




Future Water Use Planning by Water Evaluation and Planning System Model

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Received: 2 July 2020 / Accepted: 20 September 2020 /

Published online: 1 October 2020

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Abstract

Assessment of future water availability is a challenging task under changing climatic conditions and anthropogenic interventions. The current research focuses on future water resources scenario generation for contributing areas of proposed hydraulic structures generated from the Water Evaluation and Planning (WEAP) System model. The proposed methodology was implemented for the Dwarakeswar-Gandherswari river basin (India) which needs a long-term future water use plan. Bias-corrected Representative Concentration Pathways (RCPs) data were used for climate change analysis through a hydrological model. Different simulation model outputs [e.g. Dynamic Conversion of Land-Use and its Effects (Dyna-CLUE), Soil and Water Assessment Tool (SWAT), Modular Finite-Difference Flow Model (MODFLOW)] were utilized in water evaluation model for a generation of future water resources scenarios. Four scenarios (2010–2030–2050–2080) were generated for the sustainability of limited water resources management strategies. SWAT simulated results show an increase in river discharge for 2030 or 2080 and a decrease for 2050. MODFLOW simulated results show a visible groundwater storage change for 2030 but minimal change for 2050 and 2080 scenarios. The results also show a decrease in agricultural land and an increase in population for the contributing areas of three hydraulic structures during 2010–2030–2050–2080. These results provide a piece of valuable information for decision-makers in future water management plan preparation.

Keywords MODFLOW · River basin management · SWAT · Water availability · Water demand · WEAP model

Electronic supplementary material The online version of this article (<https://doi.org/10.1007/s11269-020-02680-8>) contains supplementary material, which is available to authorized users.

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1 Introduction

Assessment of water availability are generally performed through the dynamic balance between precipitation, infiltration, and evapotranspiration (Kourgialas et al. 2019). Both surface water and groundwater availability information are equally important for future water use planning framework under changing climatic conditions (Zhang 2015). Thus future water availability estimation through hydrogeological models is not meaningful without bias correction of weather data (Shrestha et al. 2017). Optimum water resource allocation is challenging for agricultural and domestic activities in any river basin (Wang et al. 2016). In the present work, we have proposed an integrated framework for future water use planning based on the Water Evaluation and Planning System (WEAP) for the proposed hydraulic structures contributing areas in the Dwarakeswar-Gandheswari river basin (India).

Only a few studies are available on future water use planning, considering climate change impacts. Zhou and Li (2011) studied the exponential growth of regional groundwater flow modeling for the demand for future regional impacts of human inferences. In this study, large-scale transient groundwater models were developed to simulate water budget components. Jingli et al. (2013) established 3D groundwater flow modeling of average annual groundwater recharge for groundwater resources management in the North China Plain. They performed the water budget analysis for the 2002–2003 period. Maheswaran et al. (2016) performed simulations of the transient numerical model using Visual MODFLOW for the stream-aquifer interaction in the Ganga Basin System of North and East India. Their analysis focused on the future scenario generation of groundwater resources, considering losing and gaining stretches along the main river.

Mani et al. (2016) performed a conjunctive use planning based on a mixed-integer linear fractional programming (MILFP) method under future climate change conditions. The Variable Infiltration Capacity (VIC) model was used for the estimation of projected runoff. Finally, the Bayesian model was adopted to quantify uncertainty in future climate projection. Gao et al. (2017) simulated irrigation efficiency, treatment, and the reuse of water from the Water Evaluation and Planning System (WEAP). It was a decision-making tool developed for strategic environmental assessments (SEA) of arid/semi-arid regions in northwest China. Maliehe and Mulungu (2017) assessed water availability using the SWAT and WEAP hydrological model in South Phuthiatsana catchment in Lesotho. Two scenarios were developed for industrial demands and environmental demand. In a more recent work, Yaykiran et al. (2019) performed WEAP-PGM (Water Evaluation and Planning System – Plant Growth Model) for sustainable management of water resources in the Sakarya River basin of Turkey. The main objective of their research is the calculation of water budget components on an annual basis by the WEAP model. Tena et al. (2019) estimated the catchment water balance and assessed the available water resources using the WEAP model in the Chongwe River Catchment. In another work, Gedefaw et al. (2019) developed a WEAP model to allocate water supplies for sector-based analysis on economic parameters considering the climatic condition of the Awash River Basin of Ethiopia. Three future scenarios were developed (1981–2016, 2017–2030, and 2031–2050) with a baseline period of 1980 for a systematic analysis of the water resources allocation system. Willet et al. (2020) performed a water supply network model by allocating local renewal water resources of Zeeuws-Vlaanderen in the Netherlands. This model was tested to supply industrial water users with groundwater resources by WSN within sustainable yields. More recently, Xiang et al. (2020) developed a new DSSAT-MODFLOW model to simulate groundwater flow considering crop

yield on water use efficiency of managing the aquifer sustainably. Their study considered a linkage between the agronomic model (DSSAT) and the groundwater flow model (MODFLOW) for changes in irrigation technologies under climatic conditions. Sabzzadeh and Shourian (2020) developed a hydro-agronomic model (PSO-SWAT-MODFLOW) for the generation of a groundwater-irrigation plan by the simulation-optimization approach of plain in West Iran. Niswonger (2020) studied MODFLOW and GSFLOW for simulating demand to drive agriculture water use scenarios. This study considered the energy and soil-water balance model to determine crop water demand for irrigation practices.

