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A comprehensive assessment framework for attributing trends in streamflow and groundwater storage to climatic and anthropogenic changes: A case study in the typical semi-arid catchments of southern India

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Abstract

The clearest signs of hydrologic change can be observed from the trends in streamflow and groundwater levels in a catchment. During 1980–2007, significant declines in streamflow (−3.03 mm/year) and groundwater levels (−0.22 m/year) were observed in Himayat Sagar (HS) catchment, India. We examined the degree to which hydrologic changes observed in the HS catchment can be attributed to various internal and external drivers of change (climatic and anthropogenic changes). This study used an investigative approach to attribute hydrologic changes. First, it involves to develop a model and test its ability to predict hydrologic trends in a catchment that has undergone significant changes. Second, it examines the relative importance of different causes of change on the hydrologic response. The analysis was carried out using Modified Soil and Water Assessment Tool (SWAT), a semi-distributed rainfall-runoff model coupled with a lumped groundwater model for each sub- catchment. The model results indicated that the decline in potential evapotranspiration (PET) appears to be partially offset by a significant response to changes in rainfall. Measures that enhance recharge, such as watershed hydrological structures, have had limited success in terms of reducing impacts on the catchment-scale water balance. Groundwater storage has declined at a rate of 5 mm/y due to impact of land use changes and this was replaced by a net addition of 2 mm/y by hydrological structures. The impact of land use change on streamflow is an order of magnitude larger than the impact of hydrological structures and about is 2.5 times higher in terms of groundwater impact. Model results indicate that both exogenous and endogenous changes can have large impacts on catchment hydrology and should be considered together. The proposed comprehensive framework and approach demonstrated here is valuable in attributing trends in streamflow and groundwater levels to catchment climatic and anthropogenic changes.

KEYWORDS

climate and anthropogenic changes, coupled catchment model, potential evapotranspiration decline, streamflow and groundwater trends, watershed development

1 | INTRODUCTION

Water shortages pose significant current and future challenges to managers and policy makers aiming for sustainable development of water resources in many regions of the world. Studies indicated that climate variability and change, deforestation, afforestation, land use change, catchment development and irrigation can have significant impacts on streamflow and groundwater storages in many regions (Chiew & McMahon, 2002; Brown et al., 2005; Siriwardena et al., 2006; McBean & Motiee, 2008; Huisman et al., 2009; Shaw et al., 2014; Sun et al., 2014; Garg, Anantha, et al., 2020). Availability of water resource is strongly influenced by climate variability and change, management of water resources by the users, changes in land use and land cover, and changes in catchment characteristics.

Detecting change in hydrological behaviour and identifying the relative contribution of multiple causes of that change has received greater attention during the past two decades, particularly the impact of climate change on the catchment response (Estrada & Perron, 2014; Ribes et al., 2017; Rosenzweig & Neofotis, 2013; Stone & Hansen, 2016; Zhang et al., 2020). Detecting hydrological changes (streamflow and groundwater storage) and attributing them to the relative contribution of all the drivers such as climate variability and change, land use change and watershed development in the catchment area, provides useful information for water resources managers to understand and manage current and future water resources.

As an example, Nune et al. (2014) identified declining trends in streamflow and groundwater levels, though no significant trend in rainfall was observed in the Himayat Sagar (HS) catchment during the 1980 to 2004 period, using statistical methods. Based on survey and secondary data they have assessed the impact of different drivers of change on the overall water balance by examining changes in cropping pattern, land use change, groundwater abstractions, hydrologic engineering measures such as check dams, percolation tanks and so forth. The study reported that the streamflow reduction was mainly due to the increased evapotranspiration associated with irrigation and land use change, and that most of the hydrological changes examined are interrelated and occurred simultaneously, making it difficult to separate the individual impacts. In the HS catchment, a variety of policy interventions influenced both hydrologic engineering and land and water management leading to hydrologic impacts at different levels. This study illustrates a situation where an improved quantitative understanding of the role of different drivers of change and their importance is important for prioritizing policy responses.

More broadly, several studies have been conducted using different methodological approaches to analyse the relative impacts of changes observed in the catchments. Most often these studies apply the classical controlled experimental approach of paired catchment studies (Brown et al., 2005). From a general catchment management perspective, several studies have used empirical methods to determine the impacts of a range of simultaneous catchment changes on streamflow due to human activity and climate variability (Adnan & Atkinson, 2011; Brown et al., 2005; Burn & Hag Elnur, 2002; Kahya & Kalaycl, 2004; Kundzewicz & Robson, 2004; McBean & Motiee, 2008; Nune et al., 2014; Wang et al., 2013; Zhao et al., 2014).

Modelling is an improved alternative approach to data analysis. Modelling can potentially provide a better understanding of changes in surface and groundwater processes, especially where climatic variability might mask other signals, as well as providing future predictive capabilities (Bouwer et al., 2006; Garg, Singh, et al., 2020; Mango et al., 2010; Singh et al., 2020; Sridhar & Nayak, 2010; Zhan et al., 2014). Typically, several studies have focussed on either surface water hydrology or groundwater hydrology of the catchment using conceptual models.

Another improved alternative approach is to use integrated surface and groundwater hydrological models to analyse the impacts of catchment changes. They provide a comprehensive description of the combined hydrological and hydrogeological processes. For example, the impact of land use and irrigation on river flows and groundwater levels have been successfully analysed using an integrated model for the lower Republican River Basin (SWAT-MODFLOW) (Sophocleous et al., 1999; Sophocleous & Perkins, 2000).

In addition to model selection, the modelling approach adopted to assess the impacts of the changes is also critically important. There are two general approaches to the modelling: predictive and investigative. The predictive approach uses scenario analysis, where a model is typically calibrated using historic conditions and then used to generate predictions under different scenarios. Hanson et al. (2014) used an integrated surface and groundwater model to analyse the impact of groundwater extractions on the availability of future water resources by projecting the current agricultural and urban supply and demands. Montenegro and Ragab (2010) analysed the future impacts of land use and climate changes on future hydrologic components. Pulido-Valazquez et al. (2015) examined the responses of streamflow and groundwater quantity and quality to changes in climate and land use (historical and hypothetical changes into future). Similarly, the impact of groundwater extraction on groundwater recharge rates, groundwater levels and discharges have been analysed by a number of researchers (Condon & Maxwell, 2014; Kim et al., 2008). Most of these studies have examined a single cause (e.g., climate variability or land use change or groundwater extractions or watershed structures, etc.) and then predicted future impacts on a single response (e.g. either streamflow or groundwater storage/level) in the catchment.

The investigative approach also typically uses models calibrated using historic conditions, but it then tests the model's ability to predict past observed trends in streamflow and groundwater levels. In many catchments, there are multiple drivers of change and separating the impacts of such a mixture of change is a challenge with important implications for developing water resource management strategies. This approach has been used in very few studies and it is suggested that it is a potentially useful approach for better disentanglement of the impacts of multiple drivers. Major changes in the catchment can be modelled and the results of multiple runs with various combinations of historical changes are tested against past-observed data to determine which influences are the more important ones.

This study used an investigative approach to attribute hydrologic changes. First, it involves developing and testing a model to predict hydrologic trends in a catchment that has undergone significant change (incorporating changes in land use and development of a range of watershed hydrological structures). Second, it examines the relative importance of different causes of change on the hydrologic response. It is important to test the model's ability to capture trends, given that models are often relied on to only make predictions. However, this has rarely been undertaken. The ability to separate the impacts of change is also important to better inform management.

We modelled the HS catchment, which is a sub-catchment of the Krishna river basin, located in the southern part of India. We attempted to capture the trends in streamflow and groundwater levels by modelling historic changes in the HS catchment using an integrated surface and groundwater model named Modified Soil and Water Assessment Tool (SWAT), which is an integration of SWAT model with a simple groundwater model to deal with groundwater processes at sub-basin level. The main goal of this study is to analyse the rate of change in hydrological processes in response to the multiple changes observed in the HS catchment and to determine the relative importance of each change on the hydrological response through modelling effort and to compare the results with the observed data. The objectives of the study are:

- To develop an integrated surface and groundwater model that can model/capture all the hydrological changes that occurred in HS catchment (model development and calibration);
- To test the ability of the model to predict the trends observed in the catchment over a period of major change (1990–2007) (model validation); and
- To separate the impact of different changes on the catchment hydrology.

2 | METHODS AND STUDY CATCHMENT

2.1 | Study catchment

The total geographical area of the HS catchment is 1340 km^2. The runoff produced from the catchment in response to rainfall flows into the HS reservoir constructed near the outlet of the catchment. This reservoir is located 9.6 km upstream of Hyderabad city, the capital city of Telangana State, a southern state in India. The reservoir was constructed in 1927 to control flood water and to supply drinking water to Hyderabad city (Figure 1). The Hyderabad Metropolitan Water Supply and Sewerage Board (HMWSSB, 2009), Telangana State, has been recording daily level data on water storage levels, inflows and outflows in the reservoir.

