alice_pempena@yahoo.com[6]

Date Received: October 15, 2018; Date Revised: October 20, 2019

***Abstract** – Mathematical modelling is one way of studying the effects of climate change in different parts of this world. This investigated the hydrologic condition of watersheds with focus on examining the hydrologic input-output situation in Mt. Isarog. Specifically, the following were answered: to delineate and describe the watershed areas and boundaries; to analyse the precipitation and river discharges behaviour on several portions of the mountain by mathematical modelling. Remote sensing, GIS map reading and satellite fed data for last three years were utilized. The basic formula was used to arrive in mathematical modelling for discharge. Computer excel programming was applied for statistical analysis employing both t-test and ANOVA. The study found the watersheds to be characterized in different areas, location, boundaries and precipitation which were found as factors affecting discharges of rivers. The precipitations for the last three years were used to arrive at different mathematical models, trend lines and slopes. The mathematical models, computed discharges, trend lines and slopes for every river vary with each other. The mathematical models were found useful in describing river discharges in the area. The obtained data may be used in projecting the future precipitation and river discharges which is useful to different sectors of the society engaged in agriculture, forecasting, administering irrigation system, construction, environmental awareness, and many more.*

***Keywords** – Mathematical models, hydrology, watershed, water discharge, Mt. Isarog.*

INTRODUCTION

Climate change is affecting whole portions of the earth. It transformed the climatic condition resulting to global warming and decrease of water sources. Analysing the hydrologic condition in every watershed is thus necessary. Modelling is one way of understanding the tremendously complex hydrologic systems that generalization to understand some characteristics of behavior is needed [1]. The relationship between climate and water resources are smoothly examined and structured using hydrologic models [2] in which worldwide are applied to analize different kind of watersheds to investigate the hydrological development and availability of water [3].

Several studies on input-output modelling considered the input process as the total rainfall and the discharging water at the river outlet of the watershed as the output [4]. In economic planning, they were used to analyze the potential on the economy and consumption of water resources [5]. It is used to analyze stream flow for land use development, impact of climate change and to perform spatial analysis [6].

Mt. Isarog is a primary water source of municipalities in the province of Camarines Sur. The mountain is surrounded by watersheds but with important application related to land use [7] every behaviour of surface runoff, peak flow, and soil erosion is needed to be analysed. Mathematical modelling is useful in predicting the long-term effects of precipitation on river flow of the mountain. It can be used to find effective strategies in maximizing water utilization and even mitigating pollution in watershed processes [8]. Mathematical modelling can be utilized to quantify and analyse quality of water as it will enable simulation of a wide variety of processes, including the production of water and sediments, and the dynamics of point and nonpoint sources of pollution [9]. In order to obtain data, it is imperative that the hydrological condition of the mountain be studied particularly the hydrologic input and output situation.

Objectives of the Study

This analysed the hydrologic input and output situation in Mt. Isarog watersheds. Specifically, the following were completed: to delineate and describe the watershed boundaries; to describe the behaviour of precipitation on different parts of the mountain; and to analyse the behaviour of river discharges by mathematical modelling.

Materials and Methods

Remote sensing was applied in delineating boundaries. Through this process, the data were gathered by scanning portions of Mt. Isarog utilizing the Geologic Information System (GIS) maps. The data were then verified through site visit and field survey. In precipitation and discharge analysis, the obtained data were used as inputs in deriving the mathematical models of every river surrounding the mountain. Satellite fed data taken from www.worldweatheronline.com was used as the precipitation data. They were utilized in determining the previous discharges excluding hydrographic losses like evaporation, transpiration, seepages etc. The mathematical models were derived based from the basic discharge formula while the slope and area were computed based from the contour lines presented in the GIS map. The discharge of rivers was computed through the derived mathematical models applying the area measured from the delineated watersheds. The trend line models for discharge and precipitation were derived using word excel programming. The trend line slope model was determined through derivatives. The t-test and analysis of variance (ANOVA) were the statistical tools applied to analyse the significance on the computed data, which were treated at 0.05 level.

Results and Discussion

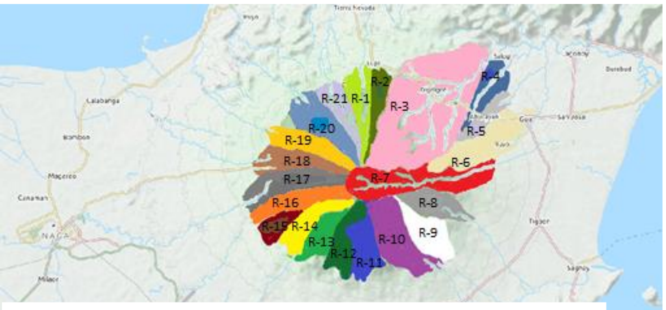

Figure 1. Location of rivers and watersheds

The Watersheds

There are 21 catchment areas covering the entire mountain being drained by corresponding rivers downslope. These catchment areas are responsible for collecting the vast amount of rainfall needed to supply the rivers with flowing water. The amount depends on the collected rainfall which made the larger catchment area and greater precipitation to produce bigger river flow. Figure 1 shows the location of rivers and delineated catchment areas.

