Working Paper

The impacts of land cover and climate change on present and future watershed condition.

Study case: Tugasan, Alanib and Kulasihan Sub-watershed of Manupali Watershed, Lantapan, Bukidnon, Philippines

Lisa Tanika, Edwin R. Abucay, Kharmina Paola A Evangelista and Regine Joy P Evangelista

World Agroforestry Centre

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Lisa Tanika joins ICRAF since 2008 as an ecological modeler. Lisa has a background in Mathematics (BSc) and Applied Climatology (MSc) from Bogor Agriculture University. Her research focuses use of Generic River Flow (GenRiver). Model for assessing watershed functions, in particular to explore the effect of land cover change and climate change on the overall hydrological functions of a watershed. She also interested in developing and applying participatory approaches to monitor watershed functions by local stakeholders.

Prof. Edwin R. Abucay has more than 10 years research experience in various research projects funded locally and internationally. His expertise include Geographic Information System (GIS) and Remote Sensing (RS) in environmental and resource management, mapping, climate change risk and vulnerability assessments; land use planning, watershed management/planning and land use change analysis; disaster risk reduction and management using LiDAR; agent-based modeling for landslide, adaptation responses and vulnerabilities; indigenous knowledge and practices on agriculture and environment; environmental and ecological modeling below and above-ground tree-crop interactions in agroforestry systems; nutrient dynamics and hydrologic functions of agroforestry systems; information and database development, management and programming.

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Regine Joy. P. Evangelista was a research consultant and capacity building specialist of the three-year project of ICRAF Philippines entitled *Climate-smart, tree-based, co-investment in adaptation and mitigation in Asia (Smart Tree-Invest)*. Her research is focused on social dimension of climate change. She has a Master’s Degree in Environmental Science from the University of the Philippines Los Baños, where she also completed her BS Degree in Development Communication.

Abstract

Manupali watershed where is located in central Bukidnon, northern Mindanao provides various ecosystem service for communities particularly on water source. Some recent studies said that the water quantity in Manupali watershed has started to declined. Climate and land cover change is suspected to be one of the causes of this water degradation. Tugasan, Alanib dan Kulasihan sub-watershed of Manupali watershed in municipality of Lantapan were selected as the focus area in this study to see the impact of climate and land cover change on water quantity.

The objective of this study is to assess the impact of climate and land cover change on present and future water balance in Tugasan, Alanib and Kulasihan sub-watershed using the GenRiver model. This objective was accomplished through some activities, such as gathering secondary climate and hydrology data, analysis of climate, hydrology and special data, development of land cover and climate change scenario, simulation of GenRiver model and analysis of simulation result.

The present water balance was simulated based on the actual climate and land cover data from 1990-2015. The future water balance (2016-2050) was simulated based on four scenarios of land cover change: Business As Usual (BAU), crop expansion, banana plantation expansion and agroforestry, which combined with the prediction of climate change (rainfall and temperature) for the Bukidnon area.

The result of GenRiver model for the present condition (1990-2015) did not show any significant change of water balance in Tugasan, Alanib and Kulasihan sub-watershed since not much land cover change over the last 25 years. The analysis result for the future sub-watershed condition showed that the agroforestry can be considered as the best scenario while crop expansion as the worse scenario, while the climate change scenario will lead to an increase of evapotranspiration and reduce the river flow.

Keywords:

Watershed assessment, GenRiver, Manupali watershed

Acknowledgements

Ecosystems Research and Development Bureau, Region X, Philippines where we got the raw data on river discharge, and Dr. Jun Tiburan of the University of the Philippines Los Baños (UPLB) for the raw data on land cover change used in scenario modelling. Also include the staff of the Municipal Agriculturist Office for the assistance they provided during groundtruthing.

Contents

List of Figures

List of Tables

1. Introduction

Philippines is among the countries in Asia most vulnerable to the effects of climate change ranking third based on the report UN World Risk Index (Garschagen et al 2015). Geographically, the Philippines experience almost all types of natural hazards such as typhoon, earthquake, flooding, landslide among others. In general, the dramatic landscape change in the country has made communities more prone to such weather and climate related events. The significant loss in forest cover has rendered the upland susceptible to soil erosion and landslides. Moreover, surface runoff in the mountainous region has resulted to frequent flooding of low-lying communities during rainy season. During dry months, drought is experienced in agricultural lands as well as in cities that relies on water from reservoirs for domestic and commercial use.

The complex processes and interaction between the environment and human activities has resulted to land use and land cover changes (Global Land Project 2005; Lantman et al 2011; LUCC 2002; Milne et al 2009; Verburg et al 2009). These has affected the water-related ecosystem services (Sample et al 2016; Trang et al 2017; Song and Deng 2017; Eum et al 2016), ecosystem carbon-sequestrations (Jiang et al 2016), grassland ecosystems (Li et al 2016) and major watersheds (Göncü and Albek 2007).

The Manupali watershed which covers about 51,000 ha is located in central part of Bukidnon, Philippines provides various ecosystem services to the different communities adjacent to it. This watershed with its headwaters from Mt. Kitanglad is an important water source (irrigation and hydropower) which drains to the Pulangi river. About 60% of the watershed area falls within the upland municipality of Lantapan. In a study by Rola et al (2004), the water quality and quantity of the watershed has steadily declined attributed to soil erosion and domestic waste contamination. The implementation of watershed plan is deemed necessary to address these problems. The implementation of such plans for the watershed however faces challenges such as financial sustainability, limited economic instruments, weak property rights, lack of administrative mechanisms, human capital and institutional constraints and legal basis for the management structure (Rola et al 2004).

This study aims to assess the impacts of land cover and climate change on the present and future watershed condition of Tugasan, Alanib and Kulasihan sub-watershed through hydrologic modelling using GenRiver.

2. Methodology

1. 2.1 GenRiver Model

Hydrological modelling approach is used to estimate the water balance including river discharge in a landscape. The hydrological model that used in this study is Generic River Flow (GenRiver) model. GenRiver is a generic river flow model that responds to changes in vegetation and soil (van

Noordwijk et al 2010). Through this model, the historical of water balance due to the changes of land cover can be understood and the future water balance can be predicted based on some possible land cover scenarios.

GenRiver model uses a simple equation of water balance that used by hydrological model in general (eq. 1). Conservation of mass in a closed system make precipitation (P) is transferred into river discharge (Q), evapotranspiration (E) and soil water (ΔS).

$$P = Q + E + \Delta S \qquad (1)$$

The core of GenRiver model is the dynamic of daily water balance in plot level that driven by local rainfall and influenced by land cover change and soil characteristics (Figure 1). The model output in the plot level is river flow as the sum of surface flow, subsurface flow (soil quick flow) and base flow. From plot level, the river discharge is converted into landscape level (watershed) through river network (the distance from sub-catchment to final outlet). The minimum data requirement to run the GenRiver model is presented in Table 1.

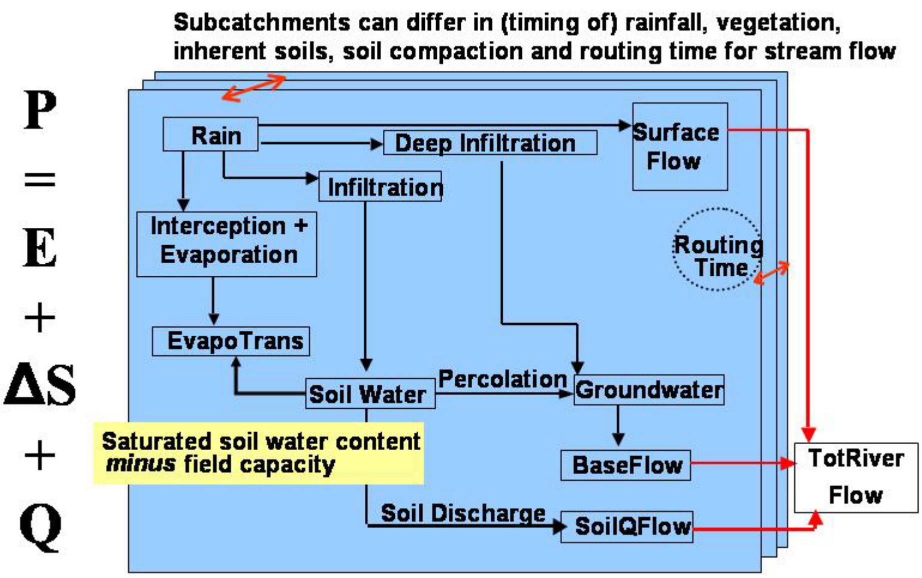

Figure 1. The GenRiver model: water balance in the multiple sub-catchments (plot level) that make up water balance in the catchment level.

Table 1. Minimum data requirement to run GenRiver model

No	Input		Period	Minimum data
1	Climate	Rainfall	Daily	10 years data
		Temperature	Daily/monthly	1 year data
		Evaporation	Daily/monthly	1 year data
2	Hydrology	Actual river discharge/river flow	Daily	10 years data
3	Spatial	Land cover map	-	2 transition year
		Soil map	-	-
		DEM*) map	-	
		River map	-	-

*) Digital Elevation Model

2. 2.2 Modelling stages

There are three stages in conducting hydrological modelling using GenRiver model to accomplish the objectives of this research (Figure 2).

1. Data preparation including data collection and analysis. In this stage, we prepare data that is needed to simulate the GenRiver model. After that, the data was analyzed to identify the quality of the data that we will use for modeling. We also analyze the LEK (Local ecological knowledge) and PEK (Public Ecological Knowledge) to get information that can be used to develop scenarios of future land cover change. For further spatial data analysis and climate and hydrology data analysis can refer to 'A study of rapid Hydrological Appraisal in Krueng Peusangan Watershed, NAD, Sumatra' (Khasanah et al 2010).
2. After all those input ready, we start the modeling step with model parameterization to determine some inputs inside the GenRiver model. We also conduct model calibration to adjust some parameters so that model can represent the real condition of the watershed. After the calibration process finished, we can simulate various scenario of land cover change to see the possible impact of land cover change.
3. By comparing various impact of future land cover change, we can propose some recommendation for watershed management.

