Evaluating the effects of climate change on groundwater level in the Varamin plain

Hamidreza Azizi, Hossein Ebrahimi, Hossein Mohammad Vali Samani and Vida Khaki

ABSTRACT

In this research, a number of paired three-dimensional Atmosphere-Ocean General Circulation Models (AOGCM) from CMIP (Climate Model Inter Comparison Project) 5 group with the base period of 1989–2005 have been evaluated and the output of these models was micro-scaled and calibrated by LARS-WG software. The appropriate model was selected to simulate temperature and rainfall data under the emission scenarios of RCP (Representative Concentration Pathway) 2.6, RCP4.5 and RCP8.5 for the future period of 2020–2050, and then to model the groundwater level of the region, GMS software for both stable and transient states for one water year was calibrated and then was validated by observation data. The results in the future periods showed an increase of 1–1.5 degrees in temperature and an increase in rainfall in the early months of the year to late spring season and a decrease in rainfall in autumn season. Generally, the RCP4.5 scenario showed slightly more annual rainfall increase over the next 30 years compared to the base period than the other two scenarios. The time series investigation of the average of groundwater level shows that the implementation of RCP 2.6, RCP 4.5 and RCP 8.5 scenarios respectively leads to an average monthly increase of 4.2, 4.3 and 4.6 cm of the groundwater level.

Key words | aquifer simulation, climate change, GMS, groundwater, LARS-WG

Hamidreza Azizi
Hossein Ebrahimi (corresponding author)
Hossein Mohammad Vali Samani
Vida Khaki
Department of Civil engineering,
Shahr-e-Qods Branch, Islamic Azad University,
Tehran,
Iran
E-mail: *ebrahimi.hossein@srbiau.ac.ir*

HIGHLIGHTS

- Using the models and scenarios of the fifth IPCC report in Varamin and Tehran plains to study the trend of climate change.
- Using a step-by-step approach to investigate the effect of climate change on groundwater level in the Varamin plain.
- A view of the future of the Varamin plain aquifer under different climate change scenarios for groundwater resources management.

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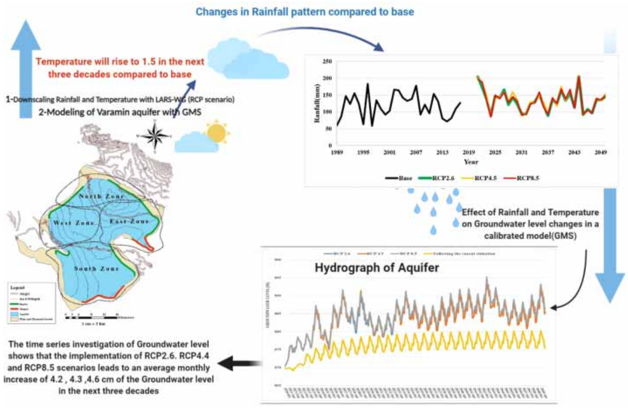
GRAPHICAL ABSTRACT



NOMENCLATURE

Q_{in}	the sum of the effective factors
Q_{out}	the sum of the effective factors
ΔV	changes in the volume of water storage
A	area of the balance extent in terms of square kilometers
Δh	average annual changes in groundwater level in the balance period in terms of meter
Sy	the average storage coefficient of the balance area
k	the hydraulic conductivity
σ	the standard deviation of the data
h	the potential load
w	indicates the volume flux per unit volume
s_s	the specific storage for porous materials
t	time

INTRODUCTION

In recent years, climate changes have engaged all regions of the world with their issues and crises. According to the fifth evaluation report of the Intergovernmental Panel on Climate Change (IPCC), global temperatures have risen by 0.85 °C from 1880 to 2012, and if global greenhouse gas emission is not reduced, the average global temperature could rise by 1.1–4.6 ratio by 2100 (IPCC 2013).

Global temperature changes and its rising trend are known as climate change regarding the average weather conditions around the world. Climate change has a considerable impact on surface and groundwater resources (Hashmi *et al.* 2011). Considering that the impact of climate changes on groundwater resources is indirect and slower than surface water resources, monitoring the status of these resources and maintaining their sustainability under the influence of these changes is of great importance (Shakiba & Cheshmi 2013). The first step in investigating the effects of climate changes is to examine the impact of this phenomenon on climate parameters. Therefore, in order to investigate the effects of climate change in future periods, the amount of climate variables in the future must first be simulated (Node Farahani *et al.* 2018). One of the most reliable tools for investigating the effects of climate change is the use of climatic variables simulated by the downscaling models of climatic parameters such as LARS-W that can predict climatic parameters in local scale. In this regard, numerous studies have been conducted, and are mentioned in the following paragraphs.

Crosbie *et al.* (2013) examined the effects of climate changes on feeding aquifer groundwater in the highland plains of the United States. Groundwater feeding was modeled for different types of soil and vegetation using soil, vegetation, atmosphere and WAVES transfer model. The results of investigations showed that feeding for the northern highland plains increased by 8%, the central highland plain decreased by 3% and the southern highland plains decreased by 10%. Ahmadebrahimpour *et al.* (2019) investigated future drought conditions under a changing climate.

The results of SPI analyses revealed that under RCP 2.6 the frequency of droughts is almost constant while under RCP 8.5 drought frequency increased especially in the period 2071–2100.

Shrestha *et al.* (2016) investigated runoff and sediment uncertainty in the future for the time periods of 2030 and 2060 under the impact of climate change in the Mekong Basin using LARS-WG and Soil and Water Assessment Tool (SWAT) 2060 under the GCM model. Their results showed that sediment load and runoff will respectively increase and decrease in the future. Nistor *et al.* (2016) using the new NISTOR-CEGW method, considering the effective rainfall and De Martonne drought coefficient in the Carpathians, investigated the intensity of the effect of climate change on groundwater resources. The results showed that the intensity of the effect of climate changes on groundwater resources in the region under study was low.

