Integrated hydrological modeling for assessment of water demand and supply under socio-economic and IPCC climate change scenarios using WEAP in Central Indus Basin

Areesha Asghar, Javed Iqbal, Ali Amin and Lars Ribbe

ABSTRACT

In the Indus River Basin, various hydrological modeling studies have been conducted in the context of climate change scenarios. However, none of these studies addressed the impact of socio-economic along with the climate change scenarios on sustainable water demand and supply. This study focused on socio-economic and Intergovernmental Panel on Climate Change (IPCC) Representative Concentration Pathways (RCPs) scenarios (RCP4.5 and RCP8.5) for 2015–2050 in the Water Evaluation and Planning (WEAP) model were used for future projection of water availability and demand. The WEAP model calibration and validation statistics of Nash–Sutcliffe efficiency and coefficient of determination values were 0.85, 0.86 and 0.89, 0.87, respectively. As per the reference scenarios results by 2050, water demand would increase 11% for domestic and 55% for agriculture and livestock sectors. The high population growth scenario reveals that by 2050, with an increase in the water consumption from 82.9 m^3 per capita per day by the year 2015 to 120 m^3 per capita per day, unmet water demands in all sectors will increase to 50%. The IPCC climate change scenario projected the average change in precipitation and temperature would be about 15.22% and 274.07 K to 274.92 K by the end of 2035.

Key words | Central Indus Basin, climate change, socio-economic scenarios, water resources management, water scarcity

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INTRODUCTION

More than one-third of the world's population (~2.4 billion people) is living in water-stressed countries and this will increase to two-thirds by the year 2025 (Vörösmarty *et al.* 2010). Globally, rivers are exhibiting significant changes in annual runoff along with a decrease in snowfall and an increase in glacier melt, causing a water shortage in the long run. This will affect global water resources as well as the water availability for domestic and agricultural sectors (Arnell & Gosling 2013). Additionally, rapid population increase, economic growth, and urbanization are putting more pressure on freshwater availability. Climate change, being one of the most important factors along with the population growth and other administrative approaches, is significantly affecting the surface water availability and groundwater resources (Santikayasa 2016). Moreover, due to climate change, the Himalayan glaciers are retreating at a faster rate, which is affecting the river flows and groundwater recharge (Xu *et al.* 2009). These factors lead to excessive usage of fresh water globally, resulting in decreased per capita water availability, especially in developing countries where water management has not been prioritized (Bakken *et al.* 2016).

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Many global scholars have used different water resources assessment tools by integrating them with socio-economic factors. For example, the Water Resources Management Model (WRMM) is used for planning water resources' allocation within a basin (Cutlac & Horbulyk 2010). Spatial Agro Hydro Salinity Model (SAHYSMOD) is a combined approach of socio-economic components with physical, hydrological issues in a basin. The approach can be used to examine water resources better and develop a sustainable structure for the future (Inam et al. 2017). The Modular Simulator (ModSim) is a decision support system for river basin management for short-/long-term planning, developing strategies and water allocation analysis (Vaghefi et al. 2015). Among all the water allocation models, Water Evaluation and Planning (WEAP) has been the most widely used model in different basins around the world in the last decades (Yates et al. 2009). WEAP has proven to be a useful tool for water resources' allocation under different socio-economic and climate change scenarios (Hum & Talib 2016). Rayej (2012) used WEAP to project the water demands in agricultural, urban, and environmental sectors up to 2050. Many scenarios of increased population growth and climate change were considered. The study found that the urban demands increased rapidly under population growth scenarios, but the future climate of the region influenced the urban water demand to a lesser extent.

In Pakistan, the Indus River along with its tributaries (Kabul, Jhelum, Chenab, Ravi, Beas, and Sutlej), is the world's most extensive and contiguous irrigation system. The Indus River system is a transboundary basin which covers an area of 1,140,000 km^2 (Frenken 2012). In Pakistan, the Indus River Basin starts from the north (Himalayan Mountains) to the dry alluvial plains of Sindh province in the south and finally flows out into the Arabian Sea (van Steenbergen et al. 2015). The Indus Basin covers a total area of about 520,000 km^2 in Pakistan which is 65% of the country's total area. The Indus Basin and its tributaries are dependent on snow and glacier melt water, about 50% of its base flow, which is affected due to accelerated glacier melting (Amin et al. 2018). The Indus River is the major source of water for agriculture in Pakistan, as 74% of the river runoff is diverted into the irrigation canals. However, the availability of water for irrigation is about 11% less than the actual crop water requirement (Yaqoob 2011). Water shortage is the most limiting factor in achieving higher crop yields while climate variability has disturbed the cropping pattern in Pakistan. To meet the water demands, groundwater is being over-exploited, resulting in continuous depletion of groundwater in canal commands. Khan et al. (2008) forecasted the drastic decline in groundwater levels from 10 m to 20 m in the Indus Basin until the end of the year 2025. Groundwater in the Central Indus Basin (CIB) has excessively been used owing to population growth and its use for livestock and agricultural purposes (Hassan et al. 2017). About 76% of the area in the Thal Doab is highly vulnerable to contamination. Some of the tube wells' water is unsuitable for irrigation in the region, because of the high concentration of salts (Shah & Ahmad 2015). Due to hydrological and socio-economic factors, water stress conditions in Pakistan are likely to increase as the water demand will grow by 2.5% in the year 2025 (UNESCO 2009). Pakistan is one of the most water-stressed countries in the world. The water resources of Pakistan are degrading at an alarming rate. Many studies have been conducted to analyze the hydrology of the Indus River Basin, and to map the water quality of the aquifer underlain by Indus River (Hussain et al. 2017). The snowmelt runoff model (SRM) was used in the Hunza River Basin to simulate the daily discharge and to analyze the impacts of climate change (Tahir et al. 2011). However, these studies have failed to suggest a comprehensive, holistic analysis for water demand and supply of a basin, under the ever-increasing pressure of water demand in the basin (Amin et al. 2018). We focused not only on hydrological modeling but also on the demand and supply conditions to analyze the current and future water availability for sustainable water management in the CIB. The study aimed to (i) gain insights into the water demand and supply management system in the area and (ii) study the effect of climate change and socio-economic scenarios together on increased irrigation withdrawal and domestic use for the long-term availability of water in the CIB. This study will contribute to understand and plan the current water resources for sustainable use in all the sectors, considering the future impact of socio-economic and climate change on the water resources of the country.

