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Hydrologic Impact Evaluation of Land Use and Land Cover Change in Palico Watershed, Batangas, Philippines Using the SWAT Model

ABSTRACT

Information on the relationship between hydrologic response and land use and land cover change (LULC) is vital for proper management of water resources and land use planning. This study aimed to evaluate the impact of LULC on the hydrologic characteristics of Palico watershed in Batangas, Philippines using the Soil and Water Assessment Tool (SWAT) model. Model inputs used were the 1989 and 2013 LULC maps and climatological and hydrologic data. Good agreement was obtained between simulated and observed streamflow values during model calibration (NSE=0.84 & R^2=0.86), and validation (NSE=0.61 & R^2=0.68). For the entire watershed, reduction in forest cover and rangeland resulted to an increase in surface runoff and decreases in baseflow or dry season flow and groundwater recharge. LULC changes affected the water quantity and timing of occurrence. Subbasin with 22% increase in forest cover and rangeland increased the baseflow by 1% to 15% and reduced the streamflow by 1% to 17% during the rainy months. Another subbasin with 54% forest loss resulted to more pronounced rainfall-runoff response with 11% to 17% decrease in baseflow and 4% to 24% increase in streamflow during rainy months. Finding the balance between these two opposite LULC change scenarios is crucial for the attainment of water security and sustainability in the watershed and in the areas it serves.

Key words: *watershed modeling, ungauged watershed, rainfall-runoff response, SWAT model, Landuse/Landcover (LULC) change, Verde Island Passage (VIP)*

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INTRODUCTION

The impact of /landuselandcover change on hydrology particularly in terms of rainfall-runoff response is a prominent topic of research in recent years (e.g., *Amini et al. 2011*; *Chen et al. 2009*; *Li and Wang, 2009*). This is because landuse/landcover (LULC) change together with precipitation, soil and topography are among the most important factors that drive the dynamics of rainfall-runoff process. Unlike soil and topography, LULC impacts on the hydrologic process occur in a short-term, providing the opportunity to evaluate their immediate influence (*Miller et al. 2002*). The increasing frequency in drought, flooding, landslide, and extreme soil erosion across the world, especially along the tropics, is not only linked with climate change, but is also affected by human activities, such as LULC change (*Collins 2009*; *Hurkmans et al. 2009*). The impacts of LULC change on hydrology at watershed scale has become an important research topic in studying human-environment interaction.

At present, various studies have been done to evaluate the impact of LULC change on hydrologic characteristics at watershed scale across the world (*Sanyal et al. 2014*; *Ayivor and Gordon 2012*; *Baker and Miller 2013*; *Nobert and Jeremiah 2012*; *Zhu and Li 2014*). These studies have used past and present LULC states or radical LULC change scenarios in event-scale hydrological models to assess the hydrological response of catchments (*Camorani et al. 2005*; *Li and Wang 2009*; *Olang and Furst 2011*; *Zhu and Li 2014*).

While hydrologic modeling is relatively new in the Philippines, results of several studies dealing with simulating the relationship of land cover with hydrology and sediment have been published. *Alibuyog et al.* (*2009*) and *Palao et al.* (*2013*) used the SWAT model to predict the effects of land use change on runoff and sediment yield in small watersheds in Mindanao. *Ella* (*2005*) used the Water Erosion Prediction Project (WEPP) model to evaluate the impact of land use change on streamflow, soil erosion and sediment yield in small upland watersheds also in Mindanao. Other studies include the use of Brook 90 model to simulate hydrological process of Molawin Creek in Mt. Makiling (*Combalicer and Im 2012*) and the Hydrologic Engineering Center-Hydrologic Modeling System (HEC-HMS) model to reconstruct the 2008 flooding in Panay Island (*Catane et al. 2012*). A number of studies have established the impacts of LULC change in hydrologic characteristics *Alibuyog et al.* (*2009*) showed that if 50% of the pasturelands and grasslands are to be converted to cultivated lands, there will be a drastic increase in sediment yield and these conversionswill consequently decrease the baseflow by 2.8% to 3.3% at their study at Manupali Watershed, Philippines. In the WEPP modeling study of *Ella* (*2005*), simulation results showed that increasing the percentage area cultivated in the watershed by 50% would result to an increase in sediment yield by close to 20%. Climate change impacts on land cover was also found to have significant impact on streamflow particularly on land with special uses according to the study of *Combalicer and Im* (*2012*) in Molawin Watershed of Mt. Makiling, Philippines. In other countries, *Nobert and Jeremiah* (*2012*) found out that a decrease in forest area, and an increase in agricultural and urban area results to a decrease on average annual river flow, an increase in surface runoff and a decrease in base flow. Most of these studies focused on the impacts of LULC change on annual hydrologic response. However, the spatial and temporal effects of LULC change on hydrologic response must also be carefully examined to better understand their relationship.

To date, no modeling study using SWAT has been made on evaluating the effects of land use change on hydrology in any watershed in Batangas, Philippines. This study specifically aimed to evaluate the effects of LULC change on stream flow, water yield and water balance in Palico Watershed in Batangas. This chosen watershed is environmentally significant since it is one of the major watersheds draining along Verde Island Passage – internationally known as "Center of Marine Shorefish Biodiversity" (*Carpenter and Springer 2005*). This study also aimed to examine the spatial and temporal impacts of LULC on seasonal fluctuations of streamflow, water yield and groundwater recharge.