Table 1. Area and Slope of the River Watersheds

River No.	Name of River	Area (sqm)	Slope
R-1	Lupi	7.54	25.44
R-2	Himoragat	3.89	23.37
R-3	Salog-maalsom	49.10	13.83
R-4	Hicot	4.96	1.68
R-5	Inansagan	4.19	2.63
R-6	Kulasi	17.14	13.41
R-7	Rangas	23.30	15.95
R-8	Unknown	7.26	20.77
R-9	Unknown	8.78	19.98
R-10	Pinit	10.19	20.77
R-11	Hibago	5.88	25.66
R-12	Ocampo	4.55	21.66
R-13	Himaao	3.74	18.77
R-14	Anayan	4.59	22.94
R-15	Cariraga	2.37	9.50
R-16	San Jose	6.63	22.52
R-17	Yabu	5.43	21.44
R-18	Naga	6.50	19.39
R-19	Inarihan	7.40	17.08
R-20	Hinaguianan	7.13	16.76
R-21	Tigman	4.17	17.32

The delineated boundaries of the watersheds were numbered with corresponding name of the identified river shown in Table 1. With largest area is R-3 having 49.10 Km^2 followed by R-7 and R-6 with 23.30 km^2 and 17.14 km^2 respectively. This capacity made the rivers possible to supply domestic water and to irrigate rice paddies. Hence, irrigation canals exist below these watersheds serving large area of farmland. The table revealed that R-11 has the highest slope followed by R-1 and R-2 while with lowest slope is R-4 followed by R-5 and R-15.

Precipitation

The on-line data [10] revealed that precipitation differs in five areas surrounding Mt. Isarog. These are the precipitations that occurred in portions of Goa and

Tigaon area (A-1), Ocampo and Pili (A-5), Calabanga (A-3), Naga (A-4), and Tinambac (A-2).

Table 2. The Three year monthly precipitation in five areas around Mt. Isarog

Year	M.	A-1 (sqm)	A-2 (sqm)	A-3 (sqm)	A-4 (sqm)	A-5 (sqm)
2014	1	201.75	196.37	131.31	111.06	108.63
	2	61.95	55.60	41.03	38.92	38.69
	3	114.25	113.90	81.97	69.42	68.15
	4	141.56	124.80	94.34	93.79	92.48
	5	132,88	97.89	98.55	112.45	113.16
	6	187.11	170.95	152.95	153.81	153.34
	7	373.18	364.05	360.81	376.37	377.87
	8	135.47	120.42	123.75	136.52	136.85
	9	337.18	339.49	311.72	307.75	307.55
	10	235.92	239.20	185.91	169.08	165.92
	11	204.64	180.38	137.81	136.17	135.03
	12	632.99	592.99	498.32	458.73	482.56
	13	412.73	382.52	292.18	253.05	248.14
2015	14	52.15	34.36	17.01	17.69	17.99
	15	77.66	51.07	41.12	49.06	49.58
	16	83.69	71.97	63.40	57.57	57.02
	17	77.34	36	24.30	29.59	29.79
	18	210.37	151.37	165.30	152.73	150.93
	19	209.49	161.07	213.83	270.54	275.32
	20	213.03	152.05	178.66	198.95	199.65
	21	280.18	190.76	196.29	196.09	196.09
	22	144.42	150.82	146.08	153.48	153.48
	23	50.94	35.46	12.59	18.58	18.58
	24	252.80	196.41	147.79	146.13	146.13
	25	82.88	62.63	39.34	37.28	36.66
2016	26	137.93	114.71	68.70	59.59	58.60
	27	63.69	41.44	26.73	37.03	37.91
	28	78.31	56.32	66.19	75.70	76.31
	29	229.42	105.22	84.49	97.75	98.34
	30	288.31	175.86	178.89	154.20	151.99
	31	280.99	192.89	244.27	258.71	288.3
	32	112.39	110.61	188.30	283.29	291.41
	33	210.87	130.78	160.98	185.08	186.77
	34	599.07	546.13	445	371.10	363.21
	35	194.80	232.90	135.50	100.70	97.50
	36	454.30	462.00	367.80	299.00	292.10
Total		7556.6	6441.39	5723.2	5666.9	5600.6

The three-year average monthly precipitation data also revealed that the highest monthly precipitation occurred in A-1 at 632.99 mm while the lowest was 50.94 mm. In A-5, the highest average monthly precipitation was 482.56 mm while the lowest was 18.97 mm. In A-3, A-4 and A-2, the highest monthly precipitations were 489.32 mm, 458.73 mm and 592.99 mm respectively while the lowest were 12.59 mm, 18.58 mm and 35.46 mm respectively. A-1 has the highest occurrence of monthly precipitation while A-5 has the lowest. The dates that the highest and the lowest precipitation occurred in the five areas are similar which means that there is a pattern of monthly precipitation in the five identified areas (See Table 2). The computed F = 1.214 < Fcrit = 2.423. The null hypothesis is rejected.

Figure 2 shows the trend of monthly precipitation from year 2014 to 2016 which is illustrating similar fluctuation lines representing the five areas. The line representing Goa/Tigaon area (A-1) is plotted higher than the other lines showing that the precipitations are more immense compared to other areas.

Figure 2 also shows that the trend line of precipitation in A-1 is drawn at the highest location in the graph which supports that it is the area that the most intensive rainfall occurs. The trend line of precipitation in A-5 is located at the lowest portion in the graph which supports that it is the area with lowest rainfall occurrence.