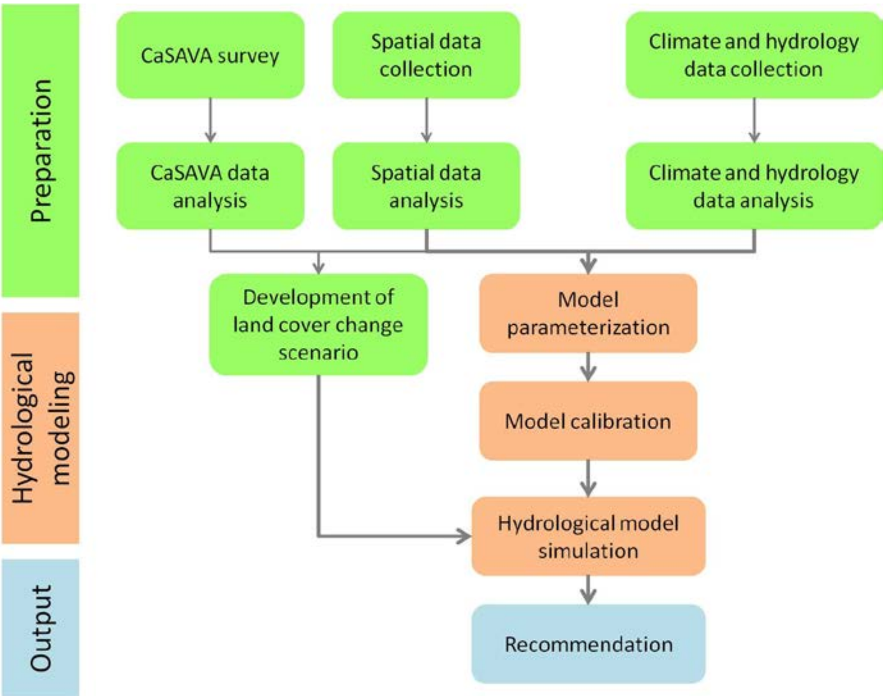

Figure 2. Modeling stages using GenRiver model

3. 2.3 Future Climate and Land Cover Change Scenarios

Four land cover change scenarios and two periods of climate change scenarios were applied to see the impact of future land use and climate change in Tugasan, Alanib and Kulasihan sub watershed. Table 2 and 3 show the land cover change scenario and climate change scenario.

Table 2. Land cover change scenarios

No	Land cover scenario	Climate scenario	
		2016 - 2025	2026 - 2050
1	Business as Usual (BAU)	Follow the pattern of land cover change from 2002 to 2015	Follow the pattern of land cover change from 2002 to 2015
2	Crop	50% of all land cover type are converted into cropland, except forest and settlement	all areas are converted into cropland, except forest and settlement
3	Banana plantation (Banana)	50% of all land cover type are converted into banana plantation, except forest and settlement	all areas are converted into banana plantation, except forest and settlement
4	Agroforestry (AF)	50% of all land cover type are converted into agroforestry, except forest and settlement	all areas are converted into agroforestry, except forest and settlement

Table 3. Climate change scenarios based on climate change projection in Bukidnon (2011)

Month	Rainfall (%)		Temperature (ºC)	
	2016-2035	2036 - 2050	2016-2035	2036- 2050
December - February	2.9	-5.1	1	1.9
March - May	-10.3	-13	1.2	2.3
June - August	-4.4	-9.7	1.2	2.4
September - November	-0.3	-5.8	1	2.1

3. Site Area of Tugasan, Alanib and Kulasihan Sub-watershed

4. 3.1 General Condition

Alanib sub-watershed has a total land area of 6,592 ha. and highest elevation of 2,900 masl (Table 4). About 50% of its land area is classified as alienable and disposable (A&D). It is located on the central northeastern side of the Manupali watershed (Fig. 3). Kulasihan sub-watershed located on the northeastern part of the Manupali wastershed has the largest land area of 10,075 ha (Table 4). About 73% of its land area is classified as A&D. On the other hand, Tugasan sub-watershed which covers only two communities (Basac and Kibangay) has the smallest land area (4,879 ha) compared to the other sub-watershed (Table 4).

The Alanib sub-watershed is considered the most degraded compared to the other two sub-wastershed. On a study by Deutsch and Orprecio (2001), the total suspended solids (TSS) and E. coli levels were highest in Alanib sub-watershed. On the other hand, Kulasihan exhibited moderate degradation while Tugasan had lower degradation rates. Ultisols or red clay soils is the major soil type in Tugasan, Alanib and Kulasihan sub-watershed, except in some area Mount Kitanglad is dominated by mountain soil.

Table 4. Land classification of Alanib, Kulasihan and Tugasan sub-watershed in Lantapan, Bukidnon.

Sub-watershed	Area (ha.)	Timberland (ha.)	A&D (ha.)	Elevation (masl)	Covered Communities
Alanib	6,595.83	3,155.84	3,439.99	500-2,900	Sungco, Alanib, Kaatuan, Baclayon, Poblacion, Balila
Kulasihan	10,075.52	2,705.75	7,369.77	300-2,700	Alanib, Poblacion, Bugcaon, Kaatuan, Bantuanon, Capt. Juan, Kulasihan
Tugasan	4,879.29	4,124.85	755.44	1,000-2,700	Basac, Kibangay

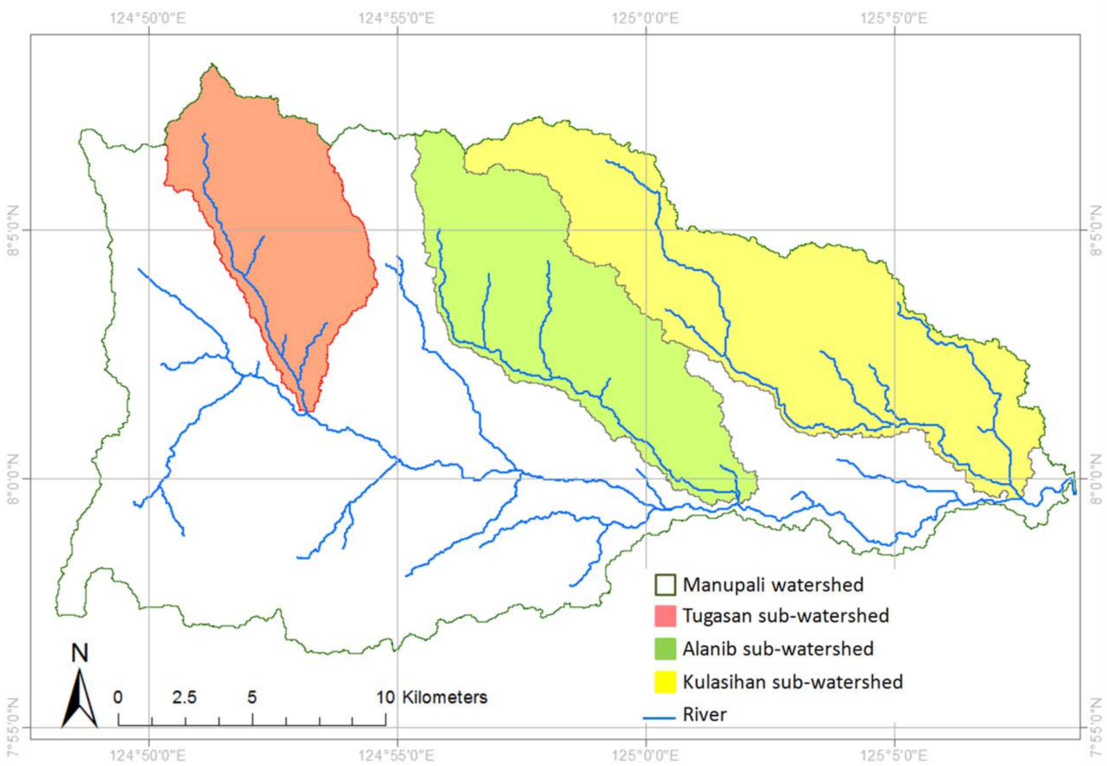

Figure 3. Manupali watershed

5. 3.2 Climate Condition

Rainfall pattern in Tugasan (represented by St. Maagnao), Alanib and Kulasihan are almost similar with peaks season in July-October and dry season in January-April (Figure 4). Among the three stations, Kulasihan has the lowest annual rainfall between 1019-2969 mm, Alanib has the highest rainfall between 304-3801 and Tugasan is the middle with the annual rainfall between 1430-3639 mm.

Potential evaporation in Tugasan, Alanib and Kulasihan sub-watershed is predicted from daily temperature of Lantapan (http://www.accuweather.com/en/ph/lantapan/262398/month/262398?monyr=12/01/2015) using Thornthwaite method. Figure xx shows the pattern of monthly potential evaporation and temperature. The mean temperature in the three sub-watersheds in relatively cooler with January to March as the coldest month.

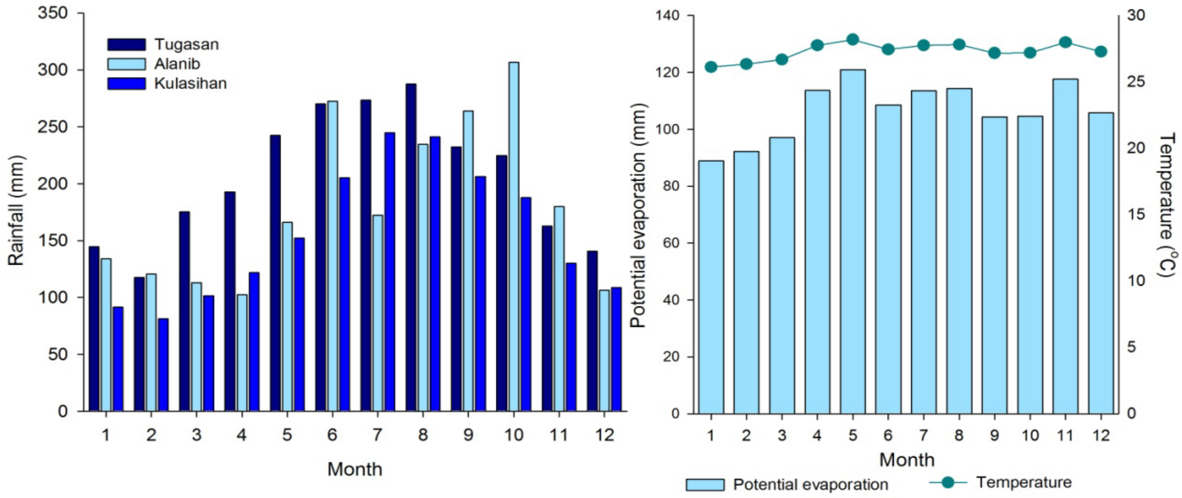

Figure 4. Rainfall pattern in Tugasan, Alanib and Kulasihan (left) and temperature and potential evaporation of Lantapan (right)

3.3 Land Cover Change

3.3.1 Tugasan sub-watershed

For 21 years (1995-2015) land cover in Tugasan subwatershed did not showed significant change (Figure 5 and Table 5). From 1995-2002, the most significant change was the decrease of high density forest from 49% to 41% that converted into low density forest, cropland and grassland. From 2003-2015, shrub and high density forest increased around 8% and 2%, but low density forest and cropland decreased around 2%.