Study Area

Palico River is one of the major watersheds of Batangas Province discharging along Verde Island Passage corridor – one of the most important biological marine areas hailed as "center of the center of marine biodiversity" (**Figure 1**). The total catchment area is 23,691 ha with altitudinal range from one meter along the coast up to 703 msl. Seventy four percent (74%) of the catchment has slope of less than 18% while the remaining twenty-six percent (26%) of the area is above 18%. Based on FAO DSMW (Digital Soil Map of the World), the soil in the area is dominated by Orthic luvisols (86%) and Ochric andosols (24%). Following SWAT 2012 LULC classification, 2013 land cover within the catchment is dominated by tropical deciduous forest mixed with some tropical lowland evergreen (FRST), rangeland and brushland (RNGE), general agricultural land (AGRC) which includes coconut (COCO) and sugarcane (SUGC), and urban areas (URHD). Climate is strongly seasonal as affected by southwest monsoon and falls under climatic Type I based on Corona classification The average total annual precipitation from 1985 to 2013 is 1,905 mm with July receiving the highest rainfall. Palico River discharges

Figure 1. The Palico Watershed Located in southern Luzon, Philippines along the Verde Island Passage Corridor.

water, sediments and nutrient along Verde Island Passage which may affect the dynamics of coastal and aquatic ecosystem. It is also a vital source of water for agricultural and domestic uses of downstream agro-industrial municipalities. As far as the knowledge of the authors is concerned, this is the first hydrologic modeling study on Palico River.

MATERIALS AND METHODS

SWAT Model

SWAT is a physically based semi-distributed hydrologic model operating on a daily time step and uses a modified Soil Conservation Service-Curve Number (SCS CN) method to calculate runoff. It was developed by the USDA Agricultural Research Service (USDA ARS) and Texas A&M AgriLife Research to predict the impact of various land uses and management practices on water, sediments, and agricultural chemical yields in large complex watersheds over long periods of time (*Neitsch et al. 2011*). The model allows the user to quantify the relative impact of management, soil, climate and vegetation changes at the sub-watershed level (*Arnold and Allen 1998*; *Hjelmfelt 1991*). Because SWAT is also a deterministic model, each successive model run that uses the same inputs will produce the same outputs. This type of model is preferred for isolating hydrologic response from a single variable, such as land cover and land use change (e.g. management decisions), allowing the impact of any change to be isolated and analyzed for its effect on hydrologic response.

Digital Elevation Model (DEM)

ASTER DEM with 30 m resolution downloaded from USGS was used in delineation and other topographic processing of the watershed. To minimize processing time, the study area was clipped and masked before processing.

Land Use/Land Cover (LULC)

Three land cover grid maps were generated using supervised classification of LandSat Images. A number of LandSat 5, 7 and 8 satellite images from years of 1989 and 2013 were downloaded from USGS Glovis and Earth Explorer. These two years were chosen to have a time interval that is long enough for LULC change to have measureable impacts on hydrologic response. All downloaded images were captured during the dry season months from November to May. Satellite images underwent pre-processing procedures such as geometric correction and calibration, cloud-masking, noise reduction, haze reduction and histogram matching before finally subjecting to supervised classification. Both LULC maps were generated through supervised classification using Google Earth 2013 and Google Earth historical imagery as references. To minimize classification bias. Google earth images were used to validate and classify recent satellite images (*Sanyal et al. 2014*; *Zhu and Li, 2013*).

Soil

Hydrologic modeling studies in developing countries including the Philippines is challenged by the availability of input data (topography, soil, landuse/landcover and weather) with high spatial and temporal resolution due to inadequate environmental monitoring situation in the country during the past decades. Digital soil map with comprehensive data on physical and chemical characteristics that is readable and compatible with most models is one of the most limited if not unavailable data. In this study, two soil maps considered as input data for SWAT simulation - Philippine soil map and FAO Digital Soil Map of the World (DSMW). Philippine soil map was produced by Bureau of Soil and Water Management of the Philippines through series of soil survey dated as early as 1964 with varying scale of 1:50,000 to 1:10,000. Spatial resolution is much higher than the FAO DSMW but with much broader classification which is up to soil order only. FAO DSMW is coarser but with complete attributes to run the model. Efforts to source for soil map with higher spatial resolution and with needed attributes at provincial and regional agencies have been made but there was no available map. Hence, the soil map derived from FAO DSWM was used in this study for practical purposes.

Weather Data

Daily precipitation data from 1980 to 2013 from Nasugbu-PAGASA (Philippine Atmospheric, Geophysical and Astronomical Services Administration) rain-gauging station located within the watershed was used as one of the primary model inputs. The accuracy of this data was improved through comparison and correction using data from PAGASA synoptic station in Ambulong, Talisay, Batangas. These are the only existing rain-gauging stations with the available precipitation data during the period of simulation based on our search from the national weather bureau (PAGASA). Nasugbu data was used as primary input and missing data were supplied by Ambulong station. Temperature, relative humidity, solar radiation and wind speed were obtained from global weather data set of the National Centers for Environmental Prediction (NCEP) Climate Forecast System Reanalysis (CFSR). CFSR was designed and executed as a global, high resolution, coupled atmosphere-ocean-land surface-sea ice system to provide the best estimate of the state of these coupled domains over the 36-year period of 1979 through 2014.

Streamflow Records

SWAT is designed to predict the impact of land use and management on water, sediment, and agricultural chemical yields in ungauged watersheds (*Srinivasan et al. 2010*). The model is run and applied even in the absence of data for calibration and validation. However, calibration and validation is still imperative in hydrologic modeling studies whenever feasible. In developing countries including the Philippines, there is high scarcity of observed long-term hydrologic data making modeling results somewhat uncertain. This is true in SWAT modeling study in Southern Philippines by *Palao et al.* (*2013*) where calibration and validation are not performed due of the lack of observed streamflow and sediment data. Historical streamflow data from 1985 to 1993 collected by Department of Public Works and Highways – Bureau of Research and Standard (DPWH-BRS) through establishment of hydrograph and installation of staff gauge was used to calibrate and validate the model. Streamflow data was the form of daily flow rate with a unit of LS^{-1} and was average to monthly discharge with unit of $m^3.s^{-1}$. The availability of observed streamflow data in Palico Watershed enabled the model calibration, validation and uncertainty analysis before its application for LULC change evaluation. This is a much better approach than not performing any model calibration and validation as in other studies without observed streamflow data. Attempts have been made to utilize longer and recent flow data. However only a nine-year (1985-1993) data was available since the gauging station was permanently abandoned by the DPWH-BRS due to construction of water impounding structure in the upstream portion making flow observation inaccurate. Simulation using monthly-time step was done in this study for practical purposes and since SWAT has been designed for continuous hydrologic modeling. Moreover, monthly streamflow simulation would suffice for water management strategies. The first 5 years of the streamflow data was used for model calibration while the remaining four was used for validation.