The HS catchment is spread over Rangareddy (87%) and Mahabubnagar (13%) districts in Telangana State. The soils are predominantly clay (>70% of catchment area) along with loam and gravel soils. It is observed that the HS catchment has undergone many complex changes during the study period (1980–2007), particularly activities such as increased groundwater extractions for irrigation purpose and interceptions of runoff through watershed development structures (Biggs et al., 2008; George et al., 2011; Massuel et al., 2013; Nune et al., 2014). In this study, the term 'watershed development structures' applies to particular structures such as check dams, percolation tanks, mini-percolation tanks, sunken pits, farm ponds and feeder channels. These structures play important roles such as controlling soil erosion, reducing runoff velocity and improving groundwater recharge in the catchment. Land use data showed that the net irrigated area doubled between 1980 and 2007. It has also been observed that from 1995 to 2007, the total runoff intercepted by watershed development structures increased from 1.1×10^6 to 6×10^6 m^3 (water spread area increased from 1 to 3 km^2) as a result of promoting a watershed development programme in the catchment. This is an Indian Government programme aimed at conserving soil and water resources in the semi-arid regions of India. In addition to the above changes, the catchment hydrology is impacted by variability in the climate (decreasing wind speed and increasing relative humidity) which has caused a decline in potential evapotranspiration (PET) in the catchment. However, the contribution of each individual change to the overall hydrologic change is unclear. Overall, it has been observed that HS streamflow declined due to a mixture of different anthropogenic changes in the HS catchment as shown in Figure 2 (Nune et al., 2014).

2.2 | Overview of modified SWAT model

The Modified SWAT model was developed to capture the trends in streamflow and groundwater storage/levels due to the effect of climatic and anthropogenic changes that have taken place in the study catchment. It is an integrated surface and groundwater model that operates on a daily time step. The surface, plant and soil profile processes of the model are similar to those in the SWAT model, and they estimate processes for each Hydrological Response Unit (HRUs) (Arnold et al., 1998).

It differs from SWAT in the estimation of the recharge component. The recharge from all HRUs in a sub-basin is aggregated which then becomes the input to the lumped groundwater storage model which simulates groundwater processes at the sub-basin level. It also differs from SWAT, in that a time series of land use details and reservoir/pond storage capacities can be given as input in the model. Modified SWAT estimates the potential evapotranspiration using the Modified FAO Penman Monteith equation as in the SWAT model (Allen et al., 1998). Actual evapotranspiration constitutes evaporation from soils, water bodies (watershed development structures, village water bodies and depression storages) and transpiration by vegetation. The volume of watershed development structures is aggregated and simulated within each HRU, while the total volume of large water bodies (village natural lakes/tanks) are aggregated within a sub-basin and represented as a reservoir at the outlet of each sub-basin. Both the watershed development structures and village water bodies are spatially simulated taking into account their daily capacity, inflow and outflow, seepage and evaporation. Figure 3 describes the details of model processes and their inter-connections at each sub-catchment level.

The Soil Conservation Service Curve Number (SCS-CN) method was used to generate surface runoff in each HRU with the remaining water being infiltrated through the multi-layer soil profile modelled using the SCS curve number Equations (2:1.1.1, 2:1.1.2 and 2:1.1.3 in SWAT Theoretical manual) as used in SWAT (Arnold et al., 1998). The curve number (CN) of a given day is calculated by using a retention parameter, which changes with the soil water content of the soil profile (Neitsch et al., 2009). The runoff generated in each HRU is first captured by the watershed development structures within the HRU and then any spill goes into the storage reservoir located at the end of each sub-basin. In addition to overflow from HRUs within a sub-basin, streamflow from the upstream sub-basin will also join the reservoirs in each sub-basin. Furthermore, the reservoir spills are routed downstream through the stream network using a cascade of two linear stores approach and eventually reach the catchment outlet (Figure 3).

Unlike SWAT, the groundwater system is modelled at the sub-catchment level rather than at the HRU level as contribution of groundwater storage during irrigation varies from HRU to HRU based on their areas and their storage capacities leading to non-linearity in the groundwater response to recharge and groundwater extraction in a sub-basin. The groundwater model includes a threshold of

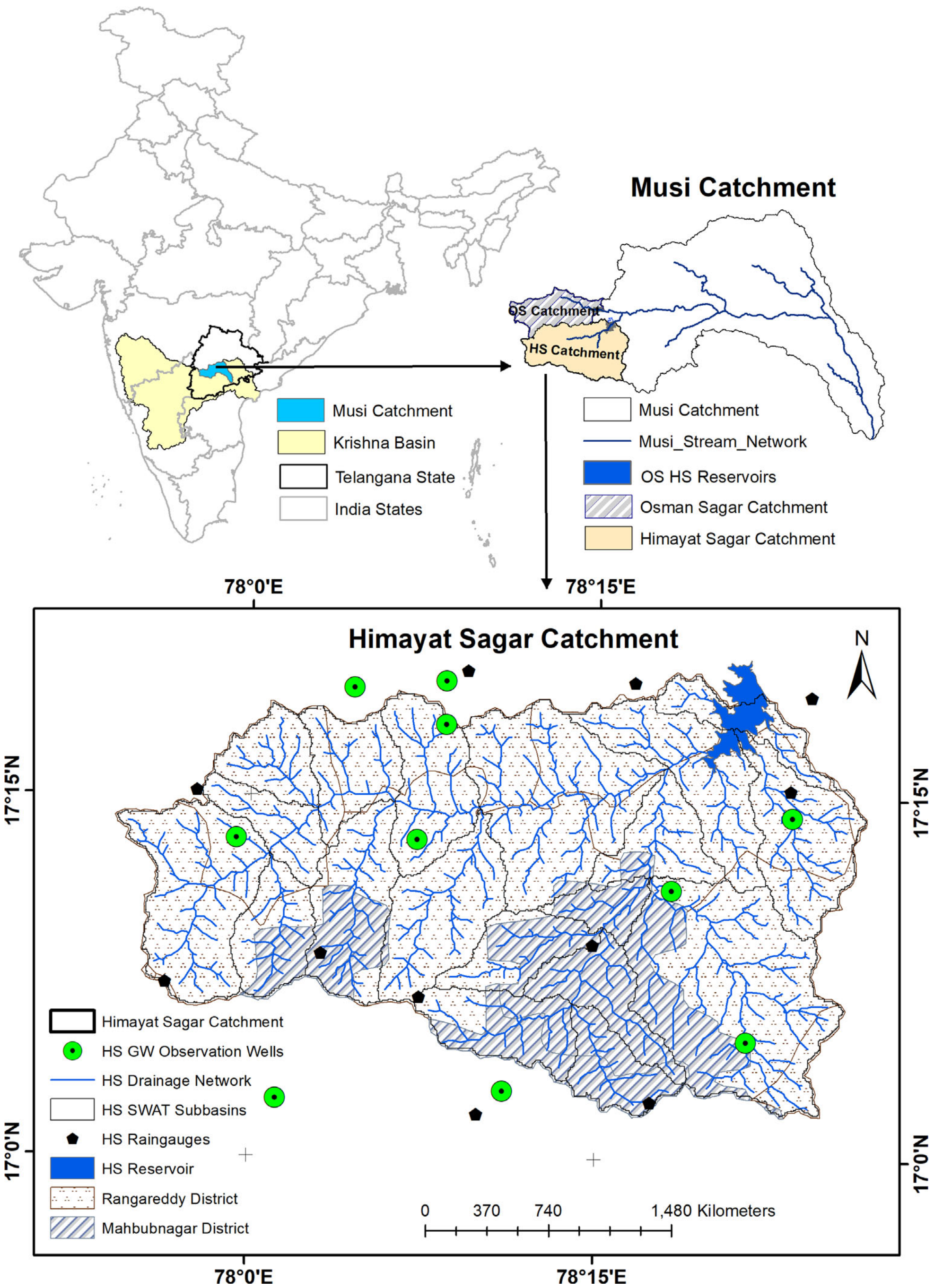

FIGURE 1 The location of the HS catchment in southern India

groundwater storage limit below which baseflow becomes zero. Since groundwater extractions in irrigated sub-basins may lead to decline of the groundwater storage below this threshold, the baseflow from this sub-basin can be zero. An area-weighted average of recharge from all the HRUs in a sub-basin is calculated and added to the groundwater storage. This recharge includes vertical soil drainage and seepage from hydrological structures. The baseflow contribution to streamflow is calculated using a baseflow recession constant (ALPHA_BF) for all sub-basins. Groundwater is extracted for irrigation and this can lead to groundwater levels falling below zero (recharge), in which case baseflow is set to zero. An area weighted average groundwater storage depth from all sub-basins is calculated and converted into average groundwater level by assuming a specific yield of 0.02 to enable comparisons against groundwater level observations.

