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# Forecasting of Future Irrigation Water Demand for Salah-addin Province under Various Scenarios of Climate Change

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## Abstract

Irrigation water demand of a crop is largely dependent on climate conditions. The impact of climate change on the demand of irrigation water needs more investigation. This paper aims to analyze the future trend in irrigation demand under RCPs 2.6, 4.5 and 8.5-Based climate changes scenarios for Salah-addin Province, Iraq. The climate data recorded during 1990-2019 was projected to 2080 with 20 years of time steps using LARS-WG model. The current and future weather data were inserted into CROPWAT-8. The results showed that the climate of Salah-addin Province tends to become hotter and drier by year 2080 due to increased average temperature by 5.72, 10.67 and 17.82% under RCPs 2.6, 4.5 and 8.5, respectively. Consequently, the evapotranspiration tends to increase by 4.6, 8.6 and 12.9% 5.72, 10.67 and 17.82% under RCPs 2.6, 4.5 and 8.5, respectively. Moreover, the projected precipitation showed negative trend with -0.2, -1.7 and -1.9% under RCPs 2.6, 4.5 and 8.5, respectively. Therefore, the annual irrigation water demand for studied area is expected to increase from 112.0 $m^3/s$ in reference period to 115.8, 119.7, 122.9 $m^3/s$ under RCPs 2.6, 4.5 and 8.5, respectively. Results indicated that irrigation demand should be adapted by improving irrigation efficiency for sustainable management water resources.

**Key words:** LARS-WG, CROPWAT, Irrigation, Climate change, Salah-addin

# التنبؤ بالطلب المستقبلي على مياه الري لمحافظة صلاح الدين في ظل سيناريوهات مختلفة لتغير المناخ

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**المستخلص**

يعتمد الطلب على مياه الري لمحصول معين بشكل أساسي على الظروف المناخية. ان تأثير تغير بالمناخ على الطلب على مياه الري إلى يحتاج الى مزيد من البحث. تهدف هذه الورقة إلى تحليل التوجه المستقبلي للطلب على مياه الري لمحافظة صلاح الدين الواقعة في العراق بموجب مسارات التركيز التمثيلية (RCPs) ٢,٦ و ٤,٥ و ٨,٥. تم تسقيط بيانات المناخ المسجلة خلال الفترة ١٩٩٠-٢٠١٩ (كفترة مرجعية) الى عام ٢٠٨٠ باستخدام ٢٠ عامًا من كخطوة زمنية باستخدام نموذج LARS-WG.حيث تم إدراج بيانات الطقس الحالية والمستقبلية في CROPWAT-8. أظهرت النتائج أن المنطقة تتجه إلى أن تصبح أكثر احترار وجفافًا بحلول عام ٢٠٨٠ بسبب زيادة متوسط درجة الحرارة بمقدار ٥,٧٢ و ١٠,٦٧ و ١٧,٨٢٪ تحت RCPs 2.6 و ٤,٥ و ٨,٥ على التوالي. وفقًا لذلك ، يميل التبخر-النتح إلى الزيادة بنسبة ٤,٦ و ٨,٦ و ١٢,٩٪ ٥,٧٢ و ١٠,٦٧ و ١٧,٨٢٪ في ظل RCPs 2.6 و ٤,٥ و ٨,٥ على التوالي. علاوة على ذلك ، أظهر هطول الأمطار المتوقع اتجاهًا سلبيًا بنسبة -٠,٢ و -١,٧ و -١,٩٪ في إطار RCPs 2.6 و ٤,٥ و ٨,٥ على التوالي. لذلك ، من المتوقع أن يزداد الطلب السنوي على مياه الري للمنطقة المدروسة من ١١٢,٠ متر مكعب / ثانية في الفترة المرجعية إلى ١١٥,٨ ، ١١٩,٧ ، ١٢٢,٩ متر مكعب / ثانية في إطار RCPs 2.6 و ٤,٥ و ٨,٥ على التوالي. أظهرت النتائج كذلك أن الطلب على مياه الري يجب أن يتم تكييفه من خلال تحسين كفاءة الري لموارد المياه المستدامة.

**الكلمات المفتاحية**: LARS-WG ، CROPWAT، الري ، التغيرات المناخية ، صلاح الدين

## Introduction

Water is a crucial role of agricultural production and its most important input (Fischer et al. 2007). Agriculture is the largest water demanded among human activities with almost 70% of surface and ground water consumed by irrigation processes (Barsukova, 2017). The irrigation water for crops is mainly dependent on climate conditions (Konzmann, Gerten, and Heinke 2013). Furthermore, climate change plays a crucial role in determining future needs of irrigation water (Gorguner and Kavvas ,2020). In arid and semi-arid regions, climate change is expected to put more pressure on water resources (Liwenga, 2008). Global climate models showed that global warming will accelerate with expected increase in surface air temperature by 2-6 ˚C (Cayan, et al., 2007).