MATERIALS AND METHODS

Study area

The study area covers six districts, i.e., Mianwali, Khushab, Bhakkar, Jhang, Layyah, Muzaffargarh of Punjab province (Figure 1). It lies between longitude 70°32′18.3″–71°26′17.1″ E and latitude 29°01′01.7″–33°14′20.9″N, bordering between the Punjab and Khyber Pakhtunkhwa provinces. The total area of all six districts is 43,853 km^2 with a population of 2,677,581. The Indus River flows west of the study area. The climate of the region is characterized as arid with mild winters. The mean maximum and minimum temperatures ranged from 54 °C to −1 °C with mean annual rainfall of 617 mm (Shah & Ahmad 2015).

Dataset used

Table 1 lists the data and description required to run the WEAP model. Figure 2 shows a schematic diagram of the data flow in the WEAP model. The land cover data were collected from MODIS (Moderate-resolution Imaging Spectroradiometer) land cover dataset archives (https://earthexplorer.usgs.gov/). Figure 3 shows the land cover classes in the study area.

Water evaluation and planning system model setup

WEAP is a comprehensive system for maintaining water demand and supply, flows, storage, discharge, and many other hydrological processes. It provides a set of model objects and procedures that can resolve problems faced by water management using a scenario-based approach, which works on the natural watershed, reservoirs, streams, and canals. It has built-in algorithms that use climate time series data and simulates rainfall-runoff of basins and sub-basins. To set up the WEAP model for application in a watershed, it includes various steps such as study period, study area boundary, actual water demand and supply and setting up the alternative set of future assumption based on robust policies that affect the water demand and supply and hydrology of the watershed. The variability in developing the key assumption is kept realistic regarding its cost and benefit and compatibility with the environment.

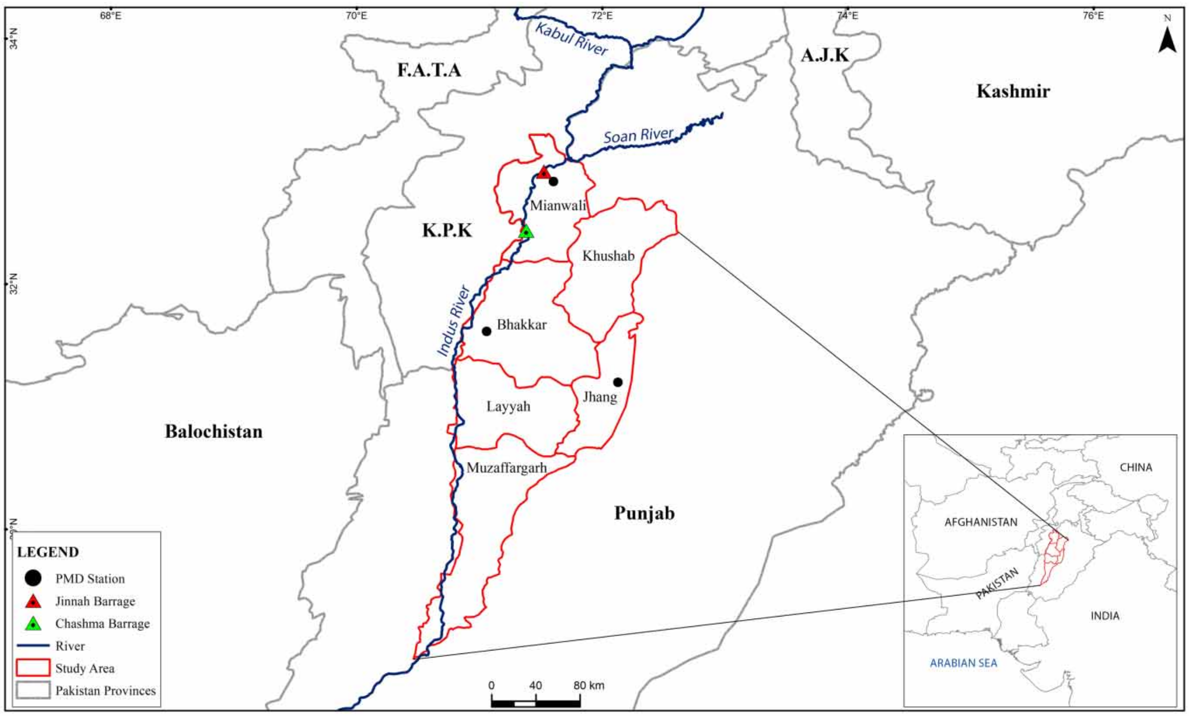

Figure 1 | Geographical location of the study area showing all six districts and the main Indus River in the Central Indus River Basin.

Table 1 | List of datasets used in the Water Evaluation and Planning model along with its description and sources

Data	Description	Sources
Meteorological data (1995–2014)	Precipitation, Evapotranspiration	Pakistan Meteorological Department (PMD), Lahore
Climatological data (2015–2050)	RCP4.5, RCP8.5	Pakistan Meteorological Department (PMD), Islamabad
Hydrological data (1995–2014)	River Discharge data	Water and Power Development Authority Lahore, Indus River System Authority, Lahore
Land cover data (2009)	Land cover from MODIS	USGS (https://earthexplorer.usgs.gov/)
Demographic data (1995–2050)	Land use data. Population and growth rates. Water consumption rates. Agricultural water demand	Pakistan Bureau of Statistics, Islamabad. Reports of Punjab Development Statistics

