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Streamflow forecasts due precipitation water in a tropical large watershed at Brazil for flood early warning, based on SWAT model

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ABSTRACT

The Tocantins-Araguaia Watershed, which is distributed equivalent to 11% of Brazilian territory, conveys waters to the northern portion of Brazil with average discharge of 11000 m^3 s^{-1}, with contribution from the Tocantins River (40%), the Araguaia River (45%), and the Itacaiúnas River (5%), making possible an intangible flood in the Marabá city and Tucuruí Hydroelectric Plant (Downstream) during periods of high rainfall within the tropical watershed without provide timely warnings. For flash flood forecasting in a tropical large watershed, streamflow forecasts due precipitation water is required for flood early warning and in this sense, numerical prediction models are fundamental to extend streamflow forecast of a watershed due to precipitation. The paper focuses on the use Soil and Water Assessment Tool (SWAT), January 2007 to December 2010 period, to comparison of streamflows obtained from the post-processed precipitation forecasts, in providing skilful flood forecasts. In this sense, the basin was divided into 109 sub-basins and 1969 HRUs, and the model was calibrated and validated based on flow rate data in three monitoring points located next of Marabá city and Tucuruí hydroelectric. Posteriorly, simulated discharges scenario due to climatic variability extreme were generated under three strategies: 10%, 50% and 100% increase in ambient temperature (24°C) due natural and/or anthropogenic events within the watershed. The model results show that stream flows obtained adds value to the flood early warning system when compared to precipitation forecasts. Considering that climate is a direct function of temperature it is obvious that all relevant phenomena undergo changes. The scenarios results show that 50% increase in ambient temperature this leads to greater and faster evaporation. Thus, the gradual increase of precipitation in tropical watershed large alters flow rates over time and increase flood potentials in areas downstream of the basins. However, the need for more detailed evaluation of the model results in the study area is highlighted, due adequately represent the convective precipitation within the large tropical watershed.

Keywords: Streamflow forecasts; SWAT model; climatic variability; Watershed Management.

I. INTRODUCTION

Watersheds are complex systems where water dynamics is affected by natural factors and anthropogenic activities, such as precipitation, topography, soil properties and land use, which also affect the quality of groundwater and surface water [1]. Streamflow, which is known an integrated process of atmospheric and topographic processes, is of prime importance to water resources planning [2]. In a wide spectrum of engineering applications, it is critical to have reliable long-term or short-term flow forecasts. The lead time of day is often used for the flood warning systems. However, the tools for forecast are not free of error and usually expensive when they are set in a physical base. Stochastic and conceptual models have been always common in use [3]. It is possible to work on a model considering both hydrologic and climatologic variables, such as precipitation, runoff, temperature, evaporation and/or historical observations. Changes in the precipitation regime have a reflection on the flow regime, altering the hydrological response of a basin. Hydrological response is the production of water from a basin, obtained by the ratio between flow and. The accuracy of model results depends heavily on the accuracy of model inputs, especially precipitation, which is the driving force behind all hydrologic processe). Considering that climate is a direct function of temperature it is obvious that all relevant phenomena undergo changes. Increase in ambient temperature this leads to greater and faster evaporation. Thus, the gradual increase of precipitation in tropical watershed large alters flow rates over time and increase flood potentials in areas downstream of the basins.

The Tocantins-Araguaia basin (see Figure 1), located in Brazilian Amazon, becomes of importance large by presents itself as one of the preferred areas and most promising for expansion Brazilian economic growth in the coming decades with catchment area of 767 000 km^2, lying between 46 ° W and 55° W, and between 2° S and 18° S, equivalent to 11% of Brazilian territory (ANEEL, 2002). The area includes major cities, agricultural and pasture activities, and electric power plants, distributed throughout the states of Goiás, Tocantins, Pará, Maranhão, Mato Grosso and Distrito Federal. The drainage area includes 343 000 km^2 corresponding to the Tocantins river, 382 000 km^2 to the Araguaia river (its main tributary) and 42 000 km^2 to the Itacaiúnas river (the largest contributor to its lower course). The basin of the Tocantins-Araguaia has an average discharge of 11 000 m^3 s^{-1}, with contribution from the Tocantins River (40%), the Araguaia River (45%), and the Itacaiúnas River (5%) [4]. The rivers convey the water downstream, in the northern region, where Maraba city and Tucuruí Hydroelectric Plant are located (the second largest hydroelectric plant in the country producing 8 million KW, equivalent to 32% of the total potential of the basin) [5-6]. It is noteworthy that in the months from October to April (high rainfall period) [7-8], the watershed in its northern portion (Marabá city (MARA) and Tucuruí hydroelectric), suffer repeated severe floods affected by regional climate variations and by natural factors and anthropogenic activities.

