Journal of Positive School Psychology http://journalppw.com
2022, Vol. 6, No. 3, 4379 – 4386

Land Use and Climate Change Impact Assessment of Hydrological Characteristics Of Addalam Watershed Using Soil And Water Assessment Tool (SWAT)

Sean L. Agbanlog

MSAE
seanagbanlog09@gmail.com

Abstract

Assessing the future environmental impact of climate change and land use change as it greatly affects the hydrologic processes and physical condition of the watershed is important as a mitigation and adaptation strategies to minimize risks and vulnerability of the watershed.

Prediction of the possible outcome of rainfall change in 2050 to the watershed was one important index that SWAT model has generated. The measures for the goodness-of-fit of model predictions used during the calibration and validation periods were the Coefficient of determination (R2) and the Nash Sutcliffe Simulation Efficiency (NSE), these numerical model performance measures the fraction of the variation in the measured data that is replicated in the simulated result of the model which was the basis of the acceptability of the model simulated values.

The SWAT model was parameterized and calibrated to simulate the hydrologic responses of the Addalam watershed to land use and climate changes using the A1B medium range climate scenario of PAGASA using the PRECIS (Providing Regional Climates for Impacts Studies, pronounced pray-sea) model. The A1B medium range climate scenario of PAGASA was used to capture the future impact of climate change and land use change. The seasonal temperature change and rainfall change in 2050 revealed a significant change in the annual water balance parameters of the watershed.

Application of the model on analysis of integrated climate and land use changes indicated the positive impact of scenario 3 (reforestation) reveals the reduction of surface runoff and sediment yield in 2050-time frame as compared to scenario 1 which represents 2050 climate and rainfall increase and scenario 2 (50% transformation of agricultural land to urbanization) of about 4.47% converting 50% of Agricultural land and 100% of grassland to forest area.

It was concluded that the increased surface runoff and sediment yield in 2050 time slices could trigger more landslide and erosion and flooding in low lying areas. And it will be recommended that adaptation strategies should be formulated to address these issues and associated impacts affecting development in the area. An advance planting dates of crops during dry months is one way of addressing farmers on the expected rainfall reducing the impact of water scarcity and hazards.

INTRODUCTION

The Addalam watershed of the Cagayan River Basin is home to the people of Quirino province and lower downstream is partly belongs to Isabela province. The Addalam river caters to the irrigation needs of ricelands in Cabarroguis, Aglipay and Saguday in Quirino, and nearby towns in Isabela. Didipio is a high-grade underground gold and copper mine located on the island of Luzon, where one of the gold mining company was operating. Oceana Gold Philippines Incorporation acquired Didipio, Nueva Vizcaya in 2006 through a merger with Climax Mining Ltd. and commenced commercial production as an open pit operation in 2013. In 2016, the mine transitioned from an open pit to underground operation, with production from the underground commencing in early 2017. This existence of mining company catches major concern in watershed management especially increasing of surface runoff and sediments.

Watershed Management is the process of implementing land use and water management practices to protect and improve quality of water and other natural resource within a watershed. It also defines the relationship between people, nature, land and water. Hence, balance between natural resources and the society should be achieved because people cannot be separated from nature. Quantitative prediction of land cover and climate change impacts on hydrologic processes is widely used to develop sound watershed management strategies. However, not much is yet understood about the hydrologic behavior of watersheds in the Philippines in response to land cover change and climate variability (Maria Graciela Anna S. Arceo et.al., 2018).

The increased agricultural land area, variability of rainfall and vegetation damage as influenced by Climate Change and changes in land use pattern can lead to the change in hydrological equilibrium in a watershed system. Climate change and other factors aggravates the unnatural hydrologic processes that contributes destructive phenomena such as droughts and floods. Flash floods causes severe natural disasters over the world generating property and infrastructures damages, poverty and loss of human life, among others (J. Abellan, et.al., 2018).

