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IMPACT OF CLIMATE CHANGE ON STREAM FLOW OF TIGRIS WATERSHED, BAGHDAD, IRAQ

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Abstract

According to Intergovernmental Panel on Climate Change (IPCC) future projections, precipitation and temperature will increase over Baghdad in the coming century. The main objectives of the study was to investigate the possible impact of climate change on runoff and stream flow of Tigris river basin, by downscaling can ESM2 global climate model using Statistical Downscaling Model (SDSM). Based on IPCC recommendation baseline periods (2008-2018) were used for baseline scenario analysis. Future scenario analysis was performed for the 2020s and 2050s. Globally, canESM2 model is widely applied for climate change studies and it consists of Representative Concentration Pathway (RCP) RCP 8.5 (medium to high emission) and RCP 4.5 (medium low emission) scenarios. Impact assessment on stream flow and sediment yield was done by Soil and Water Assessment Tool (SWAT) hydrological model. To set up the model for simulation a 20×20m DEM (Digital Elevations Model), land use map and soil map were used. The daily recorded weather data from 2008 to 2018 were used as input to the model. Monthly stream flow and sediment yield data were available from 2008 to 2018. In this study both local (one-at-a-time) and global sensitivity analysis were performed and the ranking of the parameters in both cases compared. The model was calibrated by using both automated and manual calibration for monthly stream flow and sediment yield by using stream flow and sediment yield data from 2008 to 2010. SWAT model performance in simulating monthly stream flow for the study area was satisfactory with Nash-Sutcliffe Efficiency (NSE) coefficient of determination (R2) and percent error (D).

Mean annual changes of precipitation and temperature (maximum and minimum) were applied to quantify these impacts. The result of down scaled precipitation and temperature reveals a systematic increase in all future time periods for both RCP 6.5 and RCP 3.5 scenarios.

Key words: Climate Change, Tigris River, Water Quality.

Introduction

Background

Climate changes pose significant economic and environmental risks worldwide. It is a global phenomenon exhibited by three prominent signals, that is: (1) global average temperatures are gradually increasing, (2) changes in global rainfall patterns and (3) rising of sea levels. One of the major impacts of this phenomenon is on local water resource availability, whose impact will be felt by many sectors, including agriculture (Stocker, 2013).

According to the Intergovernmental Panel on Climate Change (IPCC) Scientific Assessment Report, global average temperature would rise between 1.4 and 5.8°C by 2100 with the doubling of the CO_2 concentration in the atmosphere. Sea level rise, change in precipitation pattern (up to±20%) and change in other local climate conditions are expected to occur as a consequence of rising global temperature (IPCC-TGICA, 2007).

From water resource systems design and management point of view, hydrologists are required to make accurate predictions of the impacts of climate change on the intensity, amount and spatial and temporal variability of rainfall. Furthermore and perhaps most important, they also must examine how the stream flow regime (stream flow hydrographs, peak flow, etc.) and sedimentation of water bodies at different spatial and temporal scales is affected by rainfall variability and by the expected changes in that variability as a result of climate change (Boosik *et al.,* 2007).

Tigris river in Baghdad City is located in the

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Mesopotamian alluvial plain between latitudes 33°14'-33°25' N and longitudes 44°31'-44°17' E. The general altitude ranges between 30.5 m and 34.85 m. The area is characterized by arid climate with dry hot summers and cold winters, the mean annual rainfall is about 151.8 mm. Environmental interesting in capital town of Baghdad is much important requirement the surface water suffering from effect of conservative pollutants. Baghdad city has two rivers, the main river Tigris River and Diyala River in boundary of Baghdad city (Diyala Bridge) eastern of Baghdad. The population of Baghdad is more than 6 million from government statistics within the sector of flat sedimentary plain. The borders of the municipality of Baghdad encompass 14 administrative units, eight in Rusafa (east of Tigris River) and six in Karkh (west of Tigris River) and area of the municipality of Baghdad (870 km^2). Advantage of the characteristics of study area is essential great extremism in temperature, little precipitation, low relative humidity and high brightness of the sun, sources pollution in aquatic systems which are atmospheric deposition, erosion, urban discharges, agricultural materials, mining, composition and industrial discharges.