Shahvari *et al.* (2019) investigated the effects of climate change on water resources in the Varamin plain basin using the SWAT model. Their results showed that the ratio of runoff in the period of 2011–2030 under all three scenarios will increase in spring and summer seasons and decrease in autumn and winter seasons. This seasonal shift in runoff is due to the effects of climate change in the form of rising temperature, changing rainfall pattern, and so on. Klaas *et al.* (2020) investigated the effect of climate change on groundwater level in the Karst region under the HadCM3 model. Their results showed a reduction in the amount of feeding and the storage of groundwater resources. Haidu & Nistor (2020) using the NISTOR index, investigated the intensity of the effect of climate change on a spatial scale in eastern France. Their results showed that the intensity of the effect of climate change on groundwater resources is moderate and low.

With regard to the importance of the effects of climate change on water resources, especially valuable groundwater resources, research in this field is necessary. The present research with the aim of investigating climate change and its effects on groundwater level due to rainfall and temperature has been conducted in a case study in the semi-arid climate region of Iran. Regarding the position of the region, increasing removals for agricultural water consumption has caused a drop in water level in the plain, and that by conducting this research and determining the status of the aquifer under climate change scenarios in the future period, a principled planning to control removal and aquifer development plans in the region can be presented.

MATERIALS AND METHODS

Study area

Varamin plain, a strategic region in terms of agriculture, is located at a distance of 40–45 km south to southeast of Tehran province. The climatic situation of this plain is in many ways similar to the climate of the central plateau of Iran and is located in an arid to semi-arid region. Varamin plain catchment basin with an area of 1,720 square kilometers is one of the sub-basins of Namak Lake, which is located in the geographical area of $35°0'0''$ to $36°0'0''$N latitude and $51°0'0''$ to $52°0'0''$E longitude (Figure 1). The Jajrood, Kondrood, Galandūak and Damavand Rivers have been located in the study catchment basin, the most important of which is the Jajrood River, on which the Latian Dam has been constructed in the upstream. Latian Dam is one of the factors in the hydrological cycle of the basin and also downstream agriculture development itself has a great impact.

Hydroclimatology studies

Meteorological information including pluviometry, thermometry and climatology (relative humidity, frosty days, sunny hours, wind, evaporation and transpiration) have been collected from Varamin Synoptic Station, which is the plain station representation. The average annual temperature in this basin is 16.9 °C and the warmest month of the year is July with an average temperature of 29.5 °C and the coldest month of the year is January with an average temperature of 3.3 °C; also the average annual rainfall is 156 mm in the year. The driest month of the year is August, with an average of 0 mm rainfall and the highest rainfall is related to March with 35 mm ratio.

Hydrological information including hydrometric network and water flow calculation has been obtained from hydrometric stations in the aquifer area. Hydrogeological characteristics of the aquifer are obtained by preparing a

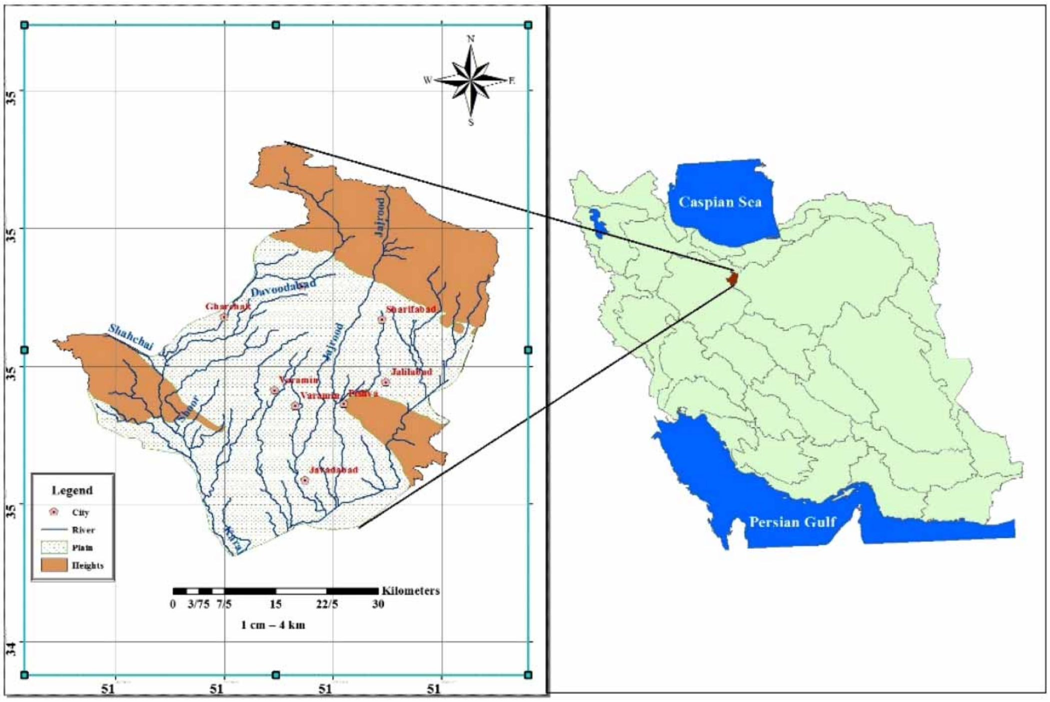


Figure 1 | Geographical Location of the study area (Varamin plain).

single hydrograph, groundwater average level map and hydraulic conduction map, having monthly statistics of 48 observation well rings in the plain surface, a groundwater average level map is drawn for the water year of 2014–2015, and having a map of transfer capability obtained from (T pumping test) and the layer thickness of the output of GIS software, the k hydraulic conduction map is obtained.