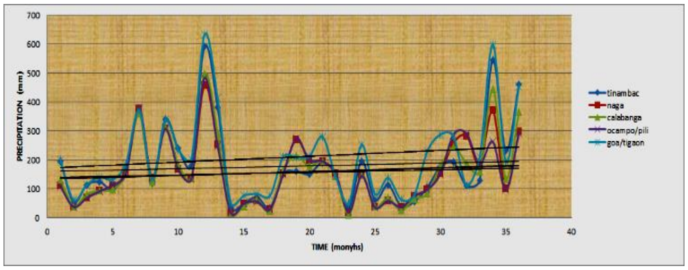

Figure 2. The Trend of monthly precipitation

Delineated areas affected by precipitation

The areas affected by precipitation were divided into five categories. The effect was categorized according to colors shown in Figure 3 which displays that A-1 has largest area. This is followed by A-5 and A-3.

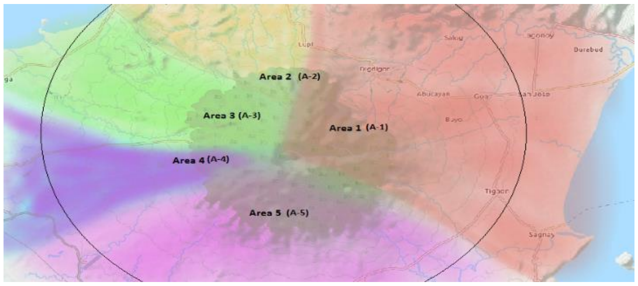

Figure 3. The delineated areas affected by monthly precipitation

Precipitation Trend Lines and Slopes

Table 3 reveals that the precipitation in different areas varies. With x in the equation representing time in months and y as precipitation in mm units appeared that precipitation in A-1 is the uppermost while Area 5 is the lowest. Since A-1 has more immense precipitation, discharges or rivers in the area could be excessive. The trend line slope models exposed A-1 to have highest slope with A-5 as the lowest showing monthly precipitation in A-1 as highly accelerating with A-5 as the lowest.

Table 3. The precipitation trend line model and the trend line slope

Area	Precipitation trend line model	Trend line slope model
A-2	$y = 1.0239x + 159.99$	$dy/dx = 1.0239$
A-4	$y = 1.2262x + 134.73$	$dy/dx = 1.2262$
A-3	$y = 1.3111x + 134.72$	$dy/dx = 1.3111$
A-5	$y = 0.8677x + 139.52$	$dy/dx = 0.8677$
A-1	$y = 2.0804x + 171.42$	$dy/dx = 2.0804$
Total	$y = 6.5093x + 740.38$	$dy/dx = 6.5093$
Mean	$y = 1.302x + 140.08$	$dy/dx = 1.302$

The Discharge Mathematical Model

The mathematical models of the rivers shown in Table 4 are expressing relationship between discharge, time and precipitation. Each models differ with each other for if the equations were used in computing could result differently on the amount of discharges. With similar period and precipitation, it is R-3 that will produce the highest river discharge while R-15 will be the lowest.

The mathematical models were derived through the definitions of discharge: $Q = V/t_c$. where Q is referring to the river discharge in m^3/s unit, t_c is the precipitation time length (s), V is the volume of water that precipitated in the watershed area which is equated as $V = PA$ where A is the area in sqm unit of the watershed and P_r is the height of accumulated water in the watershed in mm unit, assuming that the watershed is in a regular shape of square, and to compute the volume is in the form of a regular box so that the following steps were done to derive the mathematical model of R-1 (Lupi River) with watershed area of 7.54 sqkm. The derivation of the model is shown:

$$Q = \frac{V}{t_c} = \frac{P_r\,A}{t_c}$$

$$Q = \frac{P_r\,(7.53875)}{t_c}\;\frac{Km^2\,mm}{s}$$

$$Q = \frac{P_r\,(7.53875)}{t_c}\;\frac{\cancel{Km^2}\,\cancel{mm}}{s}\;\frac{(1000\,m)^2}{\cancel{km^2}}\;\frac{m}{1000\,\cancel{mm}}$$

$$Q = \frac{7.53875\,P_r}{t_c}$$

Table 4. The discharge mathematical equation of rivers

River No	Equation	River no	Equation	River no	Equation
R-1	$Q_1 = 7{,}538.75\,\frac{P_R}{t_c}$	R-8	$Q_8 = 7{,}260.06\,\frac{P_R}{t_c}$	R-15	$Q_{15} = 2{,}366.55\,\frac{P_R}{t_c}$
R-2	$Q_2 = 3{,}890.77\,\frac{P_R}{t_c}$	R-9	$Q_9 = 8{,}779.12\,\frac{P_R}{t_c}$	R-16	$Q_{16} = 6{,}629.87\,\frac{P_R}{t_c}$
R-3	$Q_3 = 49{,}099.54\,\frac{P_R}{t_c}$	R-10	$Q_{10} = 10{,}188.52\,\frac{P_R}{t_c}$	R-17	$Q_{17} = 5{,}434.69\,\frac{P_R}{t_c}$
R-4	$Q_4 = 4{,}964.90\,\frac{P_R}{t_c}$	R-11	$Q_{11} = 5{,}879.45\,\frac{P_R}{t_c}$	R-18	$Q_{18} = 6{,}501.56\,\frac{P_R}{t_c}$
R-5	$Q_5 = 4{,}189.45\,\frac{P_R}{t_c}$	R-12	$Q_{12} = 4{,}545.67\,\frac{P_R}{t_c}$	R-19	$Q_{19} = 7{,}400.79\,\frac{P_R}{t_c}$
R-6	$Q_6 = 17{,}139.15\,\frac{P_R}{t_c}$	R-13	$Q_{13} = 3{,}739.99\,\frac{P_R}{t_c}$	R-20	$Q_{20} = 7{,}134.85\,\frac{P_R}{t_c}$
R-7	$Q_7 = 23{,}296.13\,\frac{P_R}{t_c}$	R-14	$Q_{14} = 4{,}591.34\,\frac{P_R}{t_c}$	R-21	$Q_{21} = 4{,}166.05\,\frac{P_R}{t_c}$