Setting up of Model

Watershed boundary was delineated from ASTER DEM 30 and was discretized into 18 subwatersheds using 1,000 ha as minimum threshold for upstream drainage area. The stream network was corrected based on 2014 Google Earth images and used as burn-in to improve accuracy and precision watershed boundary delineation. Additional sub basin outlet was manually added along the stream where DPWH-BRS stream gauging station was located for calibration and validation. Rasterized DSMW soil map and land cover maps were reclassified and overlaid with slope map creating 71 hydrologic response units (HRUs). HRUs are sub-watershed units treated as homogenous block of land use, management techniques and soil properties (*Arnold and Allen 1998*; *Hjelmfelt 1991*). Since a significant portion of the catchment is mountainous, orographic effect on precipitation was incorporated in the model through setting up of elevation bands. Elevation bands were set with specific interval from 200 m to 700 m. The model uses Manning's equation to define the rate and velocity of flow and water is routed through the channel network using the variable storage routing method. To simulate plant development, SWAT utilized plant growth parameters summarized in SWAT database. Leaf area index (LAI) and bio mass are calculated based on these growth parameters. For this component, the model employs the heat unit theory in which plant growth and development is predicted based on the amount of heat absorbed. Finally, the model was run using SCS curve number method to calculate surface run-off and Penman-Monteith equation to calculate evapotranspiration.

Model Evaluation

To evaluate the simulating power of the model, the coefficient of determination, R^2 and Nash-Sutcliffe model efficiency (NSE) were used during model calibration and validation. Scatter plot of simulated and measured data together with their linear fit plotted against 45° line was also used The Nash-Sutcliffe (*Nash and Sutcliffe 1976*) model efficiency was computed using the following equation,

$$NSE = 1 - \frac{\sum_{t=1}^{T}\left(Q_o^t - Q_m^t\right)^2}{\sum_{t=1}^{T}\left(Q_o^t - \overline{Q_o}\right)^2} \quad (1)$$

where Q_o is the mean of observed discharges, and Q_m is modeled discharge. Q_o^t is the observed discharge at time *t*. Nash–Sutcliffe model efficiencies can range from −∞ to 1. An efficiency of 1 (*NSE* = 1) corresponds to a perfect match of modeled discharge to the observed data. An efficiency of 0 (*NSE* = 0) indicates that the model predictions are as accurate as the mean of the observed data, whereas an efficiency less than zero (*NSE* < 0) indicates that the observed mean is a better predictor than the model. Essentially, the closer the model efficiency is to 1, the more accurate the model is.

The coefficient of determination (R^2) was computed using the equation:

$$R^2 \equiv 1 - \frac{SS_{\rm res}}{SS_{\rm tot}} \quad (2)$$

Where SS_{tot} is the the total sum of squares and SS_{tot} is the sum of squares of residuals. All calibration, validation and uncertainty analyses were performed through SWAT Calibration and Uncertainty Program (CUP).

RESULTS AND DISCUSSION

Pre-calibrated Simulation

The pre-calibrated simulation (**Figure 2**) yielded an acceptable result with NSE and R2 of 0.81 and 0.84 respectively (**Figure 5a**). This result is considerably satisfactory and consistent with study of Baker and *Miller* (*2013*) on land use impact on water resources in an East African watershed using SWAT and with study of *Srinivasan et al.* (*2010*) on hydrological budget and crop yield prediction in the upper Mississippi River basin which also yield good uncalibrated run using SWAT model. This uncalibrated result adds to SWAT's credibility to simulate poorly gauged or completely gauged catchment. This also supports the model's main purpose, which is to assess the role of topography, soils, land use, and climate in the dynamics of hydrologic response of ungauged basins where data used to develop input parameters may be scarce or absent entirely (*Arnold and Allen 1998; Srinivasan et al. 2010*). However, the model tends to overestimate the flow during the rainy season especially during periods of excessive rainfall occurrences and underestimate the baseflow or the flow during the dry season. Several studies on LULC change and hydrologic response also encountered similar model behavior (*Baker and Miller 2013; Gitau and Chaubey 2010; and Palao et al. 2013; Zhu and Li 2014*). In spite of these, there is a good agreement between precipitation and simulated flow (**Figure 5a and b**). The uncalibrated result agrees very well with the monthly streamflow records of DPWH-BRS from 1985 to 1990 (**Figure 2**).

Calibration, Validation and Uncertainty Analysis

SWAT simulation covered a total of 9 years from 1985 to 1993. Calibration was done using 1985 to 1989 streamflow data and validation using the remaining data from 1990 to 1993. Calibration of the model using identified set of parameters and their corresponding values has improved the model prediction capability. The procedure improved the uncalibrated model *NSE* from 0.81 to 0.85 and R^2 from 0.84 to 0.86 (**Figure 5b**). These calibrated values are relatively high compare to other SWAT modeling studies: *Easton et al.* (*2008*) with calibration R^2 and *NSE* of 0.78 and 0.77, *Meaurio et al.,* (*2015*) 0.75 for *NSE* and 0.87 for R^2 and with *Singh et al*. (*2012*) with R^2 and *NSE* values of 0.78 and 0.76. Furthermore, an *NSE* > 0.5 and R^2 values of over 0.5 are considered "satisfactory and acceptable" based on the criteria reported by *Santhi et al.* (*2001*) and *Van Liew et al.* (*2003*).