The irrigation module operates only during the crop growing periods, which is the period from planting to maturity, that is until the

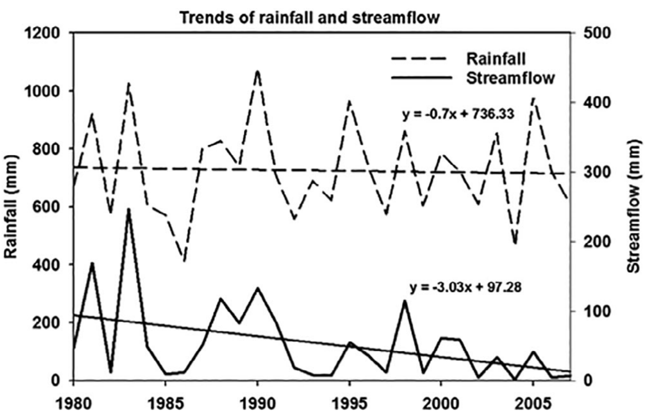

FIGURE 2 Trends of mean annual rainfall and observed annual streamflow in HS catchment

accumulated heat units reach the threshold value (at maturity). The HRU is designed as a depression storage for paddy crop with a defined storage capacity and a threshold level below which auto irrigation is triggered. In the case of non-paddy and vegetable crop HRUs, the auto irrigation is triggered when the soil moisture storage in the root zone falls below a threshold level during crop period and it irrigates the HRUs up to the soil field capacity. The total quantity of water required for irrigation to all HRUs in a sub-basin is deducted from the groundwater storage of that sub-basin.

2.3 | Change in land use and storages

Modified SWAT has been structured to allow changes/trends in land use, groundwater extraction and hydrologic engineering of the catchment to be easily included into the model as a time series input so that the spatial and temporal variations (dynamic changes) in input data can be updated during model simulations. Continuous information of land use and watershed development structures can be updated between the years wherever such information becomes available using linear interpolation between dates.

2.4 | Data preparation

A range of sources were used to obtain input data for the Modified SWAT model including the SWAT database, relevant data from Government departments of the Telangana State and field surveys.

1. Rainfall and weather data: The weather data such as average temperature, wind speed, relative humidity and solar radiation for the HS catchment were obtained from the nearest meteorological

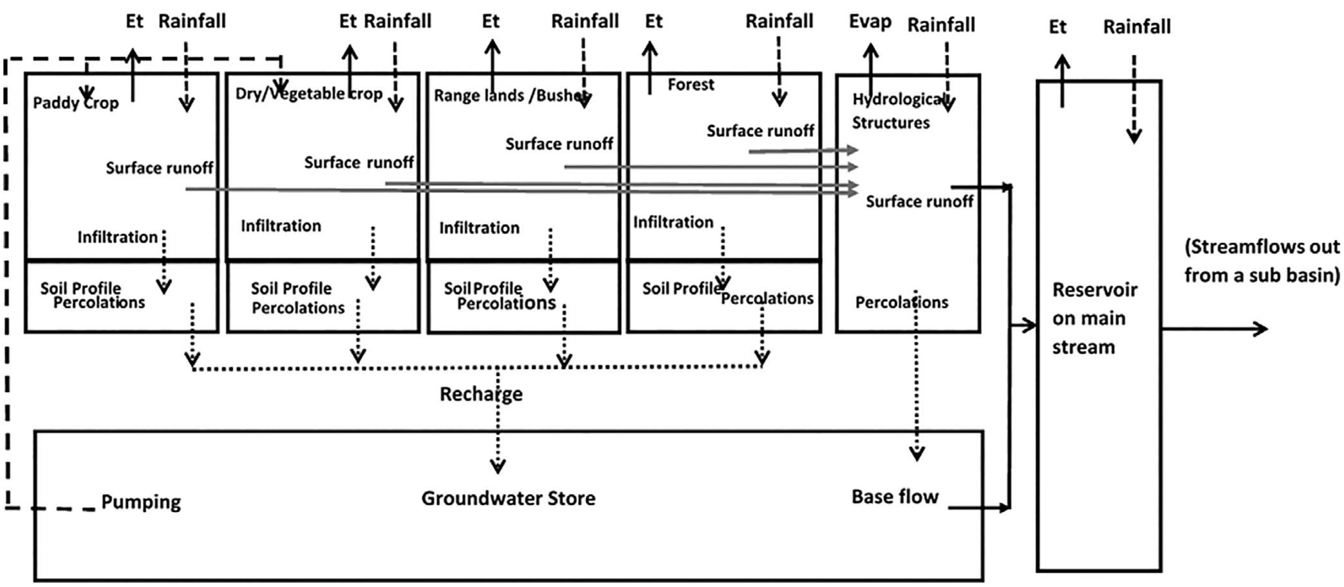

FIGURE 3 Details of different hydrological components and their interactions in the modified SWAT model

station at Rajendra Nagar. The daily measured rainfall data recorded by the Directorate of Economics and Statistics (DES) at five rain gauge stations in and around the HS catchment for the period 1980–2007 was used for this study and sub-catchment rainfall was calculated using Thiessen Polygons (Nune et al., 2014).

2. The soil map developed by the International Water Management Institute (IWMI), Hyderabad was used in this study. Physical properties such as depth of layers, permanent wilting point, field capacity, soil albedo, soil drainable limits and so forth of soils collected in each *mandal* (sub-district) and analysed at the Water Technology Centre by Professor Jayashankar, Telangana State Agricultural University (PJTSAU), Telangana State (Parupalli et al., 2019; Water Technology Centre, 2008) were obtained for this study area. The Field Capacity (FC), Permanent Wilting Point (PWP) and Saturation water contents (SAT), and hydraulic conductivity of the reservoirs and structures were used for the model calibration.

(3) Land use information: The *mandal* level land use information was collected from the DES, Telangana State. All the land use types were aggregated into 9 major land use classes, as given in Table 1. The land use in 1985 was assumed to be representative of the entire period 1980–1989. Annual land use data for the entire period 1990–1999 was interpolated using data available in the 1990s (1985 data) and 2000s. Similarly, the land use data for the entire period 2001–2007 was interpolated using the data available in 2000 and 2007.

(4) Watershed development structures/village water bodies/tanks: Data available on watershed development structures in the HS catchment were collected from the District Water Management Agency, Rangareddy district, Telangana State, for the period 1995 to 2005. The water-spread areas and corresponding volumes of different watershed development structures (1995–2005) were estimated based on field survey data collected in the HS catchment. Information of village water bodies/large natural lakes/tanks in the HS catchment was estimated by analysing remote sensing images (LandSat) for the post monsoon period (November) for the years 1981, 1989, and 2000, which were used in this study (average surface area = 13.39 km^2, Storage Capacity = 30 466 ML of water bodies in the catchment) (Nune et al., 2014). The total capacity of all watershed development structures in each sub-basin was spatially distributed across all the HRUs of the sub-basin in proportion to their areas.

(5) Streamflow and groundwater levels: Daily HS streamflow were calculated using the water level-area-volume relationship and daily water levels measured at the HS reservoir. The monthly streamflow estimated from the daily streamflow is strongly correlated with the HMWSSB estimated monthly inflows (Nune et al., 2014). Evaporation losses from the HS reservoir were estimated using reservoir water-spread area and pan evaporation depths recorded at HS reservoir during the time period. Seepage losses were assumed to be negligible due to data constraints. The groundwater level data recorded (1990–2004) and monitored by the Central Groundwater Board, Hyderabad, at five piezometric groundwater wells was used in this study. The number of groundwater wells in the HS catchment increased from 13 280 in 1993 to 31 600 in 2004.

TABLE 1 Change in land use in the HS catchment

Area (km^2)	1985	2000	2007
Forest	65	67	64
Range bush	122	135	154
Range lands	573	561	687.5
Rainfed paddy	0	0	0.5
Rainfed sorghum	474	354	273
Rainfed vegetables	20	52	37
Irrigated paddy *Kharif* (*Rabi*)	34 (29)	75 (73)	37 (37)
Irrigated sorghum *Kharif* (*Rabi*)	2 (2)	1 (1)	2 (2)
Irrigated vegetables *Kharif* (*Rabi*)	9 (9)	54 (47)	44 (26)
Total area (km^2)	1299	1299	1299

2.5 | Model setup

The entire HS catchment area was divided into 19 sub-catchments (sub-basins) based on delineated drainage network using the Digital Elevation Model (DEM). The land use details for each sub-basin for the years 1985, 2000 and 2007 were extracted from the *mandal* land use statistical data obtained from the DES, Telangana State and using the proportionate contribution of *mandals* in each sub-basin. Based on the spatial intersection of land use classes and soil types, 41 unique soil-land use combinations (HRU) were defined and areas of each HRU of each sub-basin were extracted.

The HS catchment was characterized with four soil layers with varying thickness. In the study area, the southwest monsoon (June–September) subsides completely by the end of October and the soil water content will be more than field capacity for that month. Since the model run started in January, we expected the soil water content to be less than field capacity. The model calculates the next day's soil water content based on the irrigation provided to the crop, rainfall amount and previous soil moisture content, as crops are usually irrigated in this study area during the rabi (post-rainy) season. Based on field experience, observations and discussions with farmers during field visits while collecting data required to build the model, the total available water content that time of the year is estimated to be 75% of its maximum total water available. The maximum total available water for the plant is calculated as the difference between field capacity and wilting point water content multiplied by the root zone depth.