River Discharges Under A-1

There are seven rivers influenced by precipitation under A-1. Using the derived mathematical model their monthly discharges were computed showing varying result (See Figure 4 and Table 5. The highest computed monthly discharge for R-3 is 11.99 cum/s while the lowest is 0.96 cum/s; the highest computed monthly discharges are 1.21 cum/s, 1.0 cum/s, 4.18 cum/s, 5.69 cum/s, 1.77 cum/s, and 2.14 cum/s while the lowest are 0.10 cum/s, 0.08 cum/s, 0.34 cum/s, 0.46 cum/s, 0.14 cum/s and 0.17 cum/s for R-4, R-5, R- 6, R-7 ,R-8 and R-9 respectively. The computed monthly discharges are highest in R-3 while the lowest are in R-5.

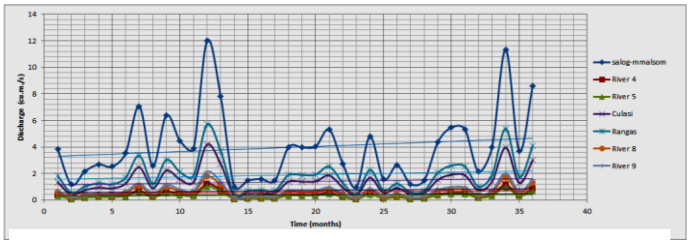

Figure 4. Discharges of rivers under A-1 from year 2014 to 2016

There is no significant difference on the computed monthly discharge data on the seven rivers for year 2014 to 2016 as the computed F = 40.70 > F crit. = 2.14. The computed discharge data are fluctuating similarly as illustrated in Figure 4 with R-3 or the Salog-Maalsom River plotted in utmost discharge data and R-5 in the lowermost. The trend line for R-3 is also occupying the utmost with R-5 as the lowermost. The condition could be attributed to the area of watershed. R-3 has the largest catchment area that could collect the highest amount of precipitation water.

Table 5. Computed monthly discharge of rivers under A-1 from year 2014-2016 (See Appendix).

Table 6. Discharge Trend Line and Slope Models of Rivers in A-1 for year 2014-2016

River	Discharge trend line model	Trend line slope model
R – 3	y = 0.0394x + 3.2471	dy/dx = 0.0394
R – 4	y = 0.004x + 0.3283	dy/dx = 0.004
R- 5	y = 0.0034x + 0.2771	dy/dx = 0.0034
R – 6	y = 0.0138x + 1.1335	dy/dx = 0.0138
R – 7	y = 0.0187x + 1.5407	dy/dx = 0.0187
R – 8	y = 0.0058x + 0.4801	dy/dx = 0.0058
R – 9	y = 0.007x + 0.5806	dy/dx = 0.007

The trend lines mathematical models of river discharge under A-1 conforms with each other for they are all straight line equation and are positive. If precipitation (y) is computed with x representing time in month (M), the highest computed monthly discharge will occur at R-3 and the lowest will be at R-5.

The trend line slope model is referring to an increase of discharge per month. The highest increase will occur in River 3 while the lowest is in River 5.

River Discharges under A-2

Table 7. The computed monthly (M) river discharges (Q in cum/s) located in A-2

R-1						R-2					
2014		2015		2016		2014		2015		2016	
M	Q	M	Q	M	Q	M	Q	M	Q	M	Q
1	0.57	13	1.11	25	0.18	1	0.29	13	0.57	25	0.09
2	0.16	14	0.10	26	0.33	2	0.08	14	0.05	26	0.17
3	0.33	15	0.15	27	0.12	3	0.17	15	0.08	27	0.06
4	0.36	16	0.21	28	0.16	4	0.19	16	0.11	28	0.08
5	0.28	17	0.10	29	0.31	5	0.15	17	0.05	29	0.16
6	0.50	18	0.44	30	0.51	6	0.26	18	0.23	30	0.26
7	1.06	19	0.47	31	0.56	7	0.55	19	0.24	31	0.29
8	0.35	20	0.44	32	0.32	8	0.18	20	0.23	32	0.17
9	0.99	21	0.55	33	0.38	9	0.51	21	0.29	33	0.20
10	0.70	22	0.44	34	1.59	10	0.36	22	0.23	34	0.82
11	0.52	23	0.10	35	0.68	11	0.27	23	0.05	35	0.35
12	1.72	24	0.57	36	1.34	12	0.89	24	0.29	36	0.69

Note: $t = 3.30 > t_{crit} = 1.99$, null hypothesis is accepted

R-1 (Lupi) and R-2 (Himoragat) are the two rivers that are under influenced by A-2. The highest computed monthly discharge for R-1 is 1.72 cum/s while the lowest is 0.10 cum/s' The highest computed discharge for R-2 is 0.89 cum/s while the lowest is 0.052 cum/s. It is remarkable that the occurrence of the highest and lowest computed discharge of the two rivers is within the same date. There is no significant difference on the computed discharges between the two rivers. The t-test result shows that the computed t = 3.30 is greater than the critical t = 1.99. There are similarities on the discharge trend line model for both the two equations are straight line which is positive (See Table 8). However, if the discharge representing y in the equation is computed in terms of x, R-1 will have the higher amount of discharges.

