Gomti River : Hydrological Modelling In Lucknow City By WEAP Module For Predicting The Climate Variations For Future Year 2030

Sanjana Singh[1], Asit Singh[2], JB Srivastava[3]

[1] *M.Tech Student, Civil Engineering Department, IET Lucknow, Uttar Pradesh, India*
[2] *Assistant Professor, Civil Engineering Department, IET Lucknow, Uttar Pradesh, India*
[3] *Proffesor, Civil Engineering Department, IET Lucknow, Uttar Pradesh, India*

ABSTRACT

Despite several infrastructure, awareness-raising, and policy efforts, water pollution continues to be a difficult problem for the sustainable development of the Gomti River. The research evaluates the viability of the Gomti River in Lucknow region for future climate variations under various cases by performing hydrological simulation under . Analysis of the Gomti River pollution case study a scenario based on the two for present-day and future wastewater production and treatment significant markers of aquatic health. In order to mimic the present (year 2022) and future (year 2030), the planning (WEAP) model river water quality between 2022 and 2030. The outcomes revealed that the Climate change and population growth will lead to water quality degrading by a further 71.2% and 11.4% respectively on a median basis in 2030, compared to today. However, if the study area were to be collected by 100% sewerage collection rate and treated at increased WWTP capacities of 900 MLD, the results for simulated water quality would be better. Observations from IMD station for 2021 showed 927 mm of precipitation. For 2030, MRIC GCM predicted 966.7 mm and 918.8 mm of annual precipitation using RCP 4.5 and RCP 8.5, respectively. In contrast, the same projected precipitation value by MIROC GCM with RCP 4.5 and RCP 8.5 was 885.3 mm and 903.1 mm, respectively. This indicates that the annual precipitation within the simulation from GCM output is similar to that observed currently. Also the effect percentage global climate change on BOD and ECOLI on simulated water quality was found 13% and 11% respectively. Thus global climate change isn't much concerning comparing to population change. Based on UNDESA projected rates, the ratio method was used to calculate the population distribution and future trend at the considered demand sites, based on the populations being considered for year 2021 and 2030, these numbers are 5778637 and 7038464 respectively and therefore the percentage contribution of population change on simulated water quality was found 87% and 89% for BOD and ECOLI respectively which is concerning.

Keyword : - *Environmental Engineering, Hydrology*

1. INTRODUCTION

The Gomti River, a tributary of the Ganges and an Indian river fed by groundwater and monsoons, rises in Pilibhit. After travelling 190 kilometres, the Gomti arrives in Lucknow, where it supplies the city with water for the next 12 kilometres. A few decades ago, the Gomti River in Lucknow City, India, was a crucial source of water for many purposes. The river's current condition is particularly critical from the standpoints of the environment, aesthetics, and economic utilisation due to the rapid global developments, nevertheless. From this point on, the focus of this research will be on evaluating the present as well as projecting its future state while taking important global change factors into account. Hydrological modelling of river Gomti river based on the business as usual (BAU) scenario and mitigation scenarios is being done using WEAP, an evaluation and planning tool.

The findings from a scenario with mitigation measures will suggest present wastewater treatment facilities and regulations as well as future cures. The results from a comparison of the simulated water quality parameters with the BAU status by 2030 will signal the quality of thewater by 2030. There are several factors Lucknow should be taken into consideration; The largest state's capital, Lucknow, has one of the most significant economic hubs in the entire nation (Uttar Pradesh). High economic activity and uncoordinated urbanisation as a result of rapid urban expansion lead to harmful circumstances around water bodies like the Gomti basin. Despite its critical importance, nothing is known about its current state or potential management plans. This study aims to produce comprehensive data for the planning of planned water resource capacity as well as suggestions for how to enhance river water quality considering hydrological factors such as climatic changes, precipitation patterns and population growth for the year 2030.

1.1 Objectives Of The Study

The objective of this study are :

- Hydrological Simulation including climatic changes, stream flow precipitation patterns and population growth for the year 2030.