It is evident that estimating irrigation withdrawal is very important for water resources planning and management purposes. Most of the countries are facing a water shortage problem due to freshwater management challenges, environmental quality, and policy. These problems can be addressed from an integrated water management approach using WEAP model. However, changes in water resource considering climate change impact raises these research questions:

- (i) How significant is the contribution of climatic conditions in changing water resources?
- (ii) How significant is the impact of better hydrological analysis in an integrated framework plan?
- (iii) Is multi-model coupling required for an integrated framework plan?
- (iv) How significant is the contribution of future agriculture and domestic water demand on a sustainable integrated framework plan?

Thus, there is a scope for the development of methods for future water use planning under climate uncertainty. A hydro-environmentally sustainable conjunctive water use plan is required for water-scarce Dwarakeswar-Gandheswari River Basin for the post-construction irrigation planning. The proposed plan should include future scenarios for quantification of anthropogenic and climatic impact on individual components of the hydrological cycle. The focus of this present study is to develop an integrated surface water and groundwater management framework for future water planning. Future estimated agricultural areas, population, river discharge, groundwater recharge, were considered for future water use planning from the hydrological model (SWAT) and groundwater model (MODFLOW). We established a multi-model output-based new framework for long-term water resources planning from the WEAP environment.

2 Study Area

The eastern flowing river Dwarakeswar (Fig. 1) originates from Tilboni hill in Purulia district and enters the Bankura district near Chhatna in India (Sahoo et al. 2019). Gandheswari River is the main tributary of the Dwarakeswar River (Sahoo et al. 2018a). Other tributaries are Kukhra River and Birai River on the left side and Shilabati River on the right side of the Dwarakeswar River. The discharge location is the Rupnarayan River. The hydraulic structures and command areas were planned within the District of Bankura, West Bengal (Sahoo et al. 2018b). Two reservoirs (Dwarakeswar and Gandheswari) and one barrage (Pratappur) were proposed in the Dwarakeswar- Gandheswari River for sustainable water resources management. The Dwarakeswar-Gandheswari has a total basin area of 4341.765 km². The contributing areas for the proposed Dwarakeswar, Gandheswari, and Pratappur points (location of hydraulic

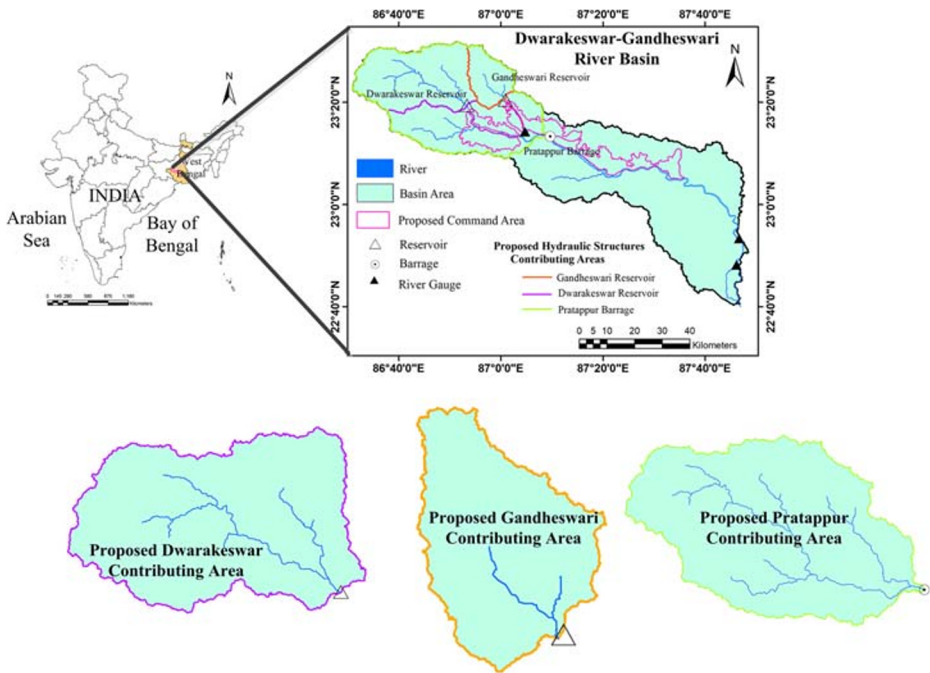


Fig. 1 Location map of the study area

structures) on the rivers are 779.66km², 237.43km², 1826km², respectively. The topographic structure of Dwarakeswar watershed consists of both mountainous and plain land areas. The maximum elevation is seen in the extreme north-western corner and western (> 176 m) part of the study site, and the minimum elevation was noticed in the eastern and southeastern (<52 m) part of the study area. The average annual rainfall is 1357 mm with 90% precipitation occurring during monsoon months of June–October. The mean daily minimum temperature is 12–13 °C and the maximum highest temperature is 47 °C. The maximum and minimum wind speed is 3.42 km/h and 0.03 km/h for July and January. The major geology is granite gneiss (37.32%). The maximum area is covered by the fine loamy soil (55.06%) and major agriculture is paddy rice cultivation. Three types of paddy rice pattern (Boro Rice for Feb–March, Aus Rice for May–June, Aman Rice for Aug–Oct) could be seen in the total river basin areas. The upstream portion of the river basin has high water stress zones compared to the downstream portion. Thus, the water stress problem highly impacts paddy rice cultivation in the river basin. The maximum population pressure (967–1466 person/km² according to 2011) is on the lower part of the river basin because of the rapid urbanization.