It is highly valuable resource of the area for tourism and serving as a crucial habitat for terrestrial and aquatic plants and many invertebrates, fish and birds during all or part of their life cycles (Ajmi, 2013). But the water level fluctuations are known to contribute to the loss of great diversity of ecology and socio economic development (Ajmi *et al.,* 2015). This article was focused on investigating the trend of rainfall and temperature concerned with climate variability, amount of sediment yield delivered annually to the Tigris river watershed, direct and indirect impact of climate change on the catchments and the extent due to change in climate. The models used in this study were climate and hydrological models (GCM/SDSM and SWAT) respectively. All these models have been used in global and local scale to identify the gap. To predict the change in precipitation and temperature within the catchments, climate related models are often used. The applicability of some of the model had been evaluated under different condition by different researchers in different parts of the world (Frei *et al.,* 2006, Shimelis *et al.,* 2010 and Wayne, 2013) tested GCM model by statistical down scaling model to evaluate its potential applicability under specific catchments.

Even though the GCM is coarser and used for larger catchments study, it is possible to use GCM at small catchments by down scaling the data in Statistical Downscaling model (SDSM)(Dibike and Coulibaly, 2005). GCM Model with statistical downscaling and Representative concentration path way (RCP) scenario were set up and their applicability was tested in river condition (Beyene, *et al.,* 2010, Dile *et al.,* 2013). From among the different Representative Concentration Pathway (RCP), which was developed by the IPCC, this study used the, RCP 4.5 and RCP 8.5 scenarios for this climate change impact study. These scenarios cover a range of future pathways, with respect to global *vs.* regional development and environmental *vs.* economic emphases. RCPs offer a better understanding in terms of the concentration of future greenhouse gases for running climate models than previous scenarios (Wayne, 2013).

In concurrent with climate model, hydrological models were used to simulate runoff, sediment yields and water balance and water availability in catchments, sub catchments and HRU level which is very important to predict the amount, extent and distribution of those hydrological phenomena's. There are a number of models that used to predict runoff and sediment transport from the land surface to water bodies. The types and application of some of the models had been evaluated under different condition in different parts of the world. SWAT and Agricultural None Point Source (AGNPS) model are being used to evaluate their potential applicability under data scarcity (Matamoros *et al.,* 2005). The result of their study reveal that the SWAT model with less basin subdivision showed to be more accurate than AGNPS model made a comparison of SWAT with Hydrological Simulation Program-Fortran (HSPF) model in predicting hydrological process of a small multi-vegetated watershed. Even though both SWAT and HSPF models had shown high capability of simulating runoff and sediment yield within the acceptable level of accuracy, the SWAT model being more responsible to seasonal variation of precipitation, predicted monthly stream flow and sediment yield more accurately than HSPF model (Mishra *et al.,* 2008). Thus, among all climate and hydrological models GCM/SDSM and SWAT are felt to be models for prediction and simulation of meteorological and hydrological behavior of predominantly agricultural watershed (Borah and Bera, 2003).

Accordingly, quantitative scientific evidence on stream flow and sediment yield and their future extent is vital for policy makers, researcher, planner and farmers to formulate the adaptation and mitigation options in order to increase stream flow and reduce sedimentation of water bodies under the changing future climate. Therefore, the output of this study may be utilized by researcher as well as planner, decision maker and local people to plan and implement effective land and water resource development and management strategies and climate change adaptation and mitigation measures in the study area. In general, the aim of this article of possible impact of climate change on runoff and stream flow of Tigris river using SWAT and GCM outputs. Specifically, this mainly focuses on the following specific objectives.

To determine the magnitude and extent stream flow and predict the change in stream flow of Tigris River due to change of climate in future.

Materials and Methods

Description of the Study Area

The Tigris River enters the city of Baghdad at a point 5 km from the tourist island and leaves 3 km to South of the convergence of the Daly River runs in the city of Baghdad from north west to south east. The range ranges from 160m in straight line to more than 400m in round about.

It flows westward, forming a number of folds starting from the stream 629 cm/km. Kadhimiya and the great and emotional and the door of most then straight upstream until the beginning of Karrada component.

The Tigris River in Baghdad has been changed right and left over the past years by erosion and sedimentation processes.

Still, there is a change factor and Baghdad is part of the easy sedimentation of most of its deposits. The fourth geology, most of the material of the river consists of fine sand and a small part of the mud and silt River islands can be seen clearly in the riverbed and are spread along the riverbed (Al-Krayat Island, Al-Kadhimiya, Abu Nawas, Wedding Island (or formerly pigs), Abu Ramil and Jazira Island).