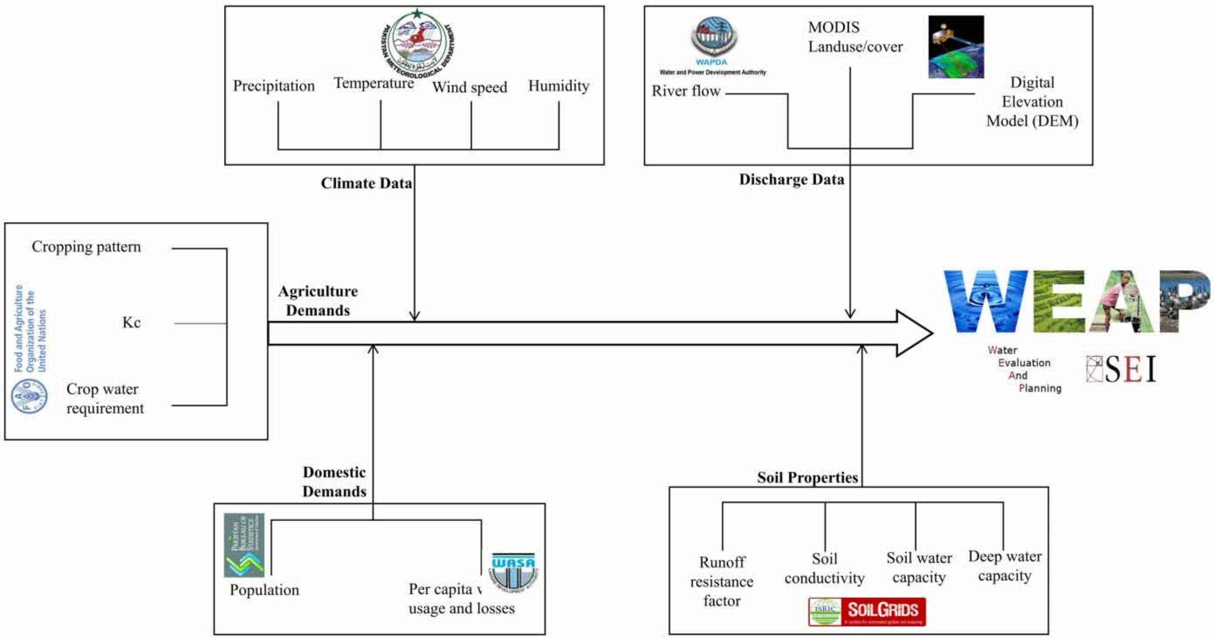

Figure 2 | Schematic diagram of data input in the Water Evaluation and Planning (WEAP) model.

The WEAP model provides five different methods for model calibration including (1) the rainfall-runoff method, (2) irrigation demands only simplified coefficient approach, (3) the soil moisture method, (4) the maitrise des besoins d'irrigation en agriculture (MABIA) method, which means 'control of irrigation needs in agriculture', and (5) the plant growth method. In this study, the rainfall-runoff method was chosen for model calibration as it assumes demand sites with simplified agro-hydrological processes, i.e., rainfall, evapotranspiration, and crop growth. It also includes non-agricultural demand sites as well.

Modeling of WEAP starts from the input of geographic layers, which include all supply and demand nodes. The schematic view links all spatial features by using nodes and transmission links. Figure 4 shows the schematic view of the lower Indus River Basin. The point features are demand sites in the study area, which are irrigation, domestic, and livestock. A transmission link is drawn from the water source to the demand sites. The domestic demand sites include Mianwali, Khushab, Bhakkar, Jhang, Layyah, Muzaffargarh districts and five agriculture demand sites of the same districts excluding Jhang district as River Chenab canals irrigate it. The livestock water demand was input as a whole for all districts, unlike other sectoral demands which were given for each district separately. Four rivers including the Indus Kabul, Soan, and Kurram rivers are the water supply resources.

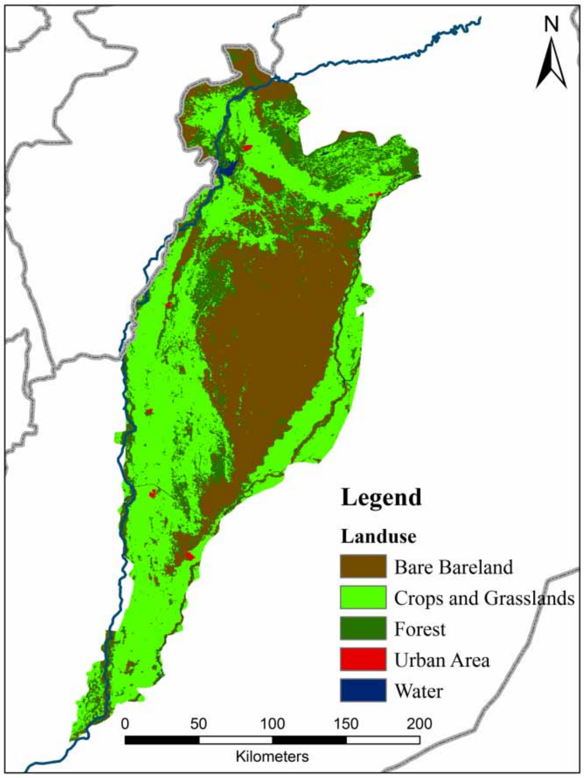

Figure 3 | Land cover classes map of Central Indus Basin using MODIS data.

Water requirements and demand estimation

The current and future water requirements were assessed for different sectors in the study area. Water demand analysis was performed for all the sectors using the disaggregated-based approach in the WEAP model. The water demands for domestic, agriculture, and livestock were estimated as a measure of socio-economic forces in the area. Water requirement for each sector was given at disaggregated level (i.e., persons, hectares, heads), which then was multiplied by the annual water use rate for each sector.

The domestic water requirement for each district included urban as well as rural areas. The population census of 1998 was used to calculate total water demand at the district level (Table 2). For the reference scenario, the population growth rate for each district was used to estimate water demand (Table 2). The water requirement for urban as well as rural areas was 60 gallons per capita per day.