3 Materials and Methodology

3.1 Data Sources

MIROC5 (Model for Interdisciplinary Research On Climate-5) model-based Representative Concentration Pathways (RCP) 2.6, 4.5, 6, and 8.5 (grid: 1 km × 1 km) scenarios were used for future climate change analysis. MIROC5 is developed by the University of

Tokyo, the National Institute for Environmental Studies, and the Japan Agency for Marine-Earth Science and Technology. In this paper, we have used a single regional climate model (RCM) based on RCPs data. However, RCM also relies on output from GCM simulations. RCPs were collected from the Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment Report (<http://gisweb.ciat.cgiar.org>). Observed (grid: $0.5^\circ \times 0.5^\circ$) precipitation and temperature data (1979–2014) were collected from the National Centers for Environmental Prediction (NCEP) Climate Forecast System Reanalysis (CFSR) [<https://globalweather.tamu.edu>]. River discharge and groundwater level data were collected from the Central Ground Water Board, Kolkata.

3.2 Methodology

3.2.1 Climate Change Prediction

Downscaled MIROC5 RCP-based climate data were used for future climate change scenarios through a hydrogeological model. Raju et al. (2017) showed that MIROC5 model data is suitable for the West Bengal region. However, bias correction is necessary before the application of RCPs. Thus, Linear scaling (LS) for precipitation and distribution mapping (DM) for temperature was applied to RCP data (Luo et al. 2018). The LS method uses a multiplicative ratio with monthly correction values based on the difference between simulated and observed data. The DM method assumes the function of error correction values between simulated and observed distribution. The gamma distribution method was applied for temperature data. These two methods are easy to implement. The details of the bias correction methods are available in Smitha et al. (2018); and Fang et al. (2015).

3.2.2 Surface Water Availability

Hydrological models are an effective tool for predicting the effects of land use/land cover (LULC) and climate change on water resources (Yan et al. 2019). Rainfall is the primary indicator of water availability (Aljerf 2018). The Dyna-CLUE (Verburg et al. 2002) considers land-use demands, location suitability, neighborhood suitability, spatial restrictions, and conversion parameters (Tizora et al. 2018) including various driving factors (e.g., elevation, slope, rainfall, population). The logistic regression method was used for location suitability in the CLUE model. The SWAT is a general water balance algorithm based comprehensive, semi-distributed watershed model (Arnold et al. 2012). The SWAT model requires a large number of input datasets, e.g., soil, LULC, slope, weather parameters, and other ancillary data (Aljerf 2018). The Penman-Monteith equation was used for the SWAT model to calculate evapotranspiration (ET) values (Jung et al. 2016). Dyna-CLUE, MIROC5, and SWAT models were integrated to predict the future surface water availability (Sahoo et al. 2018a; Sahoo et al. 2018b). Surface water availability simulation was performed for the three proposed hydraulic structures. The hydrological simulation was performed for 2030, 2050, and 2080 periods under RCPs (2.6, 4.5, 6, and 8.5) data.

3.2.3 Groundwater Availability

Modular Finite-Difference Flow Model (MODFLOW) is a physical-based three-dimensional groundwater flow model (McDonald and Harbaugh, 1988). MODFLOW was utilized

for future groundwater level prediction in an unconfined aquifer (SF1). Future population, future river discharge, future groundwater recharge, future pumping rate (considering ET) were used for this modeling (Gomo, 2019). The detailed model information is available in Chen et al. (2017).

3.2.4 Conjunctive Water Use Planning

Water Evaluation and Planning (WEAP) System is a strategic environmental assessment (SEA) model for policy analysis of the local water resources system (Lévite et al. 2003). It is an integrated water resource (climate, hydrology, water allocation, and watershed management) planning framework (Gedefaw et al. 2019). This model can address a broad range of cases like water conservation, sector demand analysis, streamflow and groundwater simulation, reservoir operations, hydropower, vulnerability, pollution, and cost-benefit analysis. The various objects like demand, node, and reservoir can be created within the system. RCP 4.5-based hydrological model simulated (e.g., surface water discharge, groundwater recharge) data were used as inputs for the WEAP model. Four scenarios were tested to simulate irrigation efficient treatment and the reuse of water. WEAP model was constructed by the demand site network connected to deliver water from the resource node to the demand site. Surface water and groundwater were both considered for potential water resource planning because they are hydrologically connected. Water allocation pattern changes with a decreasing agricultural land area and increasing population (for 2010, 2030, 2050 and 2080). However, field observations showed that the suspended sediment concentration has been increasing in the Gandheswari River because of low flow during the lean season. Thus a sustainable water management plan is required for this river. The overall methodology is shown in Fig. 2.