This improvement can be seen in calibration plot in **Figure 3** where there is marked improvement in line-fitting especially for baseflow. Validation also yielded acceptable simulation result although *NSE* and R^2 dropped to 0.61 and 0.68 (**Figure 5c**). This marked decrease in model's performance can be attributed to several factors. LULC change between calibration period (1985-1989) and validation period (1990-1993) could be one of the factors. However, this could be minimal for Palico Watershed since the 1989 landcover map was used to represent the 9-year (1985 to 1993) LULC situation. It was assumed that there was minimal landcover change within this period and its impact on hydrologic regime is not large enough. As implied in several studies (*Sanyal et al. 2014*; *Nie et al. 2011*; *Zhang et al. 2008*), impacts of LULC change on watershed hydrologic regime is usually measured at least on decadal timescale except when very drastic change in

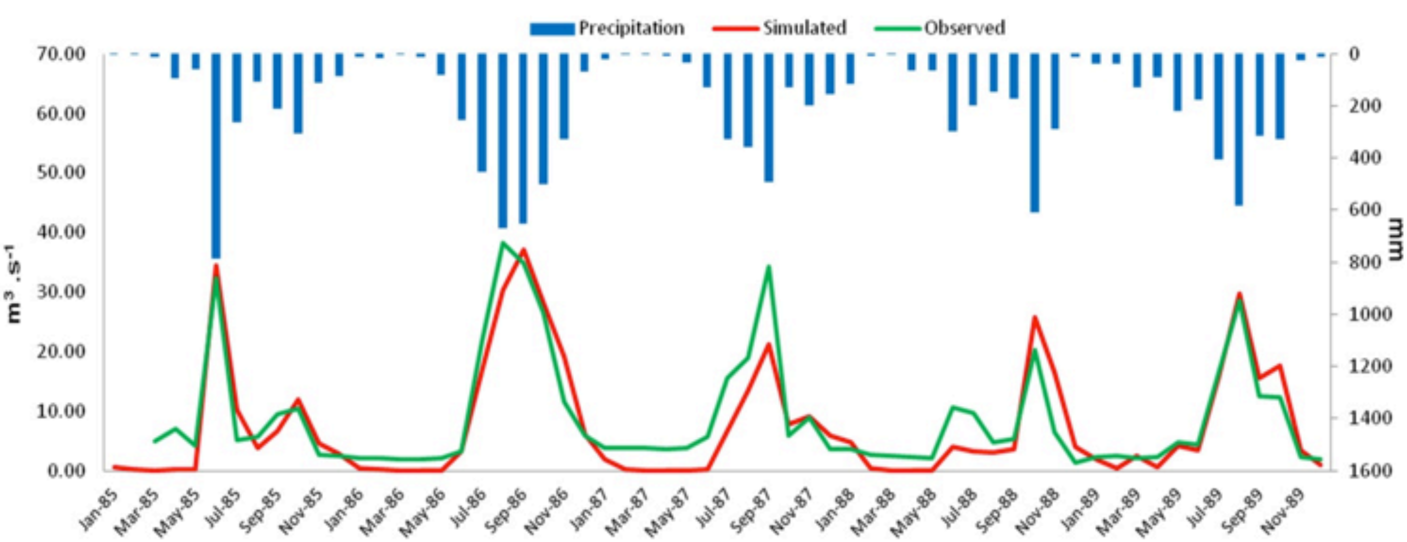

Figure 2. Pre-calibrated simulation of Palico Watershed using 1989 land cover.

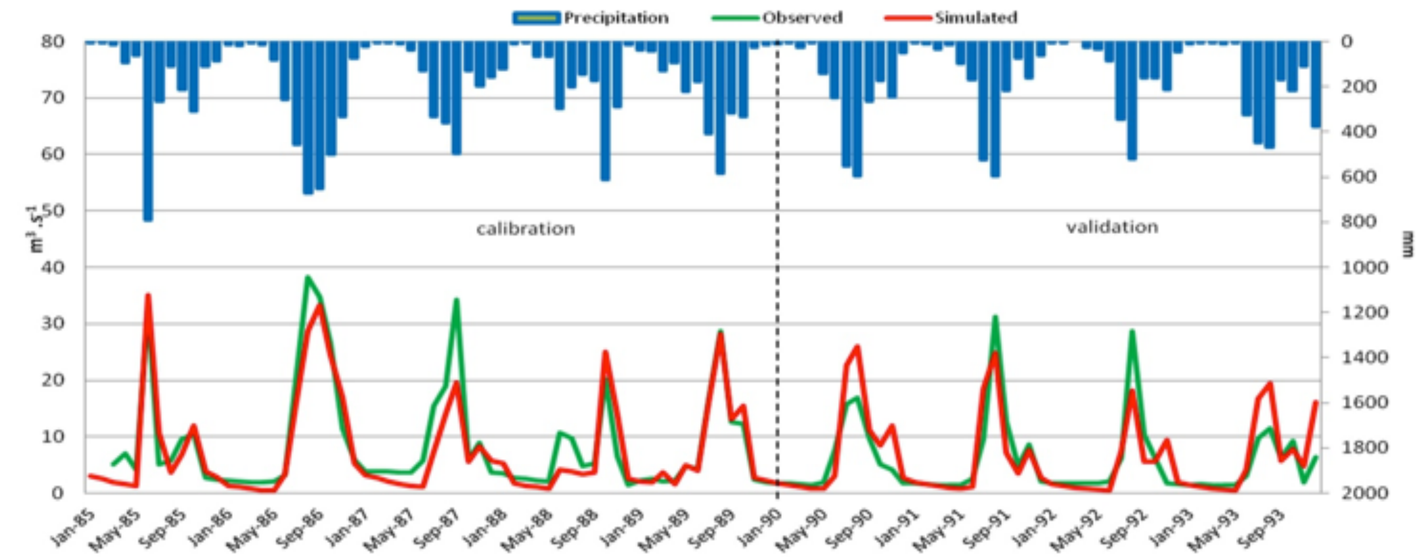

Figure 3. SWAT calibration (1985 to 1989) and validation (1990 to 1993) simulations plotted against observed streamflow data.