The water requirement for cattle/buffalo and goat/sheep was given as 15 and 2.5 gallons per head per day, respectively (Amir & Habib 2015). The crop water requirement was estimated by using the crop coefficient values from Food and Agricultural Organization (FAO) data and literature for the

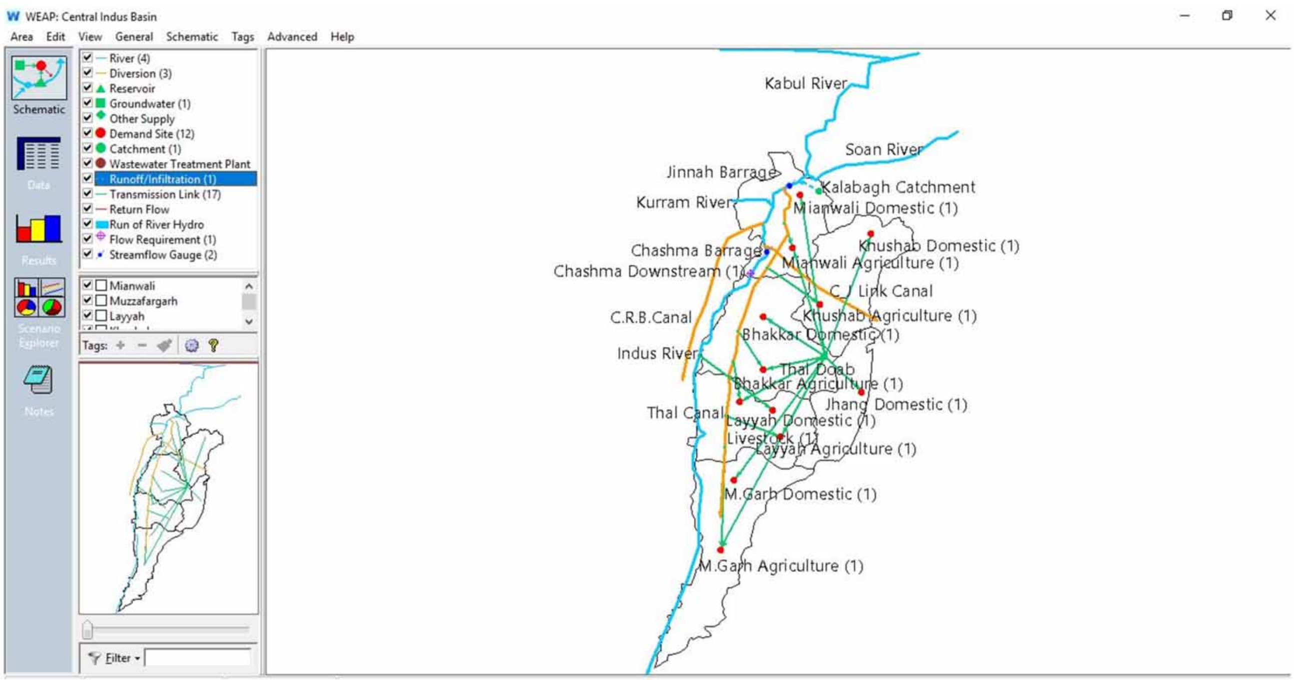

Figure 4 | Water Evaluation and Planning model schematics.

Table 2 | The district-wise population and growth rate

District	Population	Growth rate (%)
Mianwali	1,056,620	2.35
Bhakkar	1,051,456	2.72
Khushab	905,711	2.05
Jhang	2,834,545	2.16
Layyah	1,120,951	3.10
Muzaffargarh	2,635,903	3.38

existing croplands (Frenken 2012). The value of evapotranspiration and effective precipitation were obtained from the literature and PMD. The irrigation water demand was then calculated by considering the cultivated areas and patterns in CIB. The water demand data for major crops such as cotton, maize, sugarcane, rice, and vegetables were computed using the crop water requirement of the study area.

Future water demand and scenarios' development

The year 1995 data on total water demand for various sectors (agricultural, livestock, and domestic demand) were selected as a reference year/baseline year since that year data were complete in all respects to generate the socio-economic and IPCC climate change scenarios. The reference scenario refers to business, as usual, which was generated with water demand in the period 1995–2050 and climatic condition during 1995–2050. All socio-economic and climatic scenarios were developed with water demand in the period 2015–2050 and climatic condition during the same period. Table 2 shows the average population growth rate of all the districts in the reference scenario. The development of all other scenarios is the most essential part of WEAP modeling (Figure 5).

Five exploitation scenarios (reference scenario, population growth, increased irrigation demand, climate change RCP4.5, and climate change RCP8.5) and two management scenarios (the decrease in basic drinking water consumption and the decrease in basic irrigation water consumption) were suggested to assess the impacts of climate change on the water demand situation for the present and future. Development of scenarios was based on the demographic and the climatic projection data of the study area.

The climate projection data (RCP4.5 and RCP8.5) were collected from the Pakistan Meteorological Department (PMD), downscaled to 25 km and 50 km resolution. The RCPs are the result of integrated work of climate modeling and impacts' assessment. Each RCP is based on specific emissions trajectory, energy use, population, air pollutants and land use, and the resulting radiative forcing and temperature anomalies (Moss *et al.* 2010). The scenarios used in the study are as follows:

1. **Reference scenario:** refers to the current account in which all the real-time data were used. The water demand was increasing moderately.
2. **High population growth scenario:** a 5% increase in the present growth rates, and all the other parameters were used as they were in the reference scenario.
3. **Increased irrigation demands:** based on the increase in irrigated area by 7%, while all other parameters are based on the reference scenario.
4. **Climate change scenarios:** the projected climate data are used for RCP4.5 and RCP8.5, whereas population and demand data remained unchanged.
5. **Management scenarios:** for the study area they are proposed to be in domestic and agriculture sectors:
    1. The decrease in basic water consumption was decreased by 5%, and all the other parameters were based on the reference scenario.
    2. The irrigation water consumptions were decreased by 15%, where all the other parameters remain the same as a reference scenario.

Calibration process

Calibration of the WEAP model was done using the historical data from 1995 to 2004 (10 years) and then validation from 2005 to 2014. In the model calibration process, first the calibration methodology was selected among the five methods (rainfall-runoff method, irrigation demands only simplified coefficient approach, soil moisture method, MABIA method, and plant growth method) and then the parameters were identified along with their ranges that can be tuned to achieve the calibration of the model. The rainfall-runoff method for calibration of the model was selected because of the data availability according to the method's requirements.