Waha, et al., 2017 concluded that projected streamflow decrease by 15-45% and hot weather is expected to influence one-third of the Middle East area. Sowers et al., 2011 indicated that water supply in Iraq will be stressed by 2025 due to population growth and climate change. Awchi and Kalyana, 2017 showed that the north of Iraq was suffered from frequent drought events during the period from 1937 to 2010. Salman et al., 2020 found an increase in irrigation demand in Iraq during the last 50 years. Saeed et al., 2021concluded that irrigation water requirement is expected to increase due climate change in four irrigation projects located in Iraq.

Many researchers implemented Long Ashton Research Station-Weather Generator model (LARS-WG) to project climate variables such as precipitation (Pcp) minimum and maximum temperatures (Tmin and Tmax) with ability to project these variables to year 2100 under Coupled Model Intercomparison Project Phase 5 (CMIP5) and four Representative Concentration Pathways (RCP 2.6, RCP 4.5, RCP 6 and RCP 8.5) (Semenov and Barrow 2002a; Kaini et al. 2020). Tsakmakis et al., 2018; Moseki et al., 2019; Ewaid et al., 2019 successfully applied CROPWAT to calculate the irrigation water needs in arid and semi-arid regions in Iraq and other locations worldwide.

This paper aims to investigate the future climate by year 2080 including Tmin, Tmax and Pcp for Tikrit climate station under RCPs 2.6, 4.5 and 8.5 scenarios of greenhouse emissions. In addition, to evaluate the future irrigation water requirements for Salah-addin Province by year 2080 using climate data extracted from the climate model. For this purpose, the Tmin, Tmax and Pcp recorded in Tikrit climate station for the period from 1/1/1990 to 31/12/2019 were projected by LARS-WG to three future period 2021-2040 (P1), 2041-2060 (P2) and 2061-2080 (P3) and five General circulation Models (GCMs) named The Norwegian Earth System Model (NorESM1, Beijing Climate Centre Institute of Atmospheric Physics (BCC-CSM1), The Canadian Earth System-second generation Model (CanESM2), , Hadley Centre Global Environment Model-version 2 (HadGEM2-ES) and Australia's Commonwealth Scientific and Industrial Research Organization (CSIRO-MK36) these data were inserted into CROPWAT-8 model to calculate referenced evapotranspiration, net irrigation water requirement and required discharge for irrigated areas feed from Tigris, Adhaim and Lesser Zab Rivers.

## Research Methodology

## Study Area

Salah-addin Province is located in the middle of Iraq between the coordinates 43°14'37.27"E, 35°34'50.72"N and 44°15'4.73"E, 33°44'11.21"N. The province is located in arid region of Middle East with hot and dry summer and rainy and cold winter with average temperature in northern of Iraq ranged from 7-43 ˚C (Rasul, et al., 2015). Most of rainfall occurs during the month from November to May (Awchi and Kalyana ,2017).

The irrigated area fed from three sources namely Tigris River, with irrigated area of $186450\times10^3$ ha; Adhaim River, with irrigated area of $35100\times10^3$ ha and Lesser Zab River, with irrigated area of $42100\times10^3$ ha. The cultivated areas are conventionally planted by seasonal, annual crops and orchids. These crops include winter wheat, barley, autumn maize, spring maize, sunflower, sorghum, cotton, autumn potato, spring potato, tomato, alfalfa perennial, winter small vegetables, summer small vegetables, small grains, millet, soybean, table grapes, date palms and citrus (Japan International Cooperation Agency ,2016). Figure (1) shows the location map for Saladin Province.

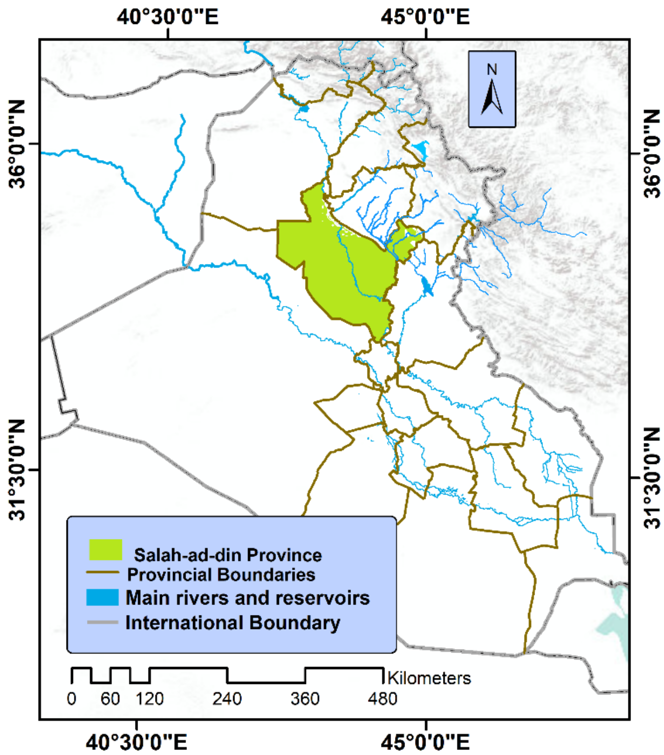


Figure 1: Location map of Salah-addin Province.