Groundwater balance in the study area

The general equation of groundwater balance is presented as Equation (1):

$$\Delta V = Q_{\text{in}} - Q_{\text{out}} \tag{1}$$

where Q_{in} is the sum of the effective factors in feeding and Q_{out} is the sum of the effective factors in discharging the aquifer and ΔV is the changes in the volume of water storage in the aquifer during the balance period. Conversely, the amount of changes in groundwater reservoir volume is calculated by Equation (2):

$$\Delta V = S_y \times \Delta h \times A \tag{2}$$

The changes in the storage volume of the balance area in terms of million cubic meters is (ΔV), the area of the balance extent in terms of square kilometers is (A), the average annual changes in groundwater level in the balance period in terms of meter is (Δh) and the average storage coefficient of the balance area is (S_y) based on calculating the amount of feeding and discharging balance, using Equations (1) and (2), was determined equal to 6%.

The ratio of groundwater inflow and outflow after determining the inflow and outflow sections was determined using the average level map of the water year of 2014–2015 and the map of the ability to transfer and the measurement of the length of each one of the sections and hydraulic gradient and Darcy equation (Figure 2).

Also, the presence of hydraulic conductivity information, aquifer floor rock level, and average groundwater level in the water year of 2014–2015 along with the aquifer

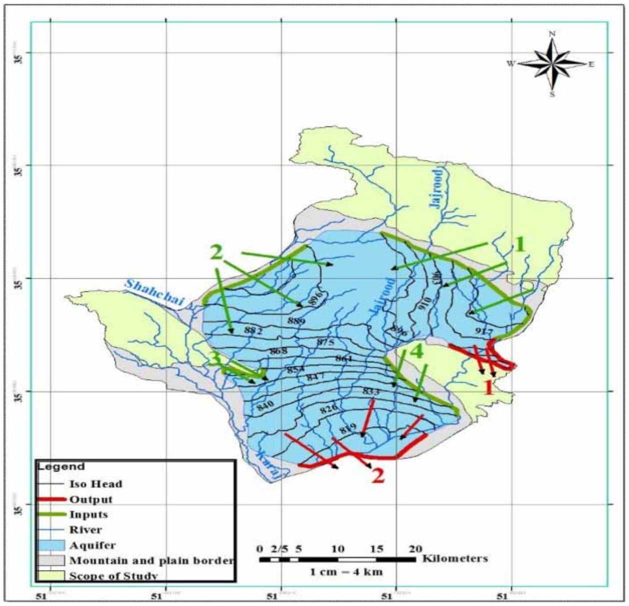


Figure 2 | Underground inlet and outlet sections of Varamin plain aquifer area.

position to determine the ratio of groundwater inflow and outflow from the groundwater aquifer is essential.

Also based on the results obtained from water balance parameters underground in Varamin aquifer, The groundwater balance for 2014–2015 of the Varamin aquifer is presented in Table 1.

As is clear from the groundwater balance sheet table of the study area, the changes in inflow and outflow in the target year were negative, which can be a sign of uncontrolled extraction from exploitation wells. Therefore, the study of the effects of climate change on groundwater changes in the study area will be more important than ever.

Table 1 | Varamin plain aquifer balance for 2014–2015 (MCM)

Drainage	Recharge	Balance component	
	116/07	Inlet flow from the aquifer border	
	12/66	Recharge of rainfall	
	30/81	Infiltration of surface currents	
	187/14	Agriculture	Water returned from consumption
	48/1	Drinking and industry	
41/43		Outlet flow from the aquifer boundary	
0		Evaporation rate from the aquifer	
389/94		Harvesting from wells	
3		Drainage from the river	
434/37	394/78	Total	
– 39/59		**Tank volume changes**	

Groundwater modeling by GMS software

In this research, GMS10.3 software was used to establish a relationship between GIS software and MODFLOW code (McDonald & Harbaugh 1988) to construct a conceptual and numerical model of the aquifer. The MODFLOW numerical model is based on solving the groundwater motion equation so that the three-dimensional motion of groundwater with constant density is solved by the partial differential equation, Equation (3), using the finite difference method and based on the continuity equation:

$$\left(k_{xx}\frac{\partial h}{\partial x}\right)+\frac{\partial}{\partial y}\left(k_{yy}\frac{\partial h}{\partial y}\right)+\frac{\partial}{\partial z}\left(k_{zz}\frac{\partial h}{\partial z}\right)-w=\left(s_s\frac{\partial h}{\partial t}\right) \qquad (3)$$

where k is the hydraulic conductivity, h is the potential load, w indicates the volume flux per unit volume, which shows the feeding and discharge, s_s is the specific storage for porous materials, and t is time.

Conceptual and numerical model of Varamin aquifer

The conceptual model of the aquifer is a three-dimensional view of structure, hydraulics, hydrodynamics, and so on, characteristics that have been obtained based on the analysis of the discharge data of exploitation wells and their return water ratio, observation wells, aqueducts and springs, the ratio of surface feeding (rainfall and runoff) to the aquifer, temperature and evapotranspiration potential and boundary conditions of the aquifer (Figure 3). The more data are obtained from the aquifer, the closer the conceptual model is to the real conditions. In general, in Varamin plain, there is in practise a main free aquifer corresponding to the groundwater balance area between the clay layers in its southern parts, and the wells are also located in this main layer. The highest aquifer thickness is in the north of the plain at 280 meters and the lowest alluvial thickness is in the southwest of the region at 150 meters. The bedrock of the main aquifer is generally composed of clay sediments, marl, congenital Miocene and Myo-Pliocene with low

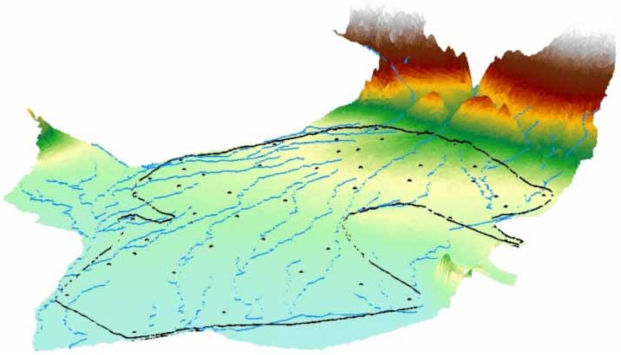


Figure 3 | Conceptual Model of Varamin Plain Aquifer.