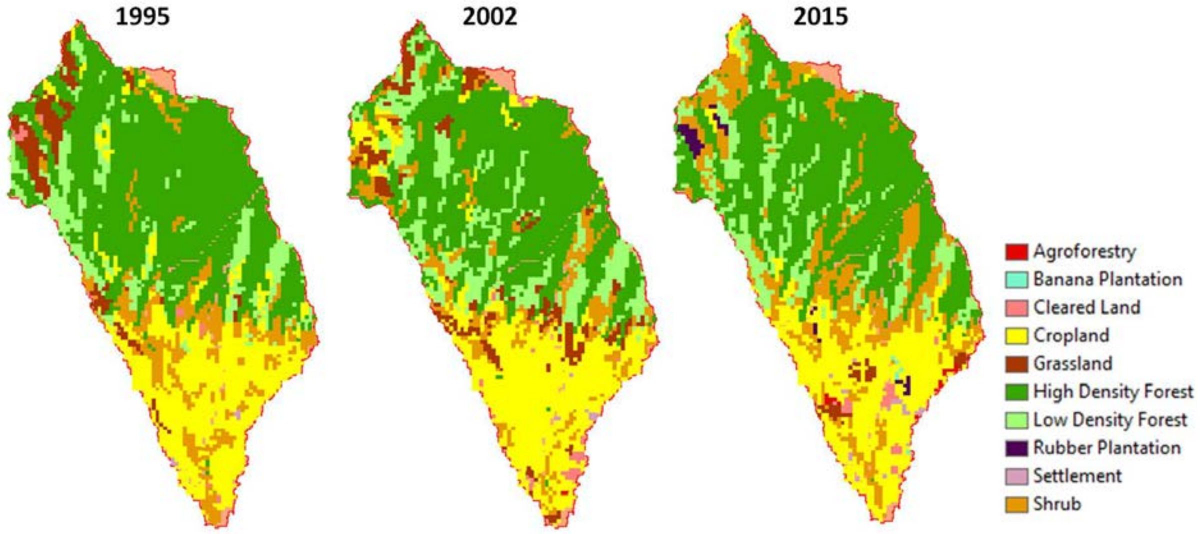

Figure 5. land cover maps of Tugasan subwatershed

Table 5. Land cover type of Tugasan sub-watershed

Land cover type	Area (%)		
	1995	2002	2015
High density forest	49.0	41.1	43.2
Low density forest	10.4	15.1	12.7
Agroforestry	-	0.0	0.3
Banana plantation	-	-	0.1
Rubber plantation	-	-	1.1
Cropland	23.3	25.5	22.0
Grassland	5.0	7.2	1.0
Cleared land	0.5	0.8	0.8
Shrub	11.7	10.1	18.3
Settlement	0.1	0.2	0.4
TOTAL	**100**	**100**	**100**

3.3.2 Alanib sub-watershed

Similar with Tugasan sub-watershed, for 21 years (1995-2015) land cover of Alanib sub-watershed has not changed significantly (Figure 6 and Table 6). From 1995-2002, high density forest declined by about 5.6% and then increased by about 1.1% in 2015. The other land cover which showed changes is shrub, increasing from 11.7% in 1995 to 18.3% in 2015.

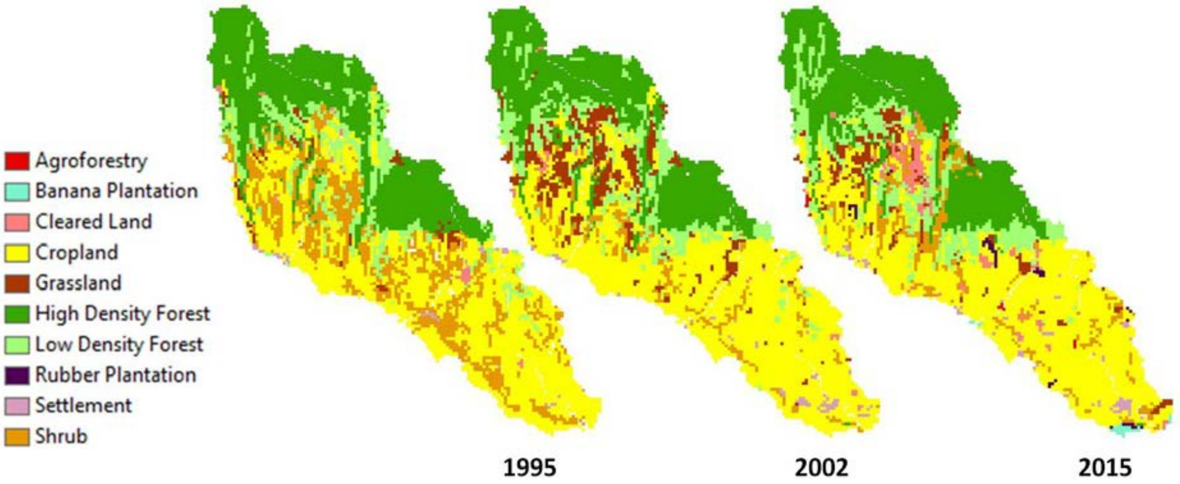

Figure 6. Land cover maps of Alanib subwatershed

Table 6. Land cover type of Alanib sub-watershed

Land cover type	Area (%)		
	1995	**2002**	**2015**
High density forest	28.5	22.9	24.0
Low density forest	11.6	9.8	11.6
Agroforestry	-	0.4	0.2
Banana plantation	0.0	0.9	0.4
Rubber plantation	-	-	0.7
Cropland	38.1	42.7	34.8
Grassland	1.4	8.6	2.7
Cleared land	0.6	0.8	2.8
Shrub	18.9	11.3	17.3
Settlement	0.6	0.9	1.0
No data	0.3	1.9	4.4
TOTAL	**100**	**100**	**100**

3.3.3 Kulasihan sub-watershed

Land cover maps of Kulasihan sub-watershed have more no-data from shadow and cloud than Tugasan and Alanib sub-watershed (Figure 7 and Table 7). As a result, decrease in land cover area occurred in almost all types of land cover.

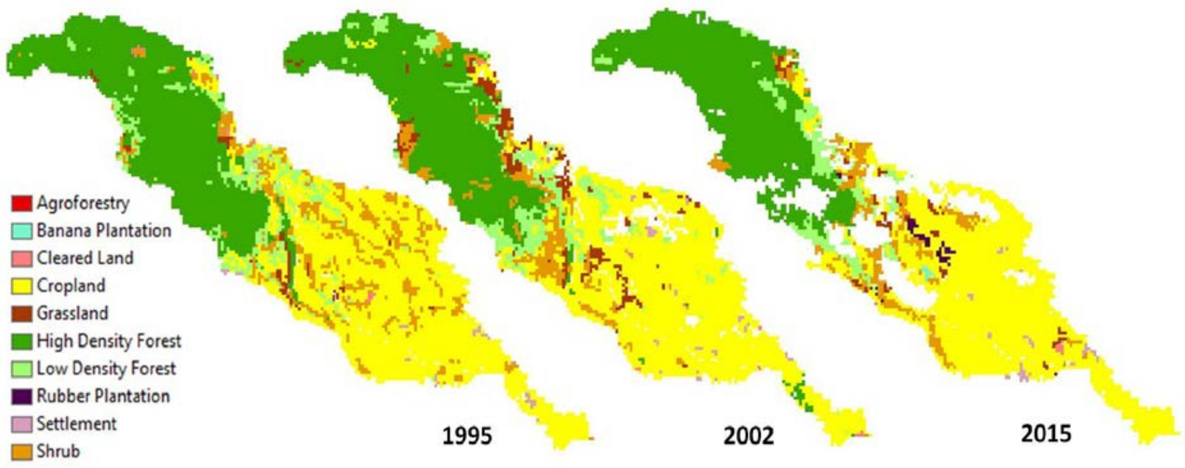

Figure 7. land cover maps of Kulasihan sub-watershed

Table 7. Land cover type of Kulasihan sub-watershed

Land cover type	Area (%)		
	1995	2002	2015
High density forest	35.4	31.4	30.9
Low density forest	7.2	8.2	5.3
Agroforestry	-	0.2	-
Banana plantation	-	-	0.2
Rubber plantation	-	-	0.7
Cropland	44.9	45.3	40.4
Grassland	1.1	4.4	1.5
Cleared land	0.4	0.4	0.2
Shrub	10.4	9.5	6.9
Settlement	0.5	0.5	0.6
No data	0.0	0.0	13.4
TOTAL	**100**	**100**	**100**

3.4 Sub-watershed Properties

Besides the daily rainfall, river discharge and land cover as the main input of Genriver Model, there are some additional inputs that needed to simulate GenRiver model. Table 8-10 presents the area and routing distance of sub-sub-watershed in Tugasan, Alanib and Kulasihan that obtained based on delineation in the spatial data analysis process.

Table 8. Sub-sub-watershed properties of Tugasan

Sub-sub-watershed	Area (km^2)	Routing distance (km)
SC 4	27.8	10.9
SC 5	9.9	5.6
SC 6	12.4	6.0
Total	**50.1**	**-**

Table 9. Sub-sub-watershed properties of Alanib

Sub-sub-watershed	Area (km^2)	Routing distance (km)
SC 18	20.4	17.6
SC 19	18.5	14.4
SC 20	10.5	11.1
SC 21	14.1	6.1
SC 22	7	4
Total	**70.5**	**-**

Table 10. Sub-sub-watershed properties of Kulasihan

Sub-sub-watershed	Area (km^2)	Routing distance (km)
SC 25	34.5	22.3
SC 26	7.4	10.4
SC 27	25.2	12.2
SC 28	4.3	3.9
Total	**71.4**	**-**

4. Result

4.1 Model Parameterization and Calibration

Although the main input can be obtained from secondary data, but there are still some parameters that need to be adjusted such as interception, infiltration rate, soil water capacity, flow velocity, tortuosity, etc. This parameter can be obtained through measurement but it will take a long time and costly. Tabel 11-13 are the parameters that need to be adjusted through the parameterization process. The way to determine the value of those parameters can be seen in user manual of GenRiver and FlowPer model (van Noordwijk et al 2010).