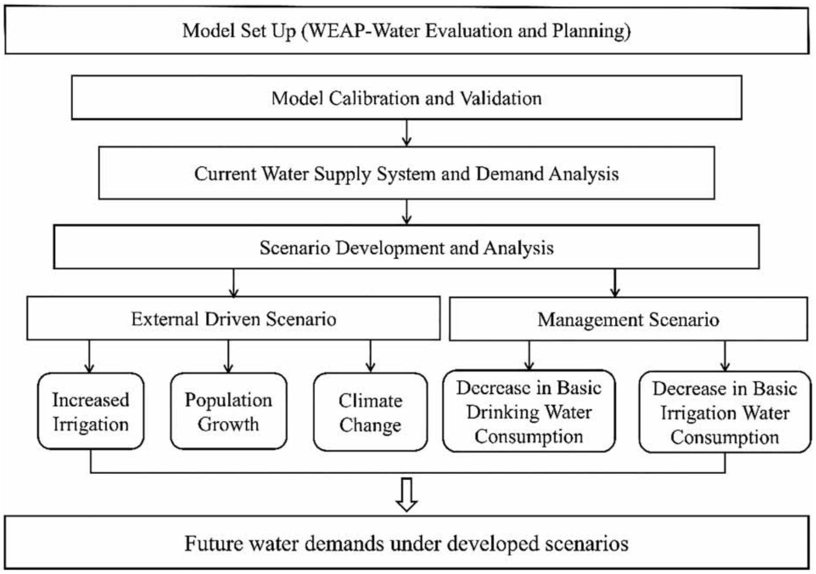

Figure 5 | Development of scenarios within the Water Evaluation and Planning model.

RESULTS

Model calibration and validation

The crop coefficient was the only sensitive parameter to tune up the model in this study. The performance of the model was evaluated by computing the coefficient of determination and the Nash–Sutcliffe efficiency index for calibration and validation periods, as they were found to be the best indices (Gupta & Kling 2011). The values of Nash–Sutcliffe efficiency index and coefficient of determination were 0.85 and 0.86, respectively, for the calibration period. The results showed that the WEAP model has accurately simulated the streamflow in the study area, and similar results were reported by Khan *et al.* (2017). The calibration result showed excellent agreement with the validation result of the model (Figure 6).

Reference scenario

Figure 7 shows the water demand simulation and analysis of the reference scenario. All the other scenarios, e.g., increased irrigation and population growth were computed based on this simulation. The results showed that by the year 2050 the water demand would increase to 6,800 million cubic meter (MCM), 15,400 MCM, and 270 MCM for domestic, agriculture, and livestock sectors, respectively. There was a 11% increase in domestic water demand. Similarly, the agriculture and livestock water demand increased to 55% in the year 2050.

Socio-economic scenarios

High population growth

Figure 8 shows a comparison of water demand under reference and high population growth scenarios. Under the reference scenario, the water demand was 1,307 MCM in 2015 and will increase to 6,800 MCM in 2050. In comparison, the water demand in the high population growth scenario was increased to 8,500 MCM by the year 2050. The increase in domestic water for CIB is justified by the relatively high population growth rate (5%), an increase in the water consumption by from 82.9 m^3 per capita per day by the year 2015 to 120 m^3 per capita per day by the year 2050. The domestic water demand, for the population growth scenario, is higher than reference scenarios in future because of the gradual increase in population in the study area. There were still no changes considered in the water supply system in the high population growth scenario. The future projection showed that no developments in water supply management would lead to severe water shortage problems.

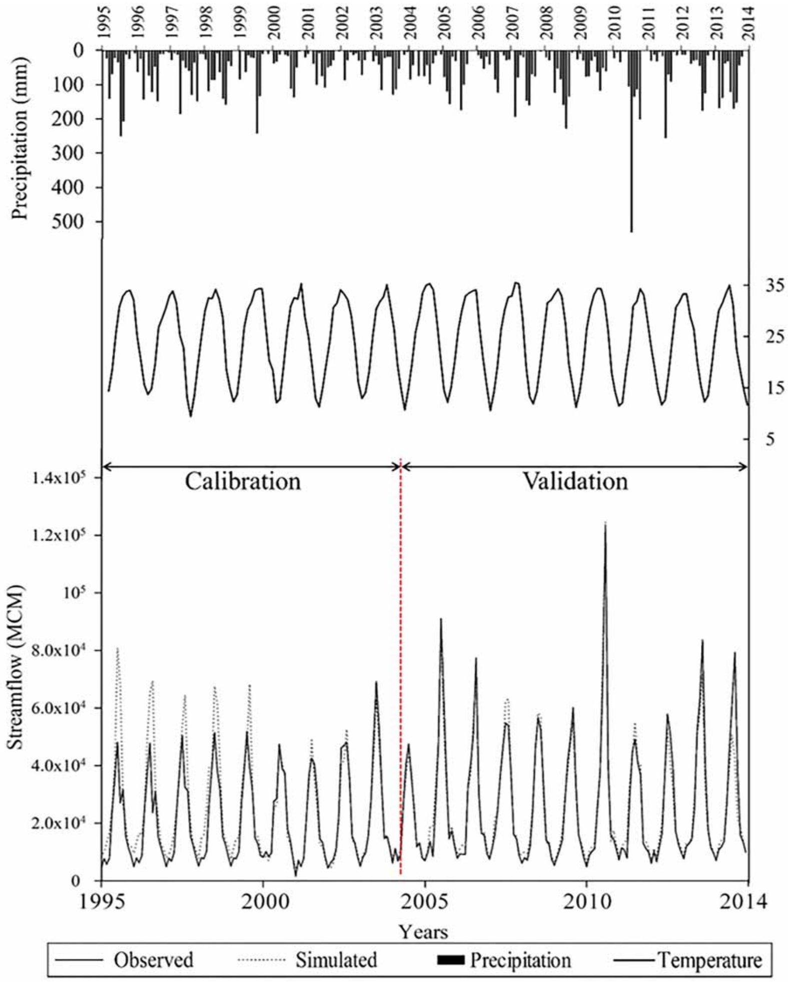

Figure 6 | Observed vs. simulated streamflow (monthly) with precipitation and temperature of the Central Indus Basin during calibration and validation processes.