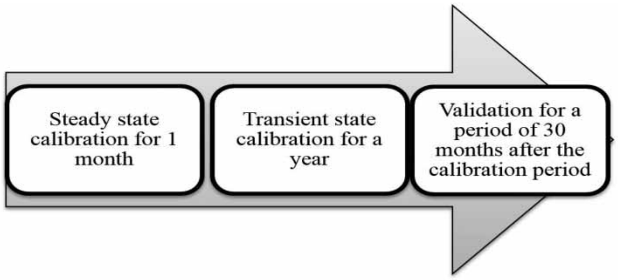


Figure 4 | Calibration and validation time steps.

permeability. The main sources of feeding the Varamin plain are rainfall, main waterways, wastewater treatment plant in the south of Tehran and subsurface feeding. Groundwater depth in the main aquifer is between 30 and 170 meters below the ground surface and the general direction of groundwater flow in the region from northwest to southeast.

Creating and preparing Varamin aquifer flow model

Necessary stages to set up the model in GMS10.3 software include networking the case study area, determining the model area, spatial and temporal division, defining the model boundaries and how to assign the values of the initial parameters to various nodes of the model. It is necessary to mention that in the modeling stage, the aim was as much as possible that the groundwater model area corresponded to the balance area.

Calibration and validation stage of GMS software

The purpose of this stage was calibration of various parameters of the model and to minimize the error in successive time steps. In this study, The model was calibrated and validated with different time steps (Figure 4) according to the existence of observation well information under stable and transient conditions. In this study, the maximum acceptable error ratio between the observed static level and the simulated observation wells was set at ±2 m.

AOGCM climate models and climate data extraction

Currently, the most reliable tool for generating climate scenarios are the paired three-dimensional Atmosphere-Ocean General Circulation Model, abbreviated as AOGCM (Wilby & Harris 2006). This part of the research investigated the effects of climate change using the Climate Model Inter Comparison Project (CMIP5) group models under Representative Concentration Pathway (RCP) emission scenarios on groundwater levels in the Varamin plain basin. The satellite conditions of the models and the climatic conditions of the case study area, among 61 paired three-dimensional Atmosphere-Ocean models of the fifth report of the IPCC, named as CMIP5, were used and 10 models were selected and evaluated. To investigate the performance of these models in simulating the temperature and rainfall variables of the region, the average monthly levels of temperature and rainfall simulated by this model in the base period of 1989–2005 were compared with the corresponding observation amounts of the station under study in the same period. To investigate the performance of the models, four criteria of Determination Coefficient (R^2), Correlation Coefficient (ρ), Root Mean Square Error (RMSE) and Bias Error Criterion were used.

Downscaling

Due to the low resolution power of AOGCM models, it was necessary and essential to make them microscale. In this research, in order to downscale the data to generate climate change scenarios, the LARS-WG stochastic climate generator was used to simulate atmospheric data (Racsko *et al.* 1991; Semenov & Brooks 1999).

Calibration of LARS-WG model in the case study area

Initially, the specification of station name, geographical latitude and longitude, height from sea level and 16-year observation data from 1989 to 2005 including minimum temperature, maximum temperature and rainfall were entered into the model. During calibration operations, the model using input files and the analysis of station data determines the characteristics of the statistical parameters of the observed data and uses them in the validation stage and time series generation.

Meteorological data production

This stage includes simulating meteorological data (minimum temperature, maximum temperature and rainfall) for any number of arbitrary years according to the considered climate change scenario (Semenov & Stratonovitch 2010).

At this stage, the data of monthly changes of minimum temperature, maximum temperature and rainfall simulated by the appropriate model of the region under the three emission scenarios of RCP2.6, RCP4.5 and RCP8.5, in the period of 2020–2050 were generated and investigated with observation values in the base period in the study area.

Investigating the effects of climate change using a calibrated GMS model

Based on the proposed approach prepared (Figure 5), to investigate the quantitative behavior of the groundwater aquifer under the generated CMIP5 emission scenarios, it was necessary to simulate the GMS simulation model whose parameters have already been calibrated according to the climate parameters of temperature and rainfall under the scenarios RCP2. 6, RCP 4.5, RCP 8.5 for a period of 30 years.

Due to changes occurring in climatic parameters of temperature and rainfall under various RCP scenarios, the quantitative behavior of the aquifer will also have fluctuations. Based on these changes and comparing them with the existing conditions, the effects due to climate change of the region on groundwater can be realized.

RESULTS AND DISCUSSION

Calibration results of GMS model

In order to calibrate the aquifer in the Varamin plain under stable and transient conditions, groundwater levels associated with 48 observation wells were used. In the stable state, the hydraulic conductivity parameter and in the transient state, the specific water flow parameter were calibrated and the final simulation error values were obtained at the location of each of the piezometers.