Land use, land cover and climate change (CC) can significantly influence the hydrologic balance and biogeochemical processes of watershed systems. These changes can alter interception, evapotranspiration (ET), infiltration, soil moisture, water balance, and biogeochemical cycling of carbon, nitrogen, and other elements. Changes in climate and land cover increase surface runoff significantly by 2100 as well as stream discharge. Combined change in land cover and climate cause 10% increase in peak volume with 7% increase in precipitation and 75% increase in effective impervious area. Climate and land use changes can intensify the water cycle and introduce seasonal changes in watershed systems. Understanding dynamic changes in watershed systems is critical for mitigation and adaptation options. (A. Talib, et.al., 2017).

DISCUSSION OF RESULTS

Simulated Water Balance Components Production in Addalam Watershed.

Table 6 and 7 shows the annual and monthly components of water balance in the watershed including the amount of sediment or erosion rate and as graphically showed in Figure 12. As presented, average monthly hydrological processes peaks during rainy season in the watershed except for evapotranspiration which is largest during dry months. From the annual average rainfall from 1986 to 2016 computed at 2,137.9 mm, 3.05% were transformed in a form of runoff, 16.98% for shallow ground water recharge, smallest amount of 1.33% for deep aquifer recharge having its total aquifer recharge of 26.51% and gaining the Water yield (Streamflow) gained the highest amount of rainfall of 73.93% and 17.72% are being consumed to meet evapotranspiration demand. Evapotranspiration rate are highest during the months of February to June. Total sediment yield range was 7.024 ton/ha at 19.09% average monthly increase attributed to projected higher rainfall from July to December. The highest monthly value and rate is computed in the month of November at 2.11 tons/ha and 29.97% respectively.

Table 6. Annual Water Balance in Addalam Watershed.

PARAMETERS	AMOUNT (mm)	PERCENT OF RAINFALL
Rainfall	2137.9	

Surface Runoff	65.28	3.05
Shallow Groundwater Recharge	362.97	16.98
Deep Aquifer Recharge	28.34	1.33
Total Aquifer Recharge	566.85	26.51
Total Water Yield (Streamflow)	1580.59	73.93
Percolation	569.66	26.65
Potential Evapotranspiration	903.7	42.27
Evapotranspiration	378.8	17.72

Table 7. Average Monthly Parameter Values of Addalam Watershed.

MONTH	RAIN (mm)	SURF Q (mm)	LAT Q (mm)	WATER YIED (mm)	ET (mm)	SEDIMENT YIELD (T/Ha)	PET (mm)
JAN	71.86	1.75	36.09	85.09	19.19	0.23	45.18
FEB	55.36	0.15	27.09	47.58	18.64	0.03	63.88
MAR	57.18	0.11	26.19	36.5	23.75	0	69.43
APR	68.56	0.09	31.91	38.22	33.57	0	103.76
MAY	199.17	1.71	99.67	111.17	46.49	0.03	102.13
JUN	171.46	1.86	86.65	109.61	41.2	0.03	97.41
JUL	211.51	4.48	108.03	137.77	40.35	0.17	92.66
AUG	230.25	7.04	120.64	161	40	0.42	94.92
SEP	242.96	6.06	131.17	177.56	36.27	0.7	77.71
OCT	278.04	11.43	151.45	213.23	32.84	1.39	68.44
NOV	310.94	18.37	171.62	249.1	25.47	2.11	49.59
DEC	242.04	12.25	134.29	215	21.54	1.93	40.27
TOTAL	**2139.3**	**65.3**	**1124.8**	**1581.83**	**379.31**	**7.04**	**905.38**