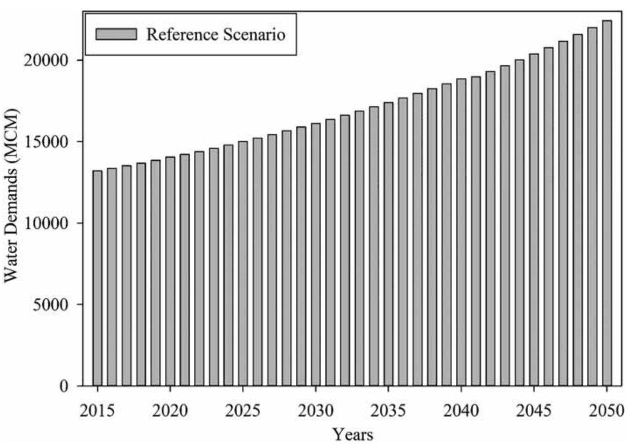

Figure 7 | Annual water demands (MCM) for the reference (business as usual) for domestic, agriculture, and livestock sectors (2015–2050).

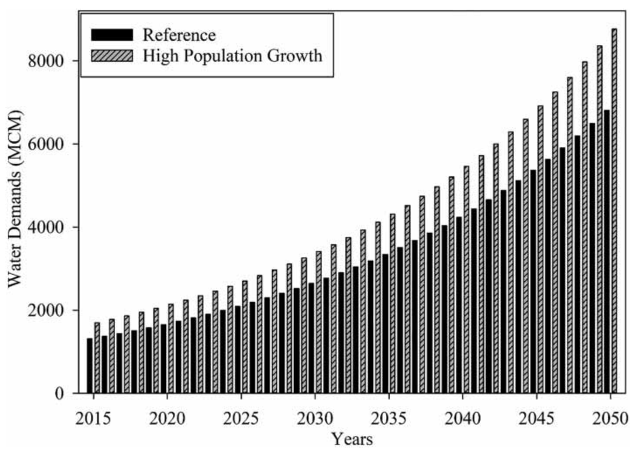

Figure 8 | Annual water demand for domestic sector in reference and high population growth scenarios (2015–2050).

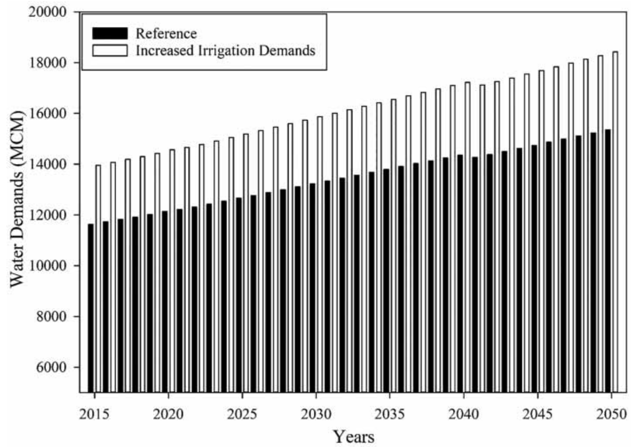

Figure 9 | The future projection for irrigation sector under reference and increased irrigation demand scenarios (2015–2050).

Increased irrigation demand scenarios

With an increasing growth rate of irrigated land, by 7%, the agriculture water demand will increase from 11 BCM in 2015 to 15 BCM in 2050 under increased irrigation demand scenario. The projected agriculture demand for the period 2015–2050 showed that the water demand in this sector is increasing gradually (Figure 9). The population growth is also affecting the increased demand for irrigation.

The livestock demand was set constant in all the scenarios over the simulation period. As reference scenario is the baseline for all other scenarios for water demand data, livestock water demand is the same in all the three scenarios. Hence, only the reference scenario shows that the livestock demand is much less than other sectors (Figure 10).

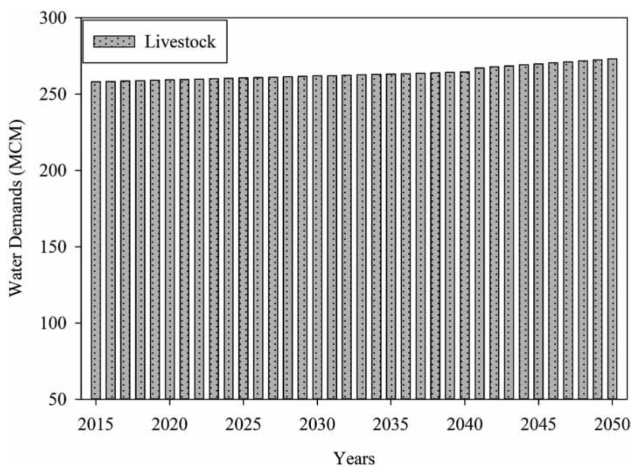

Figure 10 | The future projection for the livestock sector.

Climate change scenarios

The development of climate change scenarios, i.e., RCP4.5 (relatively wet climate) and RCP8.5 (extreme dry climate) are based on the changing trend in the climate of the study area. According to the scenarios, the average projected change in precipitation and temperature are about 15.22% and 274.07 K to 274.92 K by the end of 2035. The change in precipitation frequency in the study area will also affect the recharge in the Thal Doab aquifer. The future water availability projections and demand analysis were done to highlight the water deficiency that is resulting from these climate change scenarios (Figure 11).