Table 11. BD/BDref, potential interception and relative drought threshold

Land cover type	Potential Interception (mm day^{-1})	Relative Drought Threshold	BD/BDref
High density forest	4.00	0.40	0.70
Low density forest	3.50	0.50	0.80
Agroforestry	3.00	0.60	0.95
Banana plantation	2.00	0.85	1.00
Rubber plantation	2.50	0.60	0.90
Cropland	1.00	0.50	1.10
Grassland	2.00	0.55	1.00
Cleared land	0.50	0.70	1.30
Shrub	3.00	0.60	1.07
Settlement	0.05	0.01	1.30
No data	0.00	0.00	0.00

Table 12. Multiplier of daily potential evapotranspiration

Land cover type	Multiplier of Daily Potential Evapotranspiration											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
High density forest	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80
Low density forest	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70
Agroforestry	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65
Banana plantation	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70
Rubber plantation	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60
Cropland	1.00	1.00	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	1.00	1.00
Grassland	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60
Cleared land	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30
Shrub	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60
Settlement	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
No data	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 13. Non-measured parameters from calibration process

Parameter	Value	Unit
RainInterceptDripRt	10	mm
RainMaxIntDripDur	0.9	hour
InterceptEffectiontrans	0.8	hour
RainIntentsMean	30	mm/hour
RainIntentsCoefVar	0.9	-
MaxInfRate	450	mm/day
MaxInfSubsoil	100	Mm/day

Parameter	Value	Unit
PerFracMultiplier	0.12	-
MaxDynGrWatStore	100	mm
GWReleaseFracVar	0.03	-
Turtuosity	0.2	-
DispersalFactor	0.3	-
RiverVelocity	0.4	m/s

After parameterization, the calibration process is done by using average rainfall from three station (St. Maagnao, St. Alanib and St. Kulasihan) and river discharge in the Manupali River from May 2004 – June 2005 (Figure 8). The catchment area for the model calibration is 247.3 km^2. The result of calibration process shows good performance and may represent the condition of Manupali watershed (Figure 9) with NSE 0.83, coefficient of correlation 0.9 and bias less than 6%.

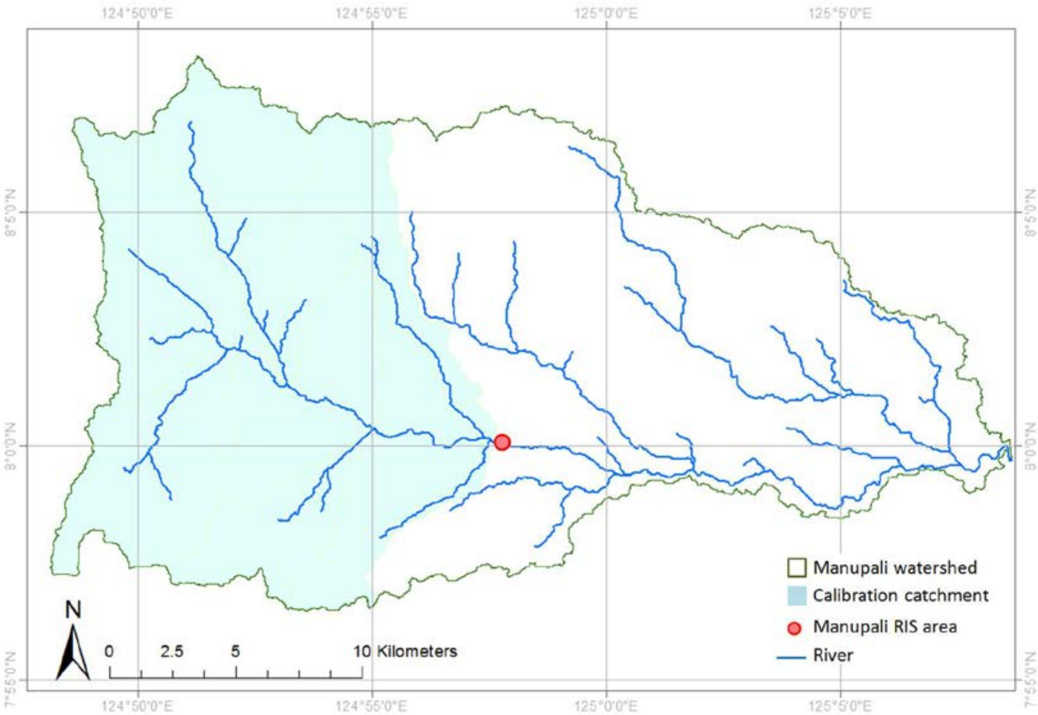

Figure 8. Catchment area that was used for GenRiver model calibration

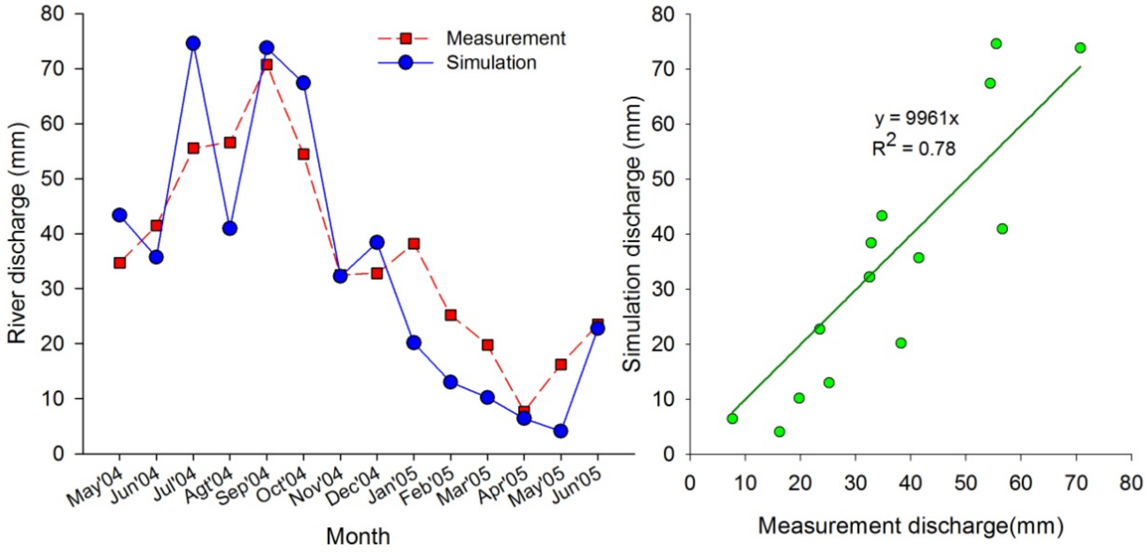

Figure 9. Result of model calibration using 2004-2005 rainfall and river flow data

4.2 Impact of Historical Land Cover Change on Water Balance (1995-2015)

4.2.1 Tugasan sub-watershed

Based on the simulation of GenRiver model, the average of evapotranspiration in Tugasan sub-watershed was about 44% of the annual rainfall (Table 14). The average of river flow (river discharge) is about 56% that derived from surface flow (19%), interflow (21%) and base flow (16%). In the wettest year, the river flow can reach 71% of rainfall and the surface flow, interflow and base flow increased by 9%, 15% and 3%, respectively.

Table 14. The summary of water balance in Tugasan sub-watershed as the result of GenRiver model simulation year 1995-2015

Water balance components	Min		Average		Max	
	mm	%*)	mm	%*)	mm	%*)
Rainfall	1430		2464		3640	
Evapotranspiration	789	30	1053	44	1107	58
River flow	640	42	1400	56	2594	71
Surface flow	224	13	481	19	896	28
Subsurface flow	134	9	537	21	1326	36
Base flow	213	12	383	16	438	19

*) percentage to rainfall

Over the 21 years simulation (1995-2015), evapotranspiration and base flow were quite stable, while the surface flow and interflow varies following similar pattern as that of its rainfall pattern (Figure 10).

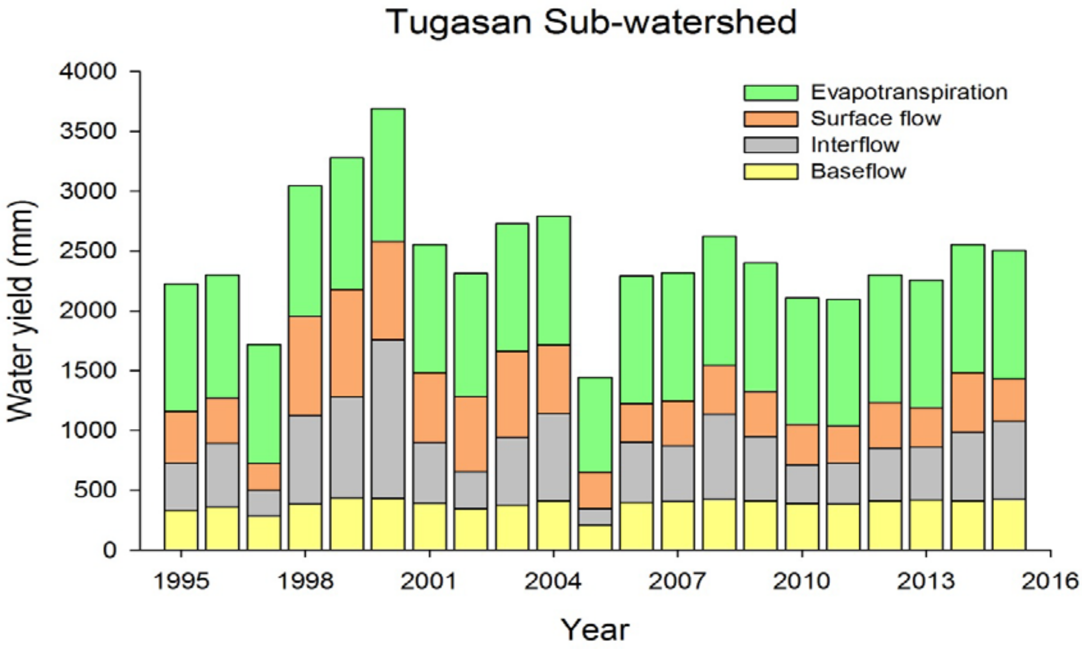

Figure 10. Flow simulation results for Tugasan sub-watershed

4.2.2 Alanib sub-watershed

Based on the simulation of GenRiver model, the average of evapotranspiration in Alanib sub-watershed was about 45% of the annual rainfall (Table 15). The average of river flow (river discharge) was about 56% that derived from surface flow (34%), interflow (8%) and base flow (13%). In the wettest year, the river flow can reach 69% of rainfall and the surface flow, interflow and base flow increased by 6%, 13% and 5%.

Table 15. The summary of water balance in Alanib sub-watershed as the result of GenRiver model simulation year 1995-2015

Water balance components	Min		Average		Max	
	mm	%*)	mm	%*)	mm	%*)
Rainfall	1305		2172		3802	
Evapotranspiration	686	27	925	45	1035	59
River flow	567	44	1246	56	2635	69
Surface flow	339	25	755	34	1530	40
Subsurface flow	17	1	210	8	780	21
Base flow	162	9	282	13	370	18

*) percentage to rainfall

Over 21 years simulation (1995-2015), evapotranspiration remain stable, although not as stable as in Tugasan sub-watershed. Surface flow, interflow and base flow varies and follows the pattern of rainfall in the area (Figure 11).