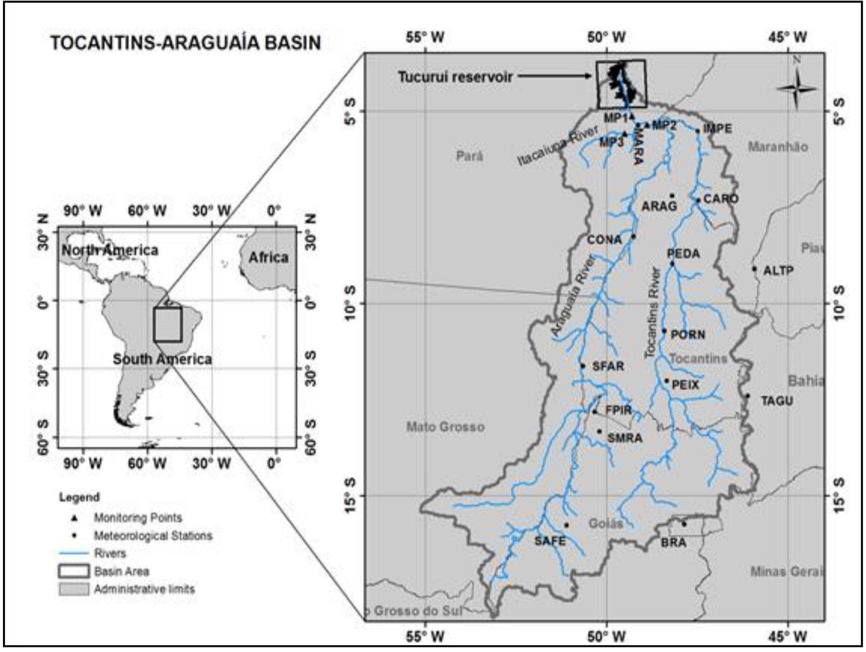

Figure 1: The catchment of the Tocantins-Araguaia, which conveys water to the Tucuruí Hydroelectric Plant.
Source: Authors, (2018).

Given this context, a research monitoring and forecasting of rivers flow rate from the Tocantins-Araguaia Basin, should involve measurements of all the variables which influence its dynamics. This is a difficult task, sometimes impossible, because the time required and the costs of measurements and monitoring are major obstacles. Thus, hydrological models, as SWAT (Soil and Water Assessment Tool) [9-10], are tools mathematical useful for evaluating the hydrologic effects of factors such as climate change, flood warning systems in basin, landscape pattern or land use change resulting from policy decisions, economic incentives or changes in the economic framework [11-13]. Given the above, the objectives of this research were: (1) Calibrating and validating the SWAT model as applied to the Tocantins-Araguaia watershed based on flow rate data in three monitoring points located next of Marabá city and Tucuruí hydroelectric, (2) Use Model streamflow forecasts due precipitation water and (3) Simulate discharges scenario due to climatic variability extreme generated under three strategies: 10%, 50% and 100% increase in ambient temperature (24℃) due natural and/or anthropogenic events within the watershed.

II. MATERIALS AND METHODS

II.1 STUDY SITE

The study was proceeded in Tocantins–Araguaia basin in Brazil delimited to the Marabá city (MARA) and Tucuruí hydroelectric (Downstream) (Figure 1). The two main rivers, Tocantins and Araguaia, are considered to be the central fluvial arteries of the country. The basin is characterized by smooth topography with altitudes ranging mainly from 200 m to 500 m, and higher than 1000 m in the southern region. The climate is continental tropical, with average annual temperatures ranging from 22.5 °C to 24.4 °C in the northern part. The average precipitation for the entire region is 1869 mm/year. However, the seasonal variability of precipitation represents a fundamental feature of this region, characterized by extreme droughts followed by large rainfall events [14]. The middle and lower Tocantins–Araguaia Basin in its northern portion (Marabá city (MARA) and Tucuruí hydroelectric), on the other hand, is dominated by extensive floodplains, prone to a more gradual flooding and receding.

II.2 SWAT MODEL DESCRIPTION

The Soil and Water Assessment Tool (SWAT 2005) with ARCGIS 9.3 [9][15-16] has been developed by the USDA Agricultural Research Service (ARS). It incorporates features of several previous ARS models and is based on the Simulator for Water Resources in Rural Basins (SWRRB) model [9]. There have also been several other models that contributed to the development of SWAT, such as the Chemicals, Runoff and Erosion from Agricultural Management Systems model (CREAMS) [17], the Groundwater Loading Effects of Agricultural Management Systems model (GLEAMS) [18], and EPIC [19]. The water budget equation is the basis for the simulation of the hydrologic cycle in SWAT (Eq. 1) [15][20-21]. Total runoff hydrographs are computed based on runoff calculated separately at each sub-basin, and then routing through several channels. A modified version of SCS curve number method [22] is used for surface runoff computation, while the Modified Universal Soil Loss Equation (MUSLE) [23] is used for erosion and sediment yield calculation. Nutrient load and concentration prediction are based on a modification of the code in the EPIC model [19][24]. Finally, soil surface and plant data are used to calculate evapotranspiration in the watershed, while precipitation and temperature data can be either provided as time series data, or simulated using a first order Markov chain model in the case when meteorological time series data are not available [25].

$$SW_t = SW_0 + \sum_{i=1}^{t} (R_{day} - Q_{surf} - E_a - w_{seep} - Q_{gw}) \qquad (1)$$

Where SW_t (mm) is the final soil water content; SW_0 (mm) is the initial soil water content on day i, t (day) is the time; R_{day} (mm) is the amount of precipitation on day i, Q_{surf} (mm) is the amount of surface runoff on day i, Q_{gw} (mm) is the amount of return flow on day i, E_a (mm) is the amount of evapotranspiration on day i, and w_{seep} (mm) is the amount of water entering the vadose zone from the soil profile on day i.