4 Results

4.1 Analysis of Future Climate Change

The maximum, minimum temperature, precipitation data were bias-corrected with the Linear scaling (LS), and distribution mapping (DM). Before and after the correction of the bias data, a huge difference was observed between the predicted results (SF2). However, the future maximum and minimum temperature and precipitation results showed a minor differences of all RCPs for the year 2030. For future years of 2050 and 2080, temperature and precipitation results showed a major difference among all RCPs. The maximum temperature values were 42.77 °C, 44.51 °C, and 46.01 °C under RCPs 4.5, 8.5, 8.5 during 2030–2050–2080 (SF3). The minimum temperature values were 28.95 °C, 28.65 °C, and 30.67 °C under RCPs 8.5, 4.5, 6 for 2030–2050–2080 years. The highest precipitation of 437.90 mm was found under RCP 8.5 for June during 2030. The highest precipitation of 575.92 mm and 82.20 mm were also found under RCP 6 for August and July during 2050–2080 (SF4). The spatiotemporal changes in groundwater level dynamics are very sensitive to heavy precipitation because of the effective way to increase groundwater recharge. The four RCPs (2.6, 4.5, 6, and 8.5) were developed using four individual modeling groups. Only RCP 4.5 based future generated hydrological outputs were used for the WEAP model because it is a stabilization scenario where total radiative forcing is stabilized before 2100 (Clarke et al. 2007). This scenario provides a common platform to explore climate system responses for anthropogenic

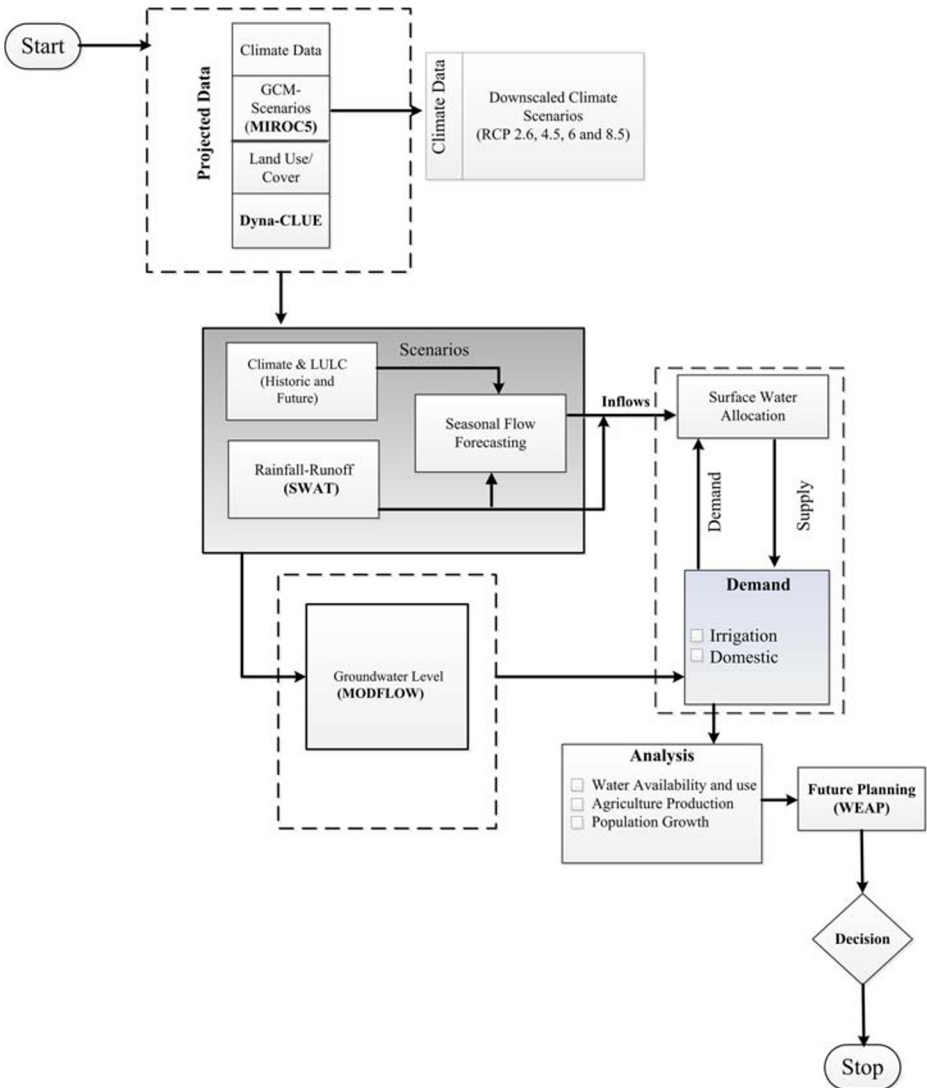


Fig. 2 Overall methodology

components. The RCP 4.5 scenario can be applied to land-use purposes (e.g., forest land). Also, it was updated for historical emissions and land cover information from the dynamic recursive economic model GCAM (Global Change Assessment Model).