Table 8. The discharge trend line and slope models of rivers located within A-2 for year 2014 to 2016

River	Discharge trend line model	Trend line slope model
R-1	y = 0.003x + 0.4653	dy/dx = 0.003
R-2	y = 0.0015x + 0,2401	dy/dx = 0.0015

Both the two rivers have positive trend line slope model. The trend line slope of R-1 is higher compared to R-2 revealing that the discharge for R-1 is increasing higher than R-2 for every month.

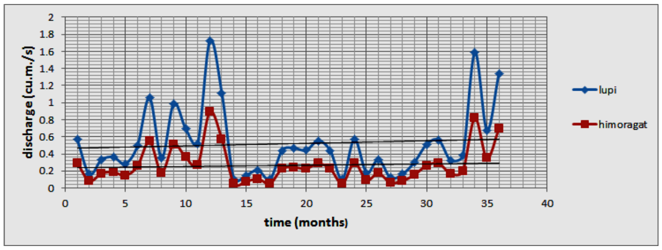

Figure 5. Trend line of rivers under A-2 from year 2014 to 2016

The trend of lines shown in Figure 8 for both two rivers is similar since the fluctuations of the lines in the graph are the same. However, the lines for R-1 are occupying the uttermost portion of the graph showing that the computed river discharges is the highest compared to other river.

River Discharges Under A-3

There are two rivers located under A-3 which are the R-20 (Hinaguianan River) and R-21 (Tigman River). The highest computed monthly discharge for R-20 is 1.37 cum/s while the lowest is 0.03 cum/s. The highest computed monthly discharge for R-21 is 0.80 cum/s while the lowest is 0.02 cum/s. The time by which the highest and lowest computed discharge of the two rivers occurs is of the same date.

There is no significant difference on the computed data between the two rivers. The computed t = 2.86 is greater compared to critical t = 1.99. There are similarities on the discharge trend line model for both rivers since they straight line equations and are increasing (See Table 10). The computed monthly discharges for R-20 would be higher than R-21 using the trend line equations. This could be attributed to the area since R-20 has larger watershed area than R-21.

Table 9. The computed monthly discharge of rivers located in A-3 for year 2014 to 2016

R-20						R-21					
2014		2015		2016		2014		20155		2016	
M	Q	M	Q	M	Q	M	Q	M.	Q	M.	
1	0.36	13	0.80	25	0.11	1	0.21	13	0.47	25	0.06
2	0.11	14	0.05	26	0.19	2	0.07	14	0.03	26	0.11
3	0.23	15	0.11	27	0.07	3	0.13	15	0.07	27	0.04
4	0.26	16	0.17	28	0.18	4	0.15	16	0.10	28	0.11
5	0.27	17	0.07	29	0.23	5	0.16	17	0.04	29	0.14
6	0.42	18	0.45	30	0.49	6	0.25	18	0.27	30	0.29
7	0.99	19	0.59	31	0.67	7	0.58	19	0.34	31	0.39
8	0.34	20	0.49	32	0.52	8	0.20	20	0.29	32	0.30
9	0.86	21	0.54	33	0.44	9	0.50	21	0.31	33	0.26
10	0.51	22	0.40	34	1.22	10	0.3	22	0.23	34	0.71
11	0.37	23	0.03	35	0.37	11	0.22	23	0.02	35	0.22
12	1.37	24	0.41	36	1.01	12	0.80	24	0.24	36	0.59

Note: t = 2.86 > tcrit = 1.99, Null hypothesis accepted

Table 10. The discharge trend line and slope models of rivers located within A-3 for year 2014 to 2016

River	Discharge trend line model	Trend line slope model
R-20	$y = 0.0036x + 0.3708$	$dy/dx = 0.0036$
R-21	$y = 0.0021x + 0.2165$	$dy/dx = 0.002$

Both the rivers have positive trend line slope model. The trend line slope of R-20 is higher than R-21 showing that the discharge for R-20 is increasing higher than R-21 for every month.

The development of lines shown in Figure 6 for both two rivers is similar since the inclination of the two lines in the graph are the same. However, the lines for R-20 are occupying the uttermost portion of the graph displaying that the computed river discharges is higher compared to R-2.

River Discharges Under A-4

Three rivers under influence of A-4 are R-17 (Yabu River), R-18 (Naga River) and R-19 (Inarihan River). The highest computed monthly discharges are 0.96 cum/s, 1.15 cum/s and 1.31 cum/s while the lowest is 0.039 cum/s, 0.05 cum/s and 0.05 cum/s for R-17, R-18 and R-19 respectively. The month by which the highest and lowest computed discharge of the three rivers occurs is of the same date (See Table 12).

There are similarities on the discharge trend line model for both the three equations are straight line which is positive (See Table 11). However, if the discharge representing y in the equation is computed in terms of x representing the length of time of precipitation, it will appear to have R-19 the highest amount of discharges.

Table 11. The discharge trend line and slope models of rivers located within A-4 for year 2014 to 2016

River	Discharge trend line model	Trend line slope model
R-17	$y = 0.0026x + 0.2825$	$dy/dx = 0.0026$
R-18	$y = 0.0031x + 0.338$	$dy/dx = 0.0031$
R-19	$y = 0.0035x + 0.3847$	$dy/dx = 0.0035$

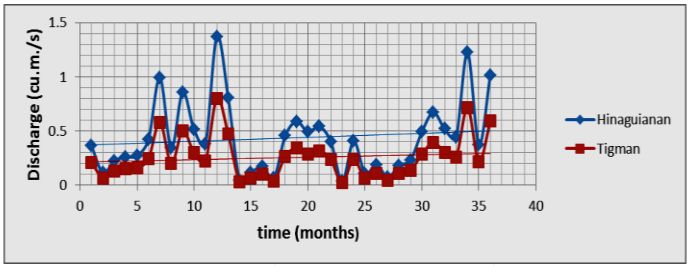

Figure 6. Trend line of rivers under A-3 from year 2014 to 2016

Similarly, the three rivers have positive trend line slope model. The trend line slope of R-19 is the highest while R-17 is the lowest. This shows that the discharge for R-19 is increasing the highest among the three for every month.