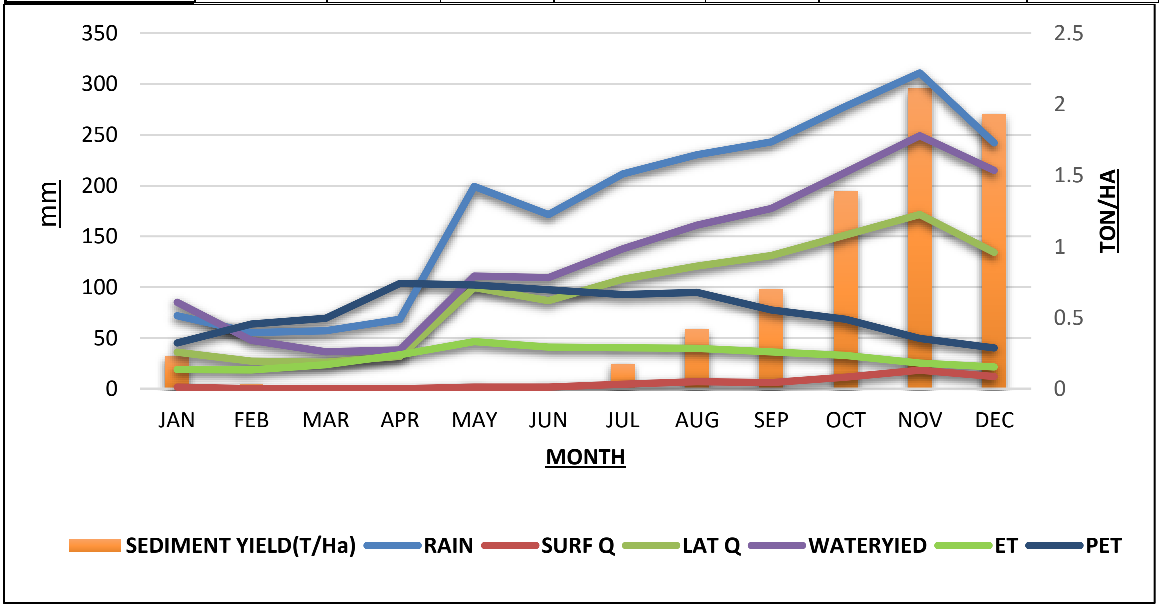


Figure 12. Average monthly values and sediment yield in tons/ha

Calibrated Values of SWAT Model Parameters for Addalam Watershed.

Table (8) below showed the calibrated parameters of the SWAT model for the Addalam watershed. These values were used for validation and later for application.

Table 8. Calibrated SWAT parameters for Addalam watershed.

Parameter	Description	Calibrated Value
SOL_AWC	Available soil water content	0.355
ESCO	Evaporation compensation factor	0.95
ALPHA_BF	ALPHA_BF	0.048
CN2	SCS curve number for soil moisture condition	35
USLE_P	USLE practice factor	1
GW_DELAY	Groundwater delay (days)	5000
GWQMN	Threshold depth of water in the shallow aquifer required	1000
GW_REVAP	Groundwater "revap" coefficient	0.1

The SWAT simulation reproduced the observed discharges and their variation in time but tended to overestimate the streamflow during dry periods. The overestimation may indicate that the model is nor entirely capturing the dynamics of the groundwater components or is not simulating adequately the evapotranspiration capacity of the vegetation. The in accuracy of the model performance during periods maybe also associated with the objective function (NSE) used to calibrate the model, which tends to rely more on model performance during flood events. In line with these results, SWAT has been shown to be weak when simulating low flows in other areas, thus calibration did not cover the most extreme rainfall events of the entire period, resulting in a poor performance during the validation (Zamora et.al., 2018).

In addition, event timing was simulated relatively accurately although a few hydrographs display a slight lag in the timing peaks. This lag tends to suggest that factors including the spatial variation and resolution of the precipitation product may impact the model performance in simulating peak timing and routing (Smith et.al., 2004). Some reasons also may indicate by unexpected storm events during dry season or absence of storm during expected wet seasons. One situation cited from the graph (Figure 15) was the occurrence of storm during the dry months of 2005.