4.2 Analysis of Future Surface Water Availability

Dyna-CLUE, MIROC5, and SWAT models were integrated to predict the future surface water availability. The Dyna-CLUE model was applied to predict the LULC features base year of 2010. The LULC map was classified into seven classes: (i) cropland, (ii) forest cover, (iii) barren land, (iv) fallow land, (v) water bodies, (vi) shrub land, and (vii) built-up land (Garg

et al. 2019). The results show that the maximum area is covered by the cropland. –About –805 ha cropland area has been changed between 2010 to 2030 because of urbanization (+2443.80 ha). Similarly, –0.620% cropland changes were seen between 2010 to 2030 within the proposed command area. Results indicated that built-up land has increased by +0.440% between 2010 to 2030. The results were verified by the field investigation and Google earth images. The accuracy achieved was 95% for the LULC of 2010. The SWAT is a sub-watershed based model. The LULC, soil, and slope were utilized to generate the Hydrologic Response Unit (HRU) using overlay method. The future precipitation and temperature data were used for future climate change impact through a hydrological model. Surface water availability simulation was performed by the SWAT model for three proposed hydraulic structures. Three proposed structures are: i) reservoir in the Gandheswari river tributary of Dwarakeswar, ii) Dwarakeswar reservoir, and iii) Pratappur barrage in the Dwarakeswar river. The hydrological simulations were performed for 2030, 2050, and 2080 time periods under different RCPs [2.6, 4.5, 6, and 8.5 from AR5 data (CMIP5)].

In the Gandheswari reservoir contributing area, results show that the maximum outflow value was 3836.05 m³/s under RCP 2.6 for the year 2030. RCP 4.5 result shows a maximum outflow value of 3716.77 m³/s for 2030. RCP 6 and RCP 8.5 results also show maximum outflow values of 3724.30 m³/s and 984.96 m³/s for 2030. RCPs (2.6, 4.5, 6 and 8.5) results show that maximum inflow and outflow values were 14,665.91 m³/s, 13470.72 m³/s, 12698.50 m³/s, 14499.05 m³/s and 14,665.91 m³/s, 13469.94 m³/s, 12627.88 m³/s, 14499.05 m³/s for the 2050 year. RCP 6 and RCP 8.5 results show that maximum inflow values of 3724.53 m³/s, 2948.74 m³/s, 3127.24 m³/s, and 4036.98 m³/s, 3356.11 m³/s for the 2030–2050–2080 years. Minor streamflow changes were observed for four RCPs. The maximum fluctuation pattern was observed under RCP 8.5 (SF5). However, it is difficult to generalize the variability of RCPs.

For the Dwarakeswar reservoir contributing area, the results for different RCPs scenarios are shown in SF6. Results also show a maximum outflow value of 17,026.80 m³/s under RCP 2.6 for 2030. RCP 4.5 results show a maximum outflow value of 16,506.81 m³/s for the year 2030. RCP 6 and RCP 8.5 results also show maximum outflow values of 15,581.70 m³/s and 17,400.10 m³/s for the year 2030.

RCPs (2.6, 4.5, 6 and 8.5) results show maximum inflow and outflow values of 14,665.91 m³/s, 13470.72 m³/s, 12698.50 m³/s, 14499.05 m³/s and 14,665.91 m³/s, 13469.94 m³/s, 12627.88 m³/s, 14499.05 m³/s for the year 2050. Among all RCPs (2.6, 4.5, 6, and 8.5), the maximum inflow and outflow values of 15,126.13 m³/s, 13632.92 m³/s, 14323.06 m³/s, 15260.40 m³/s, and 15,373.71 m³/s, 13631.37 m³/s, 14323.06 m³/s, 15260.40 m³/s were for the year 2080. However, it was observed that streamflow decreases in 2080 as compared to 2030 (Sahoo et al. 2019).

For the Pratappur barrage contributing area (SF7), a maximum outflow value of 46,617.56 m³/s was obtained under RCP 2.6 for 2030. Results also show that the maximum outflow value was 44,659.43 m³/s under RCP 4.5 for 2030. RCP 6 and RCP 8.5 results show that maximum outflow values were 44,848.17 m³/s and 44,848.17 m³/s for 2030. The results show that maximum inflow and outflow values were 42,008.07 m³/s, 40944.59 m³/s, 37365.91 m³/s, 41766.71 m³/s, and 42,006.25 m³/s, 40926.39 m³/s, 37365.91 m³/s, and 41,766.71 m³/s under four RCPs for the 2050 year. Among all RCPs (2.6, 4.5, 6, and 8.5) maximum inflow and outflow values of 41,939.11 m³/s, 37520.17 m³/s, 37561.91 m³/s, 41055.32 m³/s, and 41,939.11 m³/s, 39599.88 m³/s, 37560.09 m³/s, and 41,055.32 m³/s were obtained for the year 2080.

Finally, SWAT model calibration and validation were performed for three proposed hydraulic structures (SF8). The eighteen parameters (CN2, GW_DELAY, ALPHA_BF, GWQMN, GW_REVAP, REVAPMN, SOL_AWC, ESCO, SOOL_K, ALPHA_BNK, CH_K2, EPCO, HRU_SLP, CH_N2, OV_N, SLSUBBSN, SOL_BD, and SURLAG) are considered in the SWAT model during calibration and validation periods. The detailed calibration and validation are available in Sahoo et al. (2019).