## Climate Model

LARS-WG is a statistical model developed for project Tmin, Tmax, Pcp and solar radiation based on observed data recorded in the reference period (RP). The model implements the semi-empirical distribution to measure the frequency of wet and dry days. The model is able to project climate variables under RCPs 2.6, 4.5, 6 and 8.5 until year 2100 considering Coupled Model Intercomparison Project Phase 5 (CMIP5) (Semenov and Barrow, 2002b).

## Irrigation Water Model

CROPWAT-8 is a model developed by FAO for calculation of ETo, ETc and NIWR for multi crops based on soil and weather data. The model predicts the referenced evapotranspiration ($ET_o$) using on Penman–Monteith method (Eq. 1) to predict ETo using Tmin, Tmax, wind speed, sunshine hours and relative humidity as input for required climate station (Allen, et al., 1998). CROPWAT 8 calculates the crop evapotranspiration (ETc) based on calculated $ET_o$ and Kc as shown in Eq. 2. The effective rainfall (Re) was predicted using USDA-soil conservation service equation (Eq. 3). Moreover, the Net Irrigation Water Requirement (NIWR) was predicted by subtract $R_e$ from ETc (Eq. 4). The Gross Irrigation Water Requirement (GIWR) calculated by Eq. 5 liter/second per one hectare based on NIWR, soil and crop pattern defined by user.

$$ET_0 = \frac{0.408\,\Delta\,(Rn-G) + \frac{900\,\gamma\,U_2(e_s-e_a)}{T+273}}{\Delta+\gamma(1+0.34\,U_2)} \tag{1}$$

Where: $ET_0$ is reference evapotranspiration in mm/day; Rn is net radiation at the crop surface in MJ.m²/day; G is soil heat flux density in MJ.m²/day; T is mean daily air temperature at 2 m height in °C; $U_2$ is wind speed at 2 m height in m/s; $e_s$ is mean Saturation vapor pressure in KPa; $e_a$ is actual vapor pressure in KPa; Δ is slope of saturation vapor pressure curve in KPa/°C and γ is psychrometric constant in KPa/°C.

$$ETc = ET_0 \times Kc \tag{2}$$

Where: ETc is crop evapotranspiration in mm/day,

and Kc is dimensionless Crop coefficient.

$$R_e = R\,\frac{(125-0.2\,R)}{125} \quad \text{for } R \leq 250 \text{ mm}$$

$$R_e = 125 + 0.1\,R \quad \text{for } R > 250 \text{ mm} \tag{3}$$

Where: $R_e$ is Re (mm) and R total rainfall (mm).

$$NIWR = ETc - R_e \tag{4}$$

Where: NIWR is net irrigation water requirement in mm.

$$GIWR = \frac{NIWR+Lr}{Ea} \times 100 \tag{5}$$

Where: GIWR is gross irrigation water requirement in mm, Ea is a fraction of application efficiency and Lr is leaching requirement in mm which is predicted using the following; $Lr = f \times NIWR$, and f is in the range from 5-12 % according to available soil salinity (Rai, et al., 2017).

## Results and Discussions

It can be noticed from Figure (2) that lowest Tmin recorded in in the RP for Tikrit station was in January with 4.8 ˚C and highest Tmax was found in July with 45.1 ˚C. Furthermore, the minimum and maximum ETo was found in January and July with 62.7 and 390.6 mm, respectively, and the annual ETo reach 2612.7 mm/year. The highest rate of Pcp for RP in Tikrit station recorded in January with 32.1 mm and almost zero for months from June to September. The annual Pcp reach 155.3 mm/year.

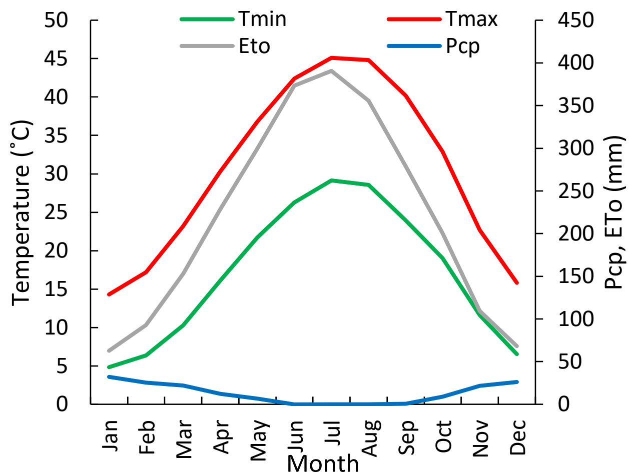


Figure 2: Recorded Tmin, Tmax, Eto and Pcp in RP for Tikrit station.