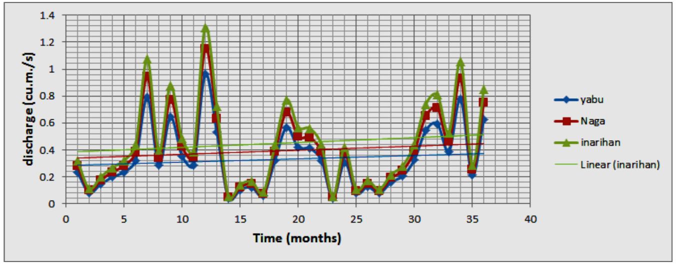

Figure 7. Trend line of rivers under A-4 from year 2014 to 2016

The trend of lines shown in Figure 7 for both the three rivers is similar since the fluctuations of the three lines in the graph are the same. However, the lines for R-19 are occupying the uttermost portion of the graph showing that the computed river discharges is the highest compared to other two rivers.

Table 12. The computed monthly river discharge under A-4

Year	Month	R-17	R-18	R-19
2014	1	0.23	0.28	0.32
	2	0.08	0.10	0.11
	3	0.14	0.17	0.20
	4	0.20	0.23	0.27
	5	0.24	0.28	0.32
	6	0.32	0.39	0.44
	7	0.79	0.94	1.07
	8	0.29	0.34	0.39
	9	0.64	0.77	0.88
	10	0.35	0.42	0.48
	11	0.29	0.34	0.39
	12	0.96	1.15	1.31
	13	0.53	0.63	0.72
2015	14	0.04	0.04	0.05
	15	0.10	0.12	0.14
	16	0.12	0.14	0.16
	17	0.062	0.07	0.08
	18	0.32	0.38	0.44
	19	0.57	0.68	0.77
	20	0.42	0.50	0.57
	21	0.41	0.49	0.56
	22	0.32	0.39	0.44
	23	0.04	0.05	0.05
	24	0.31	0.37	0.42
2016	25	0.08	0.09	0.11
	26	0.12	0.15	0.17
	27	0.08	0.09	0.11
	28	0.16	0.19	0.22
	29	0.21	0.24	0.28
	30	0.32	0.39	0.44
	31	0.54	0.65	0.74
	32	0.59	0.71	0.81
	33	0.39	0.46	0.53
	34	0.79	0.93	1.06
	35	0.21	0.25	0.29
	36	0.63	0.75	0.85

Note: F = 1.63 < Fcrit= 3.08, null hypothesis rejected

There is significant difference on the computed data. Analysis of variance (Anova) computation resulted to a value of computed F = 1.63 which is less than the critical F = 3.08.

River Discharges Under A-5

There are seven rivers located under A-5 with different result of computed monthly discharges. The highest are 1.90 cum/s, 1.09 cum/s, 0.85 cum/s, 0.70 cum/s, 0.85 cum/s, 0.44 cum/s, and 1.23 cum/s while the lowest are 0.07 cum/s, 0.04 cum/s, 0.03 cum/s, 0.03 cum/s, 0.03 cum/s, 0.02 cum/s and 0.05 cum/s for R-10, R-11, R-12, R-13, R-14, R-15 and R-16 respectively (See Table 14). The dates of occurrence for highest and lowest computed discharges in all rivers are similar.

Table 13. Discharge trend line and slope models of rivers located within A-5 from year 2014 to 2016

River	Discharge trend line model	Trend line slope model
R-10	$y = 0.0034x + 0.5484$	$dy/dx = 0.0034$
R-11	$y = 0.002x + 0.3165$	$dy/dx = 0.002$
R-12	$y = 0.0015x + 0.2447$	$dy/dx = 0.0015$
R-13	$y = 0.0013x + 0.2013$	$dy/dx = 0.0013$
R-14	$y = 0.0015x + 0.2471$	$dy/dx = 0.0015$
R-15	$y = 0.0008x + 0.1274$	$dy/dx = 0.0008$
R-16	$y = 0.0022x + 0.3569$	$dy/dx = 0.0022$

The discharge trend line models of the rivers from year 2014 to 2016 are similar for reasons that they are straight line equations and are all positive (See Table 13). Using the models in computing discharges will appear to have R-10 as the highest with R-15 as the lowest.

The trend line slope models of all the rivers are increasing with R-10 as the highest and R-15 as the lowest.

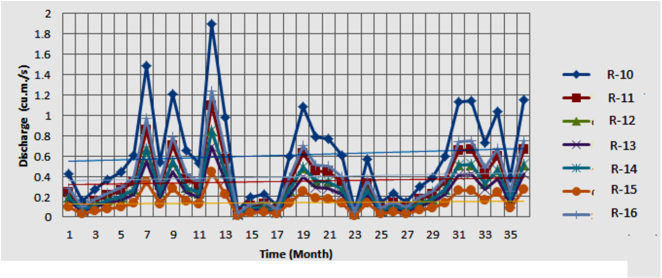

Figure 8. Trend line of rivers under A-5 from year 2014 to 2016

The trend line for R-10 is also occupying the utmost with R-15 as the lowermost. The condition could be attributed to the area of watershed. Larger catchment area could collect more precipitation water to flow within the river. R-10 has the largest while R-15 has the smallest watershed area among the rivers under A-5.

