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تأثيرات التغيرات المناخية على ري المحاصيل المستقبلية في ليبيا

دراسة حالة لمنطقة سوف الجين

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Effects Climatic Changes on Crops Irrigation in Future for Libya

A Case Study of SOFULJEEN Region.

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الملخص:

في هذه الدراسة نبحث عن كيف يؤثر تغير المناخ على الطلب على المياه لأهم ثلاث محاصيل غذائية في منطقة سوف الجين : (القمح والطماطم والبطاطس). من خلال معرفة كيفية تأثير تغير المناخ على متطلبات الري المستقبلية في منطقة سوف الجين باستخدام السيناريوهات SSP2-4.5 و .SSP5-8.5تم استخدام بيانات الأعوام 2020 - 2040 - 2060 - 2080 و2100 لتحديد أنماط درجة الحرارة وهطول الأمطار في منطقة الدراسة، وتم استخدام نموذج CROPWAT 8.0لتقدير التبخر النتح المرجعي (ETo) وصافي متطلبات مياه الري (NIWR) للمحاصيل الثلاثة الرئيسية القمح والطماطم والبطاطس، بناءً على الظروف المناخية المتوقعة. تم حساب خمسة سيناريوهات مختلفة لاحتياجات الري المستقبلية للمحاصيل الثلاثة، مقارنة بالحالة الحالية (2020)، مع 2100 ثانية تحت SSP2-4.5 وSSP5-8.5، وأظهرت النتائج أن نسبة الزيادة القصوى لدرجات الحرارة في عام 2100 ستكون 9.84%. وأعلى بنسبة 18.70٪ عما كانت عليه في عام 2020 الحالي. وفي منطقة سوف الجين ، من المتوقع أن تكون الزيادات الكبيرة في درجات الحرارة على المدى القصير والطويل. ونتيجة لذلك، ستكون هناك زيادات في التبخر والنتح المرجعي(ETo) ، وفقًا لسيناريو SSP2-4.5 و SSP5-8.5لسيناريوهات 2040-2100. ويتوقع متوسط التبخر السنوي زيادات في التبخر والنتح بمقدار 0.9 ملم/يوم (13.27%) و1.59 ملم/يوم (23.45%) على التوالي. تم تقييم صافي متطلبات مياه الري (NIWR) و متطلبات مياه الري (GIWR) مليون متر مكعب (القمح والطماطم والبطاطس) في منطقة سوف الجين للسيناريوهات الحالية SSP2-4.5 و .SSP5-8.5بالنسبة للسيناريو SSP5-8.5 ، من المتوقع أن يرتفع معدل (NIWR) (مليون متر مكعب) في القرن الحادي والعشرين للمحاصيل الثلاثة (القمح والطماطم والبطاطس)، 7191.24، 3383.39 و1702.26 على التوالي، مقارنة بالسيناريو الحالي (2020) (6050.94، 2457.94). و1287.09 مليون م^3) للمحاصيل الثلاثة السابقة.

الكلمات المفتاحية: التغيرات المناخية ،المحاصيل ،الري، سيناريوهات SSP2-4.5 وSSP5-8.5 ،SOFULJEEN.