The projected Tmin shown in Figure (3) indicated a significant increase in Tmin. Under RCP 2.6 the highest increase can be observed in March with 11.25, 14.56 and 16.21% for P1, P2 and P3, respectively. Whereas, the lower increase in Tmin was found in August with 2.32, 4.91 and 3.4 for P1, P2 and P3, respectively. Under RCP 4.5, the highest increase Tmin was found in March and reach to 11.16, 17.08 and 20.06% for P1, P2 and P3, respectively, while, the lower increase Tmin was found in August with 2.96, 6.52 and 7.94% for P1, P2 and P3, respectively. Under RCP 8.5 and P1, the highest increase in Tmin was found in March with 13.1% while, for P2 and P3 the increase in Tmin was found in January with 26.27 and 51.11%, respectively. Moreover, the lower increase in Tmin under this scenario was found in August with 3.62, 8.52 and 13.42% for P1, P2 and P3, respectively.

Figure ( 4 ) shows the percentage of increase for Tmax. Under RCP 2.6, the highest increase in Tmax can be observed in January with 5.4, 8.2 and 8.3% for P1, P2 and P3, respectively. Whereas, the lowest increase in Tmax was found in May for P1 and P2 with 1.3 and 2.2%, respectively, and in June for P3 with 2%. Under RCP 4.5 the highest increase in Tmax was observed in January and could reach 6, 11.2 and 16.1% for P1, P2 and P3, respectively. While, the lowest increase for this scenario for P1 and P2 was found in June with 2.1 and 3.8%, respectively, and in May for P3 with 5.4%. Under RCP 8.5, the figure shows the highest increase in Tmax for P1 with 6.4% in February and 13.3% and in January with 21.7% for P2 and P3, respectively. Whereas, the lowest increase for P1 was found in May with 2.4%, for P2 this increase was found 5% (in April) and for P3 the lowest increase was found in June with 8%.

Figure (5) shows the future trend in projected ETo. Under RCP 2.6, the highest rate of increase was found 3.8, 5.2 (both in November) and 5.9 (in March) for P1, P2 and P3, respectively. Whereas, the lowest increase in ETo was found in June with 1, 1.8 and 1.5% for P1, P2 and P3, respectively. Under RCP 4.5, the highest increase in ETo was 4.1, 6.8 (both in November) and 9.6% (in January) for P1, P2 and P3, respectively, while the lowest increase was found in June with 1.5, 2.7 and 4.2% for P1, P2 and P3, respectively. Under RCP 8.5, the highest increase in ETo could reach 3.8 (in January), 8.5 and 13.7% (both in November) for P1, P2 and P3, respectively. Whereas, the lowest increase was found in June with 1.6, 4.1 and 6% for P1, P2 and P3, respectively.

From the above results it can be found that Tmin, Tmax consequently ETo tend to increase in winter months more than summer months due to climate change impact. These results agree with Zhang, et al., 2005 who analyzed the trend in temperature for (Middle East and North Africa) MENA during the period from 1950 to2003, results illustrated that the variability of temperature in winter is much higher than summer.

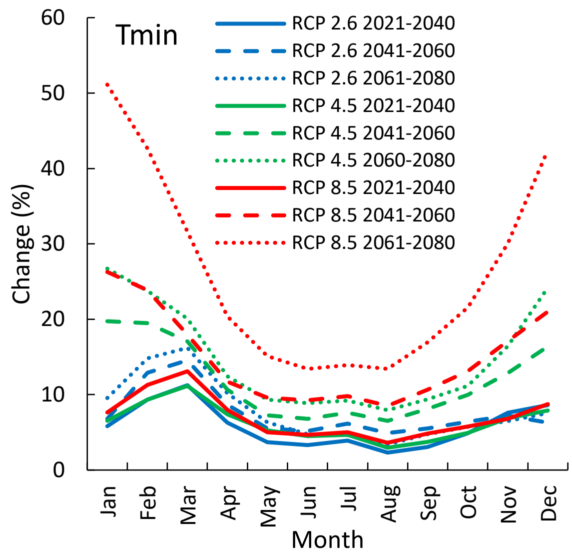


Figure 3: Future trend in Tmin.