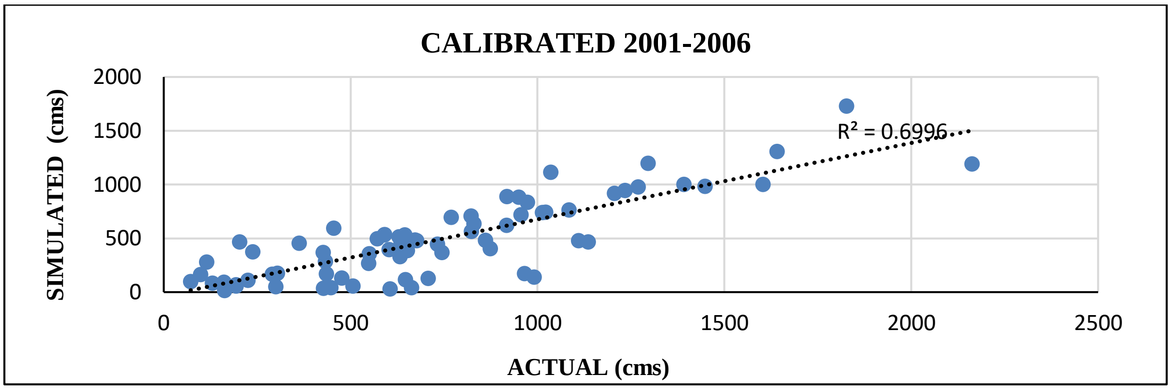


Figure 13. Comparison of the monthly simulated and actual streamflow for the calibration period.

The month of January to May 2005 showed a reverse result between the actual and calibrated streamflow indicating a sudden increase during the dry months of February to May which expectedly a decrease of water yield on that period. The increase of flow in that period showed that there was an entry of typhoons-*Auring* and *Bising* in the month of March 2005 showing an increase of water yield and caused an underestimated value of calibrated from the actual. Overall, the results, thus indicated that hydrologic processes in SWAT were modeled realistically and thus, can be extended to simulate other hydrologic process including various land use and climate change scenarios. The simulated streamflow in the gauging station were lumped into monthly totals and compared with the monthly measured streamflow.

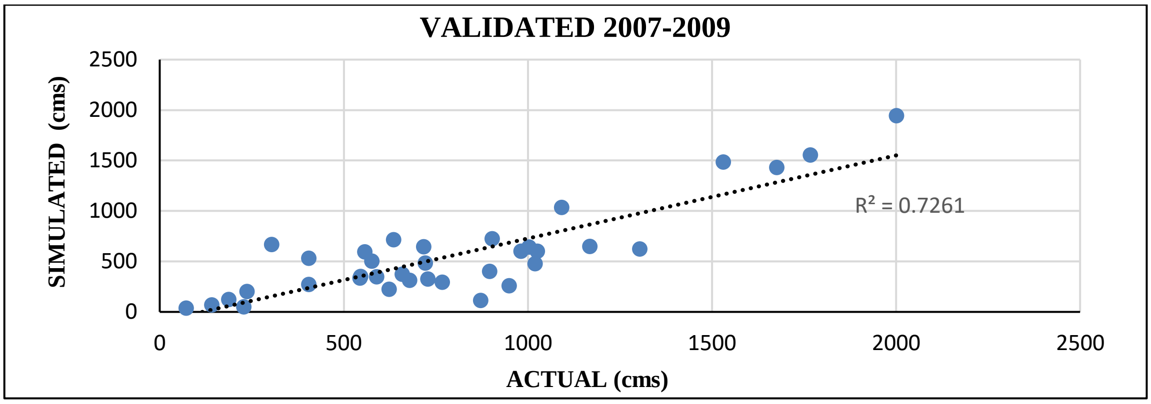


Figure 14. Comparison of the monthly simulated and actual streamflow for the validation period.