The watershed discretization in the SWAT model is done by dividing the catchment into sub-catchments based on a threshold area. Each sub-catchment is further divided into one or several homogeneous hydrological response units (HRUs) representing unique combinations of soil and land use. The responses of each HRU in terms of water, sediment, nutrient and pesticides transformations and losses are determined individually. They are then aggregated at the sub-basin level and routed to the associated reach and to the catchment outlet through the channel network [16][26].

II.3 SETTING UP THE MODEL

- DEM, land use and soil data preparation

Topography of the Tocantins-Araguaia Watershed was described by a Digital Elevation Model (DEM) with a spatial resolution of 3 km by 3 km (Figure 2). Created DEM (see Figure 2) was converted to Arcview grid format with ‘‘UTM – Zone 20 S – WGS84 Datum’’ projection. The DEM was used to delineate the watershed and to analyze the drainage patterns of the land surface terrain. The size and number of the sub watersheds were determined according to the streams. Land use grid map was prepared to be used with the image maps given in the literature cited.

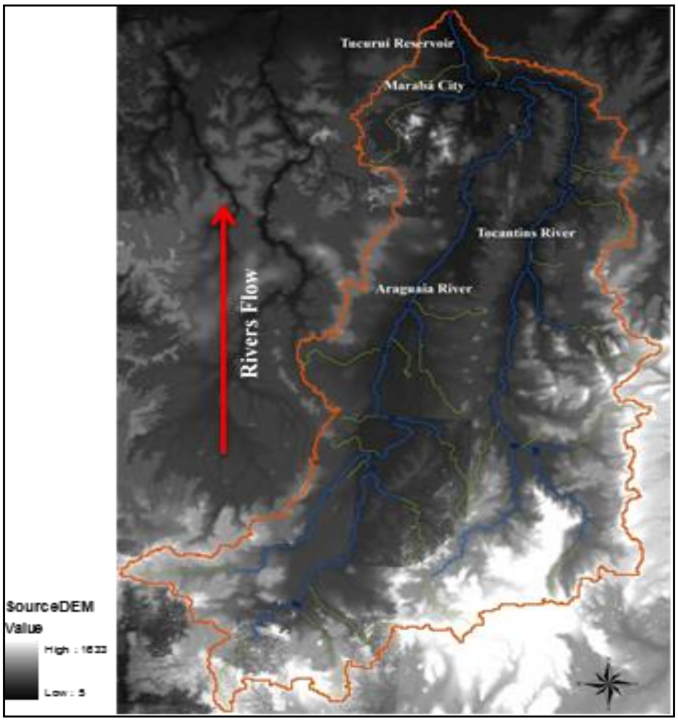

Figure 2: Digital Elevation Model (DEM) to Tocantins-Araguaia Watershed, corresponding rivers and flow path of the Tocatins-Araguaia Watershed.
Source: Authors, (2018).

Land use and soil maps (1:200 000) were provided as shape files (.shp) by the Brazilian Institute of Geography and Statistics [27], as well as a description of the texture profile for all soils. For each soil type, soil percentages of clay, silt, sand, and organic matter [28-33], were used for two layers of soil. The first layer was 40 cm deep and the second layer 80 cm deep. All these data were entered into the SWAT/2005 database manually or in dbf format.

When applying the model SWAT, the watershed is divided into sub-basins, with its size based on a user defined threshold value (CSTV). The threshold is an important parameter for defining the HRUs and to allow basin sub-division in more detail [34-35]. In total, 109 sub-basins and 1969 HRUs (Figure 3) were defined by using automatic delineation routines. The HRUs were characterized by the land use classes (Table 1).

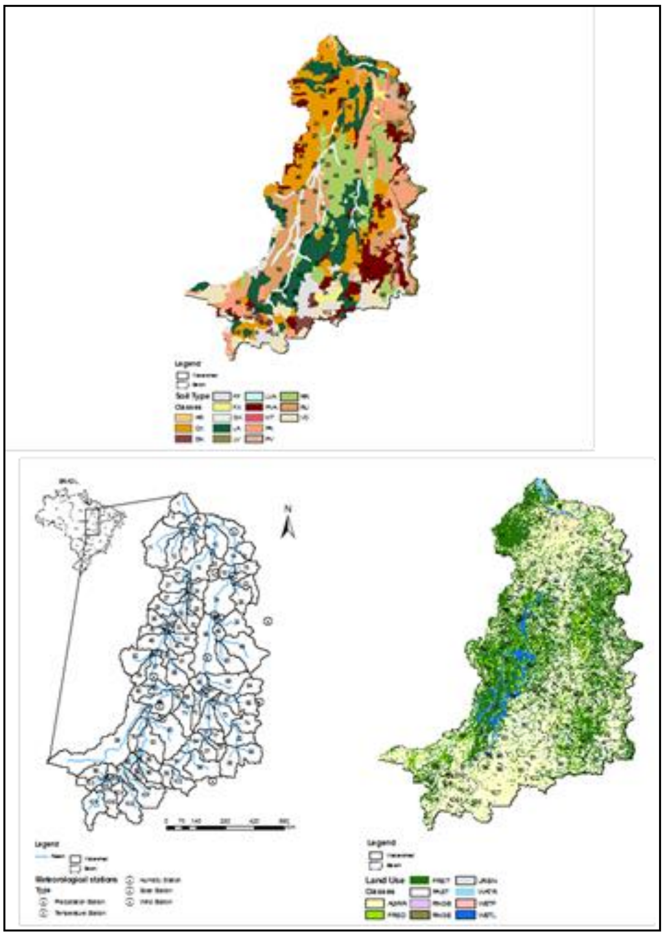

Figure 3: Map of study area, including 109 sub-basins, Monitoring Points, Meteorological Stations, Land use and Soil Type in the Tocantins-Araguaia Watershed.

