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ORIGINAL RESEARCH PAPER

# Hydrologic responses of watershed assessment to land cover and climate change using soil and water assessment tool model

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## ABSTRACT

Predicting the impact of land cover and climate change on hydrologic responses using modeling tools are essential in understanding the movement and pattern of hydrologic processes within the watershed. The paper provided potential implications of land conversions and climate change scenarios on the hydrologic processes of Muleta watershed using soil and water assessment tool model. Model inputs used include interferometric synthetic aperture radar-digital elevation model, 2016 land cover map, soil map, meteorological and hydrologic data. The model was calibrated using appropriate statistical parameters ($R^2$=0.80, NS=0.80 and RSR=0.45). Model validation using observed streamflow with the same statistical parameters ($R^2$ = 0.79, NS = 0.67 and RSR = 0.57) showed that the result was statistically acceptable. The model provided potential implications of land conversions and climate change adversely affecting hydrologic processes of critical watersheds. Climate change projections with a 13% decrease in rainfall directly influenced the decrease in hydrologic processes. Meanwhile, urbanization had influenced the increase in surface runoff, evapotranspiration, and baseflow. The increase of forest vegetation resulted in a minimal decrease in baseflow and surface runoff. The watershed hydrologic processes were influenced by changes in land cover and climate. Results of this study are useful by the localities and policy makers in coming up with a more informed decision relative to the issues and concern on hydrological responses in the uplands.

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## INTRODUCTION

It has been widely studied that climate change and anthropogenic activities, specifically extensive land cover change, are considered major factors influencing the shifting of hydrologic processes of the watershed (Petchprayoon *et al*., 2010; Khoi and Suetsugi, 2014; Li *et al*., 2015; Briones *et al*., 2016; Zhou *et al*., 2017). Climate change has influenced the recurrence of extreme rainfall events resulting to destructive soil erosion, flooding, and landslides triggered by poor land conservation practices and increasing urbanization within critical watersheds (Alibuyog *et al*., 2009; Trinh and Chui, 2013). These natural and anthropogenic environmental problems have been experienced in Muleta watershed, one of the major watersheds in the south-central

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portion of Bukidnon province. The Muleta River is one of the major tributaries of the Pulangi River Basin, a major watershed in Mindanao (Dumago *et al*., 2018). It served as the source of irrigation and potable water in neighboring municipalities within Bukidnon. However, extensive expansion of agricultural activities in higher elevated areas increases native forest and grassland conversions into agricultural land. Moreover, rapid urbanization driven by the increasing population has become prevalent in Muleta watershed. With this, Muleta watershed is critically degraded and threatened from these anthropogenic and natural stressors affecting its hydrologic processes and water balance. Predicting hydrologic responses of watersheds using models applied with scenario analysis enable to study the effects of human interventions and the impacts of climate change on water quantity and quality (Li *et al*., 2015; Teshager *et al*., 2016; Michaud *et al*., 2007). Thus, hydrologic modeling is an essential tool and cost-effective process in understanding the movement of water balance within a watershed (Combalicer *et al*., 2010). This paper used the soil and water assessment tool (SWAT) model to simulate hydrologic processes influenced by land cover and climate change scenarios within the Muleta watershed. Several published studies used the SWAT model and provided significant impacts of land cover conversions and climate change on surface runoff, sediment yield, and other hydrologic processes in watersheds across the Philippines (Alibuyog *et al*., 2009; Palao *et al*., 2013; Briones *et al*., 2016) Understanding the impact of land cover and climate change on the watershed hydrology enables to alleviate the occurrence of critical shifts on hydrologic processes. In addition, this will aid in assessing the water availability that could sustain the increasing demand of growing population, agricultural expansion, and industrialization, among others (Al-Bakri *et al*., 2013) Evaluating the impacts of land conversions and climate change are important in order for appropriate land use management practices and policy interventions to be implemented by local government units within the Muleta watershed. This paper aimed to determine the hydrologic responses to land cover and climate change of Muleta watershed using SWAT model. Specifically, this paper aimed to simulate the impact of land cover and climate change scenarios on evapotranspiration, surface runoff, and

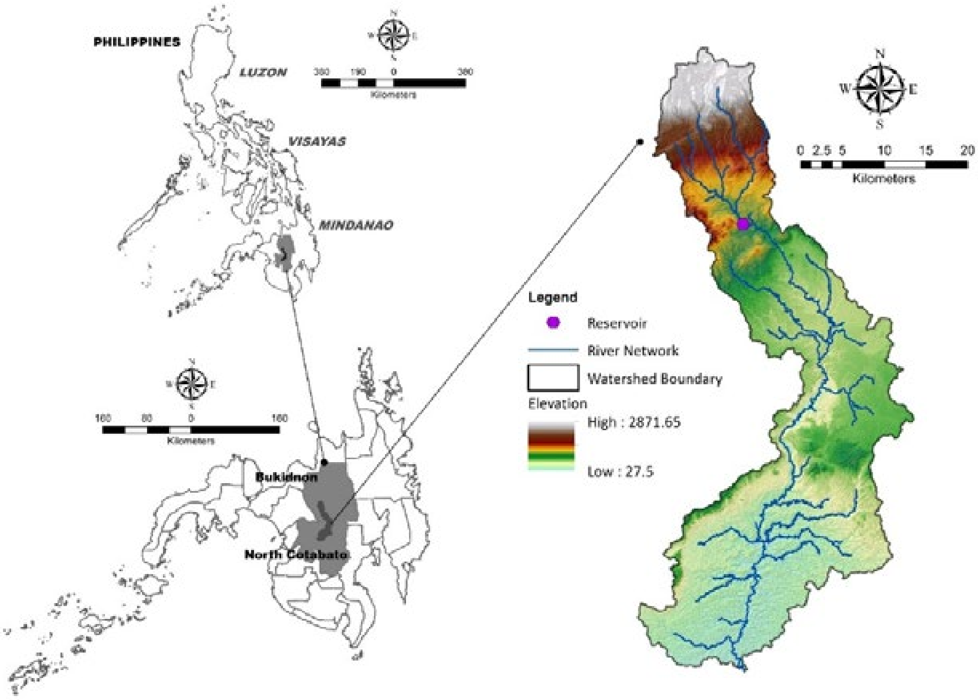

Fig. 1: Geographic location of the study area in Muleta Watershed

baseflow. This study has been carried out in Muleta Watershed in Bukidnon, Philippines during 2017 to 2018.