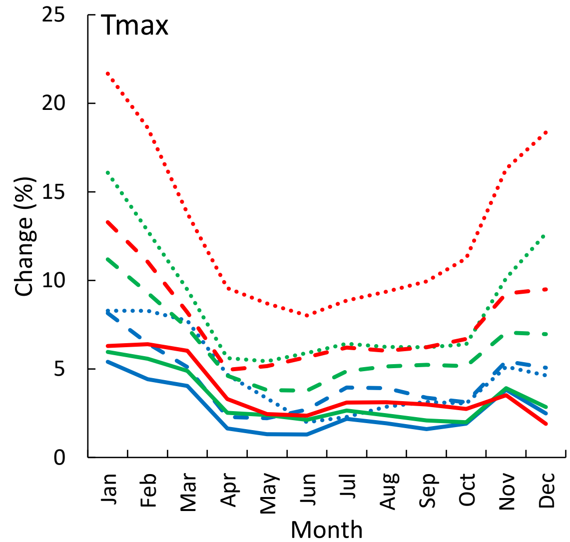


Figure 4: Future trend in Tmax.

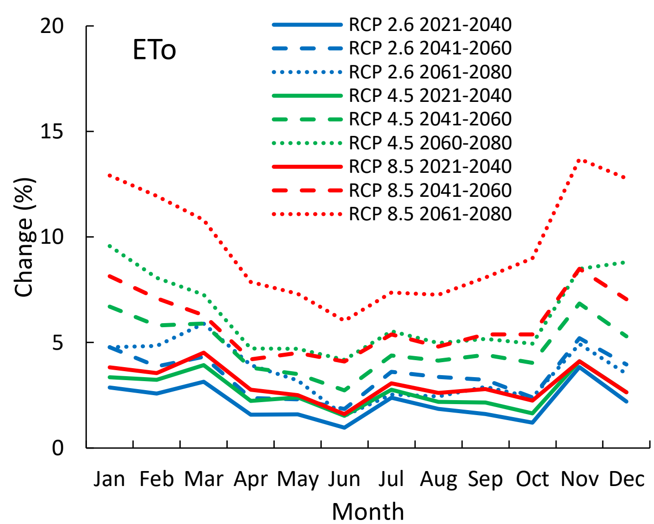


Figure 5: Future trend in ETo.

Figure (6) shows, in general, a negative trend in expected Pcp for Tikrit Station. Under RCP 2.6, the highest decrease in Pcp could reach 2.2, 2.5 (both in December) and 3.7% (in January) for P1, P2 and P3, respectively. Furthermore, under RCP 4.5, the highest negative trend was found 3.1, 3 (both in January) and 4.9% (in December) for P1, P2 and P3, respectively. More decreases in future Pcp can be found under RCP 8.5 with the highest rate of decline of 2.2 (in December), 3 (in January) and 6.3% (December) for P1, P2 and P3, respectively.

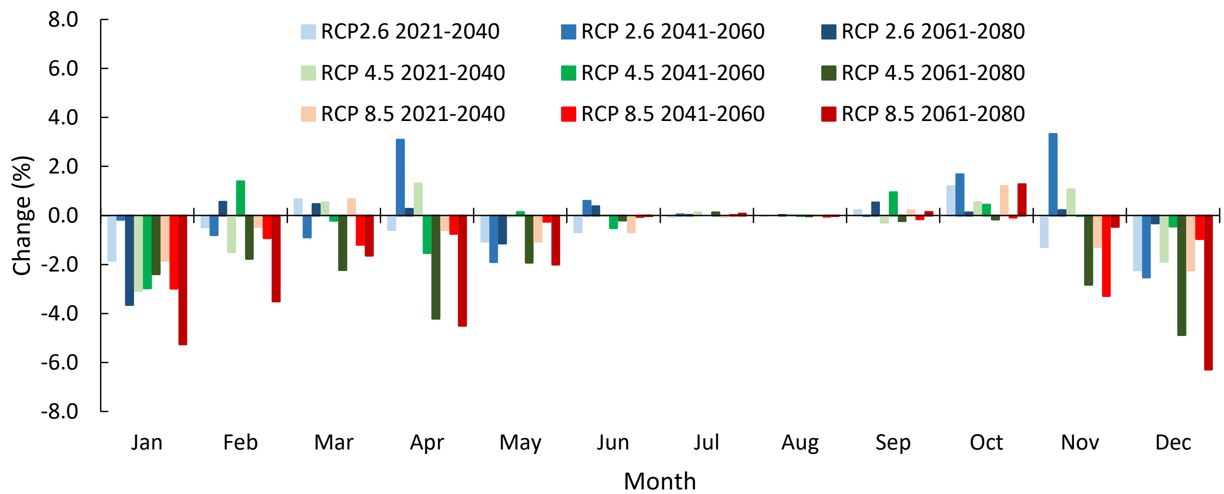


Figure 6: Future trend in Pcp.

Results of projected discharge required for agriculture indicated a positive trend in all scenarios and future periods. No change can be observed in the months of maximum and minimum demand for all areas irrigated from Tigris, Adhaim and Lesser Zab Rivers. In other words, under climate change conditions the maximum irrigation demand occurs in May and the minimum irrigation demand occurs in January.