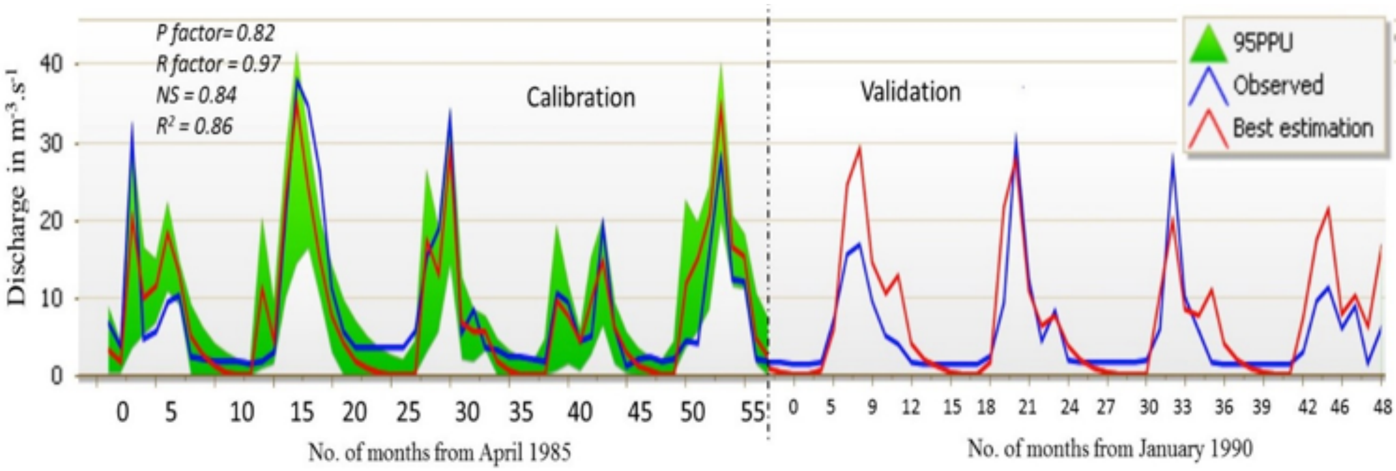

Figure 4. Uncertainly analysis using SWAT CUP showing 95% prediction uncertainty (95PPU), *P-factor, R-factor, NS* and R^2 values.

cover has occurred. There are other factors to consider as most of the modeling studies reported that evaluation statistics for validation is lower than calibration (*Moriasi et al. 2007*). Underlying factors are still unclear and very few studies are conducted on this topic. There is a number of hypothetical reasons and among these are uncertainties in model structure, input data and model parameterization (*Abbaspour et al. 2015*).

Our SWAT modeling for Palico Watershed yielded *P-factor* of 0.82 and *R-factor* of 0.97, both fell within the desirable region of the two indices. *P-factor* and *R-factor* are used to judge the strength of the calibration and validation (**Figure 4**). *P-factor* is the percentage of observation points bracketed by the prediction uncertainty band and R-factor is the average thickness of the band divided by the standard deviation of the observed values showing the degree of uncertainty (*Abbaspour et al. 2015*). As recommended by *Abbaspour et al.* (*2007*), a value of >0.7 or >0.75 for *P-factor* and <1.5 for *R-factor* would be desirable for this index for streamflow discharge.

Land Use/Land Cover (LULC) Change

Parameter settings identified during model calibration (**Table 1**) were used to parameterize the SWAT model with additional land use inputs for the two-time period. Coupled with NSE results, there is a strong justification for using the identified parameters as input to hydrologic modeling efforts for the entire watershed over a longer period to assess watershed response to land use change (*Miller et al. 2002*; *Srinivasan, Zhang and Arnold 2010*). LULC change in Palico Watershed from 1989 to 2013 (**Figure 6a and b**) showed a remarkable increase in sugarcane plantation, coconut plantation and urban areas while decrease in forest, rangeland and general agricultural land. General agricultural land (AGRL), rangeland (RNGE) and forest (FRST) was reduced by 2.46%, 5.54% and 4.36% respectively while

Table 1. SWAT parameters used to calibrate the model.

Parameter	Description	Initial Value/Range	Calibrated Value/Range	Method of Modification
CN2.mgt	SCS runoff curve number f	35 - 98	58.4 – 69.6	Multiply
SOL_AWC.sol	Available water capacity of the soil layer	0 - 1	0.175 – 0.19	Multiply
GW_DELAY.gw	Groundwater delay (days)	0 - 500	91.25	Replace
ALPHA_BF	Baseflow alpha factor (days)	0 - 1	0.5175	Replace
GWQMN	Threshold depth of water in the shallow aquifer required for return flow to occur (mm)	0 - 5000 0.02 – 0.2	500.5 0.0357	Replace Replace
GW_REVAP	Groundwater "revap" coefficient	0 - 500	467.45	Replace
REVAPMN	Threshold depth of water in the shallow aquifer for "revap" to occur (mm)			

Table 2. Percent area of different LULC categories for 1989 and 2013 and the changes between each period.

LULC Classes	SWAT2012 LULC code	1989 Percent Cover(%)	2013 Percent Cover(%)	Difference in % cover (2014-1989)
Agricultural Land	AGRL	27.97	25.52	-2.46
Coconut	COCO	7.58	12.71	5.12
Forest	FRST	35.96	31.60	-4.36
Rangeland	RNGE	17.44	12.90	-4.54
Sugarcane	SUGC	10.15	15.31	5.17
Urban	URMD	0.90	1.96	1.07
TOTAL		100	100	

coconut (COCO), sugarcane (SUGC) and urban (URMD) increased by 5.12%, 5.17% and 1.07% respectively within the entire catchment (**Table 2**). These changes in LULC are due to continuous agro-industrialization wherein forest and other more vegetative land cover are converted to lesser vegetative land uses like urban areas and agricultural land.

The Curve number (CN2) was found to be the most sensitive parameter in a determining the fraction of precipitation converted to surface runoff. A shift to more vegetative LULC would result to a decrease in CN2 while reduction of vegetation would result to significant increase in CN2. LULC change in Palico watershed drove the increase in average CN2 from 81.92 to 82.44 for the entire catchment driving the slight increase in surface runoff but decrease in baseflow or dry season flow and groundwater recharge. Surface runoff roughly increased from 39.5% to 40.4% while dry season flow and groundwater recharge decreased from 10.83% to 10.19% and from 0.59% to 56% respectively (**Table 3**). The increase in surface runoff can be attributed to reduced evapotranspiration and surface roughness as forest cover decreases which consequently lead to lesser available water for infiltration and percolation. Reduction of baseflow and groundwater could also be attributed to the increase on agricultural plantation like coconut and sugarcane. Several studies have demonstrated that the establishment of agricultural and forest plantation resulted in reduced baseflow or dry season flow due to increased transpiration rates and subsequent reduction in groundwater recharge (*Locatelli and Vignola 2009*). *Brüijnzeel* (*2004*) suggests that vegetation removal can increase baseflow if soil infiltration capacities remain intact. However, this study supports the claim that if vegetation clearing is followed by land use practices that compact soils and expose them to erosion, ground water recharge will diminish due to reduction in infiltration and percolation (*Bonnell et al. 2010; Chandler 2006; Zimmermann et al. 2006*).