## MATERIALS AND METHODS

### *Study area description*

Muleta Watershed is located in the southwest part of Bukidnon province and northwest of North Cotabato province (Fig. 1). It lies between 124°44'40.28" to 125°2'41.98" east longitude and 7°58'14.17" to 7°17'36.63" north latitude. The river, stretching 100.85 kilometers (km) long, runs from the Mount Kalatungan Natural Range Park (MKaNPK) in Bukidnon and drains to Pulangi River in North Cotabato. It is comprised of 12 municipalities and one city namely: Talakag, Pangantucan, Maramag, Don Carlos, Kitaotao, Pangantucan, Kibawe, Kadingilan, Dangcagan and Damulog, and Valencia City of Bukidnon Province and the municipality of Carmen of North Cotabato Province. The Muleta watershed covers a drainage area of approximately 104,826 ha. The watershed has an average altitude of 435.67 masl and mean slope of 25.18%.

### *Land cover*

Land cover data used for the SWAT model simulation was generated using Sentinel-2 image acquired on July 2016. The Sentinel-2 satellite image is equipped with the state-of-the-art Multispectral Imager Instrument (MSI) that offers high-resolution, up to 10 meters (m), optical images (Addabbo *et al.*, 2016). The year of downloaded satellite image was subjected to the image availability with less cloud cover. The Sentinel-2 image was pre-processed for atmospheric correction using Sen2Cor processor version 6.0.2 in Sentinel-2 Toolbox (Djamai and Fernandes, 2018; Louis *et al.*, 2016). This was processed through European Space Agency's Sentinel Application Platform (SNAP) version 6.0 software prior to image land cover classification. The object-based support vector machine (SVM) algorithm was performed in generating land cover data with 91% overall accuracy using the eCognition version 9.0.1 and Google Earth Pro image interpretation as the ground truth of reference (Briones *et al.*, 2016; Santillan *et al.*, 2011; Wessel *et al.*, 2018). The Muleta watershed was mostly dominated with agricultural land having a total area of 59,385.00 ha (Table 1). The SWAT name for each land cover was assigned in reference to the SWAT database.

### *Soil*

Soil type map of Muleta watershed was based from the Philippine soil map produced by the Bureau of Soil and Water Management (BSWM) of the Philippines. Soil types and identification were collected from a series of soil survey dated 1964 with varying scale of 1:50,000 to 1:10,000 (Briones *et al.*, 2016). Muleta watershed was composed of 8 soil types and Macolod clay was the dominant soil type accounted for a total of 24,061.96 ha (Table 2).

### *SWAT model simulation*

#### *Watershed delineation*

The Arc-SWAT 2012.10.2.19 extension for ArcGIS version 10.2.2 was the graphical user interface utilized

Table 1: Land cover classification of Muleta Watershed

| Land cover classification | SWAT name | Area (ha) |
|---|---|---|
| Agricultural Land | AGRL | 59385.00 |
| Forest | FRST | 15113.80 |
| Fallow | AGRL | 13075.7 |
| Perennial Plantation | ORCD | 6528.54 |
| Shrubland | RNGB | 6436.52 |
| Building | URBN | 1428.56 |
| Pineapple | PINP | 730.68 |
| Road | UTRN | 521.34 |
| Water | WATR | 431.16 |
| Grassland | RNGE | 429.36 |
| Rice | RICE | 379.34 |
| Banana | BANA | 320.21 |
| Rubber | RUBR | 56.57 |
| Total | | 104,836.78 |

in the simulation of the SWAT model. This paper used the interferometric synthetic aperture radar-digital elevation model (IFSAR-DEM) with 5x5 m resolution to delineate the Muleta watershed boundary and its stream networks. During watershed delineation, the area was adjusted to 1000 as minimum threshold resulted in a total of 63 delineated subbasins and river networks (Fig. 2).

*Hydrological response units (HRUs)*

The SWAT divided the subwatersheds into smaller discrete hydrologic response units (HRUs) consist with homogenous biophysical properties of specific land cover, soil and slope class within the watershed. Slope map was generated using the IFSAR-DEM with multiple slopes of 5 classes ranging between 8, 18, 30 and 50. The HRUs delineation was completed using the multiple HRUs resulting in a total of 724 HRUs.

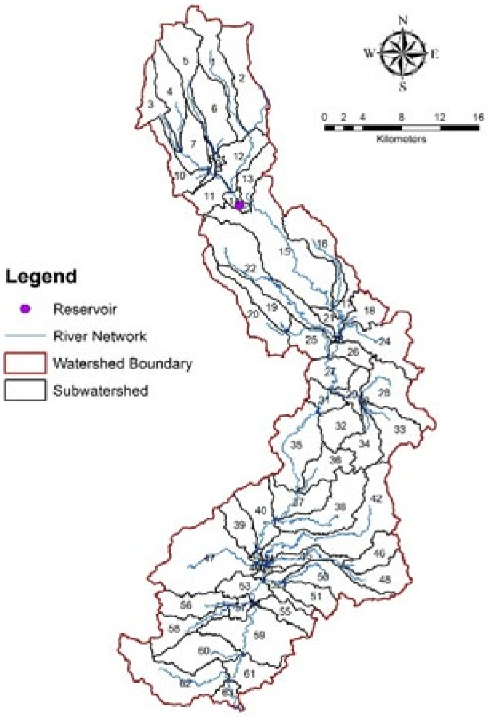

Fig. 2: Delineated Subwatersheds of Muleta

*Weather data*

Historical weather data used for SWAT model simulation was obtained from Malaybalay-PAGASA (Philippine Atmospheric, Geophysical, and Astronomical Services Administration). The weather station was located at 125°08’02.04” east longitude and 08°09’04.80” north latitude. The data included daily rainfall and temperature (minimum and maximum) from the year 1970 to 2015.