Source: Authors, (2018).

Table 1: Summary of land use types in Tocantins-Araguaia Watershed

Land Use	SWAT Code	Watershed Percentage (%)
Florest-Mixed	FRST	36.12
Agricultural Land – Row Crops	AGRR	33.10
Pasture	PAST	20.07
Florest-Decíduous	FRSD	5.72
Wetlands-Mixed	WETL	2.67
Range-Brush	RNGB	0.94
Water	WATR	0.90
Wetlands-Forested	WETF	0.46
Range-Grasses	RNGE	0.01
Residential	URBN	0.01

Source: Authors, (2018).

- Streamflow database

The streamflow database was made up of 15 streamflow gauging stations (Brasília - BRA, Marabá - MARA, Imperatriz - IMPE, Araguaia -ARAG, Carolina -CARO, Conceição do Araguaia - CONA, Pedro Afonso - PEDA, Alto do Paraíba -ALTP, Porto Nacional - PORN, Peixes - PEIX, Taguatinga - TAGU, São Felix do Araguaia -SFAR, Fazenda Piratininga -FPIR, São Miguel do Araguaia - SMRA, Santa Fé - SAFE) located Tocantins-Araguaia Watershed (see Figure 1 and Table 2), and the data is also available in the National Water Agency (ANA) by Hydrologic Information System (HIDROWEB ANA) http://www.snirh.gov.br/hidroweb/.

Table 2: Meteorological stations in Tocantins-Araguaia Watershed

ID	Responsible	Code	Station	State	Code in map	Latitude	Longitude	Elevation (m)
1	INMET	01547004	Brasília	Distrito Federal (DF)	BRA	-15.74	-47.86	1061
2	INMET	82562	Marabá	Pará (PA)	MARA	-5.36	-49.13	117
3	INMET	82564	Imperatriz	Maranhão (MA)	IMPE	-5.53	-47.48	211
4	INMET	82659	Araguaina	Tocantins (TO)	ARAG	-7.20	-48.20	351
5	INMET	82765	Carolina	Maranhão (MA)	CARO	-7.33	-47.46	448
6	INMET	82861	Conceição do Araguaia	Pará (PA)	CONA	-8.26	-49.26	182
7	INMET	82863	Pedro Afonso	Tocantins (TO)	PEDA	-8.96	-48.18	240
8	INMET	82970	Alto da Parnaíba	Maranhão (MA)	ALTP	-9.1	-45.93	481
9	INMET	83064	Porto Nacional	Tocantins (TO)	PORN	-10.71	-48.41	302
10	INMET	83228	Peixes	Tocantins (TO)	PEIX	-12.01	-48.35	304
11	INMET	83235	Taguatinga	Tocantins (TO)	TAGU	-12.4	-46.10	635
12	ANA	26350000	São Félix do Araguaia	Mato Grosso (MT)	SFAR	-11.62	-50.66	190
13	ANA	01250000	Fazenda Piratininga	Goiás (GO)	FPIR	-12.82	-50.34	220
14	ANA	01350002	São Miguel do Araguaia	Goiás (GO)	SMRA	-13.33	-50.19	249
15	ANA	01551003	Santa Fé	Goiás (GO)	SAFE	-15.77	-51.10	379

Source: Authors, (2018).

- Climate data preparation

Available data included time series of daily precipitation, air temperature, maximum and minimum, relative humidity, wind speed and solar radiation, obtained from 15 meteorological stations (Figure 1 and Table 2), administered by the National Institute of Meteorology (INMET-Brazil) and National Water Agency (ANA), and located within the basin of the Tocantins-Araguaia, for the simulation period from January 2007 to December 2010.

- Model Sensitivity

Flow data available for sensitivity analyses were obtained at three monitoring points (MP1, MP2, MP3), located within the main tributaries of the watershed (Figure 1) from January 2007 to December 2008. The validation was carried out by using the data collected in the same locations during the period from January 2009 to December 2010. The MP1 point corresponds to data obtained upstream the Tucuruí reservoir. The MP1 point corresponds to data obtained upstream of Tucuruí reservoir. The MP2 point corresponds to data located upstream of the city of Marabá, influenced by the Araguaia and Tocantins rivers. MP3 station data were obtained upstream of the city of Marabá, influenced by the river Itacaiúna. The data available in time series of daily rainfall, air temperature, relative humidity of maximum and minimum air, wind speed and solar radiation, obtained from 15 weather stations, 11 administered by the National Institute of Meteorology (INMET-Brazil) and 4 by the National Water Agency (ANA).

The sensitivity analysis method implemented in SWAT is called the Latin Hypercube One-factor-At-a-Time (LH-OAT) designed as proposed by [36-37]. The sensitivity analysis showed that the curve number (CN2), Soil evaporation compensation factor (ESCO), Plant uptake compensation factor (EPCO), Available water capacity of the soil layer (mmH2O/mmSoil) (SOL_AWC), Groundwater “revap” coefficient (GW_REVAP), Threshold depth of water in the shallow aquifer required for return flow to occur (mmH2O) (GWQMN), Deep aquifer percolation fraction (RCHRG_DP) and Base flow alpha factor (days) (ALPHA_BF), are the most sensitive parameters (see Table 3).