Spatial and Temporal Impacts of LULC change

Since LULC changes in Palico watershed occurred at various location and magnitude, their hydrologic effects also varied at temporal and spatial scale. SWAT was able to measure hydrologic response on LULC for each subbasin. The change in average CN2 is directly proportional to the change in total annual water yield of each subbasin (**Figure 7**). This means that an increase in average CN2 would result to corresponding increase in annual water yield while decrease in average CN2 will correspond to its decrease for a particular sub-basin (**Figure 8**). Eight sub basins increase in water yield with the increase in average CN2. Sub basin no.2 had the highest reduction in average CN2 and water yield with 2.22 and 62 mm respectively. On the other hand, the remaining eight sub-basins decreased in average CN2 due to enhanced vegetative cover thereby resulting in water yield reduction. Of these, sub basin 3 had the highest decrease in CN2 leading to 88 mm water yield reduction. Overall, the excessive increase in surface runoff and water yield was mainly because of LULC change occurring in upstream

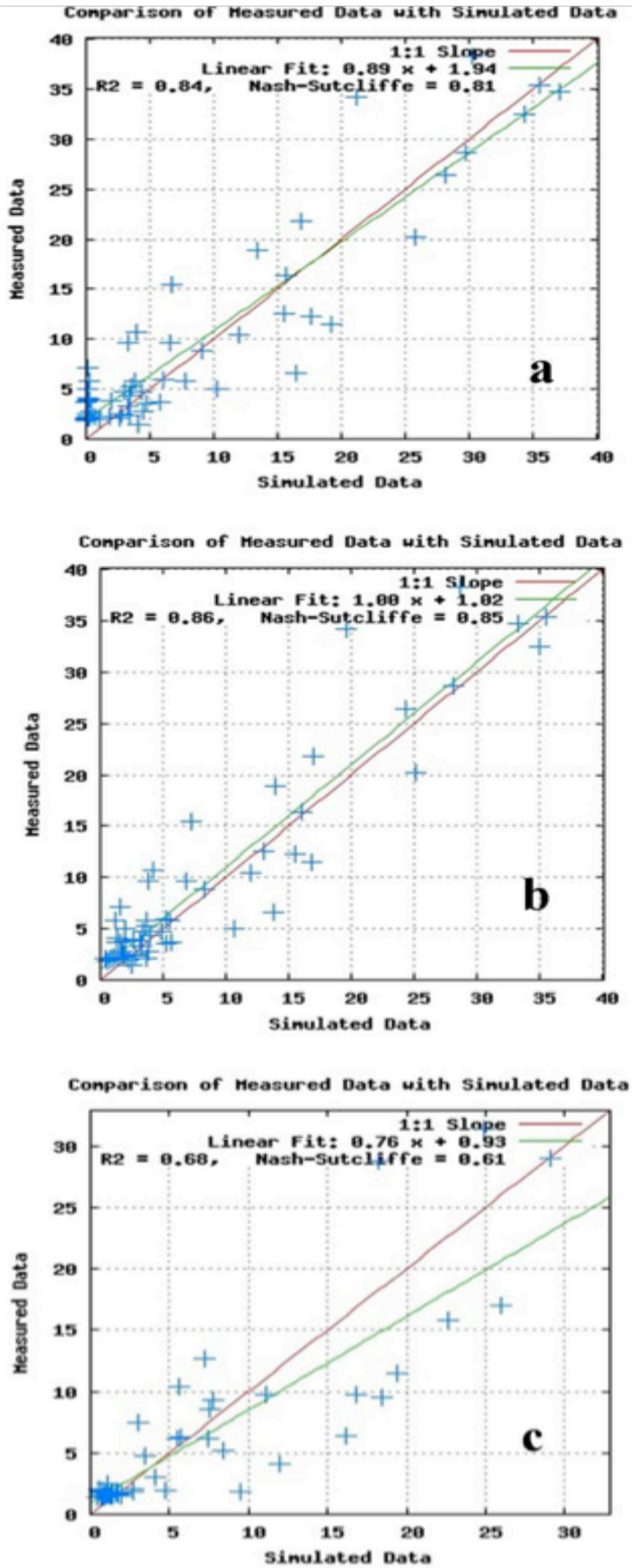

Figure 5. Nash Sutcliffe (NSE) and Coefficient of Determination (R^2) of the (a) uncalibrated, (b) during model calibration, and (c) during model validation.

Table 3. Water budget for the 1989 and 2013 LULCs.

Hydrologic Variables	1989 LULC		2013 LULC	
	Mm	%	mm	%
Surface runoff	753	39.54	770	40.41
Baseflow	206	10.83	194	10.19
Revap from shallow aquifer	44	2.33	44	2.33
Deep aquifer recharge	11.60	0.59	11.15	0.56
Evapotranspiration	891	46.76	887	46.55
Precipitation (total)	1905	100	1905	100

sub basins. The increase in amount of surface runoff and water yield can be mainly attributed to the decline in evapotranspiration due to reduction in forest and other more vegetative cover. LULC change also affects the temporal distribution of water. This is best demonstrated by sub-basin 4 and sub-basin 5, with considerable negative and positive change in LULC. The two subbasins are both located in the upstream region of the watershed (**Figure 7**). Subbasin 4 is in middle upstream portion located on the right side of the main channel while subbasin 5 is on the left upstream portion of the main channel.