*SWAT set-up*

During the SWAT model simulation, the number of years skipped was set to 7 years as the warm-up period. The output of reach and subbasin were imported to the database used for SWAT model calibration and validation.

*SWAT model calibration and validation*

The historical streamflow data from the year 1985-2004 measured by the Department of Public Works and Highways–Bureau of Design Water Projects Division (DPWH-BRWPD) was used for the calibration and validation of the model. The staff gauge instrument was installed at Omonay Bridge geographically located at 124°52’35” east longitude and 7°26’12” north latitude, along Cotabato-Bukidnon boundary road, in Omonay, Damulog, Bukidnon. The data collected was daily mean discharge and computed average monthly discharge was utilized for the calibration (1985-1994) as well as validation (1995-2004) of the model. SWAT-CUP-SUFI2 was used for model calibration, validation, sensitivity and uncertainty analysis. The observed

Table 2: Soil type of Muleta watershed

| Soil Classification | Area (ha) |
|---|---|
| Faraon clay | 5703.91 |
| La Castellana clay loam | 5803.58 |
| Tacloban clay | 7354.46 |
| Mountain soil | 9444.53 |
| Aroman clay loam | 11021.42 |
| Adtuyan clay | 17685.39 |
| Kidapawan clay; Kidapawan clay loam | 23750.68 |
| Macolod clay | 24061.96 |

streamflow data obtained from DPWH-BRWPD was specifically located within the subbasin 41 of the delineated Muleta subwatersheds. This is one of the inputs during model calibration and validation.

## RESULTS AND DISCUSSION

### *Model calibration, validation, and sensitivity analysis*

In SWAT simulation, 6 parameters (Table 3) were identified as sensitive for streamflow calibration and validation, and the final fitted values were derived from several iterations. The fitted values were then used to re-write the SWAT model inputs and simulate the land cover and climate change scenarios. The SCS runoff curve number for moisture condition II (CN2.mgt) in this study was identified as the most sensitive parameter for estimating the surface runoff. Several published studies have reported the sensitivity of CN2.mgt in calibration for estimating the surface runoff (Can *et al*., 2015). The ALPHA_BF.gw was also observed to be sensitive in baseflow and groundwater calculation. In addition, GW_DELAY.gw, GWQMN.gw, and GW_REVAP.gw were sensitive in the calculation of groundwater. Meanwhile, ESCO.hru was sensitive to the actual evapotranspiration. These parameters were identified as sensitive in the calculation of surface runoff, evapotranspiration, and baseflow as investigated in this study (Hermassi and Khadhraoui, 2017; Smarzyńska and Miatkowski, 2016).

Fig. 3 shows the calibration, validation and uncertainty statistical analysis of Muleta watershed. The SWAT model calibration obtained statistical results of $R^2$ = 0.80, NS = 0.80, RSR = 0.45 and PBIAS = -4.0 between the observed and simulated data. The results were statistically very good based on the performance criteria provided by da Silva *et al*. (2015). In addition, the calibrated model obtained a p-factor of 0.74, this indicates that 74% of observed data is within the prediction uncertainty band. Meanwhile, the obtained r-factor value of 0.77 indicates the degree of uncertainty based on the thickness of the band. The p-factor and r-factor are closely related wherein attaining larger p-factor would result in a higher r-factor value (Narsimlu *et al*., 2015)a semi distributed physically based model, was chosen and set up in the KRB for hydrologic modeling. SWAT-CUP (SWAT-Calibration and Uncertainty Programs. During the model validation, results obtained statistical values of $R^2$ = 0.79, NS = 0.67, RSR = 0.57 and PBIAS = -16.9, suggesting well ($R^2$, NS and RSR), and satisfactory (PBIAS) agreement between observed and simulated data. The results confirmed with the SWAT model validation results of da Silva *et al*. (2015).The PBIAS value during validation obtained a large and a negative value, therefore, it

Table 3. SWAT model parameters used to calibrate the Muleta watershed

| Parameter | Fitted value | Minimum value | Maximum value |
|---|---|---|---|
| CN2.mgt | -0.3075 | -0.4 | -0.3 |
| ALPHA_BF.gw | 0.000042 | 0 | 0.00008 |
| GW_DELAY.gw | 206.024994 | 150 | 399 |
| GWQMN.gw | 0.025584 | 0 | 0.113707 |
| GW_REVAP.gw | 0.055782 | 0.024500 | 0.062417 |
| ESCO.hru | 0.851062 | 0.832500 | 0.9 |

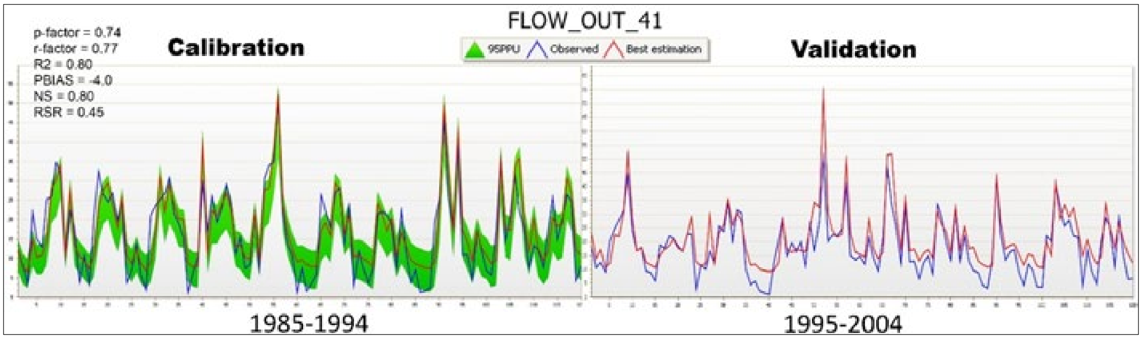

Fig. 3: Discharge calibration (1985-1994) and validation (1995-2004) of Muleta watershed