Table 3: Parameters used for calibration of the SWAT model.

Variable	Model Processes	Description	Normal Range	Value Used	Reference
CN2	Surface Runoff	Curve Number	0-100	82	This Study: [38-39].
ESCO	Evapotranspiration	Soil Evaporation Compensation Factor	0.0-1.0	0.95	This Study: [38-39].
EPCO	Groundwater	Plant Uptake Compansation Factor	0.0-1.0	1.0	This Study:[38-39].
SOL_AWC	Soil Water	Avaliable water capacity of the soil layer (mmH$_2$O/mmsoil)	0.0-1.0	0.10-0.16	This Study: [38-39].
GW_REVAP	Groundwater	Groundwater-"Revap" coefficient	0.02-0.20	0.02	This Study: [38-39].
GW_DELAY	Groundwater	Groundwater Delay Time (days)	0-50	50	This Study: [38-39].
CN_N2	Surface Runoff	Storage of "n" values for main channel	0.01-0.5	0.05	This Study: [38-39].
GWQMN	Groundwater	Water depth threshold in the surface aquifer required for return flow to occur (mmH$_2$O)	0.0-300.0	100.0	This Study: [38-39].
RCHRG_DP	Groundwater	Fraction of percolation in the deep aquifer	0.0-1.0	0.0-0.8	This Study: [38-39].
ALPHA_BF	Groundwater	Alpha flux-base factor (days)	0.0-1.0	0.1	This Study: [38-39].

Source: Authors, (2018).

- Model calibration and validation

The model calibration procedure is developed based on optimization techniques [40-41] with the assumption that an optimal set of parameters exists for the model to describe the hydrology in the Tocantins-Araguaia basin. Calibration and validation are generally referred to as either automated or manual.

Automated calibration is used to identify a set of model parameters (see Table 4) by optimizing a goodness-of-fit statistic between observed and predicted values for posterior automated validation, using the same technique of comparison for a distinct period.

Table 4: Manual calibration and validation in flow rate, applied to Tocantins-Araguaia basin in monitoring points MP1, MP2 and MP3.

Monitoring Point	**Flow Rate**								
	Calibration					**Validation**			
	January 2007 to December 2008 Period					January 2009 to December 2010 Period			
	Parameter								
	RMSE	NOF	γ	R^2		RMSE	NOF	γ	R^2
MP1	0.0002	0.1530	0.9964	0.8506		0.0006	0.6218	1.0334	0.8075
MP2	0.0008	0.6225	1.0926	0.9413		0.0004	0.3426	1.0079	0.9159
MP3	0.0014	0.3284	0.9564	0.7542		0.0004	0.1210	1.0428	0.8102

Source: Authors, (2018).

However, the manual calibration and validation is statistic application used. In this study, according to [25], were: the square of the correlation coefficient R^2, the root mean square error (RMSE), the normalized objective function (NOF) and scattergrams.

- The root mean square error (RMSE) and the normalized objective function (NOF) [40] were computed based on the following equations 2 and 3:

$$RMSE = \sqrt{\frac{\sum_{i=1}^{N}(Pi - Oi)^2}{N}} \qquad (2)$$

$$NOF = \frac{RMSE}{\bar{O}} \qquad (3)$$

Where P_i are the model predicted values, O_i are the observed values for the N observations, and $\bar{O}$ is the mean of observed values. According, the ideal value of NOF is 0.0. However, a model is acceptable for NOF values in the range from 0.0 to 1.0 when site specific data are available for calibration. According to [25], the model can be used to test scenarios associated with management practices.

- Another way to assess the model is through the use of scattergrams [42-43] where predicted quantities are plotted against observed ones. According to [25], in a scattergram, a regression straight line of the following form is also fitted through the data:

$P_i = \gamma O_i$, The value of the slope γ is a measure of the over- (γ>1.0) or under- prediction (γ<1.0) of the model compared to the observed data. In addition, the square of the correlation coefficient R^2 of the regression line is computed. The lower the value of R^2 falls below 1.0, the worse the data correlation is, i.e., the greatest is the scatter of the data around the line. Therefore, best calibration requires that values for both slope γ and R^2 be as close to 1.0 as possible.

Scenarios of annual and seasonal streamflow responses to climatic variability extreme

The ability of a SWAT model to run different management scenarios is a powerful tool for the decision-making process. After model validation, simulated discharges scenario in contribution of Tocantins-Araguaia watershed to Marabá city and Tucuruí hydroelectric reservoir due to climatic variability extreme were generated under three strategies: 10%, 50% and 100% increase in ambient temperature (24 ℃) due natural and/or anthropogenic events within the watershed.