Figure (7) shows irrigation demand for areas supplied from Tigris River. The maximum (minimum) demand in RP for these areas was found in May (January) with 167.1 (13.1) $m^3$/s. Under RCP 2.6, this maximum (minimum) demand increases to reach 169.7 (14.4), 171(14.4) and 172.3 (15.7) $m^3$/s for P1, P2 and P3, respectively. In the same context, under RCP 4.5, the maximum (minimum) irrigation water demand is expected to increase 169.7 (15.7), 172.3 (15.7 and 174.9 (17) $m^3$/s for P1, P2 and P3, respectively. Whereas, under RCP 8.5, the maximum (minimum) irrigation demand tends to increase to 171 (14.4) 171 (15.7) and 178.8 (19.9) $m^3$/s for P1, P2 and P3, respectively.

For irrigated areas feed from Adhaim River, Figure (8) shows that in the RP the maximum (minimum) irrigation demand occurs in May (January) with 31.4 (2.5) $m^3$/s, this amount tend to increase under RCP 2.6 with 31.9 (2.7), 32.2 (2.7) and 32.4 (2.9) $m^3$/s for P1, P2 and P3, respectively. Moreover, under RCP 4.5, the maximum (minimum) irrigation demand could reach 31.9 (2.9), 32.4 (2.9) and 32.9 (3.2) $m^3/s$ for P1, P2 and P3, respectively. Under RCP 8.5, the maximum (minimum) irrigation demand is expected to increase with 32.2 (2.7), 32.2 (2.9) and 33.7 (3.7) $m^3/s$ for P1, P2 and P3, respectively.

The irrigation demand for areas supplied from Lesser Zab River, Figure (9) shows that maximum (minimum) irrigation demand was 37.7 (2.9) $m^3/s$, this demand tend to increase to 38.3 (3.2), 38.6 (3.2) and 38.9 (3.5) $m^3/s$ for P1, P2 and P3, respectively. Furthermore, under RCP 4.5, the maximum (minimum) irrigation demand is expected to increase to 38.3 (3.5), 38.3 (3.5) and 39.5 (3.8) $m^3/s$ for P1, P2 and P3, respectively. Under RCP 8.5, the maximum (minimum) irrigation demand tends to increase by 38.6 (3.2), 38.6 (3.5) and 40.4 (4.4) $m^3/s$ for P1, P2 and P3, respectively.

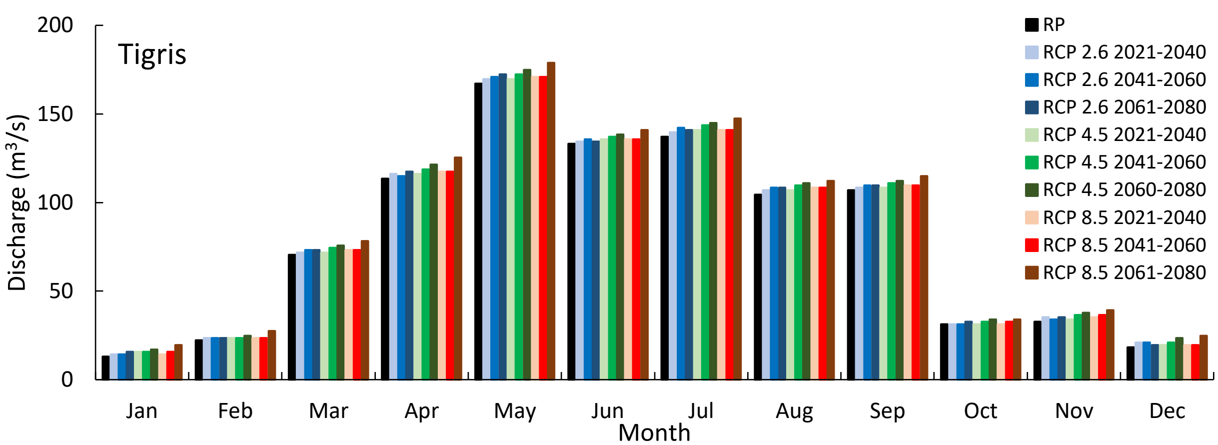


Figure 7: Future trend in irrigation water demand from Tigris River.