indicated that the model was overestimated (da Silva *et al*., 2015; Moriasi *et al*., 2017) The possibility of the low performances during model calibration and validation may be attributed to the availability of rainfall data measured at only one gauge station, along with the complex environmental aspects that the model possibly had not account (Narsimlu *et al*., 2015; Puno, 2017)a semi distributed physically based model, was chosen and set up in the KRB for hydrologic modeling. SWAT-CUP (SWAT-Calibration and Uncertainty Programs. Therefore, these factors were considered as the major limitations of the study as carried out within a large watershed area such as the Muleta.

The results of precipitation, evapotranspiration, surface runoff, and baseflow per subbasin in Muleta Watershed in the year 2015 are shown in Fig. 4. The year 2015 model output served as the current and baseline scenario of the hydrologic processes of Muleta watershed. This is dependent on the latest year of the weather data used as the model inputs in this study. It was observed that precipitation has minimal difference among subbasins across the watershed. Meanwhile, evapotranspiration was observed to be higher in forested subbasins due to the contribution of higher plant transpiration from canopy cover of forest to the soil evaporation (Gyamfi *et al*., 2016). Results of surface runoff were also

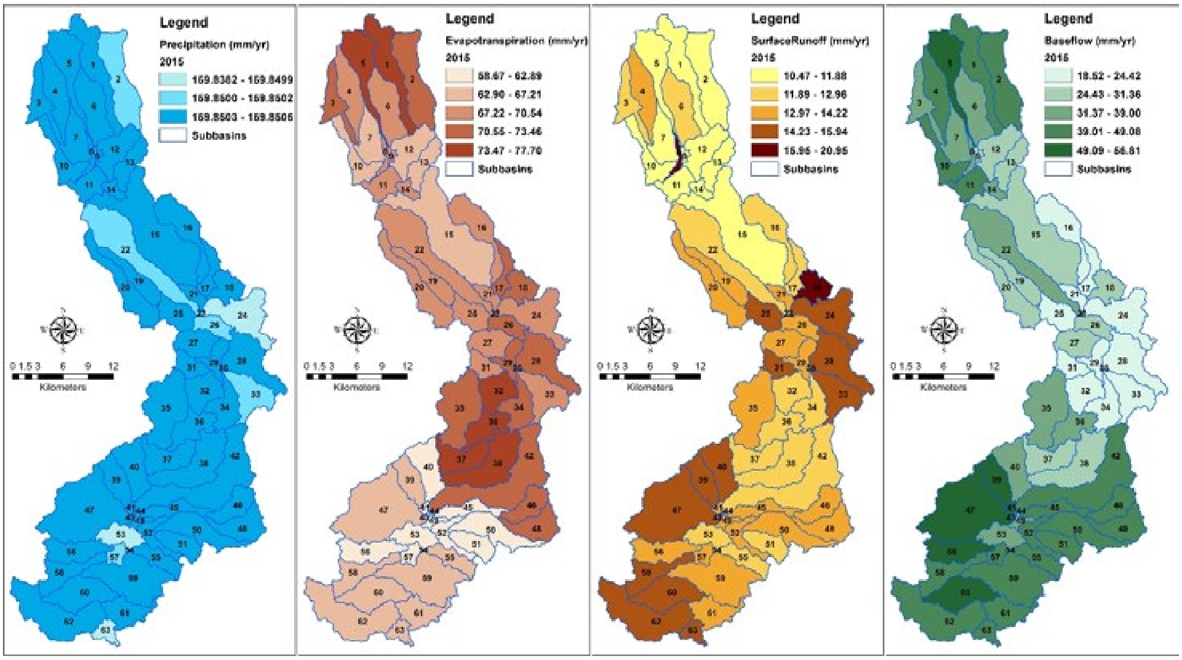

Fig. 4: Precipitation, evapotranspiration, surface runoff and baseflow map of year 2015 per subbasin of Muleta watershed

Table 4: Land cover and climate change scenarios for Muleta watershed

| Scenario | Forest (FRST) | Agricultural land (AGRL) | Shrubland (RNGB) | Rainfall |
|---|---|---|---|---|
| 1 | | | 50% to FRST | 10% increase |
| 2 | | | 75% to FRST | 10% increase |
| 3 | | | 100% to FRST | 10% increase |
| 4 | 10% to AGRL | | 50% to FRST | 10% increase |
| 5 | 10% to AGRL | | 75% to FRST | 10% increase |
| 6 | | | | 2050 projected rainfall |
| 7 | | 50% to URBN | 25% to URBN | 2050 projected rainfall |
| 8 | | 50% to URBN | 100% to FRST | 2050 projected rainfall |

observed to be higher in urbanized and cultivated subbasins. According to Coutu and Vega (2007), impervious cover reduces infiltration resulting in higher surface runoff. The agricultural areas tend to produce more runoff due to compaction of lower soil horizons during land tilling (Githui *et al*., 2009). In addition, infiltration decreases as the slope gradient increases thus resulted in higher runoff velocities within the sloped areas of the Muleta watershed. Lastly, the baseflow pattern within the watershed is conceptually dependent on climate, soils, topography, and land cover, among others. It was further observed that baseflow pattern tends to be higher in elevated areas as influenced by high rates of infiltration, recharge and groundwater storage (Rumsey *et al*., 2015).