Based from the analysis of variance (ANOVA) result, there is no significant difference in the computed monthly discharges of all rivers. The computed F = 15.54 which is greater than the Fcrit = 2.26. This means that the influence of precipitation on the monthly discharges of all rivers is very strong. This is supported by the configurations of precipitation and monthly river discharge that as drawn in the graph are similar. This finding is conclusive specifically that the effect of hydrologic losses like evaporation, transpiration, seepages etc. are not included in the analysis.

Table 14. The computed monthly discharges of rivers under A-5 from year 2014-2016 (See Appendix)

CONCLUSION AND RECOMMENDATION

Mt. Isarog is surrounded by natural watersheds that are releasing water to twenty-one main rivers. Salog-Maalsom has the largest area while the smallest is the Cariraga River. Different amount of monthly precipitation is seen on five areas as published by the identified website. The Goa and Tigaon areas have the highest amount of monthly precipitation while Pili and Ocampo areas are the lowest. The mathematical models were derived defining the discharge of the individual rivers around the mountain, the trend lines and slopes to be increasing. The derived models are useful in computing the individual monthly discharge of the rivers for the last three years. No identified rivers around the mountain are found identical for every individual river are unique in characters. No identical rivers are discharging the same amount of water. However, even if the rivers are supplied with different amount of monthly precipitation, the behaviour of monthly discharges are fluctuating similar. The monthly precipitation is also fluctuating similar to the fluctuation of monthly discharges of rivers as shown in the graphs.

The data taken from this study may be used as guide in studying the behaviour of river flow and other related topics around Mt. Isarog. The derived mathematical models on precipitation and discharge may be found helpful in computing data necessary for future development projects around the mountain. The trend line and slope models for precipitation and discharges of the rivers are necessary for projecting the future event and can also be used for the future study. Checking the satellite fed data and the computed data with the ground truth will make this study more interesting. This study strengthens the idea that the quantity of river discharge is reliant on the volume of precipitation water collected in the watershed specifically that other factors were not considered in the analysis. It is imperative for the water resource managers as well as the community to preserve the natural situation of the watershed and improve the way it is manage that will result to increased vegetation cover, surface roughness, soil depth, recharge of ground water table, production area, green environment, crop production and in contrast will reduce soil erosion, runoff, and downstream siltation [11]. Since this study is limited on precipitation and its influence to river discharge it is suggested that for future analysis may consider other parameters that may affect river flow like hydrologic losses, vegetation cover and recharge of water table.

REFERENCES

[1] Chong-yu Xu, (2002), Hydrologic models, Earth Science Center, Upsala: Villavagen16.

[2] Chong-yu Xu, (2002), Modelling the effects of climate change on water resources in central Sweden, Water Resources Management, 14(0), 177-189

[3] Sintayehu LG (2015) Application of the HEC-HMS model for runoff simulation of upper blue Nile river basin. Hydrologic Current Research. 6:199

[4] Labat, D., Ababou, R. & Mangin, (1999), A linear and output models for Karstic springflow and flood prediction at different time scales. Stochastic Environmental Research and Risk Assessment, 13, 337.

[5] Velasquez, Esther, (2006), An input–output model of water consumption: analysing intersectoral water relationships in Andalusia, Ecological Economics, 56(2006), 226-240

[6] Teshager Awoke Dagnew, Gassman, Philp W., Secchi, Sylvia, Schoof, Justin T., & Misgna, Girmaye, (2015) Modeling agricultural watersheds with the soil and water assessment tool (SWAT): calibration and validation with a novel procedure for spatially explicit HRUs. Environmental Management. 2016(57), 894-911

[7] He, Chansheng. (2003). *Integration of geographic information systems and simulation model for watershed management. Environmental Modelling and Software, 18(8*-9), 809-813

[8] Almendinger, J.E., and Murphy, M.S. (2007). Constructing a SWAT model of the Willow River watershed, western Wisconsin. St. Croix Watershed Research Station, Science Museum of Minnesota. 84 pp

[9] da Silva, M.G., de Oliveira de Aguiar Netto, A., de Jesus Neves, R.J., do Vasco, A.N., Almeida, C. and Faccioli, G.G. (2015) Sensitivity analysis and calibration of hydrological modeling of the watershed in Northeast Brazil. Journal of Environmental Protection, 6, 837-850

[10] www.worldweatheronline.com

[11] Gashaw, Temesgen, (2015), The implications of watershed management for reversing land degradation in Ehiopia, Research Journal of Agriculture and Environmental Management, 4(1), 5-12