III. RESULTS AND DISCUSSION

III.1 MODEL PERFORMANCE IN ANNUAL AND SEASONAL STREAMFLOW RESPONSES TO CLIMATE AND LAND-COVER CHANGES FROM THE TOCANTINS-ARAGUAIA BASIN

The model was calibrated and validated based on annual and seasonal streamflow using data from three monitoring points (MP1, MP2 and MP3), located next of Marabá city and Tucuruí hydroelectric. After a successful calibration that covers a 2 year period (January 2007 to December 2008 period), remaining 2 years data (January 2009 to December 2010 period) were validated against observed annual and seasonal streamflow values (Figure 4-6 and table 4). The model showed good agreement with measured data. For the calibration period the simulated average streamflow in the monitoring point MP1 was 13 419 m^3 s^{-1} versus an average value from field data of 13 258 m^3 s^{-1} (Figure 4). The simulated average streamflow in the monitoring point MP2 was 5 738 m^3 s^{-1} versus an average value from field data of 6 010 m^3 s^{-1} (Figure 5). The simulated average streamflow in the monitoring point MP3 was 1 434 m^3 s^{-1}, versus an average value from field data of 1 481 m^3 s^{-1} (Figure 6). In manual calibration for monitoring points MP1, MP2 and MP3, the slope (γ) was between 0.9564 and 1.0926, and correlation coefficient values (R^2) range between 0.7542 and 0.9413 or, in other terms, values of γ e R^2 are close to 1.0. Nevertheless, the normalized objective function (NOF) provided values lower than 1.0 (between 0.1530 and 0.6225) (see Figure 4-6 and Table 4).

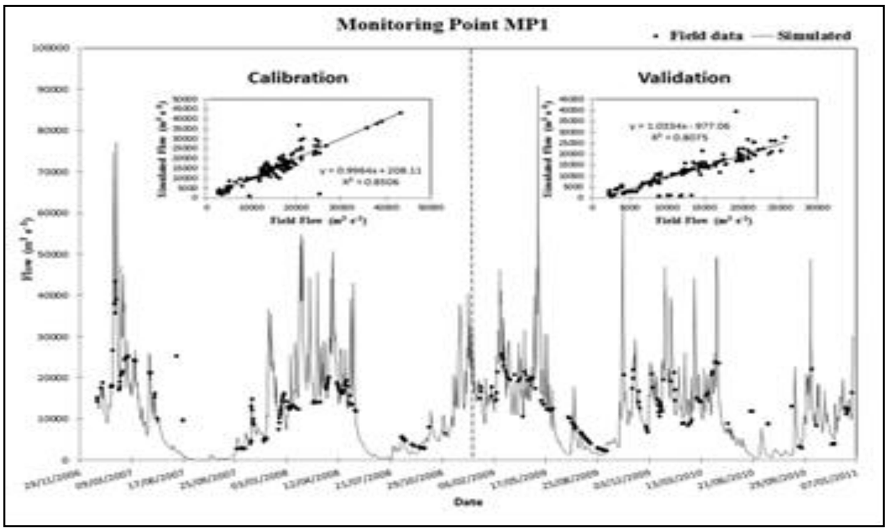

Figure 4: Measured and simulated flows, and corresponding scattergrams at each monitoring point MP1 for calibration and validation. Source: Authors, (2018).

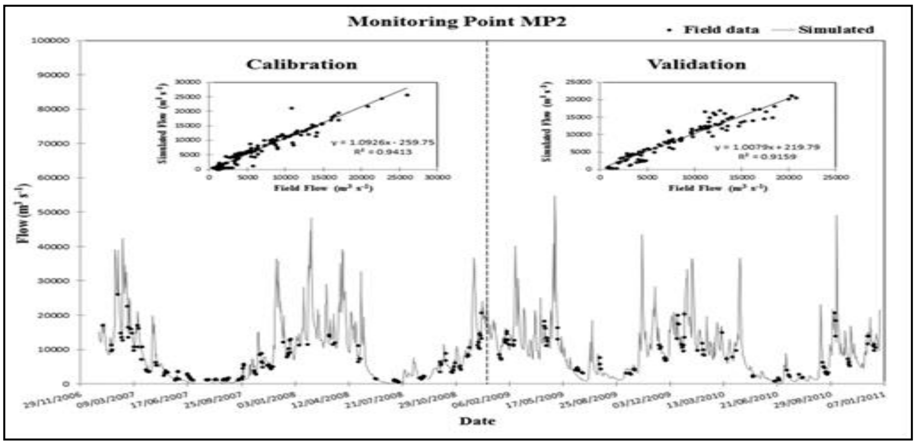

Figure 5: Measured and simulated flows, and corresponding scattergrams at each monitoring point MP2 for calibration and validation. Source: Authors, (2018).

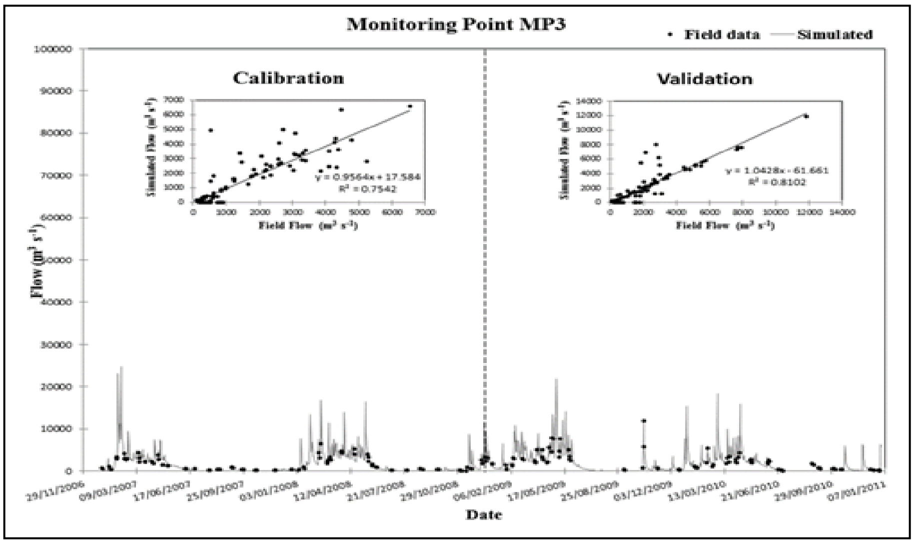

Figure 6: Measured and simulated flows, and corresponding scattergrams at each monitoring point MP3 for calibration and validation. Source: Authors, (2018).