Sub-basin 4, which is located in the upstream portion of the catchment, had an increase in its average CN2 by 2.22 due to conversion of 54% of forest area into upland agriculture (**Figure 9**). This shift in LULC led to an increase in annual water yield of about 62 mm. However, as reduction of vegetative cover enhanced surface runoff and total water yield due to decline in evapotranspiration and reduction in surface runoff, infiltration and percolation are diminished leading to decrease in groundwater recharge available for dry season flow. These impacts are manifested by 11% to 17% decrease in baseflow during the dry months from November to April and a 4% to 24% increase in streamflow during rainy period from May to October. On the other hand, subbasin 5 that is located in the upstream portion of the catchment triggered an opposite hydrologic response. Its average CN2 was reduced by 1.32 because of the 22 % increase in forest cover and emergence of the 22% rangeland from possibly abandoned or fallowed upland cultivation areas. This vegetative enhancement reduced water yield from 1,612 mm to 1,591 mm. However, the temporal distribution was also affected through increased in dry season flow by 1% to 15% and reduction of streamflow by 1% to 17% during the rainy season. These hydrologic responses are also governed by the same hydrologic principles on the relationships of LULC with surface runoff, evapotranspiration, infiltration, percolation and groundwater recharge.

This result is consistent with studies of *Baker and Miller* (*2013*) and with *Getachew and Melesse* (*2012*), where watersheds with an increase in forest cover tend to have good groundwater recharge and surface runoff delay

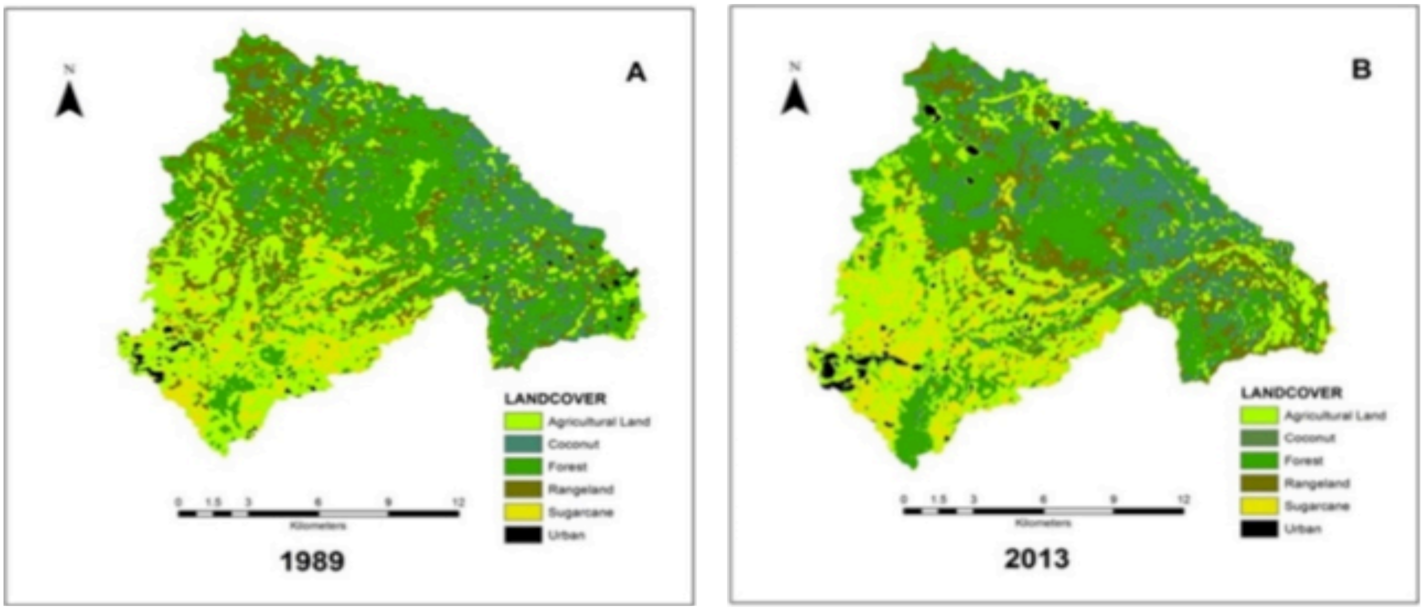

Figure 6. The (a) 1989 and (b) 2013 Landuse/ landcover (LULC) of Palico Watershed.

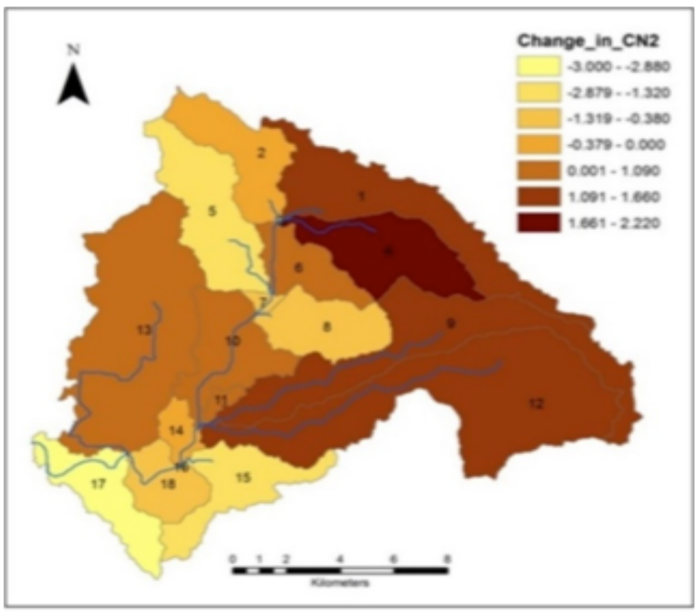

Figure 7. Change in average curve number (CN2) of each subbasin as result of LULC change.