A number of small seasonal islands appear in the drainage period. Part of the twisted river passes at the beginning of its low aging phase. The Tigris River is therefore in Baghdad.

All the geomorphological qualities that refer to this stage

First Cross-section properties: It is an important morphological characteristic of studying the course of the course through which it is possible to identify neurogenic pattern and over the concentration of geomorphological processes of erosion or sedimentation, including presentation study. Depth, cross-sectional area, surface area of the surface and wet environment, the width of the stream, is the width of the surface of the water between the banks of the course and the width of the course from cross-section depending on the location of the cross-section, such as cornering areas and areas. The presence of river islands, Thus, the width of the Tigris river course varied between one section and another and its parts. The overall average width of the course was 22126m and the average width for the first part was 24529m. For the second part 20525m and the third part reached 216 m. According to the Traditional Baghdad ecological zones. The rainfall pattern of the proposed study area is unmoral and the main rainy season is winter, which extends from end of October to April. The mean annual rainfall that the area received is about 1149mm. The annual mean minimum and maximum air temperature of the area is 13°C and 27.5°C, respectively (Molla *et al.,* 2007).

About demography system total population of 7 million in Baghdad and the surface area of the river means the area of the city of Baghdad, the total area of the Tigris River in the city 2 Baghdad 102963 km, the area of the river 1230% of the city of Baghdad.

The topographic variation. The slope class generated from 20×20 m DEM based on FAO slope classes. The dominant slope class is (15-30%) which covers 33.03% of the total area followed by (8-15%) which covers 24.45% slope class (>30%) slope covers 21.5%, (3-8%) also cover 17.53% and the remain 3.5% is included in (0-3%) slope class based on FAO slope classification for soil and water conservation (FAO, 2006). Soil and land use/cover. According to FAO (Food and Agriculture Organization) soil classification, the dominant soil type in Tigris river (49.64%) which covers water.

Data Types and Sources

The basic data that are necessary for GCM model to statistical downscaling Model version 4.2.9 was daily weather variables. However, Arc SWAT 2012. 10.8 model had been used daily weather variables, digital elevation model (DEM), soil map and land use/cover map. About the digital elevation model (DEM) is one of the input data for Arc SWAT model. The grid resolution lies at 20×20m. It is necessary for the stream network processing in SWAT model.

Data Preparation

After the data were collected from the source that used as an input for the model, they were first checked for missing values, consistency and homogeneity. The spatial data set were projected in Addendum UTM Zone 37, which is the transverse Mercator projection parameter for Baghdad, using ArcGIS 10.1. The land uses/covers data were reclassified for Arc SWAT 2012, database from the shape file of the study area map. In addition to map preparation the land use look up table was prepared with SWAT code of land use database.

The soils data those were not included in U.S. soil database were extracted and collected from Harmony world soil database (HWSD) and FAO soil Classification of world soil. The collected soil properties were edited to Arc SWAT 2012 soil database those were not included in the U.S. soil database. After the soil database has been adjusted for Arc SWAT software the soil look up table has been prepared with similar names of the database.

Weather generator data of the study area was calculated by using Excel, pcp STAT and dew02. Pcp STAT is used to calculate average monthly precipitation, standard deviation, skew coefficient, probability of a wet day following a dry day, probability of wet day following a wet day and average number of precipitation in month. The daily temperature and humidity of each station were calculated by dew 02.exe. The statistical analysis of daily precipitation of Haiq station is indicated in table 1 below.

Modeling Approach and Methods of Data Analysis

There are different modeling approaches that are used for analyzing climate related data. The first part was climate change modeling approach and the second was hydrological modeling approach. The model outputs were finally analyzed, summarized and presented as maps, graphs, tables and percentages and the data quality checking and control, the point observation from rainfall gauge may have a short breakage in the records because of instrument failure or absence of the observer. Thus, it is often necessary to estimate the missing records using data from the neighboring station. There are methods used to fill the missing data of weather station. These are arithmetic mean, normal ratio method and inverse distance weighing methods. Arithmetic mean method can be used to fill in missing data when normal annual precipitation is within 10% of the gauging station for which data are being reconstructed. The normal ratio method is used when the normal annual precipitation at any of the normal index station differs from that of the precipitation by more than 10%. In the absence of normal annual rainfall for the stations, inverse distance weighing can be used to fill the missing data, the missing data was estimated by using normal ratio method (Subramanya, 2008). For M station 1, 2, 3 …m, the annual precipitation values are p1, p2, p3 ……pm, respectively. At station X (not included in the above m station), the missing annual precipitation (px) will be found out. The normal annual precipitation N1, N2, N3… Ni at each of the above (m+1) stations including the station x is known.