Similar promising results were obtained for validation step, because average simulated streamflow in monitoring point MP1 was 11 327 m^3 s^{-1}, versus an average value from field data of 11 907 m^3 s^{-1} (Figure 4). The average simulated streamflow in monitoring point MP2 was 8 882 m^3 s^{-1}, versus an average value from field data of 8 594 m^3 s^{-1} (Figure 5). The average simulated streamflow in monitoring point MP3 was 2 028 m^3 s^{-1}, versus an average value from field data of 2 000 m^3 s^{-1} (Figure 6). In manual validation for monitoring points MP1, MP2 and MP3, the slope (γ) was between 1.0079 e 1.0428, and correlation coefficient values (R^2) range between 0.8075 and 0.9159 or, in other terms, values of γ e R^2 are close to 1.0. Nevertheless, the normalized objective function (NOF) provided values lower than 1.0 (between 0.1210 and 0.6218) (Figure 4-6 and Table 4). Finally model outputs considering the whole period (2007–2010) were plotted against the observed streamflow rates (see Figure 4-6). See Figure 4-7, streamflow level reaches the lowest values during periods of low precipitation (June – October), while during periods of high precipitation (November– May) reflection on the flow regime, altering the hydrological response of basin and during periods of extreme precipitation rate (February-April) alters flow rates in the monitoring points (MP1, MP2 and MP3) and consequently, negativity influence in northern areas with increase streamflow and increase flood potentials. This result also indicates that in periods of higher rainfall could suffer environmental problems such as erosion [44]. These results are consistent with [44], who through his publication entitled "Prospects for the urban environment: GEO Marabá-Pará." Published by the United Nations Environment Program (UNEP), United Nations Program for Human Settlements Institute of Directors (IBAM), Institute of Religious Studies (ISER), Ministry of Environment and Ministry of Cities, showed that the built environment is affected by the floods themselves, as well as by the state of the water from these floods, in view of their pollution and contamination.

Second [45], the average annual flood lasts from two to four months, between the beginning of reaching the level of 10 m, considered as "alert level", and the return to that same level, when the last inhabitants begin to return to their Houses for the cleaning and repair services, as stated in the testimonies of residents, which expresses the coexistence with the fact. The number of people affected by floods Depends on the level reached by the waters that relates the level reached to the number of people affected in 2006. This information indicates that approximately 920 people were hit when the flood reached the level of 10.88 m, which rose to around 11,316 people, when the water level reached 12.34 m which, according to Civil Defense, has been the average number reached The last two years. The Civil Defense of Marabá determines the quota 81.88 (level 10.0 m) as "alert quota". At this level, the most affected areas are: Dry Hair, Santa Rita, Santa Rosa, Marabá Pioneira and Folha 33 in Nova Marabá. It is important to note that not all affected people accept to be transferred to the shelters prepared by the City Hall, some people seek support in homes of relatives, and others build their shelters in advance on higher ground. Also, the Tucuruí Hydroelectric Power Plant began to open its spillways in the first days of February, but now it has all of its spillways open downstream of the Tocantins River to guarantee the limit of the 74 meters This, due to the release of water that arrives from Marabá in large volumes, which also has already displaced hundreds of families from Marabá, caused the rapid flooding of several points of the Tucuruí city.

Model results indicate that there is a considerable correlation between the simulated model and observations, because this situation shows that the reliability of a model is directly proportional to modifications in calibration step and thus, results show that the model generated simulates the average annual and seasonal streamflow correctly. Also, these results show that the annual and seasonal streamflow in basin during periods of high and low precipitation can be driven by responses to climatic variability extreme. For, considering that climate is a direct function of temperature it is obvious that all relevant phenomena undergo changes. Increase in ambient temperature this leads to greater and faster evaporation. Thus, the gradual increase of precipitation in tropical watershed large alters flow rates over time and increase flood potentials in areas downstream of the basins.

III.1.1 SCENARIOS OF CLIMATIC VARIABILITY EXTREME

With positive correlations between values for streamflow rate and precipitation values modeled (Figure 7), the results indicate that 10% increase in ambient temperature (24 ℃) affected insignificantly the streamflow in northern portion (MP1, MP2 and MP3 points). However, showed that gradual increase of precipitation in tropical watershed large alters flow rates model generated (Figure 8). The scenarios results show that 50% increase in ambient temperature this leads to greater and faster evaporation. Thus, the gradual increase of precipitation in tropical watershed large alters flow rates over time and increase flood potentials in areas downstream of the basins (Figure 8), causes a nearly 40% increase of the basin's annual discharge from the control run and increase flood potentials in the wet season [45-47]. Consequently, gradual increase of temperature, increase of precipitation in tropical watershed and northern areas will be devastated in periods of high precipitation. On the other hand, if drier climate is occurring in basin, the practice policy reduce streamflow and basin discharge and may enhance drought impacts on water resources in the basin and the entire Tucuruí reservoir area, affecting hydropower production.