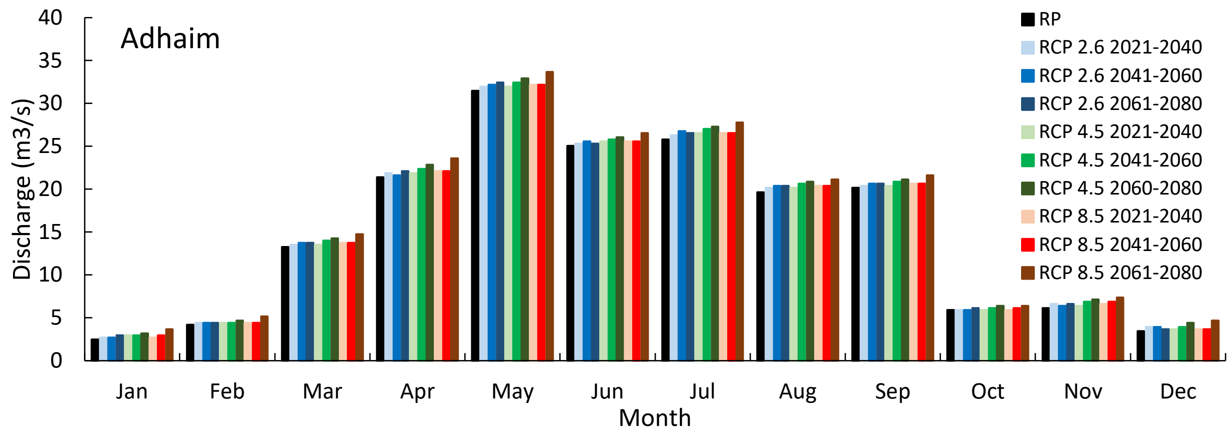


Figure 8: Future trend in irrigation water demand from Adhaim River.

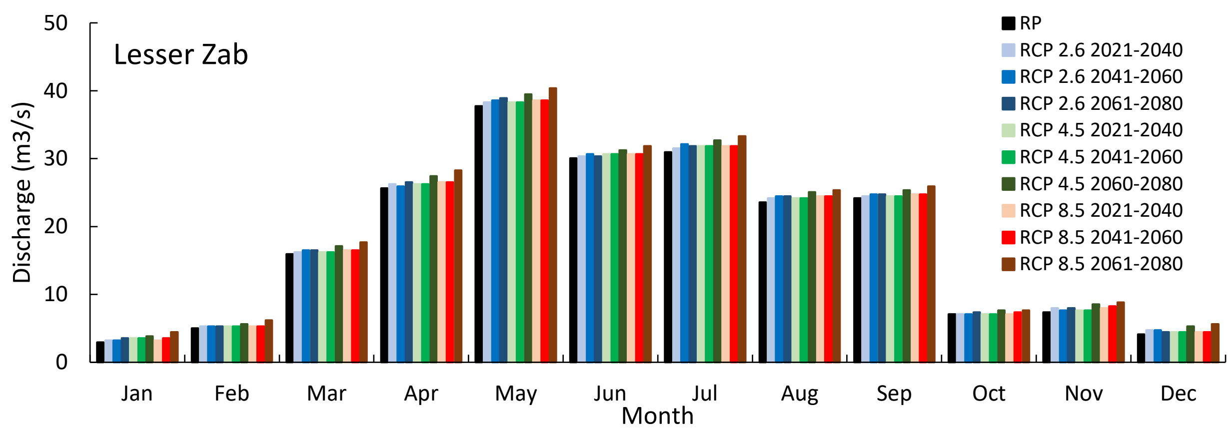


Figure 9: Future trend in irrigation water demand from Lesser Zab River.

## Conclusions

In this paper, the future irrigation water demand for Saladin Province was investigated under three scenarios of greenhouse emissions, namely RCP 2.6, RCP 4.5 and RCP 8.5 and five GCMs. Using LARS-WG model the recorded Tmin, Tmax and Pcp for Tikrit climate station during 1990-2019, which considered as a reference period (RP), were projected into 2080 by 20 years of time steps starting from 2021 (P1, P2 and P3). The climate data for RP, P1, P2 and P3 were inserted into CROPWAT-8 to simulate the current and future ETo, ETc and NIWR for 19 crops traditionally cultivated in study area.

From the results, it can be concluded that the climate of Salah-addin Province tends to become drier and hotter due to increases in Tmax and Tmin, consequently increase of ETo. In general, the projected Pcp is expected to decrease with small increase under RCP 2.6 and P2. Due to these warming conditions, the irrigation water demand is expected to increase which mean more pressure on water supplies (Tigris, Adhaim and Lesser Zab River). The worst scenario is expected under RCP 8.5 with increase in irrigation water by 10% compared with the demand in RP. In parallel of this increase in irrigation demand there is many studies showed that available water tend to decrease.

Results of this paper reflects the situation in all irrigated areas in Iraq. Therefore, it is highly recommended to adapt these conditions by increasing the irrigation efficiency, changing crop patterns, lining irrigation channels, applying deficit irrigation and improving of planting process such as selecting more productive crops and crops of lower water needs. This adaptation process could treat, to some extent, the expected decrease of water supplies and population growth for sustainable water resources.

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## References

Allen, Richard G., PEREIRA, Luis S., RAES, Dirk and SMITH, Martin. (1998). "FAO Irrigation and Drainage Paper Crop By." *Irrigation and Drainage* 300(56): 300. http://www.kimberly.uidaho.edu/water/fao56/fao56.pdf.