COPYRIGHTS

Table 5. Computed monthly discharge of rivers under A-1 from year 2014-2016

		Discharge (cum/s						
Year	M	R-3	R-4	R-5	R- 6	R-7	R-8	R- 9
2014	1	3.82	0.39	0.33	1.33	1.81	0.56	0.68
	2	1.17	0.12	0.10	0.41	0.56	0.17	0.21
	3	2.16	0.22	0.18	0.75	1.03	0.32	0.39
	4	2.68	0.27	0.23	0.94	1.27	0.40	0.48
	5	2.52	0.25	0.21	0.88	1.19	0.37	0.45
	6	3.54	0.36	0.30	1.24	1.68	0.52	0.63
	7	7.07	0.71	0.60	2.47	3.35	1.04	1.26
	8	2.57	0.26	0.22	0.90	1.22	0.38	0.46
	9	6.39	0.65	0.54	2.23	3.03	0.94	1.14
	10	4.47	0.45	0.38	1.56	2.12	0.66	0.80
	11	3.88	0.39	0.33	1.35	1.84	0.57	0.69
	12	12.00	1.21	1.02	4.18	5.69	1.77	2.14
2015	13	7.82	0.79	0.67	2.73	3.71	1.16	1.40
	14	0.99	0.10	0.08	0.34	0.47	0.15	0.18
	15	1.47	0.15	0.12	0.51	0.70	0.22	0.26
	16	1.58	0.16	0.13	0.55	0.75	0.23	0.28
	17	1.46	0.15	0.12	0.51	0.70	0.22	0.26
	18	3.98	0.40	0.34	1.39	1.89	0.59	0.71
	19	3.97	0.40	0.34	1.38	1.88	0.59	0.71
	20	4.03	0.41	0.34	1.41	1.91	0.60	0.72
	21	5.31	0.54	0.45	1.85	2.52	0.78	0.95
	22	2.74	0.28	0.23	0.95	1.30	0.40	0.49
	23	0.96	0.10	0.08	0.34	0.46	0.14	0.17
	24	4.79	0.48	0.41	1.67	2.27	0.71	0.86
2016	25	1.57	0.16	0.13	0.55	0.74	0.23	0.28
	26	2.61	0.26	0.22	0.91	1.24	0.39	0.47
	27	1.21	0.12	0.10	0.42	0.57	0.18	0.22
	28	1.48	0.15	0.13	0.52	0.70	0.22	0.26
	29	4.35	0.44	0.37	1.52	2.06	0.64	0.78
	30	5.46	0.55	0.47	1.91	2.59	0.81	0.98
	31	5.32	0.54	0.45	1.86	2.52	0.79	0.95
	32	2.13	0.21	0.18	0.74	1.01	0.31	.38
	33	3.99	0.40	0.34	1.39	1.89	0.59	0.71
	34	11.35	1.15	0.97	3.96	5.38	1.68	2.03
	35	3.69	0.37	0.31	1.29	1.75	0.55	0.66
	36	8.61	0.87	0.73	3.00	4.08	1.27	1.54

Note: computed F = 40.70 > F crit. = 2.14

Table 14. The computed monthly discharges of rivers under A-5 from year 2014-2016

year	M	R-10	R-11	R-12	R-13	R-14	R-15	R-16
2014	1	0.43	0.25	0.19	0.16	0.19	0.10	0.28
	2	0.15	0.09	0.07	0.06	0.07	0.03	0.10
	3	0.27	0.15	0.12	0.10	0.12	0.06	0.17
	4	0.36	0.21	0.16	0.13	0.16	0.08	0.24
	5	0.44	0.26	0.20	0.16	0.20	0.10	0.29
	6	0.60	0.35	0.27	0.22	0.27	0.14	0.39
	7	1.48	0.86	0.66	0.54	0.67	0.34	0.97
	8	0.54	0.31	0.24	0.20	0.24	0.12	0.35
	9	1.21	0.70	0.54	0.44	0.54	0.28	0.79
	10	0.65	0.38	0.29	0.24	0.29	0.15	0.42
	11	0.53	0.31	0.24	0.19	0.24	0.12	0.34
	12	1.90	1.09	0.85	0.70	0.85	0.44	1.23
2015	13	0.97	0.56	0.43	0.36	0.44	0.23	0.63
	14	0.07	0.04	0.03	0.03	0.03	0.02	0.05
	15	0.19	0.11	0.09	0.07	0.09	0.04	0.13
	16	0.22	0.13	0.10	0.08	0.10	0.05	0.15
	17	0.12	0.07	0.05	0.04	0.05	0.03	0.08
	18	0.59	0.34	0.26	0.22	0.27	0.14	0.39
	19	1.08	0.62	0.48	0.40	0.49	0.25	0.70
	20	0.78	0.45	0.35	0.29	0.35	0.18	0.51
	21	0.77	0.44	0.34	0.28	0.35	0.18	0.50
	22	0.60	0.35	0.27	0.22	0.27	0.14	0.39
	23	0.07	0.04	0.03	0.03	0.03	0.02	0.05
	24	0.57	0.33	0.25	0.21	0.26	0.13	0.37
2016	25	0.14	0.08	0.06	0.05	0.06	0.03	0.09
	26	0.23	0.13	0.10	0.08	0.10	0.05	0.15
	27	0.15	0.09	0.07	0.05	0.07	0.03	0.10
	28	0.30	0.17	0.13	0.11	0.13	0.07	0.19
	29	0.39	0.22	0.17	0.14	0.17	0.09	0.25
	30	0.60	0.34	0.27	0.22	0.27	0.14	0.39
	31	1.14	0.65	0.51	0.42	0.51	0.26	0.74
	32	1.14	0.66	0.51	0.42	0.52	0.27	0.74
	33	0.73	0.42	0.33	0.27	0.33	0.17	0.48
	34	1.03	0.60	0.46	0.38	0.47	0.24	0.67
	35	0.38	0.22	0.17	0.14	0.17	0.09	0.25
	36	1.15	0.66	0.51	0.42	0.52	0.27	0.75

Note: $F=15.54 > F_{crit} = 2.26$, null hypothesis is accepted