### *Hydrologic impacts of land cover and climate change*

The simulated and calibrated hydrology was investigated under 8 different hypothetical scenarios to provide deeper insights into the impacts of land cover and climate change within the Muleta watershed (Table 4). The conversion of agriculture areas did not include the specific identified agricultural crops since those occupy only a small portion of the total land area of the entire watershed. The following scenarios were applied in watershed data under the edit SWAT inputs tab in Arc-SWAT from the calibrated and validated model of year 2015 as the baseline scenario. A certain percentage of shrubland converted into forest applied with 10% increase in rainfall was investigated (scenarios 1 to 3). Meanwhile, to investigate the impact of agricultural expansion, conversion of forest to agricultural land and percentage of shrubland converted into forest with 10% increase in rainfall was simulated (scenarios 4 and 5). The projected provincial change in rainfall generated by PAGASA for the year 2050 was adopted in simulating the impact of future climate change in Muleta watershed (scenario 6). By the year 2050, it is projected that rainfall will generally decrease by 13% in the Bukidnon province, where most of the watershed and headwater of Muleta river is situated. Scenarios applying the urbanization and forest rehabilitation along with the 2050 projected rainfall were included in the investigation (scenarios 7 and 8).

The results of the simulated scenarios on precipitation, evapotranspiration, surface runoff and baseflow for Muleta watershed were shown in Fig. 5. The calibrated and validated model output of the year 2015 served as the current scenario and basis of the impact analysis.

Scenarios 1 to 5 showed no significant changes in the result of precipitation, however, the scenarios 1 to 3 showed increasing evapotranspiration, decreasing surface runoff and steady baseflow.

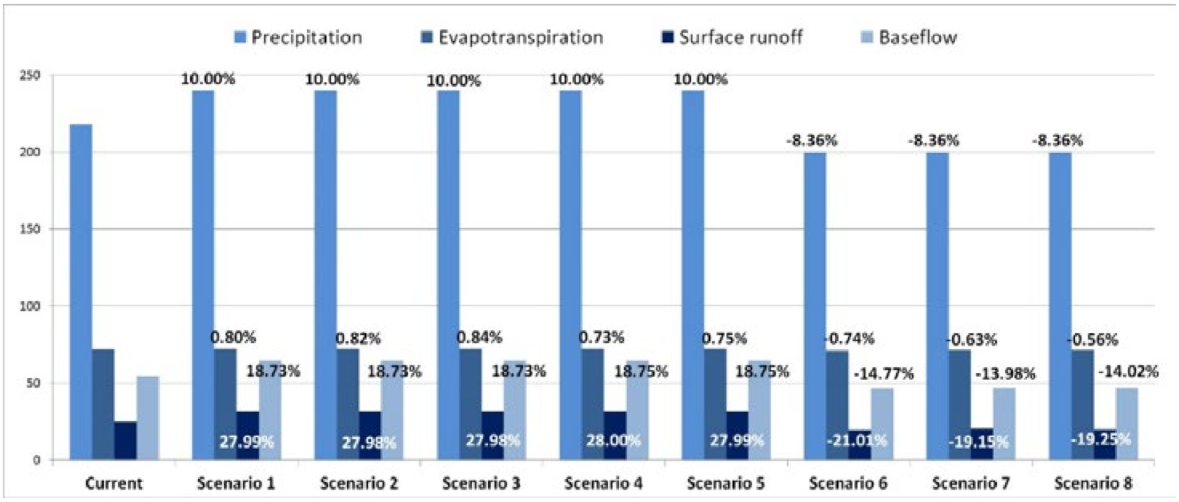

Fig. 5: Percentage change of land cover and climate change scenarios from current values on precipitation (mm/y), evapotranspiration (mm/y), surface runoff (mm/y), and baseflow (mm/y) within the Muleta watershed.

This implies that an increase in forest vegetation influence the increase in evapotranspiration and decrease in surface runoff. This confirms with the results of previous studies on land cover change scenario analysis, stating that with the expansion of forest vegetation cover, infiltration rates tend to improve, consequently decreases the rate of surface runoff (Briones *et al*., 2016; Li *et al*., 2015; Li *et al*., 2009). The conversion of 100% shrubland into forest applied in scenario 3 was observed to be the optimal scenario without any other land conversions but with the impact of an increase in rainfall. Scenario 3 showed that a higher increase in forest vegetation would lead to lesser surface runoff rates, therefore minimizes the possibility of soil erosion and flooding that could be triggered by increasing rainfall intensity within sloped and low-lying areas of Muleta watershed. Meanwhile, the conversion of 10% forest into agricultural land added with the conversion of 50% shrubland to forest in scenario 4 resulted to an increase in surface runoff and evapotranspiration. In scenario 5, 10% forest is converted into agricultural land but 75% of shrubland is converted into forest areas. The results of scenario 5 have lesser surface runoff but have higher evapotranspiration rates as compared with scenario 4. However, the increase in evapotranspiration for scenarios 4 and 5 is much lesser than the result of scenarios 1 to 3. This is attributed to the presence of forest conversion to agricultural land wherein agricultural expansion influences the increase in surface runoff, meanwhile increase in forest cover increases the rate of evapotranspiration (Githui *et al*., 2009; Gyamfi *et al*., 2016). Presence of vegetation cover is one of the factors that increase the soil surface resistance to flow resulting in a decrease in runoff rates (Puno, 2017). The results confirm with previous studies that surface runoff decreases as the forest vegetation cover increases (Can *et al*., 2015; Salsabilla and Kusratmoko, 2017).