1.2 Study Area

The study area covers 4 stations in Uttar Pradesh's capital Lucknow which are Gaughat, Manjhighat, Pipraghat and Kudiyaghat and is located between the north latitudes 26300 and 27100 and the east longitudes 80300 and 8113' (Fig.1). Located in a subtropical.climate with humid conditions, Lucknow has a cool, dry winter and a hot, humid summer. It is a city that has experienced rapid growth over the past few years. Increasing global population has significant implications for natural resources, specifically water quality as well as quantity. Life would not exist without water, the most valuable natural resource, water overuse and exploitation has resulted in deteriorating water quality. A variety of streams cut through Lucknow. The Gomti flows through the middle of the city from North-West to South-East. This is one of the important sources of public water within the city, along with groundwater. In the city, there is a serious problem with sewage generation as well as treatment and disposal of the waste. Poorly draining sewer systems and the degrading quality of river water has been attributed to the lack of sewage treatment capacity.

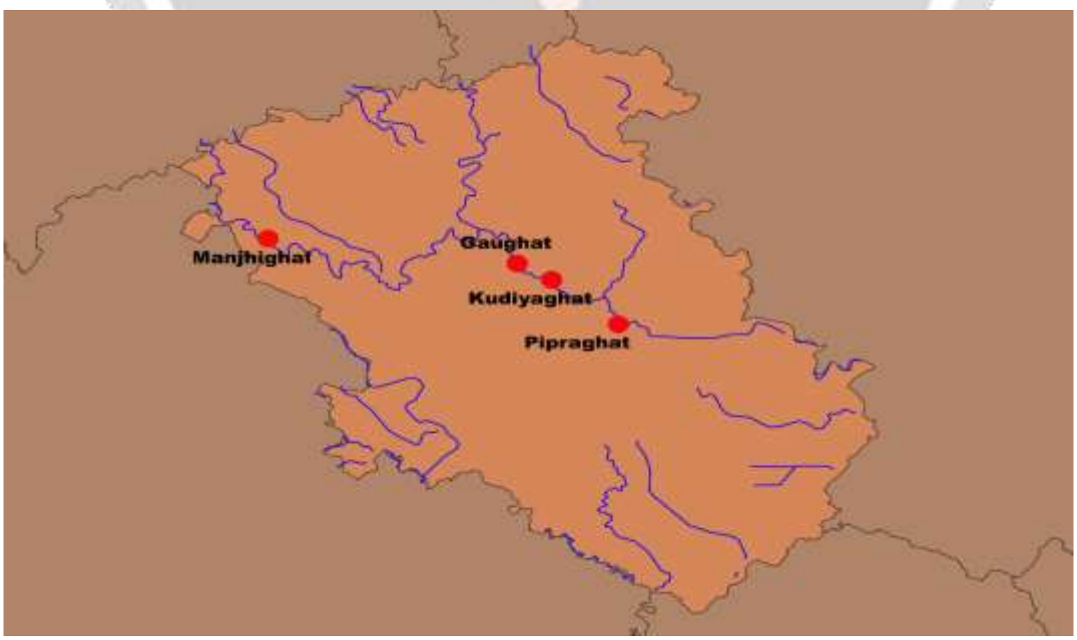

Fig 1 : Flow course of the Gomti River passing across the Lucknow City along with locations/sites considered in this study.

2. METHODOLOGY

2.1 WEAP Software Details

For WEAP to simulate hydrologically, the entire study area must be divided into smaller catchments based on confluence points, physiographic characteristics, and climate. Water quality and hydrological simulations can both be performed within WEAP's hydraulics module. There are different catchment methods available in WEAP to simulate different components of the hydrological cycle, including rainfall runoff (simplified coefficient method), irrigation demands (simplified coefficient method), and rainfall runoff (soil moisture method). In this case, rainfall-runoff is used. Water demand and supply, flows, storage, discharge, and several other hydrological activities are all maintained by the WEAP system, which is comprehensive. It offers a collection of model objects and processes that, when applied to the natural watershed, reservoirs, streams, and canals, may address water management issues using a scenario-based methodology. It features built-in algorithms that simulate rainfall-runoff of basins and sub-basins using climate time series data. Setting up the WEAP model for use in a watershed entails a number of steps, including the study period, study area boundary, actual water demand and supply, and setting up an alternative set of future assumptions based on solid policies that have an impact on the water demand and supply as well as the hydrology of the watershed. The irrigation demands only simplified coefficient approach, rainfall runoff method, the soil moisture method, the maitrise des besoins d'irrigation en agriculture (MABIA) method, which translates to "control of irrigation needs in agriculture," and the plant growth method are the five different methods that the WEAP model offers for model calibration. The rainfall-runoff technique was used in this work to calibrate the model because it takes into account demand sites with streamlined agro-hydrological processes, such as rainfall, evapotranspiration, and crop growth.