$$Px=Nx/M\ (P1/N1+P2/N2+......+Pm/Ni)$$

The precipitation data was checked for continuity and consistency before it is used for further analysis. According to (Subramanya, 2008). The quality control can be done by visual inspection, filling of missing data if there is any, by normal ratio method and double mass curve. This can help to identify if there are any gaps or unexpected peaks in data series and correct them before the data is used or input to the model. Otherwise, using the erroneous data as input to the model will give erroneous output from the model.

Table 1: The statistical analysis of daily precipitation of department of Geological Survey Baghdad station (2008-2018).

Month	PCP _MM	PCP STD	PCP SKW	PR _W1	PR _W2	PC PD
Jan.	34.42	4.22	5.73	0.08	0.51	4.74
Feb.	48.47	6.41	5.73	0.08	0.57	5.00
Mar.	112.01	8.15	3.52	0.18	0.69	11.81
Apr.	95.80	8.21	4.49	0.21	0.61	10.87
May.	56.10	6.73	5.74	0.11	0.50	6.06
Jun.	76.37	7.32	4.23	0.16	0.60	8.68
Jul.	319.30	13.44	2.12	0.62	0.80	24.23
Aug.	247.90	11.77	2.33	0.53	0.72	20.97
Sep.	84.74	6.34	3.92	0.27	0.52	11.52
Oct.	27.14	3.69	5.84	0.05	0.50	3.03
Nov.	23.57	4.39	8.65	0.05	0.43	2.42
Dec.	23.92	3.44	6.82	0.07	0.55	4.19

PCPMM = Average or mean total monthly precipitation.
PCPSTD = Standard deviation for daily precipitation in a month.
PCPSKW = Skew coefficient for daily precipitation in a month.
PR_W1 = Probability of a wet day following a dry day.
PR_W2 = probability of wet day following a wet day.
PCPD = Average number of precipitation in a month.

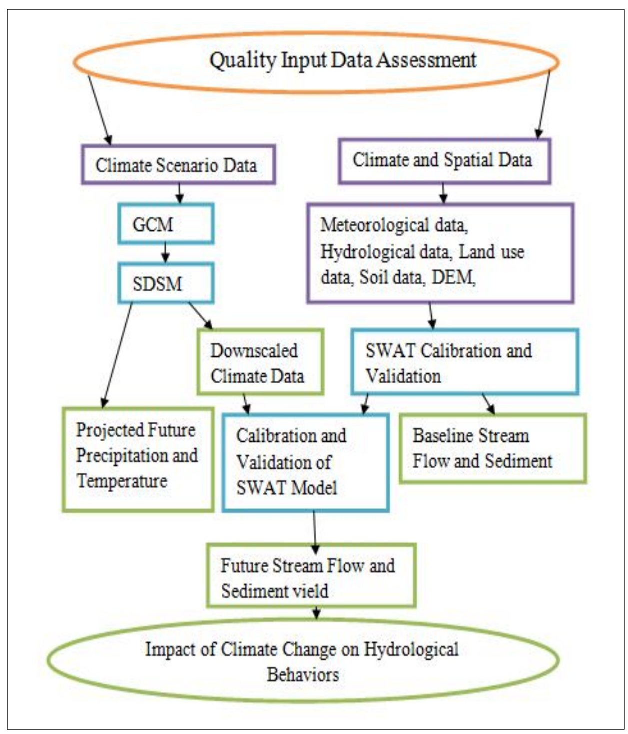

Fig. 1: Structural setup of the model.

Consistency and homogeneity test of meteorological data: The consistencies of the data set of the given stations were checked using double mass-curve method with in reference to their neighborhood stations. The double mass curve was plotted by using the annual cumulative total rainfall of the station under study as ordinate (Y-axis) and the average annual cumulative total of neighboring stations (base stations) as abscissa (X-axis). On the other hand the homogeneity of annual rainfall was tested using XLSTAT.

General structural setup of the study approaches: In order to effectively implement the study, structural skeleton of the flowchart (input/output relationships) is shown in fig. 1. The fig. shows the schematic representations of the steps to be followed in this research. It is designed to show how the parameters were interlinked each other indicating the way for estimating stream flow potentials, sediment yield and the impact of climate change on water resources.