Scenario 6 simulated the PAGASA projected rainfall by the year 2050 within the Bukidnon province where rainfall will generally decrease by 13%. This consequently influenced the decrease in precipitation, evapotranspiration, surface runoff and baseflow by -8.36%, -0.74%, -21.01%, and -14.77%, respectively. The results of this scenario showed that changes in climate such as a decrease in rainfall, without any land conversions, directly influence the decrease in hydrologic processes (Huang and Lo, 2015). Scenario 7 simulated the impact of urbanization and climate change on hydrologic processes. Conversion of 50% agricultural land and 25% shrubland into urban areas with a 13% drop in rainfall resulted to the decrease in evapotranspiration, surface runoff, and baseflow by -0.63%, -19.15%, and -13.98%, respectively. However, the results of scenario 7 as compared with scenario 6 showed that evapotranspiration, surface runoff, and baseflow increases by 0.11%, 1.86%, and 0.79%, respectively. The findings of this scenario are consistent with previous studies where increase in urbanization influence the increase in surface runoff due to reduced infiltration rates on the impervious surface (Boggs and Sun, 2011; Chithra *et al*., 2015; Kim *et al*. 2016). Moreover, the results of Pan *et al.* (2017) demonstrated that the impact of land cover changes significantly affect surface runoff as well as groundwater within an urbanized area. Lastly, in scenario 8, the conversion of 50% agricultural land to urban and 100% shrubland to forest with 13% decrease in rainfall resulted to a lesser decrease in evapotranspiration (-0.56%), further decrease in surface runoff (-19.25%) and minimal decrease in baseflow (-14.02%) as compared with the scenario 7. Therefore, scenario 5 and 8 displayed as the optimal scenarios in response to the rapid agricultural expansion and urbanization, wherein enhancing reforestation by converting idle lands such as shrubland into forested areas could minimize the negative impacts of land cover and climate change. The results of scenario 8 are associated with the impact of forest cover dissipating raindrop energy thus decelerates surface runoff velocity and increases evapotranspiration (Alibuyog *et al*., 2009). However, as the forest cover increases, there is a minimal decrease in baseflow that may be attributed to the higher evapotranspiration rates of forest vegetation along stream banks and throughout the watershed (Price, 2011). Further decrease of baseflow would as well be detrimental to flow dependable crops such as irrigated rice plantation during the dry season. Huang *et al*. (2016) reported similar conclusions, that baseflow was found to be negatively affected by land use changes mainly of the forest, followed by farmland and urban land. Generally, with the projected 13% drop in rainfall by 2050, the increasing agricultural expansion and urbanization in Muleta watershed would yield to higher surface runoff. Based on the previous studies, an increase in surface runoff triggered by increasing urbanization would lead to destructive soil erosion, sedimentation and rain-induced flooding in low-lying areas within a watershed (Coutu and Vega, 2007; Githui *et al*., 2009; Kim *et al*., 2016; Li and Wang, 2009; Petchprayoon *et al*., 2010). Therefore, appropriate watershed management interventions are essential to alleviate such impacts influenced by land cover and climate change within the Muleta watershed.

## CONCLUSION

This paper simulated the hydrologic responses to land cover and climate change scenarios applied in Muleta watershed using SWAT model. The model was calibrated and fitted to arrive at acceptable performance using appropriate statistical tests with $R^2$, NS, and RSR values of 80, 0.80 and 0.45, respectively. Model validation using observed streamflow data obtained acceptable statistical results of $R^2 = 0.79$, NS = 0.67 and RSR = 0.57. The applied land cover and climate change scenarios influenced the hydrologic responses of Muleta watershed in precipitation, evapotranspiration, surface runoff, and baseflow. Based on the results, conversion of shrubland to forest vegetation with an increase in rainfall resulted in increased evapotranspiration and decreased surface runoff. Furthermore, the decrease of rainfall by 13% from 2050 PAGASA projection, without any land conversions, directly influenced the decrease in hydrologic processes. However, the projected decrease in rainfall applied with the conversion of agricultural land and shrubland into urban areas, tend to increase the rates of evapotranspiration, surface runoff, and baseflow. The increase of urbanization influenced the increase in surface runoff due to reduced infiltration rates on the impervious land surface. Meanwhile, an increase in forest vegetation resulted in the increase in evapotranspiration and a decrease in surface runoff and baseflow. The decrease in baseflow is attributed to the higher evapotranspiration rates of forest vegetation. These climate and land cover changes negatively affect dependent agricultural activities on the river flow as well as urbanized and low-lying areas within the Muleta watershed. Findings from this study also indicate that massive conversion of forest land into other land uses such as agriculture and urbanization suggests the propensity of higher surface runoff which would eventually lead to flash floods and landslides. Common to many land watersheds, Muleta is exposed to climate-related hazards, consequently, appropriate management decisions and actions by the local government unit focusing on the reforestation of idle land or shrubland areas has to be given into consideration. A science-based generated information enables local decision-makers and other stakeholders to address possible and site-specific control measures and strategies advantageous to attain water balance and sustainable development within watersheds.

## ACKNOWLEDGMENTS

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## CONFLICT OF INTEREST

The authors declare that there are no conflicts of interest regarding the publication of this manuscript. In addition, the ethical issues; including plagiarism, informed consent, misconduct, data fabrication and/or falsification, double publication and/or submission, redundancy has been completely observed by the authors.

## ABBREVIATIONS

| | |
|---|---|
| *%* | Percent |
| *AGRL* | Agricultural land |
| *AGRL* | Fallow |
| *ALPHA_BF.gw* | Baseflow alpha factor–groundwater file |
| *ArcGIS* | Arc-geographic information system |
| *ArcSWAT* | Arc-soil and water assessment Tool |
| *BANA* | Banana |
| *BSWM* | Bureau of soil and water management |
| *CN2.mgt* | SCS runoff curve number–management file |