2.2 Detailed Data Requirements

Using the WEAP model to simulate future water quality variables in 2030, alternative management policies within the Gomti basin were assessed. For the period 2000 to 2021, daily rainfall was collected at IMD Meteorological Station. We calibrated and validated the WEAP hydrology module simulation using daily average stream flow data collected from four stations from 2016-2021, namely Gaughat, Pipraghat, Kudiyaghat, and Manjhighat. The output of different Global Climate Models (GCMs) and Representative Concentration Pathways (RCPs) is used to estimate future precipitation so as to find out the impact of climate change on water quality, i have evaluated the change in monthly average precipitation. The data is obtained at a monthly scale using statistical downscaling followed by trend analysis, a less complex technique that reduces biases in precipitation frequency and intensity. In this study, historical rainfall data of 25 years (1995-2020) was analyzed. In order to avoid dangerous levels of climate change, it is important to understand the potential impacts of temperature change. In this study, the MRIC and MIROC Global Climate Models were used with RCP4.5 and RCP8.5 emission scenarios to assess possible global climate change over the study area.The climate of the future corresponds to the years 2022-2030. We are dividing the entire study area into eight demand sites in order to estimate how population growth affects water quality. The population represented by these demand sites in this study is primarily that of various cities lying either side of the Gomti River. We chose demand sites so that it provides a symmetric representation of pollution load (in terms of domestic discharge) from the inhabitants living on either bank of the river. A ratio method was used to calculate the population distribution and its future trend based on UNDESA's projected growth rate. In addition to above mentioned components for model setup, the major considerations are the eight demand sites and the two wastewater treatment plants (WWTPs) that represent the problem domain. Demand sites are used to identify domestic (population) centers with their attributes explaining water consumption and wastewater pollution loads per capita as well as water system sources and wastewater returns. Using simulated water quality results for the current situation in 2021, the model calibration and validation are completed once the model setup is completed. In the final step, numerical simulations are carried out using two major scenarios: business as usual (BAU) scenario under which it is shown that what will be the changes in future river water quality if left as it is, the way technologies and policies are going on in present time and other scenario with mitigation measures under which it is shown that after implying various measures, mitigation strategies including increased capacity of Wastewater treatment plants etc, the river water quality in future can be improved. Hence, better environment. Fig 2 ahows different dataset that were required to the model for this study and they were collected as follows :

1. Hydrological river data
   - Climate data includes Average monthy rainfall data of 25 years 1995-2020 (SOURCE - IMD)
2. Population data (Directorate of Census Operations UTTAR PRADESH (censusindia.gov.in)

3. WWTP Capacitity, Sewerage collection rate (SOURCE – UPPCB)

4. Remote Sensing Data (Shape file/ vector data)

5. River cross section, etc (SOURCE – CPCB/UPPCB)

3. RESULTS

3.1 Variation in precipitation

Table 1 shows the comparative results of the monthly precipitation pattern. The annual precipitation for the year 2021 was 927 mm based on data collected by IMD. Meanwhile, the annual precipitation under RCP 4.5 and RCP 8.5 using MRIC GCM was 966.7 mm and 918.8 mm respectively. In contrast, with MIROC GCM and RCP 4.5 and RCP 8.5, the similar projected precipitation value was 885.3 mm and 903.1 mm, respectively. Thus the difference between current annual rainfall (2021) and simulated rainfall for future (2030) with MRIC GCM and MIROC GCM under RCP 4.5 and 8.5 is 1.6% and 3% respectively. It is clear from these values that the annual precipitation within the simulations based on GCM output isn't very different from the one observed at present. Hence, in near future there'll be not much concern for increased precipitation change.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Observed 2021	20.30	13.30	7.90	5.00	12.40	81.70	276.20	278.80	175.90	47.90	1.40	6.20
MRIC GCM RCP 4.5 Simulated 2030	25.40	16.60	8.70	5.60	12.70	82.30	314.20	254.40	189.10	49.20	1.70	6.80
MIROC GCM RCP 4.5 Simulated 2030	23.30	18.20	8.50	5.40	13.10	118.50	250.10	241.60	181.70	49.80	1.50	7.10
MRIC GCM RCP 8.5 Simulated 2030	20.60	13.40	8.10	4.10	12.10	79.90	275.80	268.20	149.30	45.60	1.30	6.20
MIROC GCM RCP 8.5 Simulated 2030	21.80	14.50	8.40	5.50	12.90	81.50	258.30	266.10	181.60	44.60	1.50	6.40