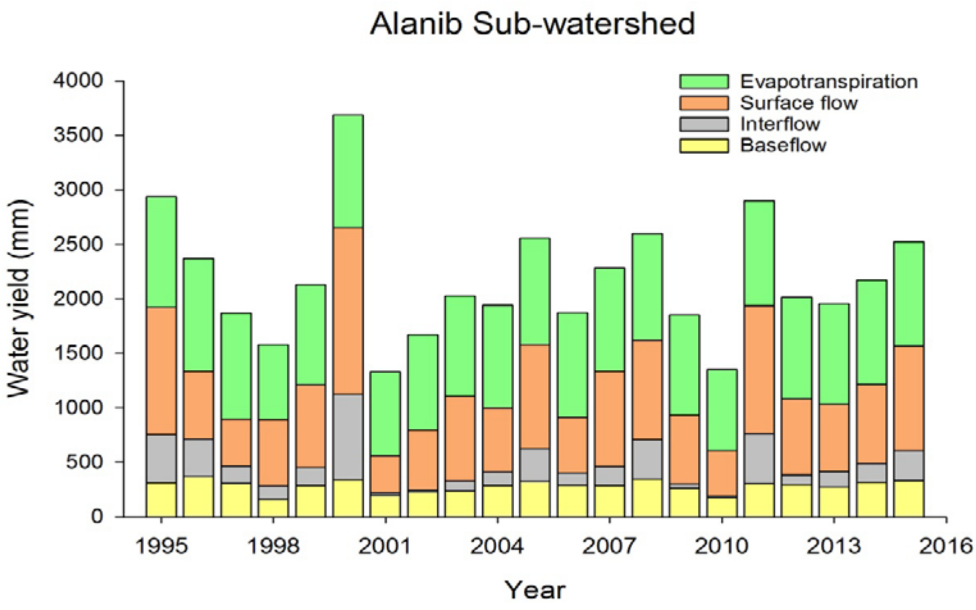

Figure 11. Flow simulation results for Alanib sub-watershed

4.2.3 Kulasihan sub-watershed

Based on the simulation of GenRiver model, the average of evapotranspiration in Kulasihan was the highest among the three, 50% of the annual rainfall (Table 16). The average of river flow (river discharge) was about 51% that derived from surface flow (26%), interflow (10%) and base flow (15%). In the wettest year, the river flow can reach 65% of rainfall and the surface flow, interflow and base flow increased by 12%, 13% and 4%.

Table 16. The summary of water balance in Kulasihan sub-watershed as the result of GenRiver model simulation year 1995-2015

Water balance components	Min		Average		Max	
	mm	%*)	mm	%*)	mm	%*)
Rainfall	1019		1873		2969	
Evapotranspiration	610	34	886	50	1059	67
River flow	412	30	987	51	1859	65
Surface flow	233	14	498	26	1052	38
Subsurface flow	1	0	223	10	553	23
Base flow	133	10	265	15	356	19

*) percentage to rainfall

Over 21 years simulation (1995-2015), evapotranspiration in Kulasihan was stable similar with Alanib sub-watershed. However, the variation of the surface flow in Kulasihan sub-watershed was the highest among the three sub-watershed (Figure 12).

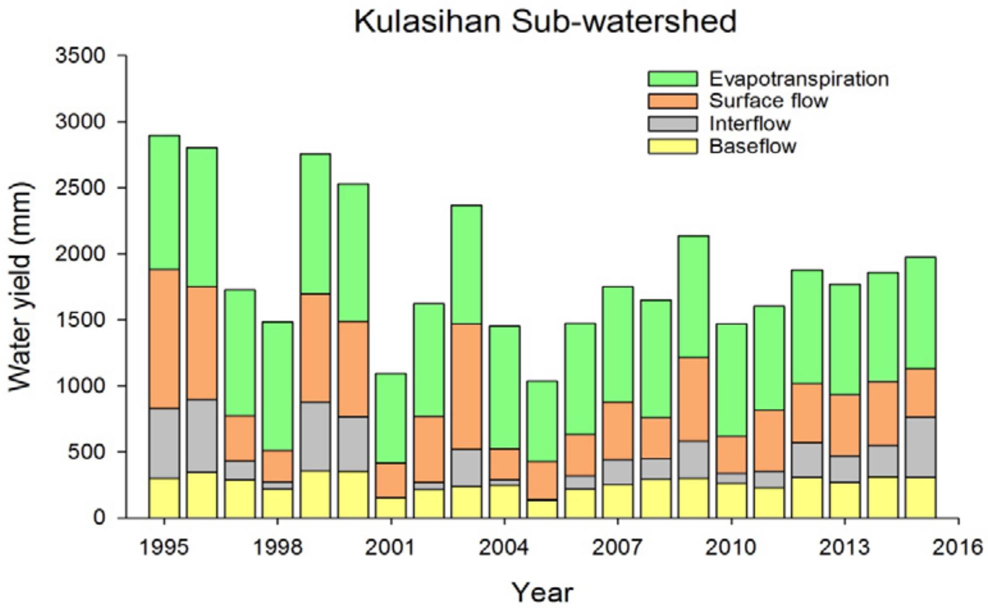

Figure 12. Flow simulation results for Kulasihan sub-watershed

4.3 Impact of Various Climate and Land Cover Change Scenarios on Future Water Balance (2016-2050)

Rainfall data that used by GenRiver model to simulate the future condition (2016-2050) used the rainfall data from 1995 to 2015, so that the rainfall in 2016 is equals to the rainfall in 1995, rainfall in 2017 is equals to the rainfall in 1996, etc. For the rainfall scenarios due to climate change, the rainfall data was corrected using the percentages from Table 3.

The temperature change will affect the amount of potential evaporation that calculated using Thornthwaite method. Table 17 shows the potential evaporation that was used in GenRiver model for the transition year 1995-2015, 2016-2035 and 2036-2050.

Table 17. Future potential evaporation for climate change scenario

Month	1995 - 2015	2016 - 2035	2036 - 2050
January	89	95	107
February	92	99	112
March	97	106	125
April	114	125	149
May	121	133	159
June	109	119	143
July	114	124	150
August	114	125	151
September	104	112	131
October	105	112	131

Month	1995 - 2015	2016 - 2035	2036 - 2050
November	118	127	149
December	106	114	131

4.3.1 Tugasan Sub-watershed

The result of GenRiver model shows that evapotranspiration and river flow from year 2015-2050 is not significantly different among the four scenarios of land cover change (Figure 13-16). However, if the river flow is separated into surface flows, subsurface flow and base flow, it showed a different trend. Converting all areas except forest and settlement into agroforestry will reduce surface flow and increase subsurface flow and base flow. On the contrary, if the cropland continually to expand, it will not have much impact on surface flow and base flow. However, a reduction in the subsurface flow at the end of year 2050 can be observed.

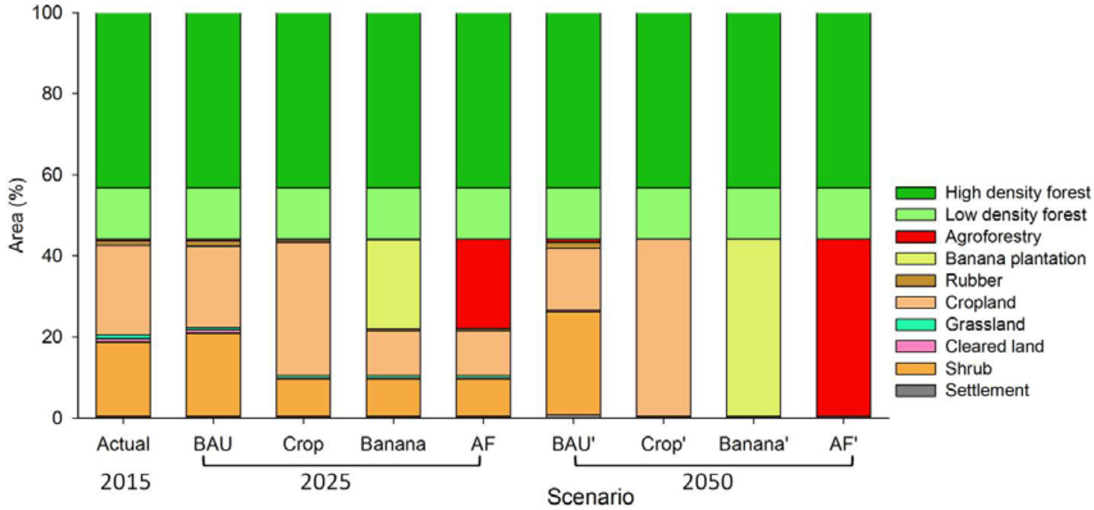

Figure 13. Various land cover scenario of Tugasan sub watershed (Note: AF = Agroforestry)

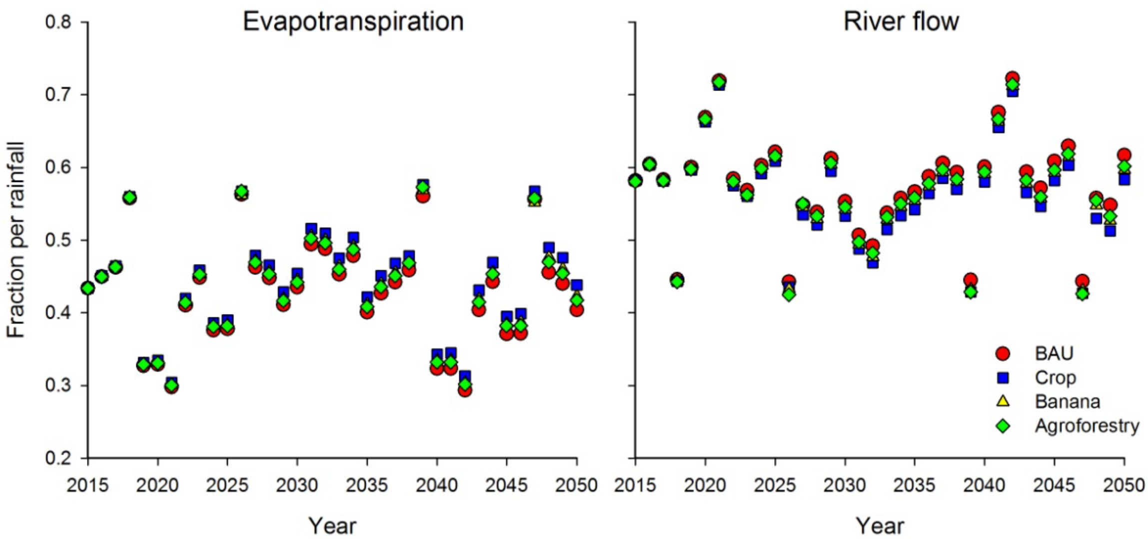

Figure 14. Evapotranspiration and river flow in Tugasan Sub-watershed for various land cover scenario from 2015-2050