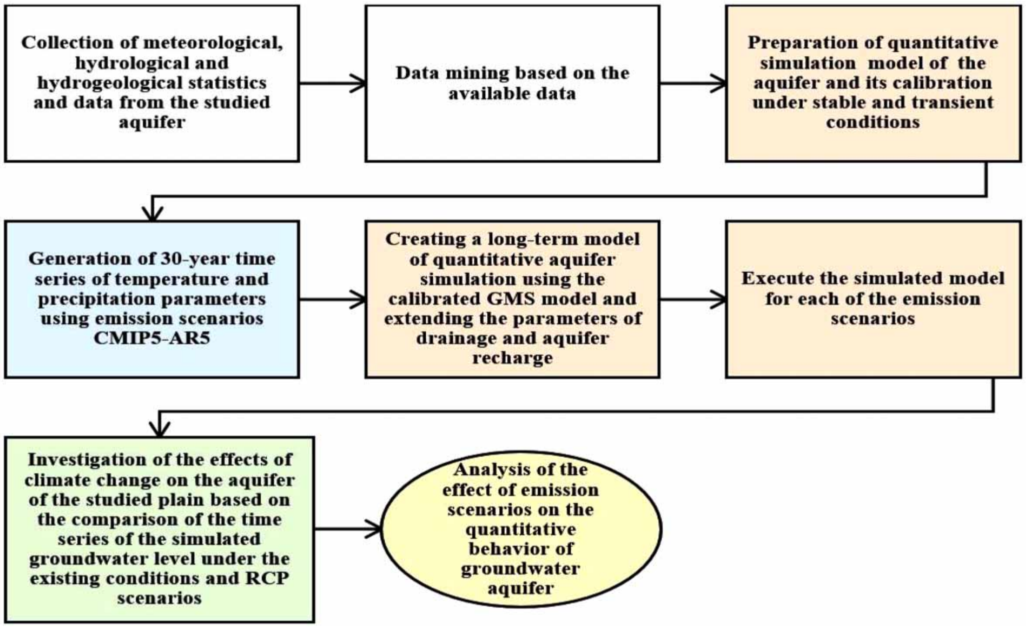


Figure 5 | Structure of the proposed approach to investigate the effects of climate change on the aquifer using GMS.

The scatter diagram of points between observation and calculation groundwater level values is shown for the observation wells of the Varamin plain aquifer in a stable state (Figure 6). According to Figure 6, the correlation coefficient between the calculated and observed values was equal to $R^2 = 0.9932$. It should be mentioned that the Root Mean Square Error value between the observation and calculation level values was equal to 3.71, which indicates a true agreement between the results of the calibrated simulation model and the real values.

In order to calibrate the model in the transient conditions, calibration operations were performed on specific water flow parameters and feeding amounts to the aquifer. Based on the results of the calibrated simulation model, it can be realized that the parameter of aquifer storage coefficient varied in the range 0.001% and 0.154%.

Now, according to the calibrated model, the quantitative behavior of the aquifer can be simulated for a short time period. In fact, based on calibrated parameters, it is possible to predict the groundwater level for future conditions. For this purpose, the calibrated model was simulated for a period of 30 months after the calibration period (according to the existence of observation well information) and its results were analyzed in the form of a groundwater level hydrograph for each piezometer. According to these results and considering an error of 2 meters it can be realized that the simulated model, despite the shortage of available information, was able to predict the quantitative behavior of the groundwater reservoir well. In fact, this model can be used to investigate the effects of various hydrological and meteorological parameters on the groundwater level.

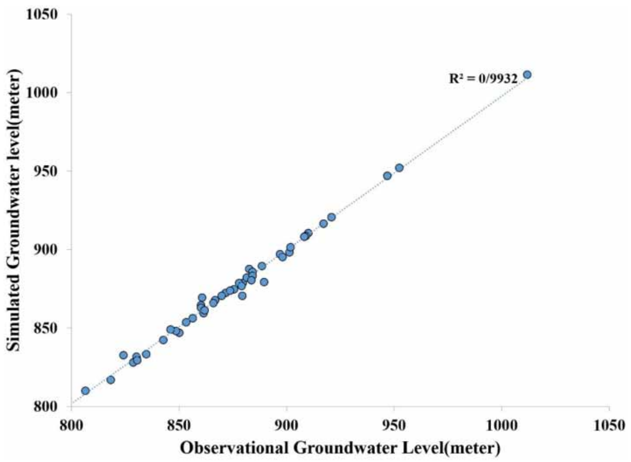


Figure 6 | Scatter diagram of points between observation and calculation groundwater level values under sustainable flow conditions.

Evaluating AOGCM models

The performance of AOGCM models in the base period of 1989–2005 was evaluated with observation data of the case study area. According to the results of Table 2, the EC-EARTH model has shown a high correlation coefficient in simulating temperature and rainfall compared with other models, The value of correlation coefficient (ρ), represents the linear relationship between the simulated data and the observations, the value of which is between zero and one. The closer the value of ρ is to one, the stronger the linear relationship between the two values. so the EC-EARTH model was acceptable and was selected for further study.

Calibration results of the LARS-WG model

To ensure the model's ability to generate data in the future, the data micro-scaled by the model were compared with the observation data at the Varamin synoptic station. The results of the Kolmogorov-Smirnov and T-test on the parameters of rainfall, minimum temperatures and maximum temperature and daily radiation in the study station showed that the *p*-values of rainfall parameters, minimum temperatures, maximum temperature and daily radiation in the study stations, in most months were reliable at the significance level of (90%), which indicated that the LARS-WG model had the necessary ability to simulate rainfall, minimum temperatures and maximum temperature and daily radiation variables in the future period.

Investigating temperature and rainfall changes under CMIP5-AR5 emission scenarios in the future period compared with the base period in Varamin synoptic station

According to Figure 7, the trend of annual temperature increase by EC-EARTH model under all the three emission scenarios of RCP8.5, RCP4.5, and RCP2.6 until 2050 was evident. Scenario RCP8.5 shows a greater temperature

Table 2 | Results of statistical indices for comparing observational and simulated climatic variables in the base period (1989–2005)

	Rainfall				Temperature			
Model	**Bias (mm)**	**RMSE (mm)**	**ρ (%)**	**R^2 (%)**	**Bias (°C)**	**RMSE (°C)**	**ρ (%)**	**R^2 (%)**
EC-EARTH	8.3	10.8	84	72	– 7.8	7.8	99	99
CAN ESM2	– 2.5	6.7	72	53	– 5	7.8	83	70
CCSM4	15.7	19	77	59	– 5.4	7.5	86	73
GFDL-CM	– 9.4	10.5	88	62	31.3	36.7	79	77
GFDL-ESM2G	20.3	23.9	74	55	– 4.6	6.9	99	72
GFDL-ESM2M	16	19.3	75	56	– 4.6	6.9	85	72
MIROC5	37	43.6	79	61	– 3.3	5.7	88	77
HADGEM2	13.8	16.9	54	30	– 6.5	9.1	77	59
BCC-CSM1.1	18.5	13.7	60	36	– 60.08	7.9	85	73
GISS-E2-H	20.09	21.4	68	46	– 5.4	6.2	99	99

increase than the other two scenarios in the next 30 years compared with the base period in the study area.