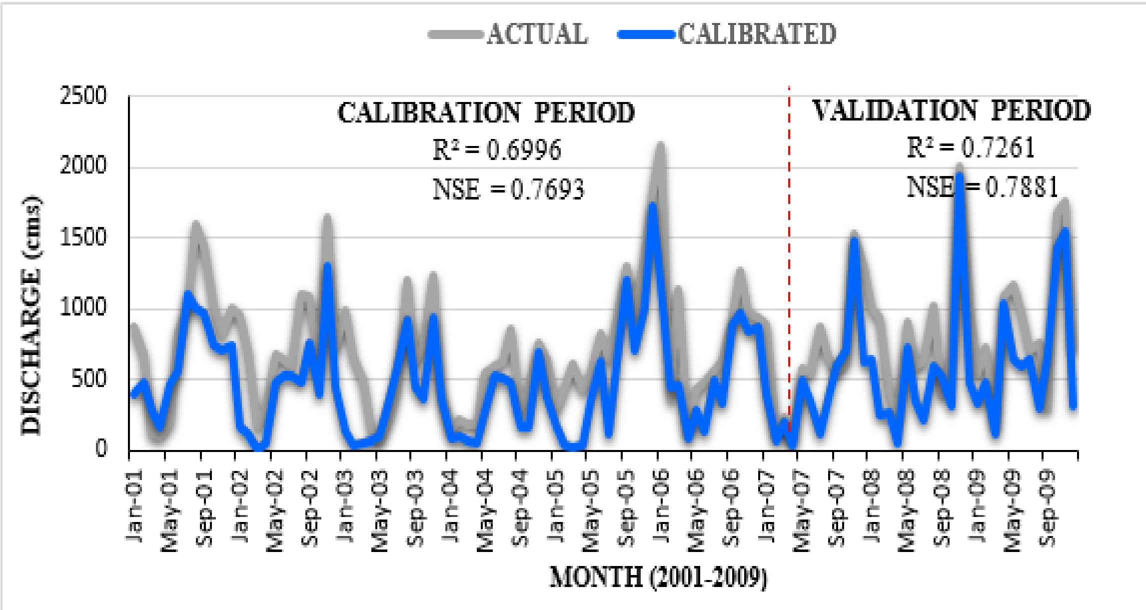


Figure 15. Monthly observed and simulated streamflow in the study area.

Results showed that the simulated and measured streamflow were matched well (Figure 15) with coefficient of determination, R^2 of 0.6996 in calibration period (Figure 13) and 0.7261 in validation period (Figure 14). The adequacy of the SWAT model to simulate the streamflow was also indicated by the positive NSE value of 0.7693 under calibration period and 0.7881 under validation period. The adequacy of the model was further indicated by its clear response to extreme rainfall events resulting in high streamflow.

Simulation of Hydrologic Impacts of Land Use and Climatic Change Scenarios

The calibrated SWAT model was used in assessing the impact of increasing temperature and rainfall changes on the water balance of the watershed. The computed seasonal temperature and rainfall changes in 2050 under the A1B medium-range scenario were used to generate synthetic rainfall and temperature data for the period 2036-2065. The generated data were then used to run the calibrated SWAT model to simulate the water balance of watershed.

Results of the simulation showed that there would be likely increase in water yield, surface runoff and sediment yield (Table 9) in 2050 time slices as a result of the increase annual rainfall amount in the watershed. Water yield during the summer months of February to May would likely decreased as consequence of less rainfall during these period. Such decrease in the water yield of the watershed during the summer months may result to shortage of water supplies affecting rainfed crop production at the later part of dry cropping season.

On the other hand, the simulated surface runoff and sediment yield also showed that there would be likely increase of surface runoff and sediment yield in 2050 time slices which could trigger more landslide and erosion and flooding in low lying areas. Adaptation strategies should be formulated to address these issues and associated impacts affecting development in the area.

Table 9. Simulated monthly baseline and 2050 percent increase of surface runoff, water yield and Sediment Yield in Addalam watershed.