In the HS catchment there are two cropping periods, the *kharif* (rainy) season (Paddy crop: July to November; sorghum: July to mid-November; vegetables: July to December) and *rabi* season (Paddy and vegetable crops: January–April). Crop season dates were fixed throughout the simulation runs. The parameters required for crop growth in Modified SWAT were obtained from the SWAT database. The major crops that are cultivated in the catchment during the *kharif* and *rabi* are rice (as an irrigated crop), sorghum (as a rainfed crop) and tomato (as an irrigated vegetable crop). To differentiate irrigated areas from rainfed during the *kharif* and *rabi* season, each irrigated area in *kharif* was divided into two parts (two HRUs) so that *rabi* area can be accommodated within the *kharif* area – one that is irrigated during both the *kharif* and *rabi* seasons and the second that is irrigated only in the *kharif* season (Table 1).

Based on area-stage-volume relationship collected from a few village water bodies/natural water tanks, all the water bodies in a sub-basin were aggregated (areas and capacities) and represented as a single reservoir in each sub-basin. All the small watershed hydrological structures (check dams, percolation tanks, farm ponds, etc.) located within the sub-basin were aggregated and redistributed as small reservoirs within each HRU in proportion to the HRU areas. All the catchment characteristics and their spatial and temporal changes were captured as realistically as possible in the model set-up.

2.6 | Model scenarios

The model was calibrated during 1980–89 and validated for the period 1990–2007 as the data indicates a low-level of water resource development and represents equilibrium conditions at the start of the subsequent development phase which show significant land use changes and water resource development (since the 1990s). This period after 1989 has hydrological data that carries with it a high uncertainty level due the farmers' intervention and interception of surface runoff. In order to address the second and third objectives (model testing and attributing impacts) various scenarios have been generated as follows:

- Base case (Base): A scenario with observed climate and consistent catchment characteristics (the same land use and watershed development structures during the calibration period [1980–89] were implemented during the validation period);
- Stationary Climate (SC): The Base case with detrended (removing trend) time series of wind speed and relative humidity, observed to have a big role for the changes in PET, for the entire simulation period;
- Water harvesting (WH): The Base case along with changes in watershed development structures that have taken place during entire simulation period (both calibration and validation period);
- Land use change (LU): The Base case along with land use change that occurred during the entire simulation period; and
- Best estimate (Best): A scenario that uses the observed climate and all the above changes indicates land use change and change in water harvesting structures during entire simulation period.

The overall trend prediction performance of the model can be tested by comparing the Best Estimate against observed streamflow and against the other scenarios that are inferior in terms of predicting observed trends. The five scenarios can also be compared to gain insight into individual impacts. Table 2 shows relevant scenario comparisons that provide insight into the impacts of different sources of hydrological change.

TABLE 2 Scenario comparisons providing insight into the impacts of different sources of hydrological change. SC means stationary climate, WH means water harvesting and LU means land use

Scenario	SC	WH	LU
Base	PET	Structures	Land use
Best	All change	Land use	Structures

3 | RESULTS

There are a variety of approaches that could be taken to simulate all the changes in the catchment, for example, adding one change at a time and gradually building up all changes or simulating all changes in the catchment as realistically as possible and then looking at sub-sets of change. In this study, we used the second approach, first evaluating the model's ability to simulate change by incorporating all changes and then evaluating the individual changes within the catchment. Finally, we explored the role of different drivers of change on the overall hydrologic change in the catchment.

3.1 | Model calibration (1980–89)

A range of key model parameters influencing surface runoff generation and groundwater storage were calibrated in a systematic order. The key parameters used in the model calibration were soil available water content (Sol_AWC), soil hydraulic conductivity (Sol_K), CN, saturated hydraulic conductivity at hydrological structures and at reservoirs (Structures_K and Reservoirs_K), baseflow recession constant (ALPHA_BH) and groundwater delay time (GW_DELAY). Initial values of these parameters were obtained from a calibrated SWAT model that was used in the Osman Sagar catchment which is a sub-catchment of the Musi river basin and adjacent to the HS catchment (Garg et al., 2012; Water Technology Centre, 2008). These parameters were systematically calibrated during model calibration. The calibration aimed to match monthly-simulated streamflow with the observed streamflow at the HS reservoir and to produce no net change in groundwater levels over the period as there had been limited groundwater development over the 1980s and a minimal trend in groundwater levels in HS catchment was expected. Unfortunately, there was no groundwater level data available during this period in the HS catchment to confirm this assumption. The details of initial and final calibrated parameters and their ranges are given in Table 3.

During the calibration period (1980–89), a good agreement was observed between simulated and observed monthly and annual streamflow R^2 (coefficient of determination) = 0.85 and 0.97, Nash-Sutcliffe model Efficiency (Nash and Sutcliffe, 1970), NSE = 0.83 and 0.92, respectively (Figure 4(a)–(c)). During the calibration period, the average annual streamflow observed at the HS reservoir was 80 mm, while the model simulated average annual streamflow was 82 mm, of which 44 mm was from surface runoff and 38 mm was from baseflow. Similarly, during this period, the average annual irrigation depth abstracted from groundwater resources for the entire HS catchment

TABLE 3 Details of key calibrated parameters: Initial range and final values

Parameter	Initial values (range)	Final / calibrated values	Source
Sand content (SAND, %)	23–63	23–63	(Garg et al., 2012; Water Technology Centre, 2008)
Silt content (SILT, %)	5.9–17.8	5.9–17.8	
Clay content (CLAY, %)	22–49.9	22–49.9	
Gravel fraction (ROCK, %)	10–15	10–15	
Bulk density (SOL_BD, g cm_3)	1.16–1.53	1.16–1.53	
Soil depth (Z, mm)	400–1360	400–1360	
Soil available water content, Sol_AWC (%)	0.13 ± (0.05–0.20)	0.10–0.23	Calibrated
Saturated hydraulic conductivity, Sol_K (mm/hr)	2.0 ± (1.0–8.0)	6–6.5	Calibrated
Curve number, CN	(70–80) ± (2–20)	54–74	Calibrated
Soil evaporation compensation coefficient, ESCO	0.8 ± (0.05–2.0)	0.9	Calibrated
Hydraulic conductivity of the structures bottom, Structures_ K (mm/hr)	4 ± (0.25–5)	6.25	Calibrated
Hydraulic conductivity of the reservoir bottom, Reservoirs _K (mm/hr)	2 ± (1.0–5.0)	3	Calibrated
Baseflow recession constant, ALPHA_BF	0.005–0.02	0.02	Calibrated
Groundwater delay time (days), GW_DELAY	22		Calibrated

was estimated to be 61 mm. The average annual recharge to groundwater storage due to rainfall (715 mm) and irrigation (61 mm) was simulated as 99 mm. The average annual actual evapotranspiration (ET) from the entire HS catchment was simulated to be 634 mm. It was observed that there was no trend in simulated average annual groundwater level of the HS catchment during calibration period 1980–1989 (Figure 4(d)).

3.2 | Best estimate scenario (validation period)

In this scenario, to integrate the impact of both climate and catchment changes, the observed meteorological data, changes in land use and watershed development structures during validation period were inputted into the model. The average annual simulated and observed streamflow (1980–2007, $R^2 = 0.90$, NSE $= 0.86$) at the HS reservoir showed a good correlation, (Figure 5(b)) and this scenario provides the best predictions of streamflow along with the land use change scenario (Table 4). Ragab et al. (2020) using five catchment river flows in the UK, found that the lowest uncertainty in predicted river flows when increasing the timescale from daily to monthly to seasonal, was associated with annual flows. Daily and monthly data commonly have more noise (sudden peaks and drops) while annual flows integrate, harmonize and smooth out such sudden variations.

During the validation period, the streamflow into the HS reservoir from the catchment decreased drastically as compared with calibration period (80 mm). The average annual streamflow observed at the HS reservoir was 39 mm, whereas the model simulated 36 mm (Table 4). Due to changes in land use and increased watershed development structures, groundwater abstraction for irrigation was increased on average to 104 mm. Similarly, the average annual recharge and average annual actual evapotranspiration of the catchment showed an increase to 105 mm and 699 mm, respectively (Figure 5(e),(f)).

Due to all changes in the HS catchment during the study period (1980–2007), the rate at which the streamflow declined was -3.03 mm/y, whereas the simulated streamflow declined with a rate of -2.65 mm/y. Similarly, it has been observed that the average groundwater levels declined at the rate of 0.19 m/y during the validation period (1990–2007). The rate of groundwater depletion observed in this study (sub-catchment of Musi river basin) is similar to that of the larger Musi catchment, where the groundwater level declined at a rate of 0.18 m/year (1998–2004) (Massuel et al., 2013). Overall, it is observed that the Best Estimate scenario indicates the greatest decline in streamflow and the second greatest decline in groundwater levels of the catchment.