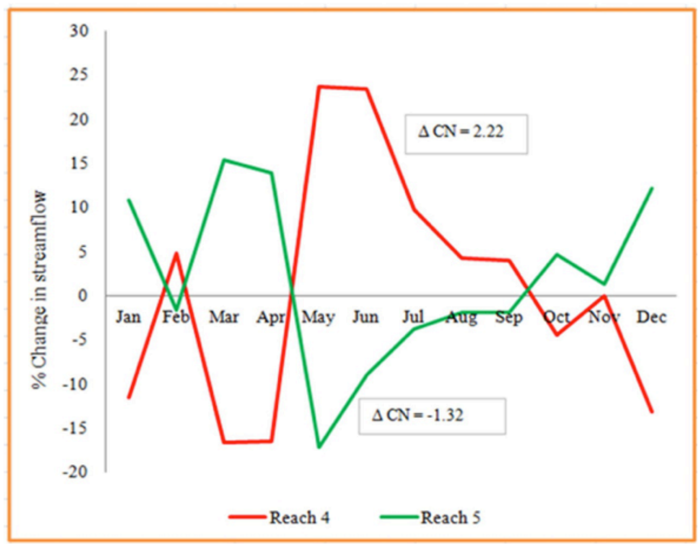

Figure 9. Change in curve number (CN2) of reach 4 and 5 due to 1989 to 2013 landcover change and the corresponding percent change in streamflow as of 2013.

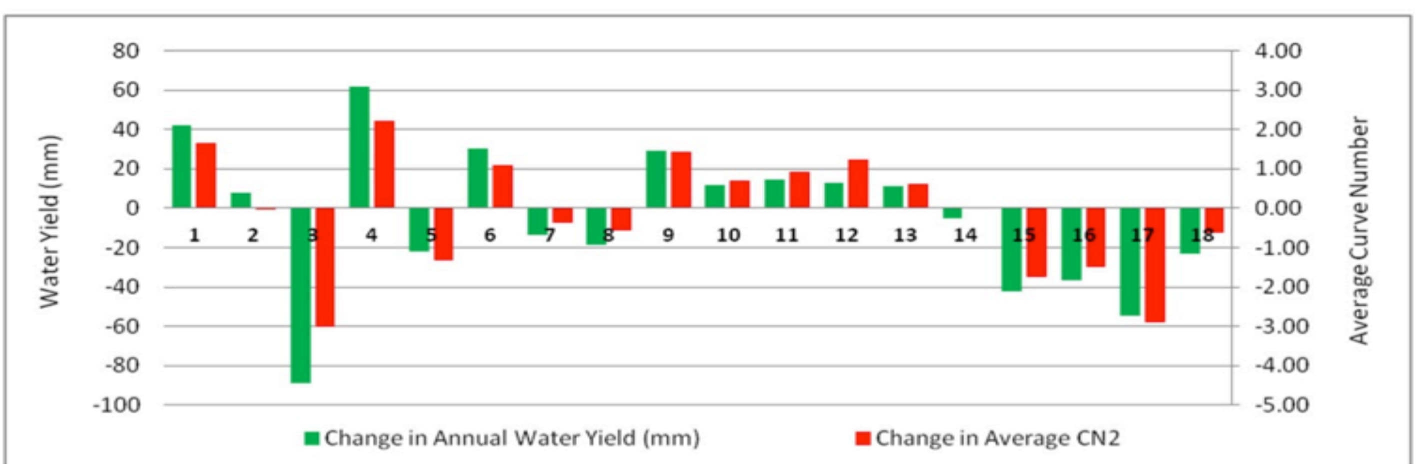

Figure 8. Change in water yield and change in average curve number for each subbasin.

while those with a decrease in forest cover result to more pronounced rainfall-runoff response. This flow regime can affect downstream agricultural production and other agro-industrial activities especially during summer months. Furthermore, continuous decrease in groundwater recharge could lead to scarcity of potable water supply in the near future since surface water is generally considered a less preferred water resource than groundwater (*Calow and MacDonald 2009; Braune and Xu 2009; Calow et al. 1997*).

Although Palico River periodically increases its volume, especially during high rainfall period, the continuous increases in surface runoff during storm period has several undesirable impacts on the downstream ecology especially to marine ecosystem of Verde Island Passage. Surface runoff is associated with high erosion and nutrient delivery, and this could lead to siltation which is an issue of serious concern for its sustainability. Lastly, while there is minimal change in total annual water yield, the increase in streamflow/stormflow during rainy season and the decrease in baseflow during the dry season can contribute to hydrologic stress of the downstream ecosystem during this period.

CONCLUSION

The study simulated the impacts of LULC change on hydrologic response of Palico Watershed using the SWAT model. This chosen study area is one of the major watersheds draining along Verde Island Passage, Philippines. The model was able to yield satisfactory simulation results during the pre-calibrated run (NSE=0.81 & R^2=0.84), calibration (NSE=0.84 & R^2=0.86), and validation (NSE=0.61 & R^2=0.68). This modeling study showed that LULC change influences the hydrologic behavior of Palico watershed in terms of water quantity and timing of hydrologic occurrence. Based on model simulations, the annual surface runoff and water yield increased while the baseflow and groundwater recharge decreased when there is loss in forest cover, reduction in rangeland and increased cultivated land and urban area. However, the impacts of LULC change on the hydrologic response are non-uniform over space and time. Sub basins with a decrease in forest cover or shift to lesser-vegetated land cover tend to increase in streamflow during rainy season and decrease flow during dry season. On the other hand, sub basins with increase in forest cover or shift to more vegetated land cover would result to opposite flow regime. Continuous increase in surface runoff during storm period and reduction of flow during dry season could have deleterious effects on downstream ecosystem especially on the marine ecosystem of Verde Island Passage (VIP). This flow regime can also negatively affect downstream agricultural production and other agro-industrial activities especially during the dry months.

Finding the balance between these two opposite scenarios is crucial for the attainment of water sustainability. This could include revisiting of the policy and strategy in crafting local Comprehensive Land Use Plan (CLUP) of the local government and determine optimum spatial and temporal LULC combination with emphasis on sustainable watershed management. Such strategy would require additional studies on LULC and climate change impacts on hydrologic response, sediment and nutrient influx of Palico and other major watersheds draining along VIP. These endeavors must be carried out to fill knowledge gaps and to build a decision support system for this important ecosystem.

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