Management scenarios

The decrease in basic domestic water consumption scenario

In this scenario, 5% reduction was assumed in the domestic water consumption of all the districts. The decrease could be the result of mass education and knowledge sharing about water conservation to the public. Other possible technological solutions are also expected to be developed to reduce losses. For example, the water supply must be according to the demand node, whether it is urban or rural. The rural water demand is always less than the urban water demand, so the rural water allocation must be different from urban water allocation. The results show that even with the smaller percentage

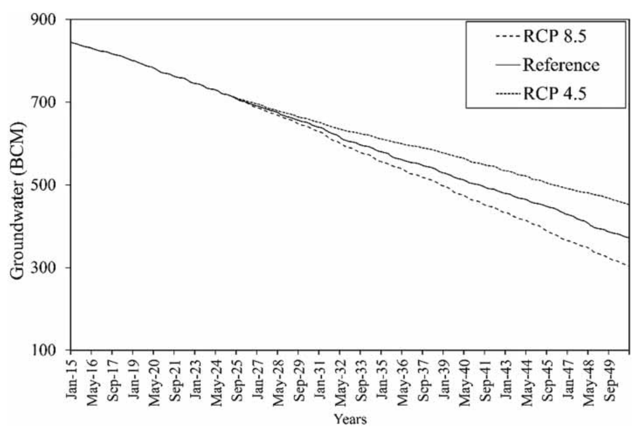

Figure 11 | Projection of groundwater under reference, RCP4.5 and RCP8.5 scenarios (2015–2050).

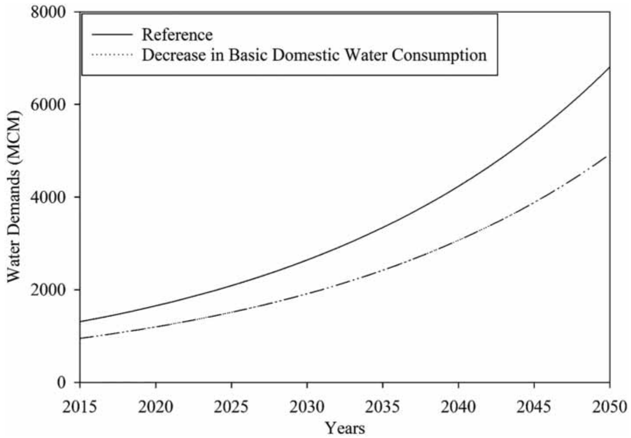

Figure 12 | Annual water demand projections for reference and decrease in basic domestic water consumption scenarios (2015–2050).

of 5% decrease in water consumption, water demand is reduced in all the six districts, i.e., 4,200 MCM in the year 2050, while under the reference scenario the demands would be more than 6,000 MCM (Figure 12).

The decrease in basic irrigation water consumption scenario

Through the implementation of different water conservation strategies, agriculture water demands can be reduced, such as sprinkler irrigation systems (35% reduction in agricultural consumption), drip irrigation systems (25% reduced irrigation demands), and canal lining (50% reduction in agricultural consumption). This scenario was developed based on the low irrigation efficiency in the study area. The losses in the current irrigation schemes are reported to be 40%. The decrease in water consumption is possible because of the awareness of farmers, the introduction of new and efficient irrigation techniques such as central pivot, drip, sprinkler irrigation systems, and the use of precision agriculture. Water demand would be reduced if the efficient irrigation schemes were introduced and getting control of losses and leakages through canal lining. Figure 13 shows the difference in water demand under the reference scenario and a decrease in basic irrigation water consumption scenario.

DISCUSSION

In Pakistan, 120 million people experience water scarcity during part of the year, about 85% of whom live in the Indus Basin, which indicates the severity of the issue (Mekonnen & Hoekstra 2016). Pakistan is one of the arid countries, that have low water storage capacity, which is 15% of the annual river flow. The per capita water availability in Pakistan was reduced from 5,260 m^3 in 1951 to 1,050 m^3 by the year 2010 (Bhatti & Nasu 2010). The shortfall of water is projected to be 32% by the year 2025, and the consequent food shortage will be 70 million tons. The role of groundwater in the agricultural economy of Pakistan plays a significant role. The economic effects of climate change on the agriculture of Punjab were estimated to be very serious. Impacts of climate change on the river flow are likely to raise scarcity in the Indus Basin irrigation system (IBIS), particularly in the downstream areas having reduced river flows in the dry season. The observed increase in temperature and the offsets in precipitation in the area will have a very harmful impact on farming patterns. The Pakistan Agricultural Research Council has identified the critical input–output issues in agricultural efficiency in Pakistan. The primary reform areas included water at the top of the list of six fundamental reforms. As India is building different water storage infrastructures on the transboundary rivers, it will have a negative impact on the water availability for the lower riparian country, Pakistan. Thus, water security will be the critical issue in the coming years. The Water and Power Development Authority (WAPDA) of Pakistan has also suggested the upgradation of watercourses of the entire IBIS, which would reduce 5 MAF (million acre feet) worth of water losses (Ahmed *et al.* 2007).

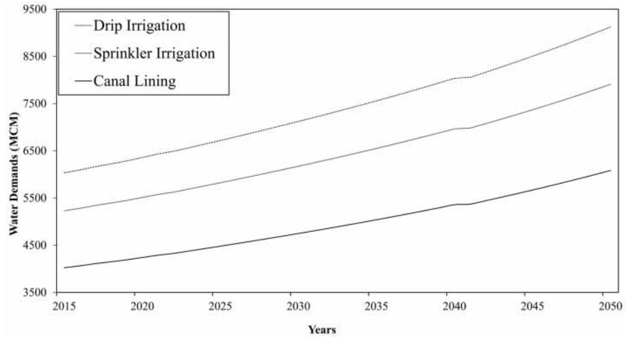

Figure 13 | Annual water demands under reference and decrease in irrigation water consumption scenarios (2015–2050).

We analyzed and proposed water management practices and policies for current and future water availability based on the socio-economic and climate change scenarios.

Water demand analysis was done based on different exploitation and potential management scenarios for sustainable water availability in the future. The first step was to identify the water demand of each sector in the study area, followed by the conditions of exploiting forces such as high population growth, increase in irrigated land, and impact of climate change. The second step was to develop different potential management scenarios, i.e., reduction in water demands in each sector, to cope with the results of exploiting scenarios.