According to Figure 8, uniform changes in annual rainfall under all three RCP emission scenarios are not observed in the future period compared with the observation period. Generally, the RCP4.5 scenario shows a slight increase in annual rainfall over the next 30 years compared with the other two scenarios.

Fluctuation of groundwater level in the future period

Due to changes occurring in rainfall and temperature ratio under various scenarios, the quantitative behavior of the aquifer will also have fluctuations. Based on these changes and comparing them with the existing conditions, the effects due to climate changes in the region on groundwater can be realized.

By implementing the proposed approach for each of the defined scenarios, the predicted groundwater level time series was determined. To better show the various sections of the aquifer in terms of groundwater level changes, and considering that 48 piezometers cover the entire surface of the plain and the aquifer can be divided into four different areas, aquifer behavior for the northern, southern, eastern and western sections (Figure 9) under various scenarios was examined separately, and extracted and presented comparatively (Figure 10).

In Figure 10, the dotted curve shows the fluctuation of the water table in each area according to the continuation of the existing conditions, also the other three curves show the fluctuation of the water level in each area under three climate

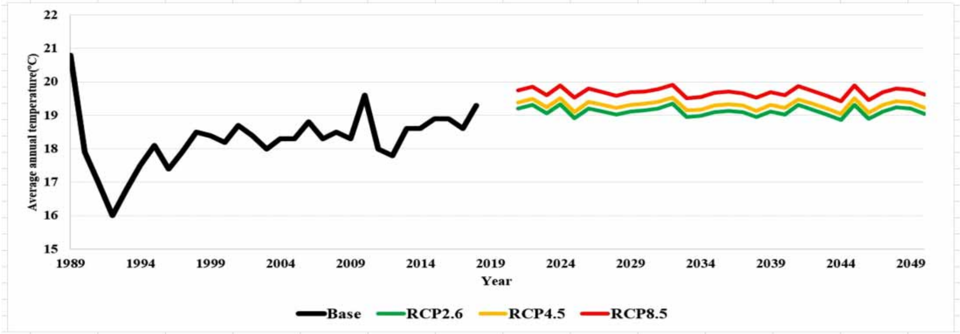


Figure 7 | Comparison of the average annual temperature simulated using the EC-EARTH model under the emission scenarios of RCP8.5, RCP4.5, and RCP2.6 in the period 2020–2050 compared with the base period of the studied station.

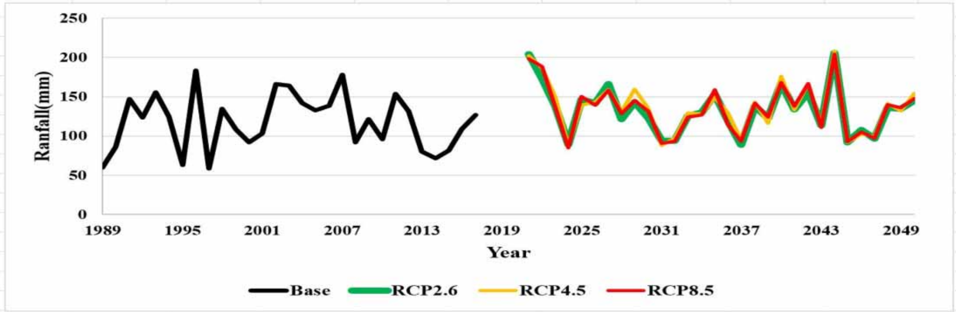


Figure 8 | Comparison of the average annual rainfall simulated using the EC-EARTH model under the emission scenarios of RCP8.5, RCP4.5, and RCP2.6 in the period 2020–2050 compared with the base period of the studied station.

change scenarios. Investigating the predicted groundwater level situation shows that in all aquifer sections, the effects of climate directly affected the quantitative situation of aquifer and has led to an increase in groundwater levels, which corresponds with the result (Shahvari *et al.* 2019) for the increase in runoff in Varamin plain. This trend has emerged as a positive effect except in the southern parts of the aquifer, which is the groundwater outlet, and prevents the increasing decline of the aquifer in the eastern parts of the plain, which is very sensitive to removal as the floor level balance is high. It should also be noted that in all zones, the increase in groundwater level in the next three decades under the RCP8.5 scenario is more than for the other two scenarios. Also as mentioned before, Varamin plain is a strategic region in terms of agriculture, so there are many exploitation wells in the plain, about 2054 active wells. so the overuse from exploitation wells have made it impossible to compensate for the lack of groundwater balance every year. It should also be considered that the density of exploitation wells and the amount of harvest varies according to the type of agricultural area in the plain. So, it can be seen that in areas where the dotted curve is far from other curves, the amount of recharge due to rainfall cannot compensate for