| | |
|---|---|
| *DPWH-BRWPD* | Department of Public Works and Highways–Bureau of Design Water Projects Division |
| *ESCO.hru* | Soil evaporation compensation factor – hydrologic response unit file |
| *Fig.* | Figure |
| *FRST* | Forest |
| *Geo-SAFER* | Geo-Informatics for the systematic assessment of flood effects and risks |
| *GW_DELAY.gw* | Groundwater delay – groundwater file |
| *GW_REVAP.gw* | Groundwater “revap” coefficient – groundwater file |
| *GWQMN.gw* | Threshold depth of water in shallow aquifer required for return flow to occur – groundwater file |
| *ha* | Hectare |
| *HRUs* | Hydrological response units |
| *IFSAR-DEM* | Interferometric synthetic aperture radar-digital elevation model |
| *km* | Kilometers |
| *m* | Meters |
| *masl* | Meters above sea level |
| *MKaNPK* | Mount Kalatungan Natural Range Park |
| *mm/y* | Millimetre/year |
| *MSI* | Multispectral imager instrument |
| *NS* | Nash-Sutcliffe efficiency |
| *ORCD* | Perennial plantation |
| *PAGASA* | Philippine Atmospheric, Geophysical, and Astronomical Services Administration |
| *PBIAS* | Percent bias |
| *PCIEERD* | Philippine Council for Industry, Energy and Emerging Technology Research and Development |
| *p-factor* | Percent of observations |
| *PINP* | Pineapple |
| $R^2$ | Coefficient of determination |
| *r-factor* | Thickness of the 95-ppu-no-observed plot envelop |
| *RICE* | Rice |
| *RNGB* | Shrubland |
| *RNGE* | Grassland |
| *RSR* | Standard deviation ratio |
| *RUBR* | Rubber |
| *SCS* | Soil conservation service |
| *Sen2Cor* | Processor for Sentinel-2 product generation and formatting |
| *SNAP* | Sentinel Application Platform |
| *SVM* | Support vector machine |
| *SWAT* | Soil and water assessment tool |
| *SWAT-CUP-SUFI2* | Soil and water assessment tool–calibration and uncertainty procedures–SUFI2 algorithm |
| *URBN* | Building |
| *UTRN* | Road |
| *WATR* | Water |

## REFERENCES

Addabbo, P.; Focareta, M.; Marcuccio, S.; Votto, C.; Ullo, S. L., (2016). Contribution of sentinel-2 data for applications in vegetation monitoring. Acta Imeko, *5*(2): 44–54 (**11 pages**).

Al-Bakri, J.; Salahat, M..; Suleiman, A.; Suifan, M.; Hamdan, M.; Khresat, S.; Kandakji, T., (2013). Impact of climate and land use changes on water and food security in Jordan: Implications for transcending “the tragedy of the commons.” Sustainability, 5(2): 724–748 (**25 pages**).

Alibuyog, N.R.; Ella, V.B.; Reyes, M.R.; Srinivasan, R.; Heatwole, C.; Dillaha, T., (2009). Predicting the effects of land use on runoff and sediment yield in selected sub-watersheds of the Manupali river using the ArcSWAT model. Int. Agric. Eng. J., 18(1-2): 15–25 (**11 pages**).

Boggs, J.L.; Sun, G., (2011). Urbanization alters watershed hydrology in the Piedmont of North Carolina. Ecohydrology, 4(2): 256-264 (**9 pages**).

Briones, R.U.; Ella, V.B.; Bantayan, N.C., (2016). Hydrologic impact evaluation of land use and land cover change in Palico watershed, Batangas, Philippines, using the SWAT model. J. Environ. Sci. Manage., 19(1): 96–107 (**12 pages**).

Can, T.; Xiaoling, C.; Jianzhong, L.; Gassman, P.W.; Sabine, S.; José-miguel, S.P., (2015). Assessing impacts of different land use scenarios on water budget of Fuhe River, China using SWAT model. Int. J. Agric. Biol. Eng., 8(3): 95–108 (**15 pages**).

Chithra, S.V.; Nair, M.V.H.; Amarnath, A.; Anjana, N.S., (2015). Impacts of impervious surfaces on the environment. Int. J. Eng. Sci. Invention, 4(5): 27-31 (**5 pages**).

Combalicer, E.A.; Cruz, R.V.O.; Lee, S.H.; Im, S., (2010). Modelling hydrologic processes distribution in a tropical forest watershed in the Philippines. J. Trop. For. Sci., 22(2): 155–169 (**15 pages**).

Coutu, G.W.; Vega, C., (2007). Impacts of land use changes on runoff generation in the east branch of the Brandywine Creek watershed using a GIS-based hydrologic model. Middle States Geogr., 40: 142–149 (**8 pages**).

da Silva, M. G.; de Oliveira de Aguiar Netto, A.; de Jesus Neves, R. J.; do Vasco, A. N.; Almeida, C., A.; Fsccioli, G. G., (2015). Sensitivity analysis and calibration of hydrological modeling of the watershed northeast Brazil. J. Environ. Prot., 6: 837–850 (**14 pages**).

Djamai, N.; Fernandes, R., (2018). Comparison of SNAP-derived Sentinel-2A L2A product to ESA product over Europe. Remote Sens., 10(6): 1-17 (**17 pages**).

Dumago, S.W.; Puno, G.R.; Ingotan, S., (2018). Water quality assessment in various land use and land cover of Muleta watershed Bukidnon, Philippines. J. Biodivers. Environ. Sci., 12(3): 201-209 (**9 pages**).

Githui, F.; Mutua, F.; Bauwens, W., (2009). Estimating the impacts of land-cover change on runoff using the soil and water assessment tool (SWAT): Case study of Nzoia catchment, Kenya. Hydrol. Sci. J., 54(5): 899–908 (**11 pages**).

Gyamfi, C.; Ndambuki, J.M.; Salim, R.W., (2016). Hydrological responses to land use/cover changes in the Olifants basin, South Africa. Water. 8(12): 1-16 (**16 pages**).

Hermassi, T.; Khadhraoui, M., (2017). Hydrological modelling of stream flows in the Rmel watershed using SWAT model. J. New Sci., 12: 2684–2692 (**9 pages**).

Huang, T.; Lo, K., (2015). Effects of land use change on sediment and water yields in Yang Ming Shan national park, Taiwan. Environments, 2(1): 32–42 (**11 pages**).

Huang, X.D., Shi, Z.H., Fang, N.F., Li, X., (2016). Influences of land use change on baseflow in mountainous watersheds. Forests, 7(1): 1–15 (**15 pages**).