3.3 | Base case scenario (base)

The calibrated model was run through the validation period with observed meteorological data and without any changes in the catchment characteristics. This is to test the hypothesis that the model without land use change can represent the trends over time. The average annual rainfall (731 mm) during the validation period is just 2%

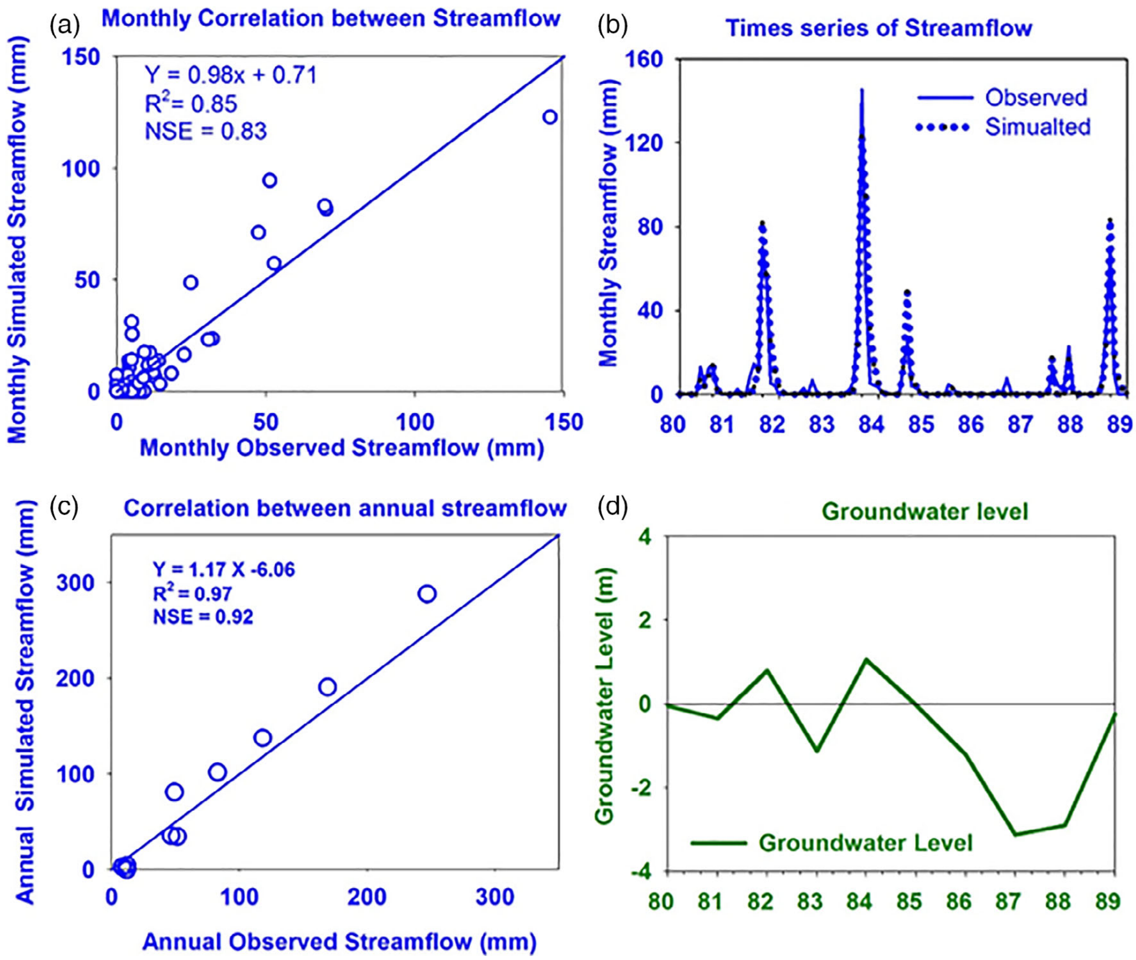

FIGURE 4 Model results for the calibration period. (a) Scatter plot of monthly simulated and observed data, (b) time series of monthly observed and simulated streamflow, (c) scatter plot of annual simulated and observed data, and (d) simulated average annual groundwater level at the start of each year (January) during the calibration period (1980–89)

higher than during the calibration period (715 mm). The average annual observed (39 mm) and simulated (56 mm) streamflow at the HS reservoir represent a significant reduction as compared with the calibration period. The observed data show that the streamflow reduced at a rate of −3.03 mm/y, whereas the simulated streamflow reduced with a rate of −1.28 mm/y, only due to the climate during the validation period. Average annual groundwater levels did not show a significant trend during the study period (1980–2007) (Figure 4(b),(c)).

The Base case scenario includes climate forcing changes but no other changes. The key change observed is that the PET declined from 1738 mm/y during the calibration period to 1662 mm/y during the validation period. Unexpectedly, the simulated actual evapotranspiration from the catchment is higher during validation period (663 mm) than during the calibration period (620 mm). This is related to changes in the seasonal pattern of rainfall and is discussed later. The irrigation amounts abstracted from the groundwater storage during calibration (61 mm) and simulation (60 mm) periods are very similar. This suggests that most of the evaporation changes occurred outside the irrigation season.

3.4 | Stationary climate scenario (SC)

Changes in PET over time are primarily caused by changes in wind speed (Figure 6(c)) and humidity (Figure 6(d)) in the watershed. The stationary climate scenario uses detrended wind speed and humidity as inputs (Figure 6(c),(d)). This eliminated most of the trend in average annual PET, which declined at the rate of 0.43 mm/y compared with 8.0 mm/y before wind speed and relative humidity were detrended.

To examine the impact of changes in PET, the calibrated model was run with the detrended wind speed (from −0.03 m/s of slope) and relative humidity (from 0.0017 of slope) data without changes in the catchment land use or hydrological structures. The detrended meteorological data led to an increase in the average annual PET from 1662 to 1790 mm (Figure 6(e)). As a result, simulated average annual AET (Actual Evapotranspiration, mm) increased from 676 to 691 mm (Figure 6(f), Table 4). HS streamflow declined more rapidly at a rate of −2.10 mm/y compared with the Base Scenario (−1.28 mm/y) (Figure 6(a)). Similarly, the groundwater levels declined at a rate of −0.05 m/y as compared with the Base case scenario (+0.01 m/y) in the catchment (Figure 6(b)). A decline in AET to PET ratio is due to higher water stress in the rainfed

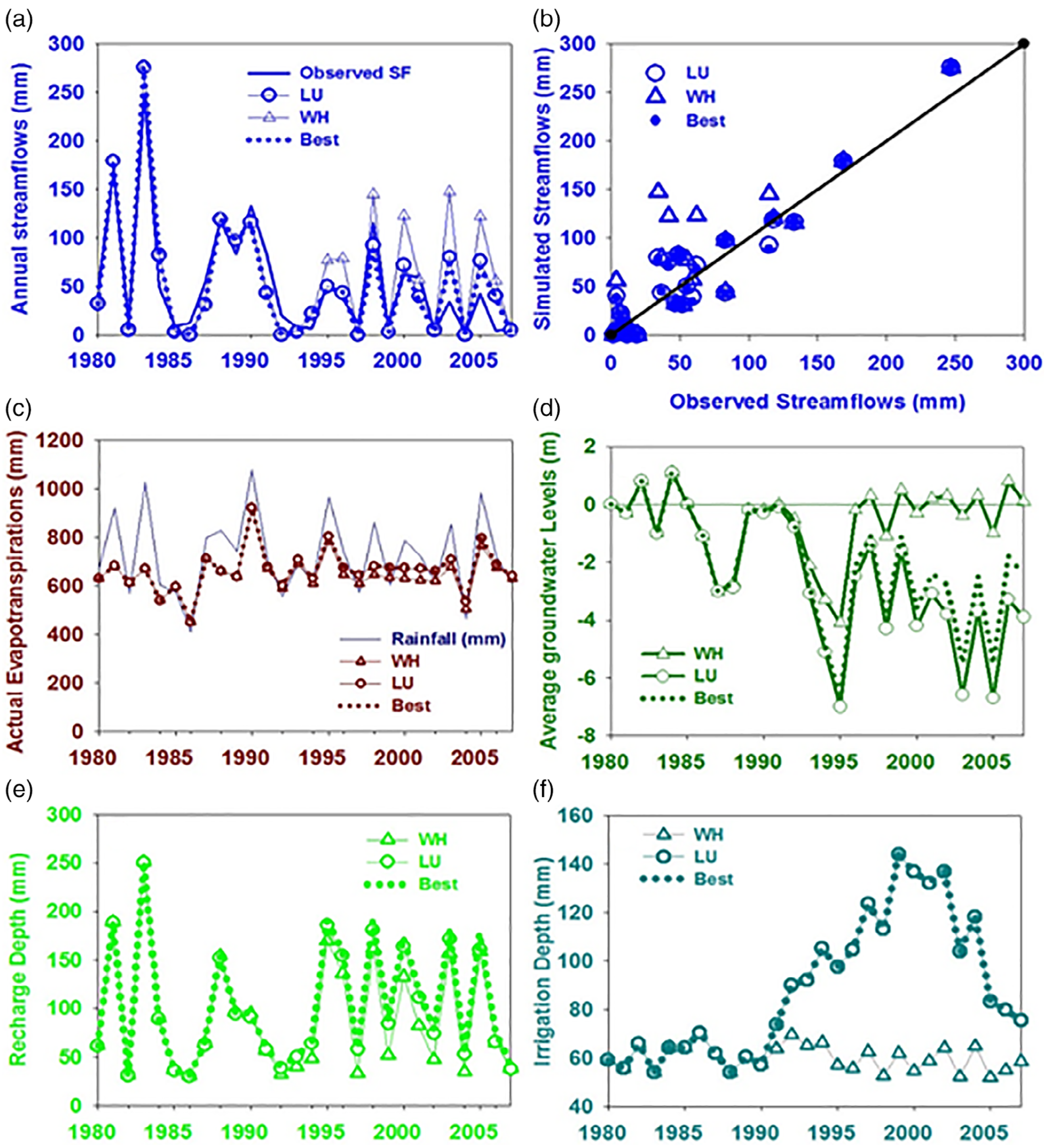

FIGURE 5 Trends of hydrological processes in different scenarios (4, 5 & 6) (a) observed and simulated streamflow, (b) correlation between observed and simulated streamflow, (c) actual evapotranspiration, (d) groundwater levels, (e) groundwater recharge, and (f) irrigation depths in the HS catchment

areas of the catchment. This would likely impact on crop productivity. The rainfed area represents a large proportion of the HS catchment, which is expected to be water constrained.