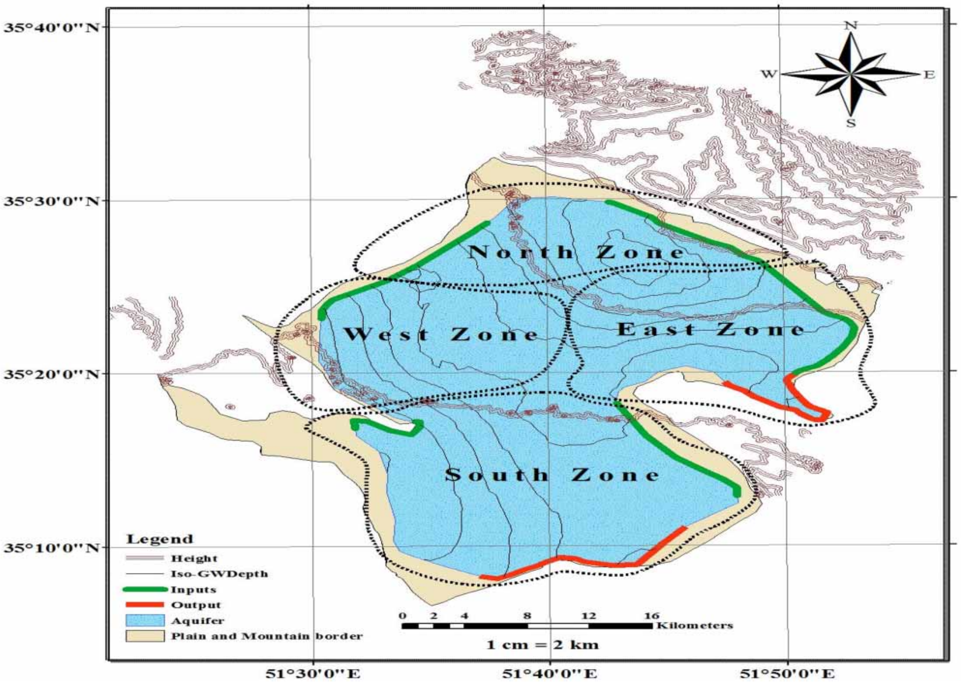


Figure 9 | How to divide the aquifer area to investigate the quantitative behavior of Varamin plain under climatic scenarios.

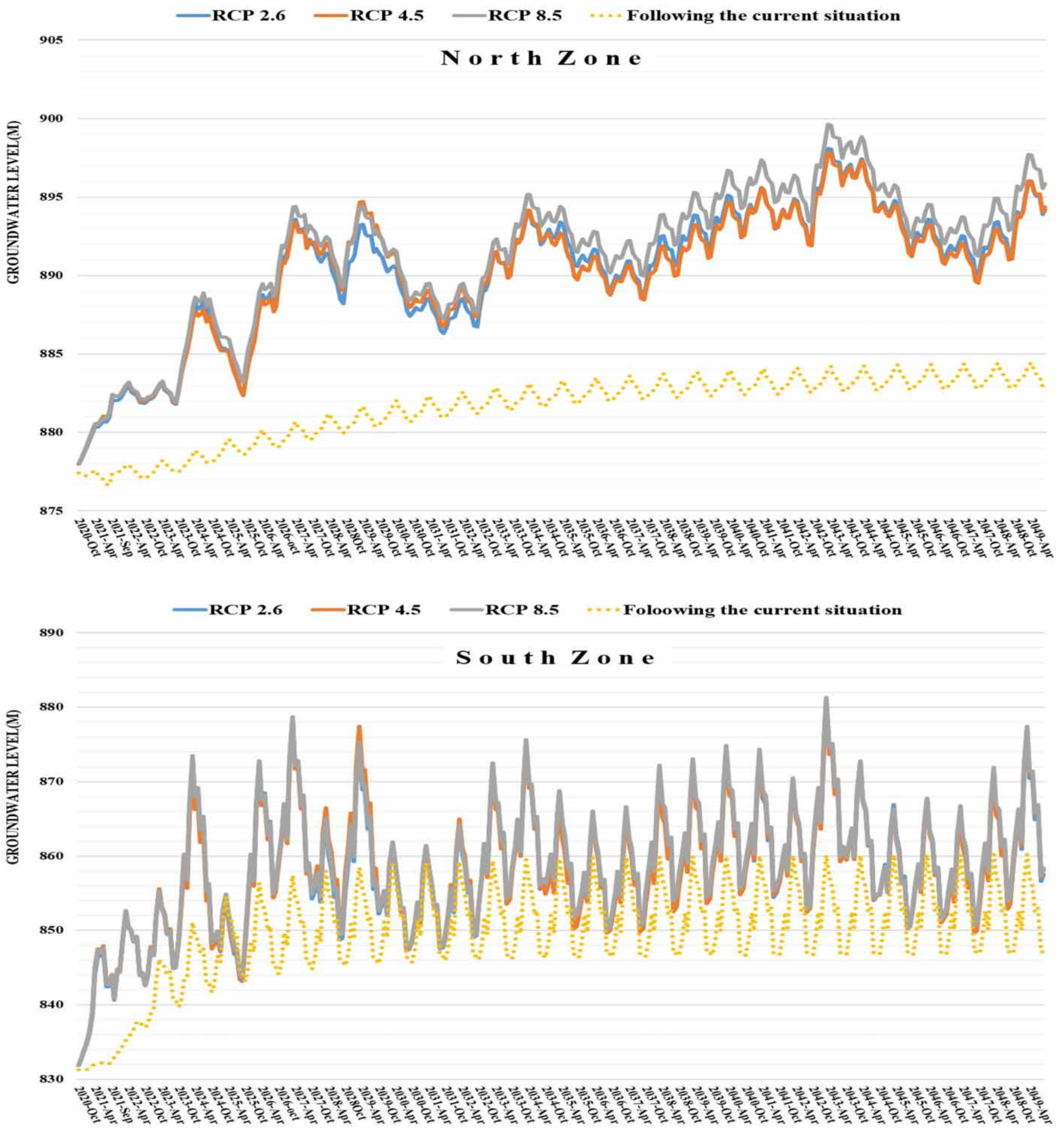


Figure 10 | Groundwater level time series predicted under various scenarios in northern, southern, eastern and western areas. *(Continued.)*

the decline in water table due to increasing overuse of wells in that area. But, if we consider the hydrograph of the whole aquifer, the result will be different. So examination of the average time series of groundwater level under the studied scenarios shows that the implementation of RCP 2.6, RCP 4.5 and RCP 8.5 scenarios on average monthly led to a 4.2, 4.3 and 4.6 cm increase respectively in groundwater levels and thus improved the saturation thickness of the aquifer.