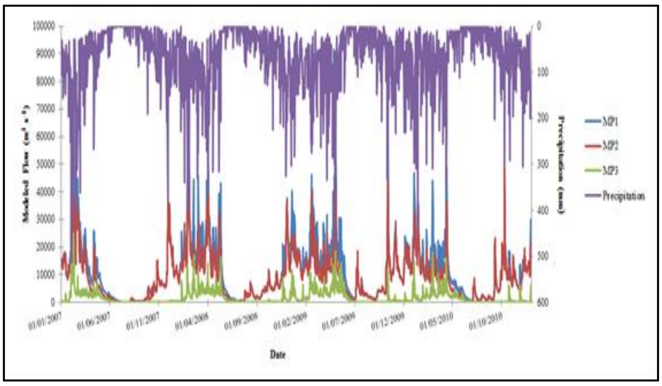

Figure 7: Simulated values for flow rate and precipitation values.
Source: Authors, (2018).

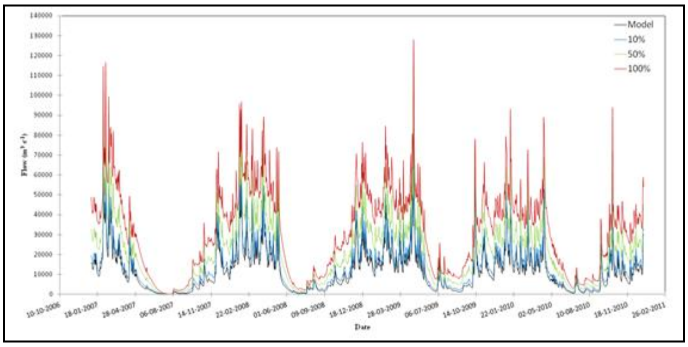

Figure 8: Simulated discharges scenario due to climatic variability extreme were generated under three strategies: 10%, 50% and 100% increase in ambient temperature (24 ℃) due natural and/or anthropogenic events within the watershed.
Source: Authors, (2018).

In the latter case 100% increase in ambient temperature this leads to greater and faster evaporation, representing an extreme combined with socioeconomic positions (Figure 8). This change caused an increase in annual basin discharge of nearly 90% compared to the control run. This would lead to an increase in the maximum flow rates and probably would result in serious disruption of the region located to the north, where human, material and environmental losses would be incalculable being able take years to overcome and recover the affected region. However, despite the extreme hypothesis, this may occur because the lack of perception about the effects of human actions over time on a natural resource, in this case, resulted in the worsening of floods and the late observation that impacts were transferred to areas downstream (basin) of the basin Urban area, almost always increasing the likelihood of flooding. In addition, the lack of a housing policy based on environmental principles and social equity pushes the poorer population to the areas subject to flooding, widening the environmental problem and sacrificing the urban and rural unassisted community. This finding indicates that through interactions of climate change and seasonal variations of basin hydrology can modify the local hydrological cycle and exert a strong control of the annual distribution of streamflow in the Tocantins-Araguaia basin. This combined effect indicate that would increase streamflow and water yield to an amount larger than that from simple additions of the individual and consequently, associated seasonal variations of its impact on evapotranspiration increase streamflow in wet season, thus increase flood potentials. The question of floods in the city of Marabá and in the reservoir of Tucuruí is a function of several causes such as: Position of the city at the confluence of two rivers: Tocantins and Itacaiúnas; Likely increase of precipitations and flows due to climatic variability; Increase in the water level of the Tucuruí reservoir due to displacement of the backwater area; Greater urban occupation. Projections for changing rain regimes and distribution to warmer climates in the future are not conclusive, and the uncertainties are still great because they depend on the regions considered. However, knowledge about possible future climatic and hydrological scenarios and their uncertainties can help to estimate water demands in the future and also to define environmental policies for water use and management for the future.

IV. CONCLUSIONS

This study illustrated monitoring and forecasting of annual and seasonal streamflow in Tocantins-Araguaia watershed, related to potential of climate change based on the SWAT model simulation. In this sense, the model result did not statistically differ from those observed at a 5% probability level, which qualifies the model for simulations to address the complexity of the system, where the SWAT model showed potential to simulate the hydrological variables analysed and showed that the an increase in the maximum flow rates and probably would result in serious disruption of the region located to the north, where human, material and environmental losses would be incalculable being able take years to overcome and recover the affected region i.e., model results showed that the temperature increase influences the causes a series of alterations in the precipitation regime have a reflection on the flow regime, altering the hydrological response of Tocantins-Araguaia watershed in its northern portion (Marabá city (MARA) and Tucuruí hydroelectric). These conclusions are consistent with some previous studies for climate change around the world [34] [48-58]. However, despite the extreme hypothesis, this may occur because the lack of perception about the effects of human actions over time on a natural resource, in this case, resulted in the worsening of floods and the late observation that impacts were transferred to areas downstream (basin) of the basin Urban area, almost always increasing the likelihood of flooding. In addition, the lack of a housing policy based on environmental principles and social equity pushes the poorer population to the areas subject to flooding, widening the environmental problem and sacrificing the urban and rural unassisted community.

Therefore, model provided reasonable estimates of trends associated with climate changes, increase in ambient temperature this leads to greater and faster evaporation. Thus, the gradual increase of precipitation in tropical watershed large alters flow rates over time and increase flood potentials in areas downstream of the basins. However, the need for more detailed evaluation of the model results in the study area is highlighted, due adequately represent the convective precipitation within the large tropical watershed.

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