4.3 Analysis of Future Groundwater Availability

We prepared a single-layered MODFLOW model of 30 m thickness. The flow boundary was demarcated based on the geological condition. The granite gneiss was considered as a no-flow boundary, and laterite was considered as a flow boundary. The recharge and ET (pumping) data were considered for sub-watershed level (ST1); and hydraulic conductivity, specific yield, and population were considered for block level. Three (e.g., 2030, 2050, and 2080) future groundwater head maps were generated from the MODFLOW. A total of 49 observation wells (2002–2017) were selected for the MODFLOW calibration and validation process. Population growth analysis was utilized for calculating future groundwater draft. Population projection was performed using an exponential growth rate baseline data of 2001 (Census of India). However, the water demand value was represented in the form areal pumping (in 50 m). The results showed that the middle (50–150 m) and upstream (150–250 m) portion of the river basin fall under moderate and high groundwater head region. Visible changes were observed between the groundwater table for 2010 and 2030. However, changes were minimal between 2030 and 2050–2080. Maximum wells showed that there will be no significant head changes between 2030 and 2050–2080 (SF9). Finally, model calibration for 2008, 2010, and validation for 2016 were performed through observed groundwater level data by 2 m observation transient head interval box plot mapping (SF10 – SF12). The results showed that green and yellow well indicating high and moderate groundwater stress levels. Whereas the red-well indicates the overflow through aquifer according to model estimation values. No significant change could be seen between 2030 and 2050–2080 for the groundwater head.

4.4 Analysis of Future Conjunctive Water Use Planning

The Dyna-CLUE (e.g., agriculture area), SWAT (e.g., river discharge, ET, groundwater recharge), MODFLOW (e.g., groundwater storage) model-generated data were used in the WEAP model for integrated water resources management and policy analysis. However, domestic (D) and agricultural (A) demand node(s) were created corresponding to each block for water need and considering rice as major crops, respectively. Other factors were selected such as transmission link and return flow between river and demand site, including the outlet of the main river. After that, all data (e.g. flow, recharge, agriculture, population) were incorporated in the WEAP model through a stepwise procedure. In the Gandherswari reservoir MODFLOW, the future generated groundwater head values vary between 0 and 400 m for the year 2030 to 2080. The results show that the downstream portion of the river basin comes under a low groundwater head (0 - contributing area, the total water supply requirement of the agricultural and domestic were 70.00 mm³ and 11.66 TCM for the year 2030 (ST2). Results indicated that agriculture water requirement is decreased (2050: 69.65 mm³) after 2030, mainly owing to urbanization. Subsequently, water requirement is increased for domestic purpose (2050: 14.36 TCM). Results showed that total groundwater storage was 22,500.02 mm³ for

2030 (ST3). It was observed that groundwater storage was decreased for 2050 (13,782.88 mm³) and 2080 (10,489.32 mm³) when compared to 2010 and 2030. This is because groundwater is mostly utilized for agriculture purposes (Fig. 3). It also depends on the level of urban development.

In the Dwarakeswar reservoir contributing area, the total water supply requirement of the agricultural and domestic were 261.89 mm³ and 4.93 TCM for 2030 (ST4). Less water requirement for agriculture purposes was noticed for 2050 (254.89 mm³) and 2080 (244.39 mm³). The total groundwater storage was 56,471.07 mm³ for 2030 (ST5). The groundwater storage decreased for 2050 (22,863.85 mm³). However, a marginal gain was observed for 2080 (32,808.93 mm³). Increase in agricultural land resulted in an increased change in water stress from May to October (Fig. 4).

In the Pratappur barrage contributing area, the total water supply requirement of the agricultural and domestic were 596.67 mm³ and 69.88 TCM for 2030 (Table 1). The agriculture water requirement decreased for 2050 (561.67 mm³) and 2080 (456.67 mm³). The total groundwater storage was 140,050.60 mm³ for 2030 (ST6). Moreover, it was observed that groundwater storage was increasing for 2050 and decreasing for 2080 (SF13). The conjunctive use of surface water and groundwater has the potential benefit for social and economic outcomes. It strongly supports greater food production per unit use of water. The