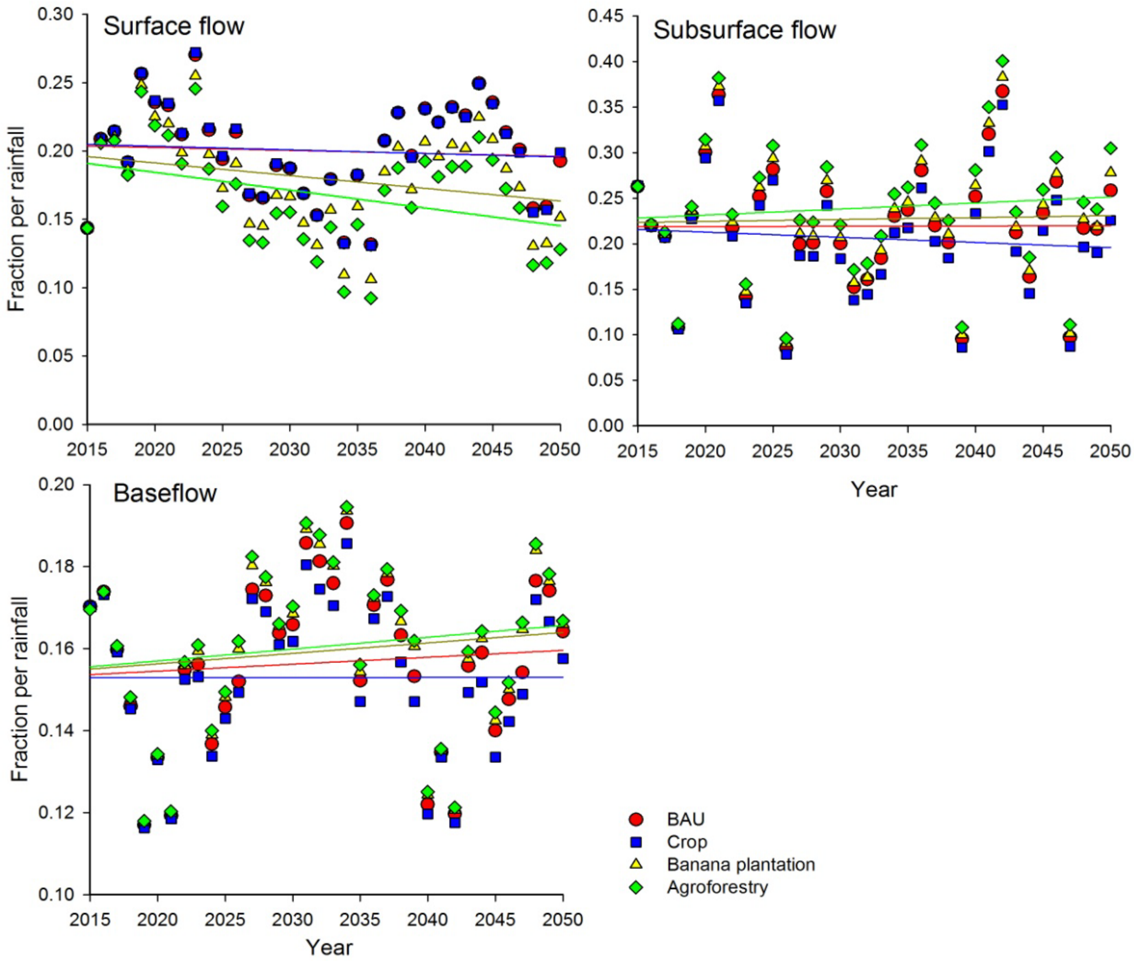

Figure 15. Fraction of river flow components for various scenario of land cover change in Tugasan Sub-watershed

The combination of land cover change and climate change scenario resulted to an increase the evapotranspiration and reduction in river flow (Figure 16). However, although all component of river flow decreased, subsurface flow was the most likely affected by climate change.

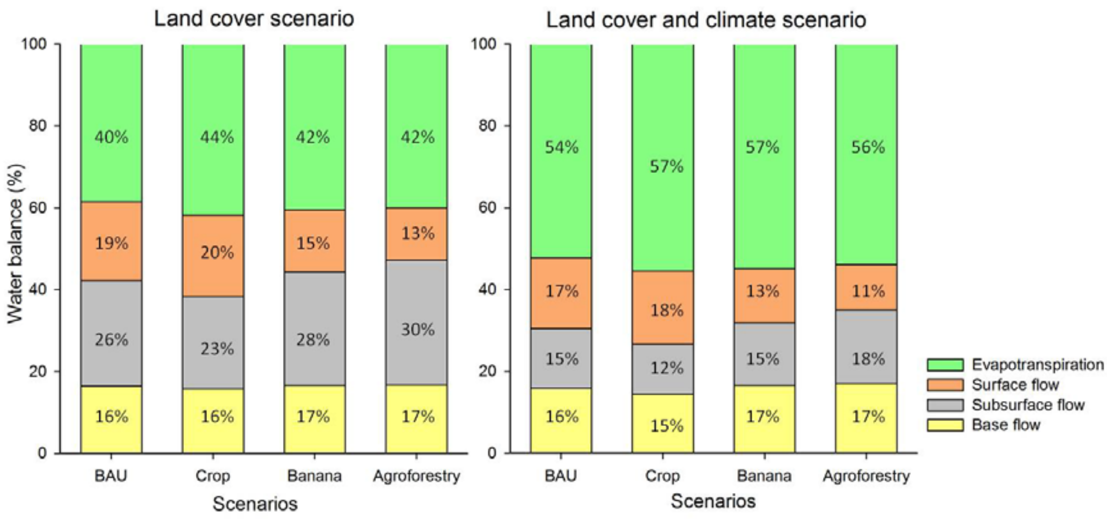

Figure 16. Water balance at year 2050 for various scenarios of land cover and climate change in Tugasan Sub-watershed

4.3.2 Alanib sub-watershed

The simulation result in Alanib sub-watershed did not show significant difference among all four scenario of land cover change from 2015-2050 (Figure 17-20). However, a different trend be observed if the river flow is sub-divided into surface flow, sub-surface flow and base flow (Figure 19). Converting 63% area of Alanib sub-watershed into Agroforestry will likely reduce the surface flow and increase the base flow, or at least keep it stable. On the contrary, BAU and crop scenario will significantly increase the surface flow.

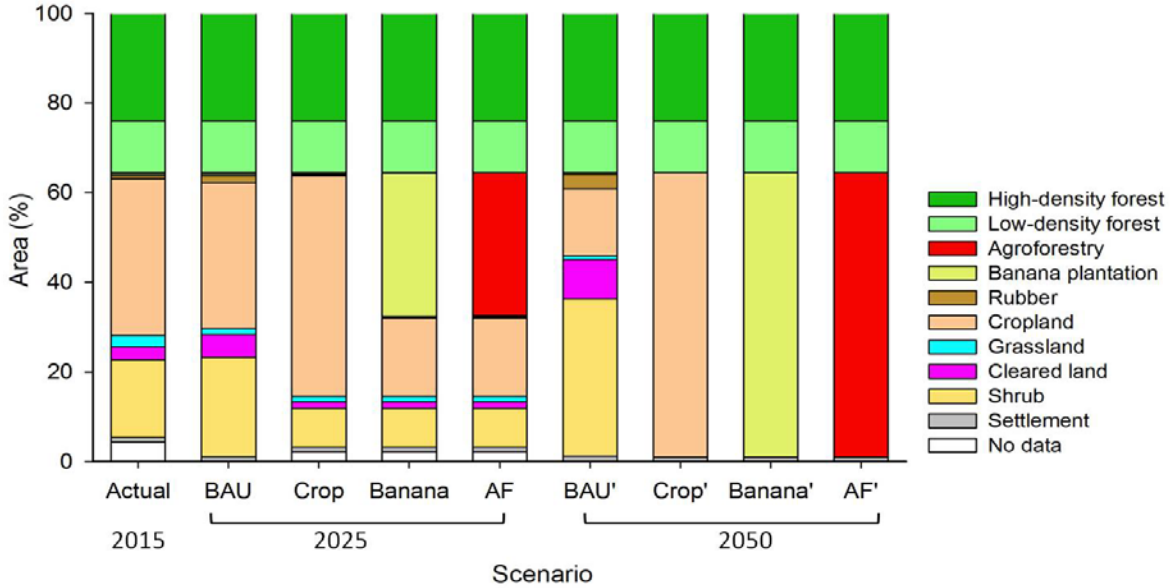

Figure 17. Various land cover scenario of Alanib Sub-watershed (Note: AF = Agroforestry)

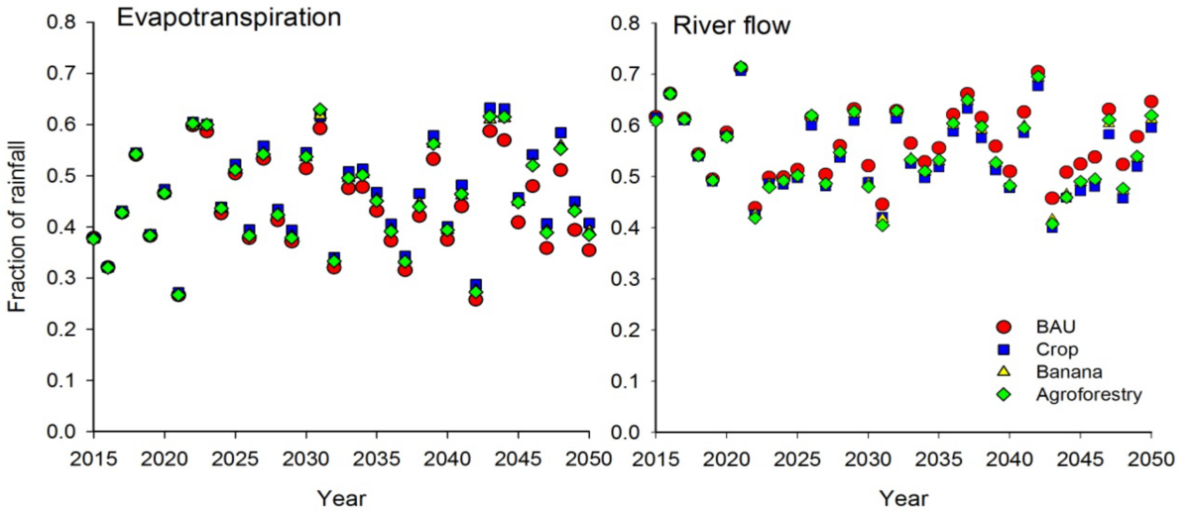

Figure 18. Evapotranspiration and river flow in Alanib Sub-watershed for various land cover scenario from 2015-2050