3.5 | Water harvesting scenario (WH)

The Water Harvesting scenario includes observed meteorological data and watershed development structures. In this scenario, the streamflow declined slightly (−1.30 mm/y corresponding flow was −1.28 mm/y) whereas the groundwater level increased slightly (0.02 m/y corresponding flow was 0.01 m/y) compared to the Base case scenario (Figure 5(a) and 6(d)). The streamflow into the HS reservoir was the same as in the Base case scenario (56 mm) while the contribution of surface runoff and baseflow to streamflow changed from 34 to 30 mm (decreased) and from 22 to 26 mm (increased), respectively. As a result, the average annual recharge increased by 5 mm (6%) and actual evapotranspiration increased slightly by 0.2 mm (from 675.9 to 676.1 mm) as compared to the Base case scenario (Figure 5(c) and 6(e), Table 4).

3.6 | Land use change (LU) scenario

The land use change scenario includes observed meteorological data and land use changes resulting in an increase in irrigation within the catchment. The rate of streamflow decline in the land use change

TABLE 4 Comparison of hydrological processes for various scenarios

	1980–89	1990–2007 (evaluation period & period of change)				
	Calibration	Base	SC	WH	LU	Best
Rainfall (mm/y)	715	731	731	731	731	731
PET (mm/y)	1738	1662	1790	1662	1662	1662
Observed Q (mm)	80	39	39	39	39	39
Simulated Q (mm)	82	56	43	56	38	36
Surface runoff (mm)	44	34	30	30	32	28
Baseflow (mm)	38	22	13	26	6	8
AET (mm/y)	634	676	691	680	699	702
Recharge (mm)	99	80	70	85	100	105
Irrigation (mm)	61	60	62	60	104	104
GWS change (mm)	0.03	−0.83	−2.53	−0.48	−5.79	−3.89
Observed streamflow (mm/y)		−3.03	−3.03	−3.03	−3.03	−3.03
Simulated streamflow (mm/y) (1980–2007)		−1.28	−2.10	−1.30	−2.51	−2.65
GWL change (m/y) (1980–2007)		0.01	−0.05	0.02	−0.20	−0.15
GWL change (m/y) (1990–2007)		0.10	0.01	0.10	−0.20	−0.11
Annual flow R^2 (−)	0.97	0.49	0.58	0.49	0.69	0.69
Annual flow NSE (−)	0.94	−0.15	0.48	−0.18	0.68	0.68
Monthly flow R^2 (−)	0.85	0.60	0.63	0.60	0.66	0.68
Monthly flow NSE (−)	0.84	0.25	0.53	0.27	0.61	0.65

Note: Base = base case scenario (observed weather, no other change), SC = stationary climate (detrended wind and humidity, not other change), WH=Water harvesting change (Water harvesting storage capacity change, observed weather), LU = Land use change, observed weather), Best = land use and water harvesting changes, observed weather, PET-Potential Evapotranspiration, Q-streamflow, AET-Actual Evapotranspiration, GWS-Groundwater Storage, and GWL-Groundwater level.

scenario (−2.51 mm/y) was significantly higher than in the Water Harvesting scenario (−1.30 mm/y) and the Base case scenario (−1.28 mm/y). The groundwater level declined at a rate of −0.20 m/y compared to both the Water Harvesting (+0.02 m/y) and Base case (+0.01 m/y) scenarios, respectively (Figure 5(a),(d)).

Including land use change led to an increase in irrigation by 44 mm/y, from 60 to 104 mm/y (Figure 5(e), Table 4). This was associated with a 20 mm increase in simulated annual average recharge (from 80 to 100 mm/y), and an increase of 23 mm in annual actual evapotranspiration (from 676 to 699 mm/y) in the watershed (Figure 5(c)). Streamflow reduced by a total of 18 mm, resulting in a 2 mm reduction in surface runoff (34 to 32 mm/y) and a substantial (20 mm/y, ~77%) reduction in contribution of baseflow (26 to 6 mm/y) (Figure 5(d)) which indicates a decrease in groundwater storage.

4 | DISCUSSION

Although non-parametric tests (the Mann-Kendall and Sprearman's Rho tests) show no significant trend was found in average annual rainfall during the period 1980–2004, the streamflow into the HS reservoir located at the catchment outlet indicates that the streamflow declined drastically, from 14% of rainfall (1980–84) to less than 5% (2000–04) (Nune et al., 2014). During the study period, pre- and post-monsoon groundwater levels indicated a declining trend in the HS catchment (Massuel et al., 2013). Nune et al. (2014) related the trend in streamflow to the climate and anthropogenic changes in the HS catchment using statistical techniques and regression models. However, it is necessary to further develop and test methods for attributing hydrological trends to climate and anthropogenic changes in the catchment. For that, the semi-distributed Modified SWAT model was developed to simulate both the response to climatic fluctuations and anthropogenic changes (land use, village water bodies/tanks and watershed development structures) in the HS catchment. The model was calibrated against observed streamflow and groundwater levels for the period 1980–89. Then the trends in streamflow and groundwater levels were simulated by changing the land use and watershed structure capacities for the rest of the study period, 1990–2007. The impact of the observed trend in wind speed and relative humidity (and hence PET) on the catchment hydrology was also examined. In separating the impacts of different drivers, we followed a similar approach to Watson et al. (1999) who separated the impacts of changes in forest Leaf Area Index (LAI) and climate forcing on mountain ash forest runoff using the Macaque water balance model. The model results for different scenarios (Table 4) can help to analyse the individual and combined impacts of climate forcing (SC), LU, WH and all internal catchment changes (Best) on streamflow and groundwater storage. The following key questions were addressed:

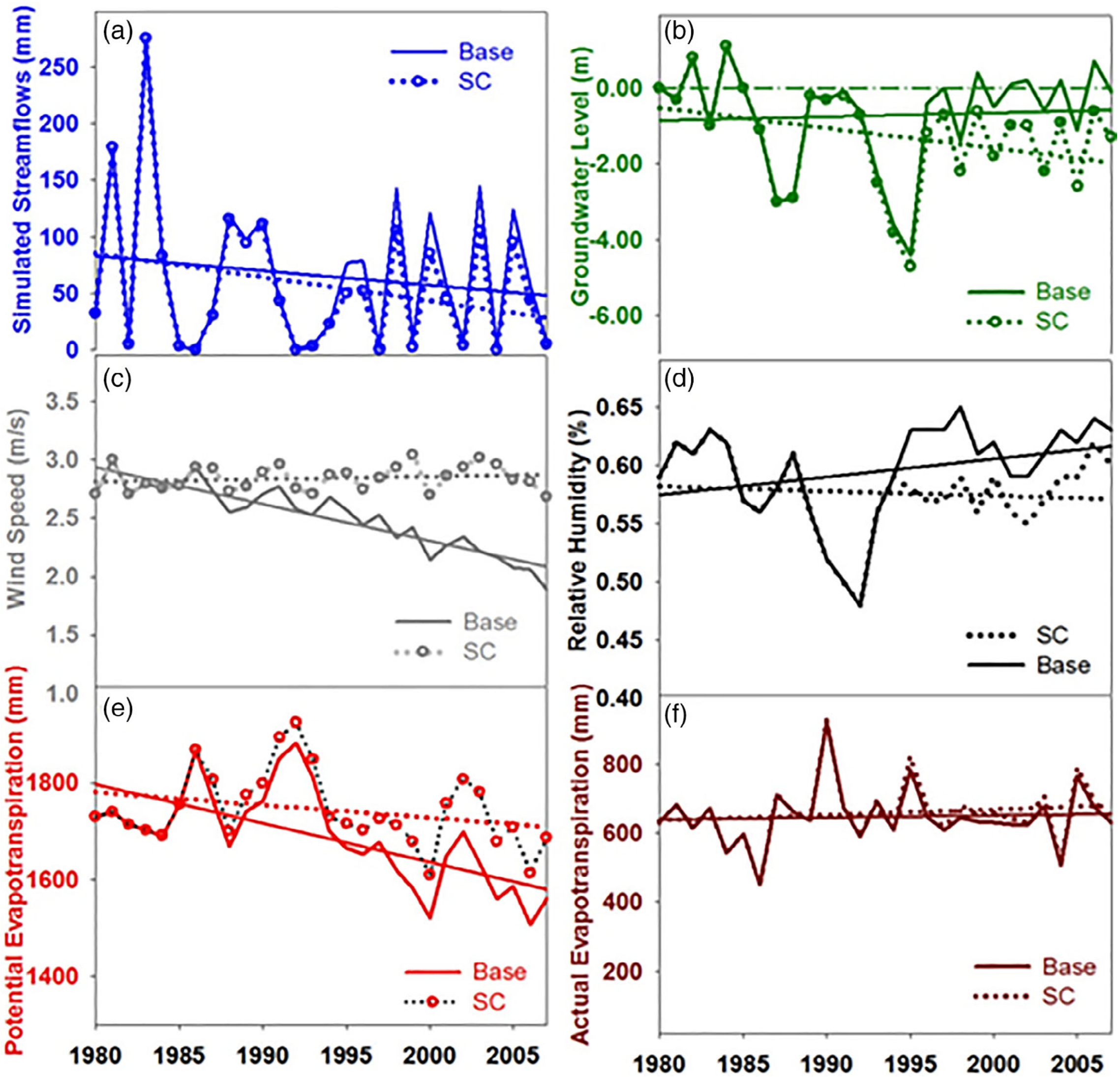

FIGURE 6 Impacts on streamflow and groundwater levels due to changes in potential evapotranspiration (PET, i.e. before and after detrending the wind speed and relative humidity in the HS catchment. (a) Mean annual simulated streamflow, (b) mean annual groundwater levels, (c) average annual wind speed before and after detrending, (d) mean annual relative humidity before and after detrending, (e) PET before and after detrending, and (f) mean annual actual evapotranspiration (AET) before and after detrending. Base = base case scenario (observed weather, no other change), SC = stationary climate (detrended wind speed and relative humidity data only)

1. What is the relative importance of climate forcing and internal catchment changes responsible for the changes in streamflow and groundwater levels?
2. Of the internal catchment changes, what is the relative importance of land use changes compared to hydrological structures? and
3. To what extent do the climatic conditions (i.e., wet, normal/average and dry years) impact the different drivers of hydrologic change?

4.1 | Climate impacts

To separate changes in catchment response between climate and catchment changes, the calibration period can be compared with the Base Scenario to find the impact of climate fluctuation trends while the Base and Best Scenarios can also be compared to find the impact of catchment changes. The climate impact can be further subdivided into rainfall (Calibration vs. SC) and PET (SC vs. Base Scenarios).

Comparing the calibration period (1980–1989) and the Base Scenario (1990–2007), although the average annual rainfall for the base scenario is slightly more than during the calibration period, the average annual HS streamflow, groundwater storage and recharge decreased by 26, 0.3 and 19 mm, respectively. At the same time, the average annual actual evapotranspiration increased by 42 mm. The decline in average streamflow is unexpected given the increase in average rainfall but it is presumed to relate to variations in temporal patterns of rainfall.

It is expected that lower PET would lead to an increase in streamflow and groundwater recharge, but the net effect of climate forcing changes was the opposite. It is possible to separate the rainfall timing and PET effects by comparing the calibration period with SC and Base scenarios. This suggests that the rainfall changes led to annual streamflow declining by 39 mm and the PET decline offset the overall climate impact on streamflow by 13 mm. The decline in PET also has some impact on catchment average irrigation which was 2 mm lower. Given that average rainfall between the calibration and validation periods is almost the same, the response to rainfall must be related to the rainfall patterns rather than the total amount.

Figure 7 gives some insight into the rainfall timing effect. It shows the mean monthly rainfall, PET and excess of rainfall over PET during both the calibration and validation periods. While the average annual rainfall in 1990–2007 was higher, rainfall excess over PET, which contributes as runoff to the streamflow, was less during the wet season (July–September). Thus, the decline in runoff can be explained by the reduced wet season rainfall. The additional rainfall in 1990–2007, compared with 1980–1989, fell during the months of May and November, when there was high evaporation demand and hence the rain did not contribute to runoff. This is an impact that was neglected in the earlier assessment by Nune et al. (2014).

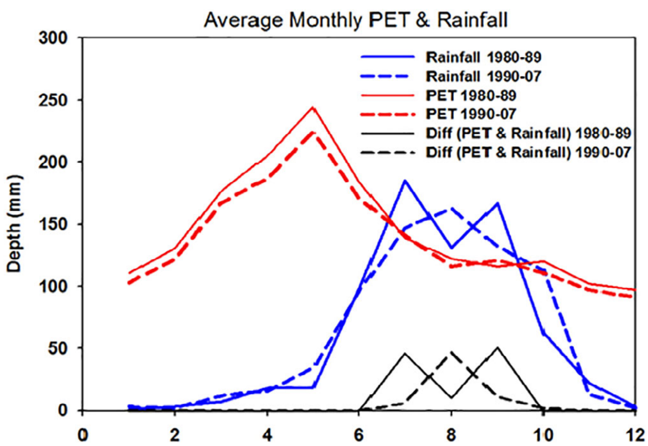

FIGURE 7 Comparison of mean monthly PET and rainfall during calibration and validation periods

The decline in potential evapotranspiration (rate of decline 8.0 mm/year) was primarily due to declining wind speed and increasing relative humidity. Similar decreases in wind speed have been widely observed in recent decades (Vautard et al., 2010), although there is little data from the Indian subcontinent in that study. Unfortunately, it is not possible to be completely confident about the uniformity of the declining wind speed over the whole HS catchment as the data came from a single meteorological station. Nevertheless, it was observed that the other stations in the Krishna basin show similar declining trends (Figure 8).

4.2 | Catchment changes

The impact of the development of watershed structures and land use changes on the catchment's stream flow changes (20 mm decline) and groundwater storage changes (3 mm decline) was investigated. Comparison of the Base scenario with the WH scenario indicates that the expansion of watershed development structures (Base vs. WH and LU vs. Best) had little impact on the streamflow. When the watershed development structure changes are added in the simulation, the decline in average annual simulated streamflow is 2 mm or less. Nearly 50% of the total amount of surface runoff harvested by the hydrologic structures ultimately contributed to simulated streamflow as baseflow from the groundwater storage.

The major land use change observed in the catchment is in the irrigated area and occurred from 1990 to 2007. Over this time, the area under irrigation almost doubled from 40 to 76 km^2. The changes include irrigated paddy area increasing by 50% and irrigated vegetables area tripling, as compared to the calibration period 1980–89. Two comparisons are relevant to determine land use impacts: Base versus LU and WH versus Best. These comparisons show that land use changes (increased irrigation) have resulted in a 44 mm

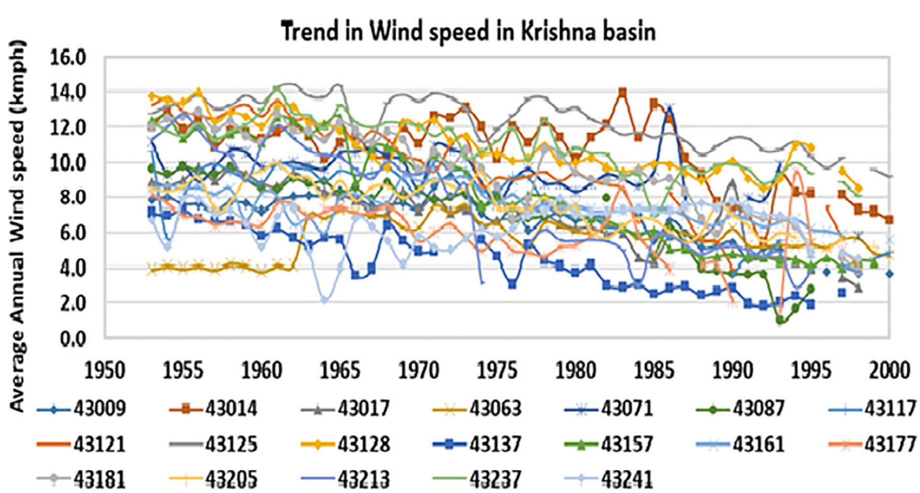

FIGURE 8 Trends in wind speed at different IMD stations across the Krishna river basin

increase in the average annual irrigation amount in the catchment, averaged across the whole catchment. The simulations suggested that the increased irrigation led to a 25 mm net groundwater withdrawal (20 mm of recharge and 5 mm of groundwater storage) which resulted in a decrease of 18 mm in streamflow. The streamflow was primarily reduced through impacts on baseflow, which was observed to decrease by 16 mm (89% of total reduced streamflow). Groundwater level declined at a rate of −0.20 m/y due to land use change and this has been offset by watershed development structures with a net addition of 0.02 m/y.