Khoi, D.N.; Suetsugi, T., (2014). Impact of climate and land-use changes on hydrological processes and sediment yield—a case study of the Be river catchment, Vietnam. Hydrol. Sci. J., 59(5): 1095–1108 (**14 pages**).

Kim, H.W.; Li, M.-H.; Kim, J.-H.; Jaber, F., (2016). Examining the Impact of suburbanization on surface runoff using the SWAT. Int. J. Environ. Res., 10(3): 379–390 (**12 pages**).

Li, Y.; Wang, C., (2009). Impacts of urbanization on surface runoff of the Dardenne Creek watershed, St. Charles County, Missouri. Phys. Geogr., 30(6): 556–573 (**18 pages**).

Li, Z.; Deng, X.; Wu, F.; Hasan, S.S., (2015). Scenario analysis for water resources in response to land use change in the middle and upper reaches of the Heihe river basin. Sustainability, 7(3): 3086–3108 (**23 pages**).

Li, Z.; Liu, W.-Z; Zhang, X.-C; Zheng, F.-Li., (2009). Impacts of land use change and climate variability on hydrology in an agricultural catchment on the Loess Plateau of China. J. Hydrol., 377(1-2): 35–42 (**8 pages**).

Louis, J.; Debaecker, V.; Pflug, B.; Main-Knorn, M.; Bieniarz, J.; Mueller-Wilm, U.; Cadau, E.; Gascon, F., (2016). Sentinel-2 SEN2COR: L2A processor for users. Conference Proceedings “Living Planet Symposium 2016”. Prague, Czech Republic 9-13 May.

Michaud, A.R.; Beaudin, I.; Deslandes, J.; Bonn, F.; Madramootoo, C.A., (2007). SWAT-predicted influence of different landscape and cropping system alterations on phosphorus mobility within the Pike river watershed of south-western Quebec. Can. J. Soil. Sci., 87(3): 329-344 (**16 page**).

Moriasi, D. N.; Arnold, J. G.; Van Liew, M. W.; Bingner, R. L.; Harmel, R. D.; Veith, T. L., (2017). Model evaluation guidelines for systematic quantification of accuracy in watershed simulations. Am. Soc. Agric. Biol. Eng., 50(3): 885–900 (**16 pages**).

Narsimlu, B.; Gosain, A.K.; Chahar, B.R.; Singh, S.K.; Srivastava, P.K., (2015). SWAT model calibration and uncertainty analysis for streamflow prediction in the Kunwari river basin, India, using sequential uncertainty fitting. Environ. Process., 2(1): 79–95 (**17 pages**).

Palao, L.K.M.; Dorado, M.M.; Anit, K. P.A.; Lasco, R.D., (2013). Using the soil and water assessment tool (SWAT) to assess material transfer in the Layawan watershed, Mindanao, Philippines and its implications on payment for ecosystem services. Int. J. Sustainable Dev., 6(6): 73–88 (**16 pages**).

Pan, S.; Liu, D.; Wang, Z.; Zhao, Q.; Zou, H.; Hou, Y.; Lui, P.; Xiong, L., (2017). Runoff responses to climate and land use/cover changes under future scenarios. Water, 9(475): 1–23 (**23 pages**).

Petchprayoon, P.; Blanken, P.D.; Ekkawatpanit, C.; Hussein, K., (2010). Hydrological impacts of land use/land cover change in a large river basin in central-northern Thailand. Int. J. Climatol., 30(13): 1917–1930 (**14 pages**).

Price, K., (2011). Effects of watershed topography, soils, land use, and climate on baseflow hydrology in humid regions: A review. Prog. Phys. Geogr., 35(4): 465–492 (**29 pages**).

Puno, G. R., (2017). Runoff and sediment yield modeling using GeoWEPP in Mapawa Catchment. CMU J. Sci., 18: 49-70 (**22 pages**).

Rumsey, C.A.; Miller, M.P.; Susong, D.D.; Tillman, F.D.; Anning, D.W., (2015). Regional scale estimates of baseflow and factors influencing baseflow in the upper Colorado river basin. J. Hydrol.: Reg. Stud., 4(B): 91–107 (**17 pages**).

Salsabilla, A.; Kusratmoko, E., (2017). Assessment of soil erosion risk in Komering watershed, South Sumatera, using SWAT model. AIP Conference Proceedings, 030192 (2017) -1-030192-7 (**7 pages**).

Santillan, J.; Makinano, M..; Paringit, E., (2011). Integrated landsat image analysis and hydrologic modeling to detect impacts of 25-year land-cover change on surface runoff in a Philippine watershed. Remote Sens., 3(6): 1067–1087 (**21 pages**).

Smarzyńska, K.; Miatkowski, Z., (2016). Calibration and validation of SWAT model for estimating water balance and nitrogen losses in a small agricultural watershed in central Poland. J. Water Land Dev., 29(1): 31–47 (**17 pages**).

Teshager, A.D.; Gassman, P.W.; Schoof, J.T.; Secchi, S., (2016). Assessment of impacts of agricultural and climate change scenarios on watershed water quantity and quality, and crop production. Hydrol. Earth Syst. Sci., 20(8): 3325–3342 (**18 pages**).

Trinh, D.H.; Chui, T.F.M., (2013). Assessing the hydrologic restoration of an urbanized area via an integrated distributed hydrological model. Hydrol. Earth Syst. Sci., 17(12): 4789–4801 (**13 pages**).

Wessel, M.; Brandmeier, M.; Tiede, D., (2018). Evaluation of different machine learning algorithms for scalable classification of tree types and tree species based on Sentinel-2 data. Remote Sens., 10(9): 1-21 (**21 pages**).

Zhou, Y.; Xu, Y. J.; Xiao, W.; Wang, J.; Huang, Y.; Yang, H., (2017). Climate change impacts on flow and suspended sediment yield in headwaters of high-latitude regions-a case study in China’s far northeast. Water, 9(12): 1-17 (**17 pages**).

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