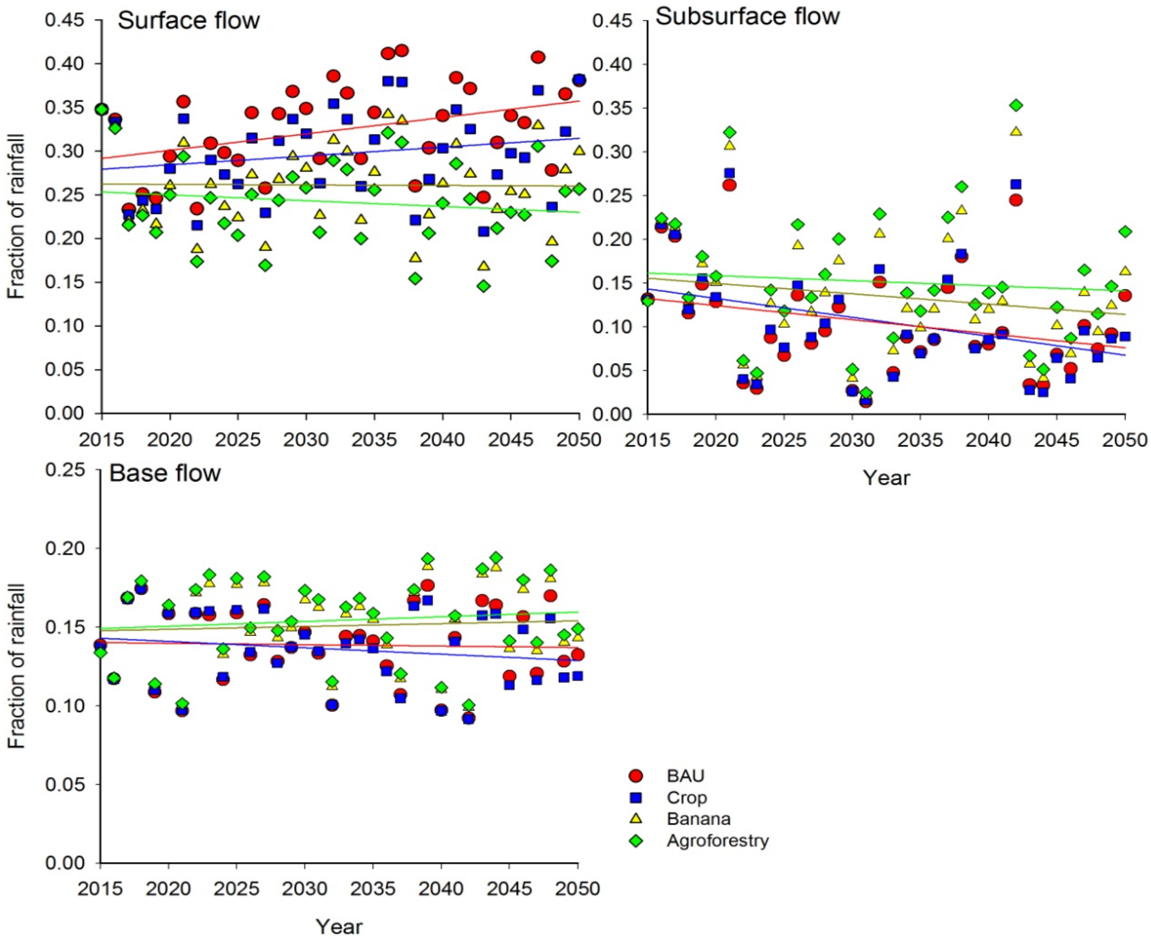

Figure 19. Fraction of river flow components for various scenario of land cover change in Alanib Sub-watershed

The impact of climate change on water balance in Alanib sub-watershed was the increase in evapotranspiration and decreased the river flow for all land cover scenarios (Figure 20). Subsurface flow was the river flow component that most affected by climate change.

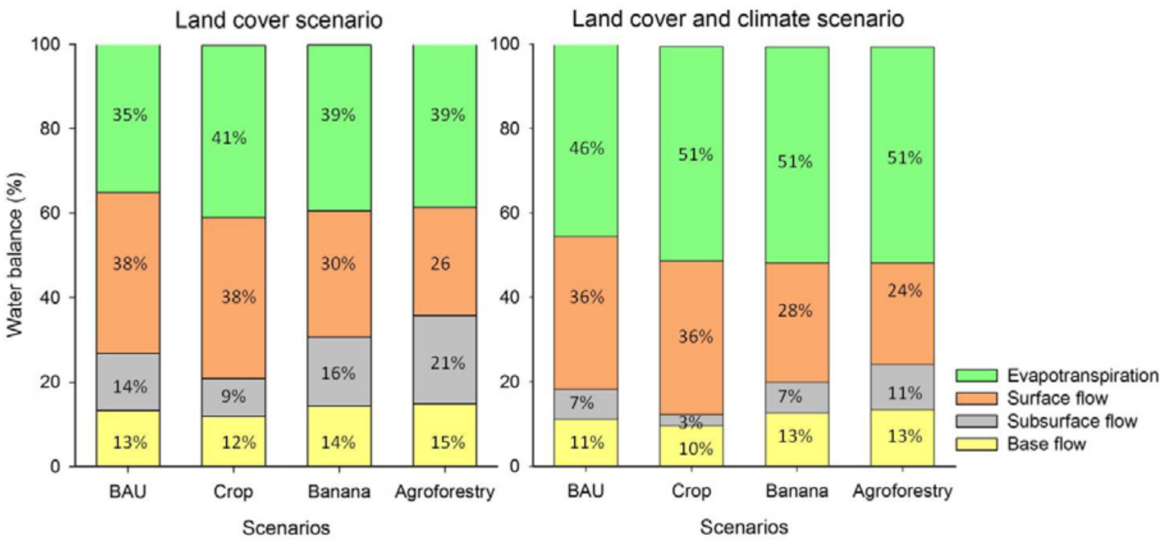

Figure 20. Water balance at year 2050 for various scenarios of land cover and climate change in Alanib sub-watershed

4.3.3 Kulasihan sub-watershed

During the 35 year of simulation period (2015-2050), all land cover scenarios show no significant difference except for the BAU scenario (Figure 21-24). Among the land cover scenarios, BAU showed the lowest evapotranspiration and the highest river flow that can be attributed to 'No data' in land cover type.

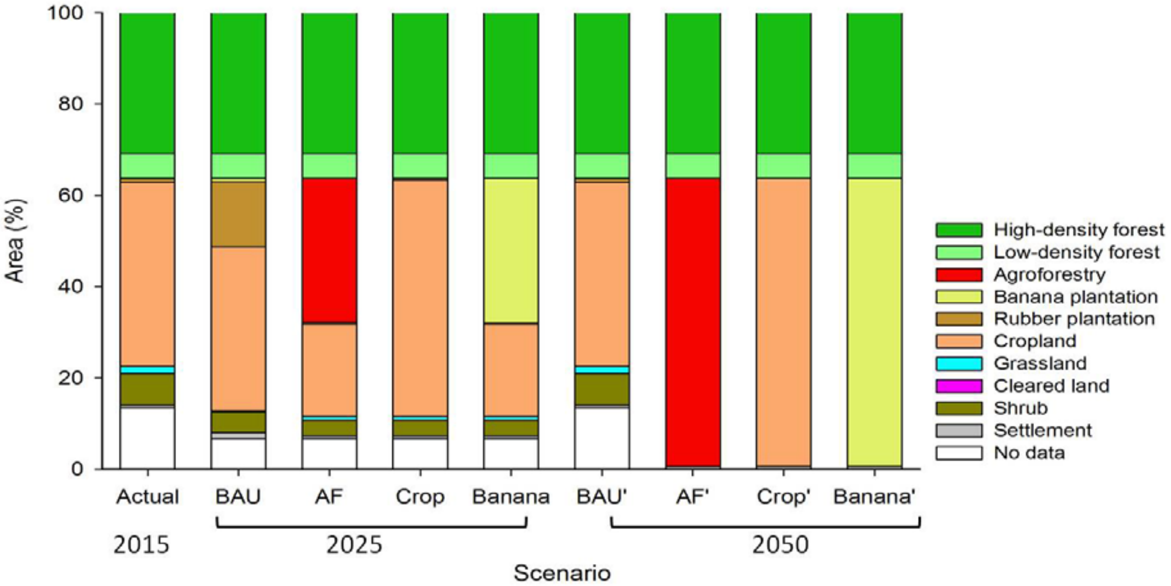

Figure 21. Various land cover scenario of Kulasihan sub-watershed (Note: AF = Agroforestry)

However, segregating the river flow components can show a different trend for each of scenarios (Figure 23). Converting almost all land cover type into crop area will likely increase the surface flow and significant reduction in the base flow. On the other hand, converting all land cover type except the forest area and settlement into agroforestry will keep the surface flow stable and increase the base flow.

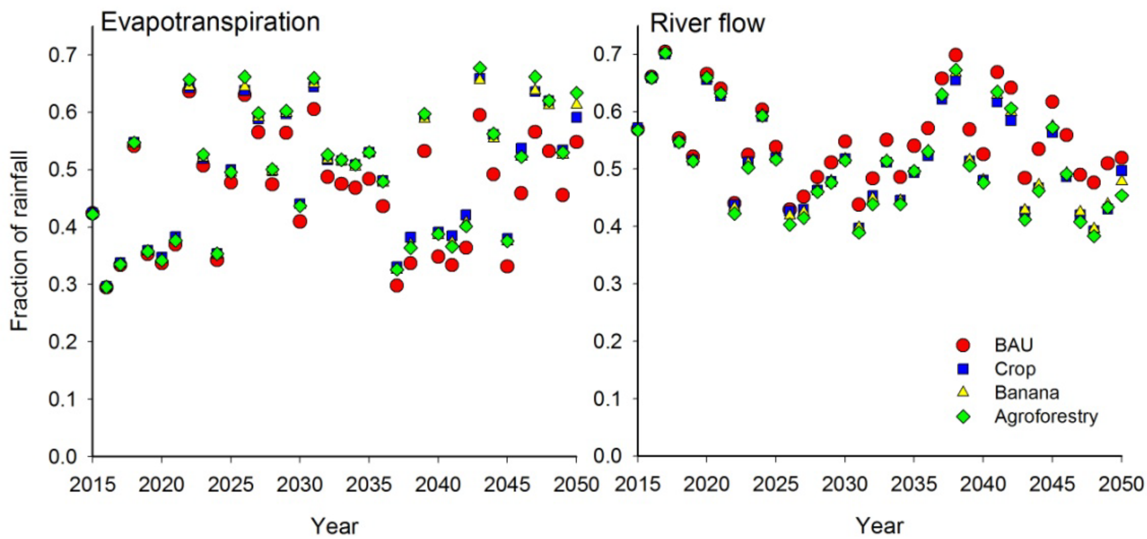

Figure 22. Evapotranspiration and river flow in Kulasihan sub-watershed for various land cover scenario from 2015-2050

The impact of climate change on water balance in Kulasihan sub-watershed were the increase in evapotranspiration and reduction of river flow for all land cover scenarios (Figure 24). Similar to Tugasan and Alanib Sub watershed, subsurface flow was also the river flow component that mostly affected by climate change.