Table -1 : Observed (2021) And Simulated (2030) Precipitaion Patterns

A GCM is a mathematical model of the general circulation of the planet's atmosphere or oceans, and is based on mathematical equations that represent the physical processes. In GCMs, greenhouse gas concentrations are simulated and future climate variables are predicted. Various socioeconomic scenarios are used to calculate future greenhouse gas emissions, which is used to generate GCMs (and the downscaled data from them). A number of socioeconomic scenarios are referred to as "representative concentration pathways" (RCPs), including RCP 2.6, RCP 4.5, RCP 6.0, and RCP 8.5. The RCPs are labeled according to the approximate global radiative-forcing level. The radiative forcing, a measure, as defined by the Intergovernmental Panel on Climate Change (IPCC), of the influence a given climatic factor has on the amount of downward-directed radiant energy impinging upon Earth's surface. In terms of climate change, RCP 2.6 estimates the least amount, in terms of climate change, RCP 4.5 estimates the moderate amount, and in terms of climate change, RCP 8.5 estimates the most.

3.2 Increase in population

As of 2011, the total population of the study area was 4589838. According to the future population prediction, the growth rate will be 2.42, 2.24, 2.26 and 2.16 for the periods 2011 to 2015, 2016 to 2020, 2021 to 2025, and 2025 to 2030, respectively. As a result, the population for current year (2021) and target year (2030) was 5778637 and 7038464 respectively. Fig.2 represents growth forecasted for 2030 under WEAP module. Water quality status in the whole study area is being divided into eight demand sites in order to calculate the impact of population growth on it. This study focuses on demand sites along either side of the Gomti River, representing primarily the population of various cities along either side. We calculated the future population distribution at these demand sites using the UNDESA projected growth rate as a ratio method.

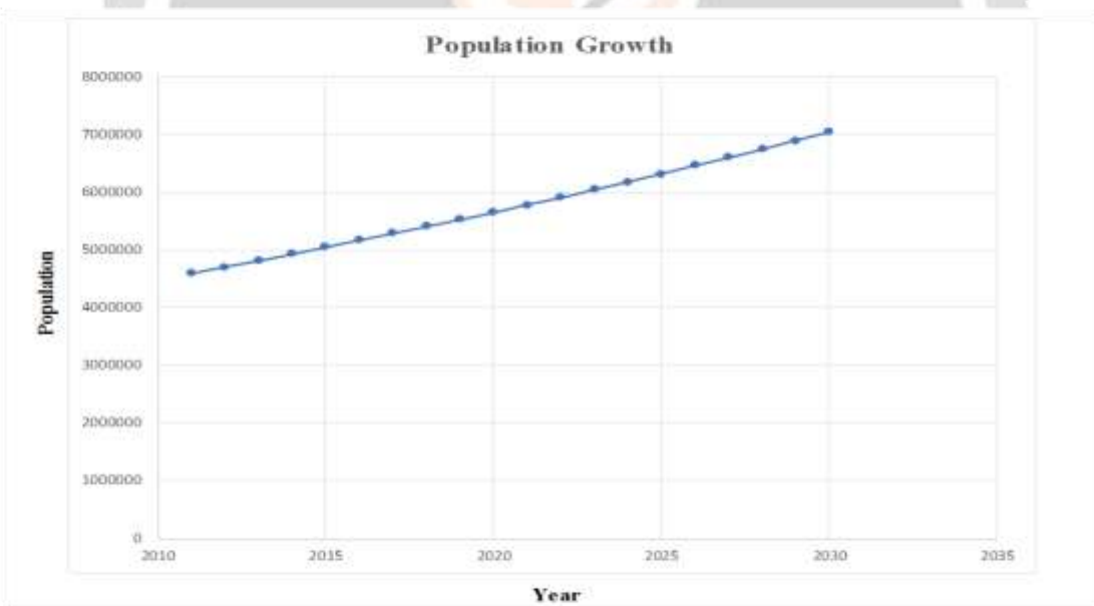

Fig 2 : Population growth forecasted for 2030 under WEAP module.