It should be mentioned that this level increase ratio can cause water storage of 25.8, 26.22 and 28 million cubic meters per year respectively in the three scenarios investigated in the aquifer.

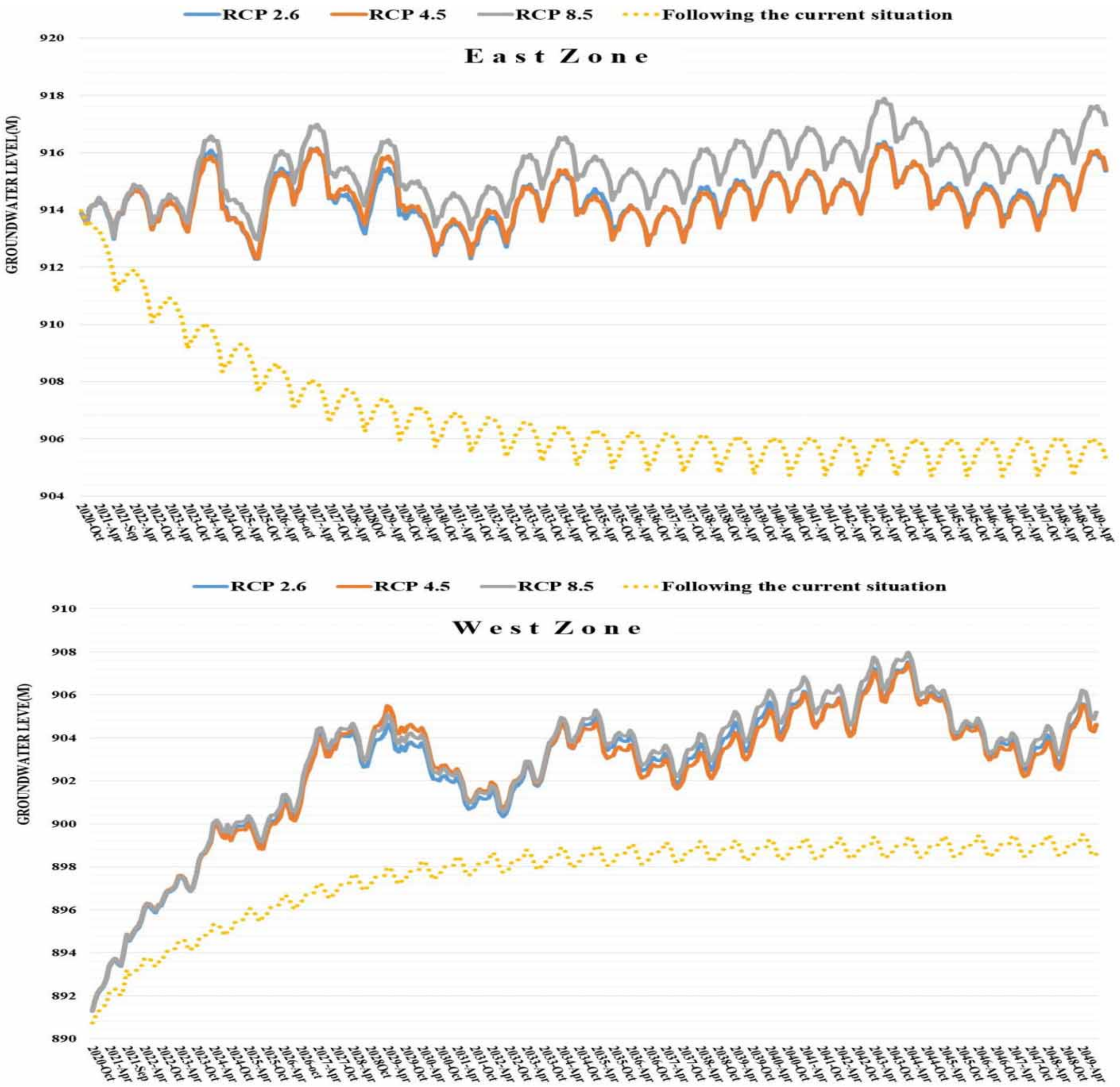


Figure 10 | Continued.

CONCLUSION

Regarding the increasing growth of water consumption and considering that the focus of much consumption is based on groundwater extraction, therefore the topic of investigating the impact of climate change scenarios over the long term on groundwater resources is very important. In this regard, using a step-by-step approach of modeling and simulation, this effect on the level of the aquifer in the region in the future was investigated. In this regard, in the present research, RCP2.6, RCP4.5 and RCP8.5 climate change scenarios were generated for two important variables of temperature and rainfall in Varamin plain area in Tehran province, and finally changes in groundwater level in all three scenarios were analyzed. It should be mentioned that the effects of climate change typically occur on a large scale, and investigating this for a study area with limited scale will certainly not be free of errors and mistakes. However, this investigation can provide an overview of the situation of the aquifer in the future to provide more appropriate management plans for the users and managers of water systems.

The results show a temperature increase of 1–1.5 degrees and in general a relative increase in the average annual rainfall in the next 30 years as well as an increase in the groundwater level compared with the base period in the region. It can be concluded that if the amount of harvesting from exploitation wells is controlled, the condition of the aquifer can be improved in the future. Otherwise, the thickness of the aquifer will deteriorate. Due to the strategic location of Varamin plain in terms of agriculture in Tehran province and the necessity to maintain the aquifer, principled planning to control the removal and to help the aquifer, including projects such as underground dam, artificial recharge, managing well harvesting and using smart controllers, modifying the cropping pattern and so on are necessary and essential. The results of this research can be further analyzed for sensitivity and evaluation in the form of other climatic scenarios as well as downscaling models and other rainfall–runoff analysis.

DATA AVAILABILITY STATEMENT

Data cannot be made publicly available; readers should contact the corresponding author for details.

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