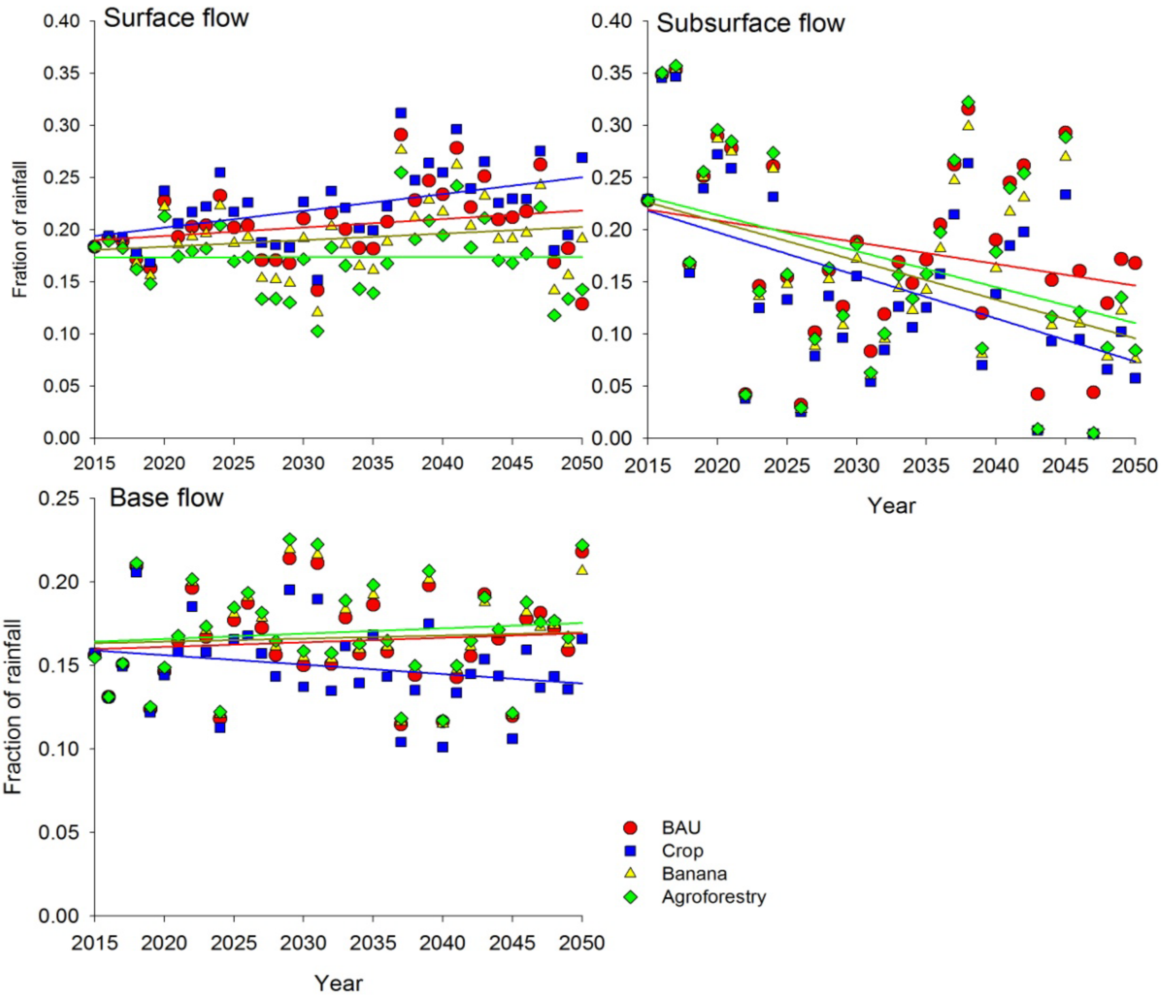

Figure 23. Fraction of river flow components for various scenario of land cover change in Kulasihan sub-watershed

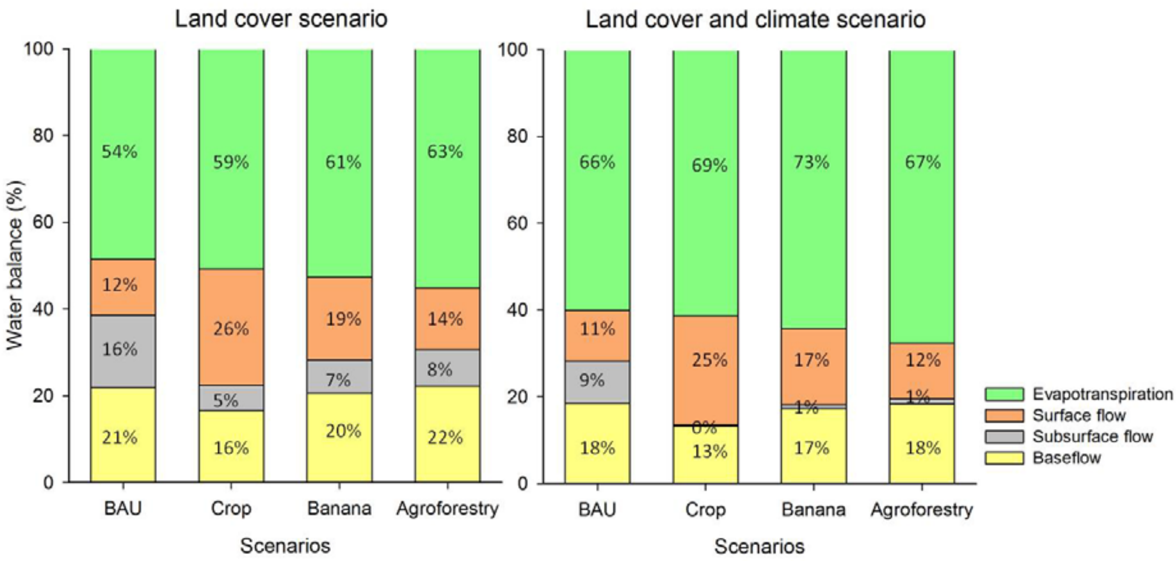

Figure 24. Water balance at year 2050 for various scenarios of land cover and climate change in Kulasihan sub-watershed

Discussion and Conclusion

During 21 years simulation period (1995-2015), the result of GenRiver model does not show any significant change of water balance in Tugasan, Alanib and Kulasihan sub-watershed. This can be attributed to lesser changes in the land cover types during the last 21 years. However, comparing the three sub-watersheds, Alanib had the highest surface flow and the lowest base flow. It can be noted that Alanib sub-watershed has smaller forest area (high-density and low –density forest) as compared the other two sub-watersheds. Conversion of other land uses or land cover from forest to agriculture significantly increased the runoff volume (Alibuyog et al 2009). Moreover, the findings of Alibuyog et al (2009) in predicting the effects of land use change on runoff in Manupali watershed suggests that if a whole watershed is converted to agriculture, about 15-32% increase in runoff volume can occur. A study conducted by Nugroho et al. (2013) using GenRiver model found that if a watershed is dominated by forest cover, surface runoff would be reduced significantly. Interestingly, the simulation results of this study conform with that of Nugroho et al (2013) and Alibuyog et al (2009) suggesting that conversion of forest land use or land cover to other uses would significantly alter the water balance resulting to an increase in surface runoff and river discharge. The forest area with various canopy layers has higher rate of rain water interception, stemflow and throughfall compared to other land cover types. This results to more water infiltrating the soil translating to increased water storage that is slowly released as discharge.

The simulation result of various land cover scenarios shows similar pattern in Tugasan, Alanib and Kulasihan sub-watershed. Agroforestry scenario can be considered as the best option for improving the watershed function thru lower surface flow and the higher base flow and subsurface flow. On the other hand, Crop and BAU scenario will significantly increase the surface flow which would result to frequent flooding of downstream communities during the rainy months while and a reduced base flow during dry season can lead to drought. The study of Trang et al (2017) suggest that land use/land cover change has significant impact on water quantity and quality in a river basin. Their study considered two land use scenarios, (1) conversion of forest to agriculture and (2) forest to grassland. Both land use scenario yielded similar change in water quantity. Macandog and Abucay (2012) in their study found that hedgerow agroforestry system significantly improved the subsurface flow of water, lesser soil evaporation rates as compared to monocropping system. Wang et al (2016) concluded in their study that agroforestry systems has greater water retention capacity and more vertical preferential water flow.

The climate change scenario based on the climate change projection in Bukidnon, Philippines, shows the decreasing amount of rainfall and increasing the air temperature. This condition will increase the evapotranspiration by vegetation, and as the result it will reduce the river flow. Additionally, climate change will reduce not only the surface flow but also the subsurface flow and base flow that which are important source of water during the dry season. Sample et al (2016) conducted a study on spatially distributed risk screening tool to assess climate and land use change impacts on water-related ecosystem services. Their study found that the combined climate and land use change scenarios have medium to high confidence in predicting the decline in water availability for irrigation. Furthermore, they also noted that future climate simulations can drastically reduce water runoff. Similarly, Jiang et al (2016) noted that rainfall and temperature play a crucial role in many hydrologic processes. An increase in rainfall can enhance water yield and soil conservation, while an increase in temperature is slightly correlated with Net Primary Productivity (NPP). For this study, the three sub-watersheds studied can expect lesser rainfall and increase in temperature based on the climate projections of the Philippine Atmospheric, Geophysical and Astronomical Services Administration (PAGASA). This would mean that while there would be positive effect on the NPP, the reduced rainfall could result to drought eventually affecting the overall productivity of various vegetation in the study area.

Anticipating the impacts of climate change therefore requires science-based decisions to consequently propose actions towards watershed management. Agroforestry system has been suggested to reduce and adapt the effects of climate change to smallholder farmers in the uplands (Luedeling et al 2014). Lasco et al (2014) has outlined socio-economic and environmental benefits of agroforestry systems to reduce risk associated with climate change. Agroforestry when complimented, supported and sustained thru proper policies for smallholder farmers can significantly reduce the impacts of climate change.

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The World Agroforestry Centre is an autonomous, non-profit research organization whose vision is a rural transformation in the developing world as smallholder households increase their use of trees in agricultural landscapes to improve food security, nutrition, income, health, shelter, social cohesion, energy resources and environmental sustainability. The Centre generates science-based knowledge about the diverse roles that trees play in agricultural landscapes, and uses its research to advance policies and practices, and their implementation that benefit the poor and the environment. It aims to ensure that all this is achieved by enhancing the quality of its science work, increasing operational efficiency, building and maintaining strong partnerships, accelerating the use and impact of its research, and promoting greater cohesion, interdependence and alignment within the organization.

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