Overall, the impact of land use changes on the catchment streamflow and particularly on groundwater storage is much larger than the impact of watershed development structures. The key change caused by land use change is change in the contribution of baseflow (B_{flow}) to the catchment streamflow. Watershed development structures have a much smaller impact on streamflow and they tend to occur mainly through the surface water system (surface runoff, Q_{st}), but were later reinforced through the groundwater system. While their effect is relatively small, the hydrological structures do help to increase groundwater recharge and these structures do improve groundwater storage and baseflow contribution to the streamflow.

4.3 | Dependence of impacts on weather conditions

Table 5 shows the water balance for the base scenario and changes in the water balance from base scenario to other scenarios during dry, average, and wet years. These differences are due to individual and combined changes in land use and hydrologic storage structures. Considering the water balance for the base scenario first, it is clear that the reduction in streamflow is strongly dependent on annual rainfall. Given the small excess of rainfall compared with potential evapotranspiration in the wet season, it is not surprising that streamflow and streamflow changes are highly sensitive to annual rainfall. Surface runoff, baseflow and recharge all follow a similar pattern to total streamflow. Irrigation depth is relatively insensitive to annual rainfall and changes in the opposite direction. Changes in groundwater storage range from strongly negative in dry years to strongly positive in wet years (Figure 9).

The total irrigation requirement in the catchment area was completely met from that year's groundwater recharge during the wet years in all scenarios. During dry and normal years, in addition to consuming the groundwater recharge, the irrigation requirement was partially met from the available groundwater storage (50% during dry years and 30% during normal years), leading to a moderate and unsustainable declines in groundwater storage over time.

Table 5 also illustrates the dependence of the change scenarios on weather conditions. In general, the differences in streamflow between scenarios are greater during wet years than during dry years, due to the greater opportunity for water to move into storage in the catchment during wetter periods. The impact of land use

TABLE 5 Details of changes in hydrological responses from scenario 1 to other scenarios for dry (<0.75 times average annual rainfall), normal (0.75 to 1.25 times average annual rainfall) and wet (>1.25 times average annual rainfall)

Scenario	Condition	Q (mm)	Qst (mm)	Bflow (mm)	Rchg (mm)	Irr (mm)	CGWS (mm)
Base	Dry	0.60	0.30	0.30	31.80	66.00	−29.29
	Normal	57.80	34.30	23.50	78.70	59.00	−3.74
	Wet	105.70	69.70	36.00	132.10	55.00	39.30
Changes Base to WH	Dry	0.6 (0%)	0.2 (−65%)	0.4 (20%)	33.1 (4%)	66.00 (0%)	−28.4 (−3%)
	Normal	57.5 (−1%)	30 (−14%)	27.6 (15%)	84.6 (7%)	59.00 (0%)	−3.6 (−5%)
	Wet	104.9 (−1%)	62.9 (−11%)	42.1 (14%)	140.7 (6%)	55.00 (0%)	39.8 (1%)
Changes Base to LU	Dry	0.073 (−500%)	0.07 (−273%)	0.003 (−12 117%)	49.7 (36%)	110 (41%)	−55.3 (−47%)
	Normal	37.3 (−55%)	31.2 (−10%)	6.1 (−284%)	101.1 (22%)	108 (45%)	−8.3 (−55%)
	Wet	80.5 (−33%)	64.6 (−8%)	15.9 (−127%)	145.7 (9%)	79 (30%)	54 (27%)
Changes Base to Best	Dry	0.037 (−1522%)	0.033 (−699%)	0.004 (−8339%)	50.9 (38%)	110 (41%)	−54.3 (−46%)
	Normal	35.4 (−63%)	26.9 (−27%)	8.4 (−180%)	106.7 (26%)	108 (45%)	−6.4 (−41%)
	Wet	77.4 (−37%)	57.5 (−21%)	19.9 (−81%)	154.1 (14%)	79 (30%)	56.4 (30%)

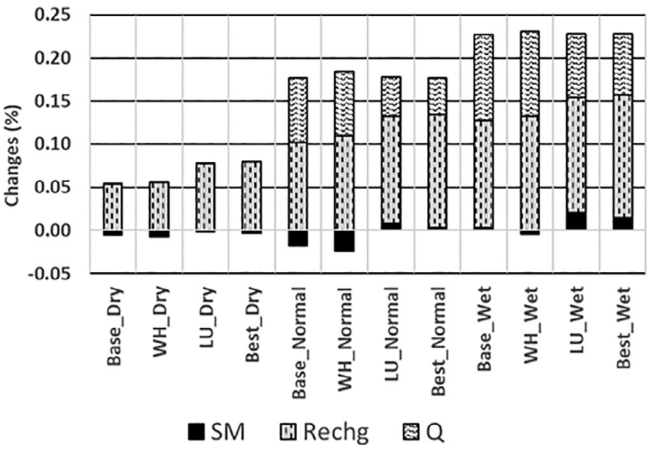

FIGURE 9 Change in hydrological responses during different rainfall years for all scenarios

on recharge changed slowly with annual rainfall, while hydrological structures had a much larger impact on recharge in wet years (6%) than in dry years (4%) due to the additional runoff flowing through them for longer periods. Irrigation changes were greater in dry years (22–38%) than in wet years (9–14%) reflecting the greater net irrigation requirement (108–110 mm/y) in those years.

4.4 | Limitations

While the modelling has captured the major change impacts in the catchment, there are many limitations. The overall changes as represented in the model are coarse in nature and subtler changes such as in crop management practice or water management practice are not incorporated. The modelling limits itself to climatic (water, temperature) limitations on plant growth, whereas other limitations including nutrients and diseases can impact plant growth and hence water use. Both disease and nutrient management are likely to have changed over the study period. This study has also ignored impacts of changing atmospheric CO_2 concentrations on plant water use.

5 | CONCLUSIONS

The study aims to analyse the rate of change in hydrological processes in response to the multiple catchment changes observed in the HS catchment and to determine which is more important by modelling various components of the change and comparing the results with the observed data. The study proposes a comprehensive framework for assessing the impact of climatic and anthropogenic changes on the HS hydrological system using a coupled surface and groundwater model. This study used an investigative approach to attribute hydrologic changes that involves first developing a coupled surface and groundwater model to capture the dynamic nature of the catchment, testing the model's ability to predict hydrologic trends in the catchment and examining the relative impact of different causes of change on the hydrologic response.

The results indicate that the Modified SWAT model can capture the dynamic nature of the catchment characteristics and predict the trends in streamflow and groundwater levels quite well. The streamflow into the HS reservoir was observed to decline at a rate of 3.03 mm/y and groundwater levels by 0.22 m/year, without significant changes in rainfall between 1980 and 2007. However, PET was also observed to decline due to the decrease in wind speeds in the HS catchment area.

Two climate-driven changes were identified a decline of 39 mm in annual stream flow due to changes in rainfall timing, which was offset by declining PET, leading to a net reduction of 26 mm. Declining PET also has some impact on catchment average irrigation, which is 2 mm/y lower during the validation period.

The comparison of Base case with Water Harvesting and Best Estimate with Land Use scenarios indicated that the reduction in average annual streamflow for the validation period was 2 mm or less due to water harvesting structures. Nearly 50% of the total amount of water harvested by the harvesting structures ultimately contributed to simulated streamflow as baseflow from the groundwater storage in the HS catchment area.

The comparison of Base case and Land Use scenarios indicated that the impact of land use change on streamflow and groundwater levels is much higher than the impact of hydrological structures. The land use change and associated water extractions led to an increase of 44 mm in the amount of annual irrigation, which led to a net water withdrawal of 25 mm and to a decrease in streamflow of 19 mm, primarily from baseflow (15 mm) reduction. Groundwater storage declined at a rate of 5 mm/y due to impact of land use changes and this was offset by a net addition of 2 mm/y by hydrological structures (Best Estimate scenario).

Overall, model results indicate that both land use change and hydrological structures impact the streamflow. The impact of land use change on streamflow is an order of magnitude larger than the impact of hydrological structures and about 2.5 time higher in terms of groundwater impacts. It was observed that hydrological structures increase recharge and groundwater storages, whereas land use change (increased irrigation) has caused declines in both streamflow and groundwater storage. The total irrigation requirement of the catchment was completely met by rainfall recharge during the wet years. During the remainder of the time, dry and normal years, the irrigation requirement was partially met from the existing groundwater storage (50% during dry years and 30% during normal years). Overall, this is leading to moderate and unsustainable declines in groundwater storage over time.

Finally, in the future both climate change and anthropogenic catchment changes are likely to continue to threaten the sustainability of water resources, presenting a large challenge in this catchment and many other regions of the world, particularly in arid and semi-arid regions of India. As demonstrated here, both exogenous and endogenous changes can have a large impact on catchment hydrology and need to be considered together. It is suggested that a combination of catchment and climate change scenarios should be considered to explore potential future conditions in the HS catchment.

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DATA AVAILABILITY STATEMENT

Data sharing is not applicable to this article as no new data were created or analyzed in this study.

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