Results and Discussion

The model results were available for RCP 4.5 (medium to low emission) and RCP 8.5 (high to medium emissions) scenarios and the result were used to produce the future scenario. This model was applied in this study because of the following reasons. Firstly the GCM model is widely applied in many climate change impact studies, the results of Can ESM2 can be easily downscaled using SDSM (Dile *et al.,* 2013) and the model provides daily predictor variables which can be used for the Statistical Downscaling Model, the secondly it provides large scale daily predictor variables which could be used for statistical downscaling model (SDSM) (Wilby and Dawson, 2007), thirdly a single run was downloaded for each scenario, and data were extracted for the pixel containing the observation stations and lastly the model has given 20 ensemble model result when statistically downscaled and correctly used RCP scenario that have high climate mitigation policy Riahi *et al*., (2007) and RCPs offer a better understanding in terms of the concentration of future greenhouse gases for running climate models than previous scenarios (Meinshausen, *et al.,* 2011).

Comparison of observed Meteorological data at four various stations

All meteorological stations in and around the rivers in Baghdaa found within the same grid boxes in climate change impact assessment. Hence, meteorological data screening for the different stations in the study area were carried out through correlation matrix and only one station was selected to down scale the large scale predictors. The daily precipitation, max. and mini. temperatures from 2008-2018 were averaged on monthly basis to calculate the correlation coefficient of each stations as shown in tables 2 and 3 by using Statistical Package for Social Science (SPSS) software. The correlation of precipitation data among four stations was done (Table 2) and the correlation coefficients were found between 0.82 and 0.95. This reveals that the agreements between stations are good. Among other stations, the precipitation showed very good agreements in which the correlation coefficient ranges from 0.88 to 0.95.

Table 2: Correlation analysis of average monthly precipitations of four stations.

Station	1	2	3	4
1	1	0.95	0.88	0.93
2		1	0.82	0.88
3			1	0.9
4				1

Table 3: Correlation analysis of average monthly temperature of four stations.

Station	Maximum Temperature			
	1	2	3	4
1	1	0.77	0.96	0.85
2		1	0.82	0.66
3			1	0.82
4				1

In general both maximum and minimum temperature this station resulted good correlation and hence used for this study. The average temperature differences from the base-period values and the average monthly precipitation change factors developed for this station can then be applied for the other stations too.

Conclusions and Recommendations

Knowing the seasonal simulated long term average annual precipitation, temperature, stream flow and sediment yield components in the base period and the future is useful to recommend better alternative and complementary action of climate change. Keeping in view, the threats to the survival of Tigris River, the following steps are recommended for its proper conservation and management. Adoption of soil conservation measures and afforestation around the wetland to prevent siltation of the lake. This will help to maintain ecological balance besides preventing sediment deposition. It will also improve the overall productivity of the ecosystem.

Results of impact studies are mainly depend on the quality of input data. As mentioned above, lack of meteorological and hydrological data were the major challenges of this study. Hence, any of the concerned bodies should give due attention for data handling and recording of reliable data. The models and model outputs used in this study possessed a certain level of uncertainty. The model simulation considered land use changes and other climatic variables such as wind speed, sunshine hours and relative humidity remain constant for the future time horizons although it is not true in the actual case. Hence, the results of this research should be taken carefully and be considered as indicative prediction of the future and further researches should be extended by considering the future land use changes and other climatic variables.

The results of this study are based on the outputs of a single GCM and only two emission scenarios (RCP 4.5 and RCP 8.5). However, it is recommended to use different GCM outputs and emission scenarios to compare the results of different models and explore a wide range of climate change scenarios that would result different hydrological impacts. Meanwhile, the GCM was downscaled to a catchments level only using statistical downscaling model which is a regression based model, even though other methods exists which are used for impact assessment. Thus, this research should be extended in the future considering other downscaling methods.

Water resources are vulnerable and have the potential to be strongly impacted by climate change, with wide-ranging consequences for human societies and ecosystems. Precipitation and temperature are highly affected by climate changes and in turn, the change of these climatic variables affects the stream flows, the recurrent floods and droughts. This study established a basis for future multidisciplinary studies on modeling sediment yields and for better understanding of correlations between potential control variables and the resulting sediment yield to reservoirs, which can also facilitate estimation of the probable lifespan of river and appropriate mitigation measures to limit River Tigris sedimentation.

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