The projected water demand in CIB under 5% high population growth rate scenario was 8,500 MCM. The results showed that how these external factors such as population growth and climate change are impacting future water demand in the CIB. The water demands under high population growth, increased irrigation demands, climate change, and decreased demand for domestic and agriculture sectors were increasing gradually. The results showed that there is an urgency to adopt water management practices. The combined simulation of water resources for various policies such as exploitation scenarios and potential management scenarios is one of the best methods. A comparative analysis of all the scenarios was analyzed to identify the best possible management strategy in the study area (Figure 14). Toure *et al.* (2017) used the socio-economic and climate change scenarios in the WEAP model to simulate the future water demand in Klela Basin, southern Mali. They reported an increase in water demands from 76 MCM (reference scenario) to 224 MCM by the year 2050. Similar results were reported by Saraswat *et al.* (2017)) in a study conducted in Kathmandu Valley. The study was focused on integrated urban water management under different scenarios. They found that 6% population growth rate will increase the water demand from 135 to 150 liters per capita per day.

The exploitation scenarios' results show that the water demands are increasing drastically. Thus, the designed potential management scenarios were applied to compare the water supply and demand analysis of the CIB. Figure 15 shows the unmet water demand in the exploitation (high population growth, increased irrigation demands) and potential management scenarios (decrease in domestic water consumption and decrease in irrigation water consumption) with the reference scenario. Water demand is still increasing in management scenarios, despite the decrease in

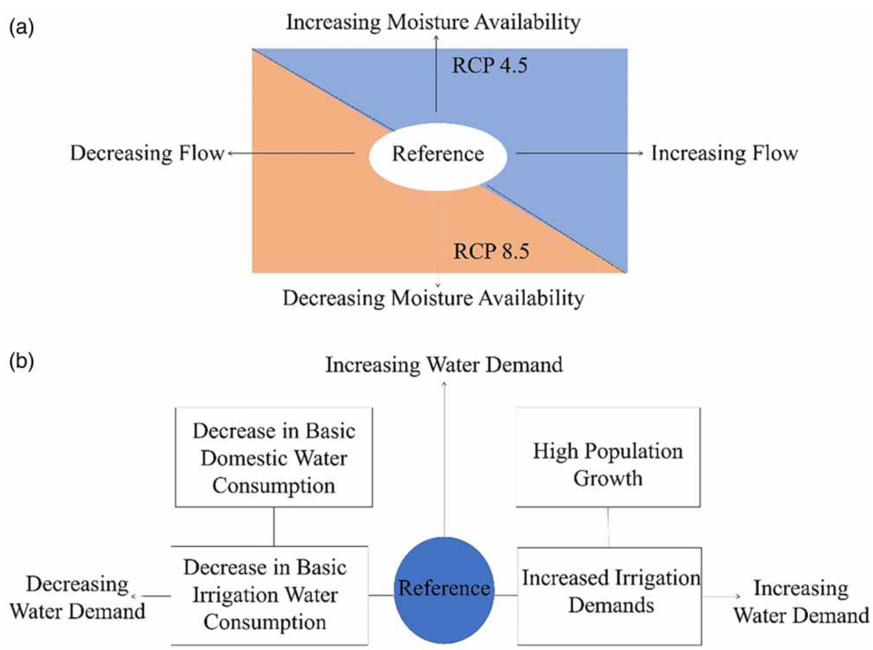

Figure 14 | (a) Climate change and (b) socio-economic scenarios, the circle indicates the current or present-day conditions in the CIB. The dashed line dividing the two climate change scenarios indicates the possible change in precipitation. The upper triangle covers RCP4.5 and shows increasing precipitation with a consequent change in moisture availability. The lower triangle covers RCP8.5 and indicates the decrease in precipitation. The socio-economic scenarios indicate the functions of agricultural and domestic water demands.

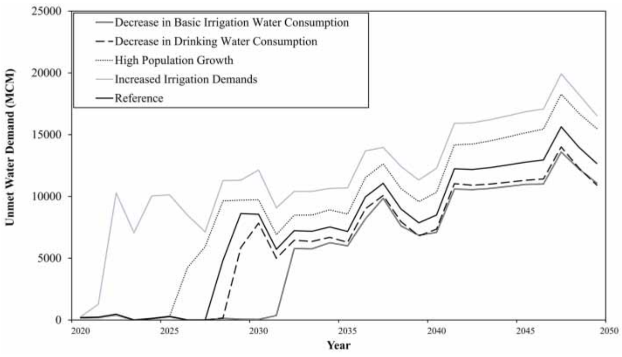

Figure 15 | The unmet water demand exploitation and potential management scenarios (2015–2050).

consumption rates. This is due to the relatively high growth rates of the population and the increase in irrigated land in the study area. Birhanu *et al.* (2018) used the WEAP model to simulate the water demand projections for the city of Addis Ababa using the high (4.6%), medium (3.8%), and low (2.8%) population growth rate in the WEAP model. They reported that a 100% water demand coverage could not be achieved by 2025 with any water management strategy.

Figure 15 highlights how these potential management scenarios can be a useful adaptation for the study area. The unmet water demands in the reference scenario were estimated to be 14.8 BCM in the year 2050 with no adaptation measures. In the exploitation scenarios, the unmet water demand is going to be increased to 18.1 BCM by the year 2050. In both the high population growth scenario and increased irrigation demand scenario, no mitigation technique was adopted. No adaptations to climate change scenario and socio-economic scenarios could result in severe water shortage in the the Thal Doab. Under the potential management scenarios, the unmet water demands are observed to decrease to a significant lowest amount.

The what–if scenarios' methodology can be applied to other basins around the world to evaluate the existing and projected water demand/supply situation for better planning water resources and ensuring food security.

CONCLUSION

This WEAP modeling study projects the future water demand under socio-economic and IPCC climate change scenarios. The high population growth scenario reveals an increase in the water consumption from 82.9 m^3 per capita per day by the year 2015 to 120 m^3 per capita per day by the year 2050. The IPCC climate change scenario (extremely dry condition) projected the average change in precipitation and temperature would be about 15.22% and 274.07 K to 274.92 K by the end of 2035.

This study has high significance for water managers for planning water resources of the country and also other stakeholders, keeping in view the socio-economic and climate change scenarios.

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