MONTH	**Baseline**			**2050**			**% Increase**		
	Surface Runoff, mm	Water Yield, mm	Sediment Yield, tons/ha	Surface Runoff, mms	Water Yield, mm	Sediment Yield, tons/ha	Surface Runoff, mm	Water Yield, mm	Sediment Yield, tons/ha
Jan	1.75	85.09	0.23	3.25	104.31	0.6	85.7	22.6	160.9
Feb	0.15	47.58	0.03	0.36	61.6	0.09	140.0	29.5	200.0
Mar	0.11	36.5	0	0	29.62	0	-100.0	-18.8	0.0
Apr	0.09	38.22	0	0	25.28	0	-100.0	-33.9	0.0
May	1.71	111.17	0.03	0.29	71.67	0	-83.0	-35.5	-100.0
Jun	1.86	109.61	0.03	2.78	110.29	0.05	49.5	0.6	66.7
Jul	4.48	137.77	0.17	5.98	146.57	0.33	33.5	6.4	94.1
Aug	7.04	161	0.42	9.01	174.13	0.7	28.0	8.2	66.7
Sep	6.06	177.56	0.7	6.23	181.73	0.86	2.8	2.3	22.9
Oct	11.43	213.23	1.39	11.82	216.5	1.59	3.4	1.5	14.4
Nov	18.37	249.1	2.11	18.93	253.44	2.41	3.0	1.7	14.2
Dec	12.25	215	1.93	23.07	260.53	4.12	88.3	21.2	113.5

Table 9 showed also a negative percentage increase of surface runoff, water yield and sediment yield in the period of March to May due to the projected Seasonal temperature increases and rainfall change in 2050 under the medium-range scenario (A1B) in the province of Isabela which showed a negative projection percentage increase of -29.2 % of rainfall and highest increased of temperature of about 2.1 ºC indicating lower amount of surface runoff, water yield and sediment yield than the actual measured value.

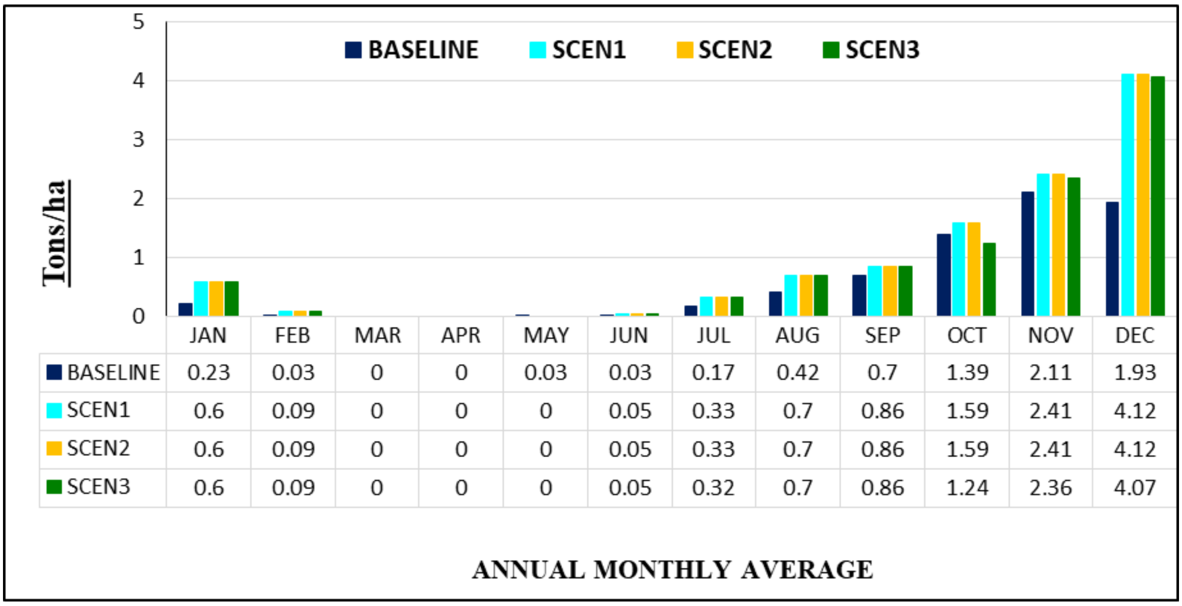
Result highlights of simulation were shown in Figure 16 and Table 10 as follows:

1) Scenario 1: As shown in Figure 16, total increase in annual rainfall would be 3.04% or 64.9 mm resulting to increases in run-off and water yield at 25.2% and 3.36%, respectively; all other parameters increases against baseline like percolation increase of about 2.45%, evapotranspiration increase of 1.95% and 52.7% sediment yield expectedly as surface runoff increased.
2) Scenario 2: Simulation showed a 25.25% or 16.48 mm increase in runoff, 3.36 % or 53.13 mm increase in water yield, 6.52% increase in percolation and 0.25% decreased in evapotranspiration.
3) Scenario 3: Result reveals that this scenario condition will result to significant reduction of erosion in 2050 by 12.09% for the month of October against baseline, 4.47% against scenario1 and scenario 2 which is translated to 0.15 during the month of October and 0.46 tons per hectare during rainy months from July to December.

Table 10. *Simulated annual water balance of the different scenarios in Addalam watershed.*

Parameters	**Baseline**		**Scenario 1**		**Scenario 2**		**Scenario 3**	
	Amount (mm)	Percent of Rainfall	Amount (mm)	Percent of Rainfall	Amount (mm)	Percent of Rainfall	Amount (mm)	Percent of Rainfall
Rainfall	2137.9		2202.8		2202.8		2202.8	
Surface Runoff	65.28	3.05	81.73	3.71	81.76	3.71	81.71	3.71
Shallow Groundwater Recharge	362.97	16.98	372.22	16.9	372.16	16.89	371.8	16.88
Deep Aquifer Recharge	28.34	1.33	29.02	1.32	29.01	1.32	28.88	1.31
Total Aquifer Recharge	566.85	26.51	580.3	26.34	580.28	26.34	579.99	26.33
Total Water Yield (Streamflow)	1580.89	73.93	1634.07	74.18	1634.02	74.18	1633.92	74.17
Percolation	569.66	26.65	583.63	26.49	583.61	26.49	583.3	26.48
Potential Evapotranspiration	903.7	42.27	959.4	43.55	959.4	43.55	959.4	43.55
Evapotranspiration	378.8	17.72	386.2	17.53	386.2	17.53	386.3	17.54

Journal of Positive School Psychology
2022, Vol. 6, No. 3, 4379 – 4386



	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
BASELINE	0.23	0.03	0	0	0.03	0.03	0.17	0.42	0.7	1.39	2.11	1.93
SCEN1	0.6	0.09	0	0	0	0.05	0.33	0.7	0.86	1.59	2.41	4.12
SCEN2	0.6	0.09	0	0	0	0.05	0.33	0.7	0.86	1.59	2.41	4.12
SCEN3	0.6	0.09	0	0	0	0.05	0.32	0.7	0.86	1.24	2.36	4.07

Figure 16. Simulated baseline sediment yield and across scenarios.

CONCLUSIONS

Based from the result of the analysis, the following conclusions were drawn;

1. Results show that the simulated and measured streamflow were matched well with coefficient of determination, R^2 of 0.6996 in calibration period and 0.7261 in validation period. The adequacy of the SWAT model to simulate the streamflow is also indicated by the positive Nash-Sutcliffe model Efficiency (NSE) value of 0.7693 under calibration period and 0.7881 under validation period which was greater than the threshold acceptable value of 0.50 and 0.60, respectively.
2. Water yield during the summer months of February to April would likely decreased as consequence of less rainfall during these period. Such decrease in the water yield of the watershed during the summer months may result to shortage of water supplies affecting rain fed crop production at the later part of dry cropping season.

The positive impact of reforestation revealed the reduction of surface runoff and sediment yield in 2050-time frame as compared to scenario 1 and 2 which was reduced of about 4.47% by converting about 50% of Agricultural land and 100% of grassland to forest area.