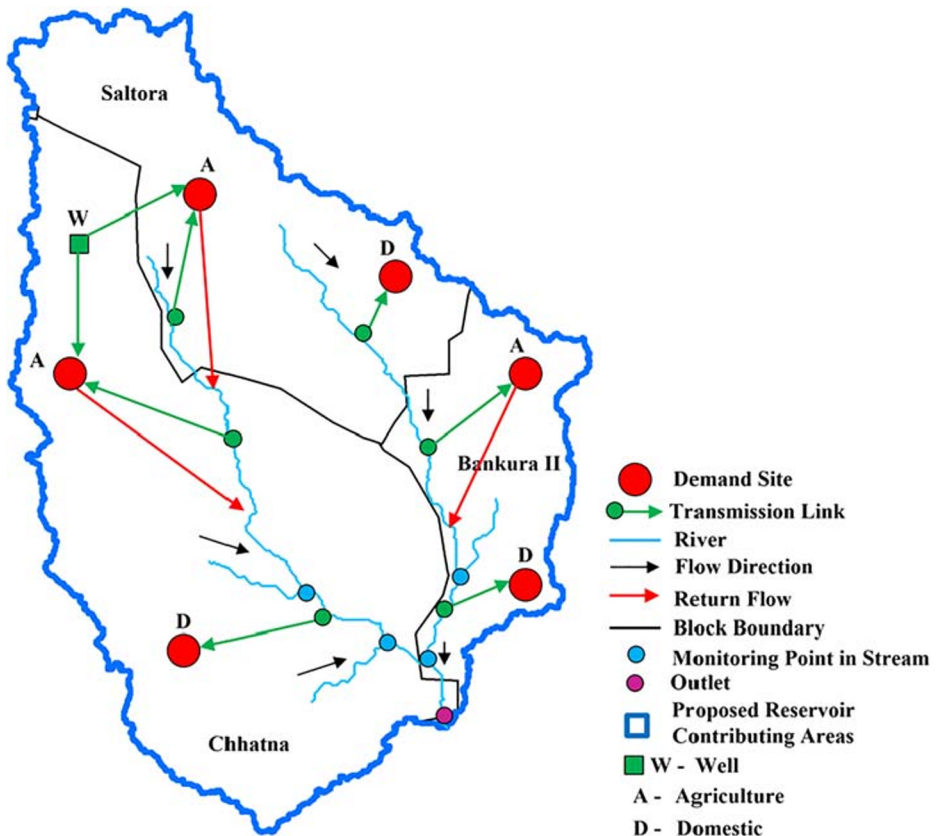


Fig. 3 Proposed Gandherswari reservoir demand sites schematic map

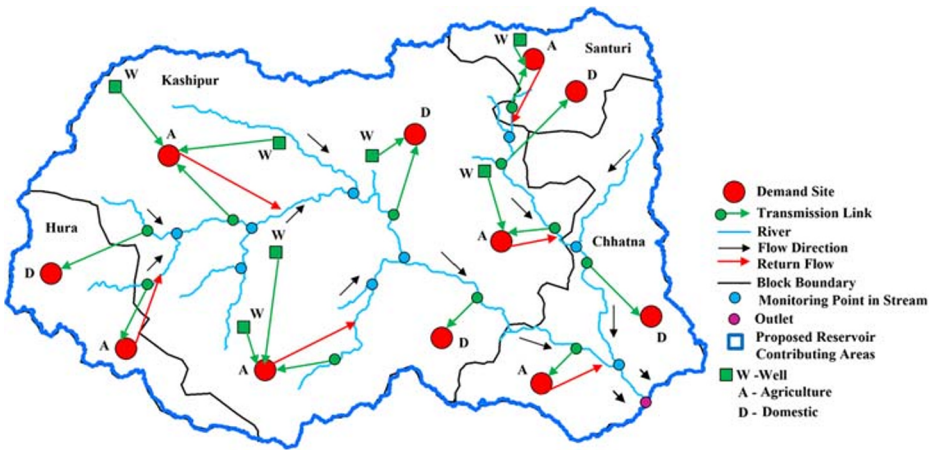


Fig. 4 Proposed Dwarakeswar reservoir demand sites schematic map

planned conjunctive use is required for a site and is significantly affected by existing hydro-physical and social systems.

The results showed the level of irrigation development that can be undertaken in the Dwarakeswar-Gandheswari river basin when the proposed hydraulic structure(s) are constructed. The upper part of the basin will get a major benefit from this project.

5 Discussion

No study on past, present, and future water use scenarios are available for the Dwarakeswar-Gandheswari river basin. The multi-model (Dyna-CLUE, MIROC5, SWAT, MODFLOW) generated outputs were utilized to establish a robust integrated framework. It can evaluate the full range of management options for multiple and competing water systems. The developed framework can be improved by incorporating the physical structure, potable water, storm water, and wastewater information from water authorities.

Water resources availability and temporal distribution are highly variable due to climate change in the river basin. The potential three hydraulic structures (two reservoirs and one barrage) are required for irrigation purposes to overcome the water deficit condition. One reservoir and barrage are proposed in the main river (Dwarakeswar) and one reservoir is proposed in the major tributary (Gandheswari). In this work, three hydraulic structures are proposed in the upstream part of the district of Bankura because of the high water stress zone. This district is economically underdeveloped and mainly depends on agriculture and land cultivation. It is one of the drought-prone districts of West Bengal. Roy and Banerjee (2010) performed an analysis of the proposed reservoir project for agriculture and municipal water requirement located at Suknibasa on the river near the district of Bankura. This reservoir was also used for controlling the flood. However, the proposed Pratappur barrage can potentially supply water for agricultural use. According to the WEAP model, the agriculture water demand has continuously decreased because of urbanization. Vissa et al. (2019) studied groundwater storage change in India from GRACE and GLDAS from 2003 to 2015. Their results have shown that the water level has decreased at the rate of 1.6 cm yr⁻¹ over northern India because of the impact of El Nino/Southern Oscillation (ENSO).