Awchi, Taymoor A., and Maad M. Kalyana. (2017). "Meteorological Drought Analysis in Northern Iraq Using SPI and GIS." *Sustainable Water Resources Management* 3(4): 451–63.

Barsukova, Svetlana. (2017). Russia: Strategy, Policy and Administration *Food and Agriculture*.

Cayan, Daniel R. et al. 2007. "Climate Change Scenarios for the California Region." *Climatic Change* 87(1 SUPPL): 21–42.

Ewaid, Salam Hussein, Salwan Ali Abed, and Nadhir Al-Ansari. (2019). “Crop Water Requirements and Irrigation Schedules for Some Major Crops in Southern Iraq.” *Water (Switzerland)* 11(4).

Fischer, Günther, Francesco N. Tubiello, Harrij van Velthuizen, and David A. Wiberg. (2007). “Climate Change Impacts on Irrigation Water Requirements: Effects of Mitigation, 1990-2080.” *Technological Forecasting and Social Change* 74(7): 1083–1107.

Gorguner, Merve, and M. Levent Kavvas. (2020). “Modeling Impacts of Future Climate Change on Reservoir Storages and Irrigation Water Demands in a Mediterranean Basin.” *Science of the Total Environment* 748: 141246. https://doi.org/10.1016/j.scitotenv.2020.141246.

Japan International Cooperation Agency, JICA. (2016). “Data Collection Survey on Water Resource Management and Agriculture Irrigation in the Republic of Iraq.” (April): 125.

Kaini, Santosh ,et al.( 2020). “Impacts of Climate Change on the Flow of the Transboundary Koshi River, with Implications for Local Irrigation.” *International Journal of Water Resources Development* 00(00): 1–26. https://doi.org/10.1080/07900627.2020.1826292.

Konzmann, Markus, Dieter Gerten, and Jens Heinke. (2013). “Impacts Climatiques Selon 19 MCG Sur Les Besoins Globaux En Irrigation Simulés Par Un Modèle d’hydrologie et de Végétation.” *Hydrological Sciences Journal* 58(1): 88–105.

Liwenga, Emma T. (2008). “Adaptive Livelihood Strategies for Coping with Water Scarcity in the Drylands of Central Tanzania.” *Physics and Chemistry of the Earth* 33(8–13): 775–79.

Moseki, Ofentse, Michael Murray-Hudson, and Keotshephile Kashe. (2019). “Crop Water and Irrigation Requirements of Jatropha Curcas L. in Semi-Arid Conditions of Botswana: Applying the CROPWAT Model.” *Agricultural Water Management* 225(August): 105754. https://doi.org/10.1016/j.agwat.2019.105754.

Rasul, Azad, Heiko Balzter, and Claire Smith. (2015). “Spatial Variation of the Daytime Surface Urban Cool Island during the Dry Season in Erbil, Iraqi Kurdistan, from Landsat 8.” *Urban Climate* 14: 176–86. http://dx.doi.org/10.1016/j.uclim.2015.09.001.

Saeed, Fouad H, and Mahmoud S and Furat A. Mahmood Al-Faraj Al-khafaji. (2021). “Sensitivity of Irrigation Water Requirement to Climate Change in Arid and Semi-Arid Regions towards

Sustainable Management of Water Resources."

Salman, Saleem A. et al.( 2020). Changes in Climatic Water Availability and Crop Water Demand for Iraq Region. *Sustainability (Switzerland)* 12(8): 14–27.

Semenov, Mikhail A., and Elaine M Barrow. (2002a.) LARS-WG: A Stochastic Weather Generator for Use in Climate Impact Studies Version 3. User Manual. *User Manual, Hertfordshire, UK* (January 2002): 27.

Semenov and Barrow (2002b). LARS-WG: A Stochastic Weather Generator for Use in Climate Impact Studies Version 3. User Manual. *User Manual, Hertfordshire, UK* (August): 27.

Sowers, Jeannie, Avner Vengosh, and Erika Weinthal. (2011). Climate Change, Water Resources, and the Politics of Adaptation in the Middle East and North Africa. *Climatic Change* 104(3–4): 599–627.

Tsakmakis, Ioannis D, Maria Zoidou, Georgios D Gikas, and Georgios K Sylaios. (2018). Impact of Irrigation Technologies and Strategies on Cotton Water Footprint Using AquaCrop and CROPWAT Models.

Waha, Katharina et al. (2017). Climate Change Impacts in the Middle East and Northern Africa (MENA) Region and Their Implications for Vulnerable Population Groups. *Regional Environmental Change* 17(6): 1623–38.

Zhang, Xuebin et al. (2005). Trends in Middle East Climate Extreme Indices from 1950 to 2003. *Journal of Geophysical Research Atmospheres* 110(22): 1–12.