4. CONCLUSIONS

Using different scenario analyses, this study provided a comprehensive picture of the hydrological quality of the Gomti River in Lucknow City, India today and in the future (2030). According to simulated results, the Gomti River has moderate to severe pollution throughout the stretch when compared to the class B given by the Uttar Pradesh Pollution Control Board. Furthermore, the quality status is predicted to deteriorate by 2030 under a business as usual (BAU) scenario. Climate change and population growth will lead to water quality degrading by a further 71.2% and 11.4% respectively on a median basis in 2030, compared to today Observations from IMD station for 2021 showed 927 mm of precipitation. For 2030, MRIC GCM predicted 966.7 mm and 918.8 mm of annual precipitation using RCP 4.5 and RCP 8.5, respectively. In contrast, the same projected precipitation value by MIROC GCM with RCP 4.5 and RCP 8.5 was 885.3 mm and 903.1 mm, respectively. This indicates that the annual precipitation within the simulation from GCM output is similar to that observed currently. Also the effect percentage global climate change on BOD and ECOLI on simulated water quality was found 13% and 11% respectively. Thus global climate change isn't much concerning comparing to population change. Based on UNDESA projected rates, the ratio method was used to calculate the population distribution and future trend at the considered demand sites, based on the populations being considered for year 2021 and 2030, these numbers are 5778637 and 7038464 respectively and therefore the percentage contribution of population change on simulated water quality was found 87% and 89% for BOD and ECOLI respectively which is concerning.

5. REFERENCES

[1]. B.K. Mishra, P. Kumar, Y. Masago, , K. Fukushi
Evaluating future stress due to combined effect of climate change and rapid urbanization for Pasig-Marikina River, Manila (2018)

[2]. A. Muley , D. Panaskar, S. Mukate,, V. Wagh, , C. Jangam, R. Pawar
Impact of anthropogenic inputs on water quality in Chincholi Industrial area of Solapur, Maharashtra, India Groundwater Sustainable Development (2017)

[3]. United Nations, Department of Economic and Social Affairs, Population Division (UNDESA)
World Urbanization Prospects: the 2014 Revision (2015)

[4]. J. Sieber, D. Purkey
Water Evaluation and Planning (WEAP), User Guide, Stockholm Environment Institute, USA (2011)
Uttar Pradesh Pollution Control Board (UPPCB)

[5]. UPPCB and You. A Ready Reckoner for Enterpreneurs (2017)

[6]. A.R. Slaughter, , D.A. Hughes, S.K. Mantel
Investigating possible climate change and development effects on water quality within an arid catchment in South Africa: a comparison of two models (2014)

[7]. D.P. Ames, N.W.T. Quinn, A.E. Rizzoli (Eds.), Proceedings of the 7th International Congress on Environmental Modelling and Software, June 15-19, San Diego, California, USA (2014)

[8]. W.J. Cosgrove, D.P. Loucks
Water management: current and future challenges and research directions, Water Resource (2015)

[9]. Tripathi, M.P., Panda, R.K., and Raghuwanshi, N.S
Runoff estimation from a small watershed using SWAT model. In: Proceedings of the international conference on Water, Environment, Ecology, Socio-Economics and Health Engineering, Seoul, Korea (1999)

[10]. Singh, J., Knapp, H.V., and Demissie, M.
Hydrologic modeling of the Iroquois river watershed using HSPF and SWAT. Illinois State Water Survey (2014)

[11]. Shrivastava, R.K., Tripathi, M.P., and Das, S.N.
Hydrological modeling of a small watershed using satellite data and GIS technique. Journal of Indian Society of Remote Sensing (2004)

[12]. Arnold, J.G., et al.
Large area hydrologic modelling and assessment part I: model development. Journal of American Water Resources Association (1998)

[13]. Shakti Suryavanshi, Ashish Pandey, Umesh Chandra Chaube
Hydrological simulation of the Betwa River basin (India) using the SWAT model (2017)

[14]. E. Ingol-Blanco, D. McKinney
Development of a hydrological model for the Rio Conchos basin (2013)

[15]. Jing Zhang, Meng Zhang, Yongyu Song, Yuequn Lai
Hydrological simulation of the Jialing River Basin using the MIKE SHE model in changing climate (2021)

BIOGRAPHIES

	Sanjana Singh is M.Tech Student in Environmental Engineering, Dept. of Civil Engineering in IET, Lucknow, Uttar Pradesh, India
	Prof. Dr. JB Srivastava is working as Professor, Dept. of Civil Engineering in IET, Lucknow, Uttar Pradesh, India
	Er. Asit Singh is working as Assistant Professor, Dept. of Civil Engineering in IET, Lucknow, Uttar Pradesh, India