Table 1 Water Requirement for agriculture and domestic purpose at proposed Pratappur barrage for 2010, 2030, 2050, and 2080 years using the WEAP model

Month	Water Requirement for Agriculture (Million Cubic Meter)				Water Requirement for Domestic (Thousand Cubic Meter)			
	2010	2030	2050	2080	2010	2030	2050	2080
	Absolute Value	Absolute Value	Absolute Value	Absolute Value	Absolute Value	Absolute Value	Absolute Value	Absolute Value
Jan	74.46	50.68	47.70	38.79	-8.40	5.09	5.94	10.73
Feb	67.25	45.77	43.09	35.03	-7.57	4.59	5.36	9.69
Mar	76.46	50.68	47.07	38.79	-8.40	5.09	5.94	10.73
Apr	72.06	49.04	46.16	37.53	-8.12	4.92	5.74	70.38
May	74.46	50.68	47.70	38.79	-8.40	5.09	5.94	10.73
Jun	72.06	49.04	46.16	37.53	-8.12	4.92	5.74	10.38
July	74.46	50.68	47.70	38.79	-8.40	5.09	5.94	10.73
Aug	74.46	50.68	47.70	38.79	-8.40	5.09	5.94	10.73
Sep	72.06	49.04	46.16	37.53	-8.12	4.92	5.74	10.38
Oct	74.46	50.68	47.70	38.79	-8.40	5.09	5.94	10.73
Nov	72.06	49.04	46.16	37.53	-8.12	4.92	5.74	10.38
Dec	74.46	50.68	47.70	37.79	-8.18	5.09	5.94	10.73
Total	878.71	596.67	561.67	456.67	59.90	69.88	88.42	126.34

Reservoir/dam discharge and tributary inflow can be used for future influences on long-term effects and changes in water quality trends (Ahn and Lyu, 2017). It is a new guideline for managing river environments. Reservoir/dam plays a very important role in mitigating water supply problems under changing climatic conditions (Carvalho-Santos et al. 2017). Climate change is not always considered in hydraulic structures for planning and management purposes. Thus, climate change can significantly impact on surface water and groundwater resources (Zhang 2015). The present study considered climate change's impact on the proposed hydraulic structure in the river basin for hydrological modeling. Sahoo et al. (2018b) provided a detailed analysis of LULC change. In another work, Sahoo et al. (2019) estimated the impact of LULC change on hydrological scenarios. The present study combines all simulated results to evaluate future water allocation scenarios. It was observed that precipitation and temperature effectively change in the upstream and downstream portion of the river basin. Groundwater is a complementary source of water to satisfy the ever-increasing water demands. Also, climate data requires bias correction before any application of RCM simulation (Shrestha et al. 2017). This study compared the bias correction of precipitation and temperature data using linear scaling and quantile mapping in the Kaligandaki River basin of Nepal. It was observed that no significant difference between the results of linear scaling and quantile mapping. However, our study considered future climate change effects through bias-corrected climatic variables in river discharge and groundwater recharge calculations. Chakraborty et al. (2020) assessed the hydrological model (SWAT) for static and dynamic causative factors for soil erosion potential mapping in the Kangsabati River Basin. They found that the soil erosion rate is moderate to high in the Kangsabati River Basin. However, soil erosion is very low in our study area because of dense vegetation.

Dhar and Mazumdar (2009) studied hydrological modeling for transmission losses, soil water content, potential evapotranspiration, evapotranspiration, and lateral flow considering projected climate change in the Kangsabati river basin in Bankura district of West Bengal. Anand et al. (2018) performed hydrological modeling for prediction of water balance, analysis of streamflow for the Ganga River Basin. Their results indicated that streamflow is decreased in the lower reaches and the non-perennial tributaries from anthropogenic interventions. The present study also considered anthropogenic interventions under changing projected climate change. Our proposed methodology can be applied to enhance the practical applicability of the river basin management framework. Surface water reservoirs could provide us with flood control, recreation service, and water supply (Liu et al., 2018a, b). However, the reservoir can flow through the fragmented rivers affecting and displacing the existing land use activities. This kind of integrated framework can be used for sustainable and integrated water resources management in a river basin (Gedefaw et al. 2019). The reservoir and barrage can be able to store more water for a dry and low-flow season for agriculture purposes. Moreover, this framework can resolve all kinds of integrated water resources management issues through optimal water allocation for water shortage during dry periods. It is one type of paradigm reformation of a policy of the basin management.

6 Conclusions

The integrated framework evaluated the local water resources systems for the impact of the proposed hydraulic structures under the changing climate on the Dwarakeswar-Gandhershvari river basin, India. Hydrological (SWAT) and groundwater models (MODFLOW) were

integrated into the water evaluation model (WEAP). Bias-corrected RCP 4.5 climate data were utilized for climate change prediction. These model results show the imbalances between water supply and demand for agriculture and domestic activities. The results also show that the upper portion of the river basin comes under high water stress conditions. The lower portion of the river basin comes under high urban growth. The drawback of the present research is the data scarcity problem. The number and spatiotemporal coverage area of validation points should be increased. The obtained maps can be applied for regional level irrigation (including crop) planning of the study area.

Acknowledgments The author thanks Irrigation and Waterways Directorate, Government of West Bengal, India for providing necessary support for this research work. The author also thanks Regional Director, Central Ground Water Board (CGWB) for providing necessary data for this research work.

Funding This paper is supported by the Centre for Advanced Modelling and Geospatial Information Systems, UTS and Researchers Supporting Project number RSP-2020/14, King Saud University, Riyadh, Saudi Arabia.

Compliance with Ethical Standards

Conflict of Interest The authors declare no conflict of interest.

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