Abstract:
This research presents how climate change affects the water demands of SOFULJEEN Region most important food crops: three (wheat, tomato and potato) study examines how climate change may impact future irrigation requirements in SOFULJEEN Region using the SSP2-4.5 and SSP5-8.5 scenarios. for 2020s–2040s-2060s-2080s and 2100s were used to determine the patterns of temperature and rainfall in study area, The CROPWAT 8.0 model was employed to estimate reference evapotranspiration) ETo) and net irrigation water requirement (NIWR) for the key three crops wheat tomato S and potatoes, based on the predicted climate conditions. Five different scenarios for the three crops' future irrigation needs were calculated, compared to the current case (2020), with 2100s by under SSP2-4.5 and SSP5-8.5,The results displayed that the maximum temperatures increase ratio in 2100 will be 9.84% and 18.70% higher than in the current 2020. In SOFULJEEN Region that both short and long-term temperature increases are anticipated to be considerable. As a result, there will be reference evapotranspiration (ETo) increases, According to the SSP2-4.5 and SSP5-8.5 for the 2040-2100.scenarios forecast annual average ETo increases of 0.9 mm/day (13.27%) and 1.59 mm/day (23.45%), respectively. Net irrigation water requirement (NIWR) and growth of irrigation water requirement (GIWR) million m3 (wheat, tomato s and potato) in SOFULJEEN Region were assessed for the current, SSP2-4.5, and SSP5-8.5 scenarios. For SSP5-8.5 the (NIWR) (million m3)are expected for the 2100s to increase for crops three(wheat, tomato s and potato), 7191.24, 3383.39 and 1702.26 respectively, compared to the current (2020)scenario (6050.94 , 2457.94 and 1287.09 million m3) for three crops Previous.

Keywords: Climatic Changes, Crops, Irrigation, SSP2-4.5, SSP5-8.5 scenarios and SOFULJEEN**.**

INTRODUCTION

Libya is generally an arid to semi-arid country, which has led to a shortage of agricultural land [1]. about 80% of the country is comprised of desert and semi-desert regions, which are distinguished by scarce surface water supplies, little rainfall. The majority of the northeastern regions, including Jabal Akhdar, the northwesterly Nafusa Mountains and Jafara Plain, receive the greatest rainfall. There is pressure to extract groundwater, the primary source of water use, of which the agricultural sector uses roughly 80% due to low rainfall rates and limited surface water resources, [2]. As evapotranspiration is the water cycle's second-largest flow, any changes would have an effect on the entire water cycle. [3] Storm activity in the eastern Mediterranean basin is increasing, affecting populated urban coastal areas that were not previously vulnerable to catastrophic flooding. On September 10, 2023, Storm Daniel made landfall on Libya's northeast coast. It brought with it severe winds of 120 km/h and up to 240 mm of precipitation over the course of 25 hours (up to 414 millimeters in Al-Bayda). The precipitation observed during the storm landfall is nearly equal to the yearly average of 270 mm yr^{-1} for this region. This resulted in unparalleled flash floods, resulting in a significant number of fatalities and extensive damage to infrastructure. by destroying essential topsoil for 4.6% of the agricultural area and ruining harvests on 16209 ha. Furthermore, 74363 animals died, making up 3.2% of the livestock strategic reserve in the area. Three categories of damage severity can be distinguished within the flooded area of Derna: severe, moderate, and low. In particular, 29% of the surface area has moderate damages, 27% has low damages, and 36.5% has significant damages. Amazingly, 7.5% of the component is still intact. Currently, we discover that 14% of Susah's surface area exhibits high damages, 34% exhibits moderate damages, 39% indicates minor damages, and 13% is unaffected. [4].

The overall greenhouse gas emissions (GHGE) of Libya accounted for 130.60 $MtCO_2e$ of global GHG emissions in 2012, or 0.28% of total emissions. According to a sector-by-sector analysis of Libya's GHG emissions, exports and production—rather than local demand—drive emissions. The great bulk of Libya's greenhouse gas emissions are caused by the energy industry. It accounted for almost 95% of total emissions in 1990 and 2012. The production of natural gas and crude oil accounts for the majority of these emissions (64% in 2012). transportation, manufacturing, and power production account for 34% of greenhouse gas emissions. Only 6.1 $MtCO_2e$, or 5%, of Libya's total emissions come from non-energy sectors; 48% of these emissions come from agriculture. Within the energy industry, the most significant increases occurred in absconder emissions and emissions from transportation between 1990 and 2012. The 1990–2012 transportation emissions increased from 6.12 $MtCO_2e$ to 16.59 $MtCO_2e$, while the fugitive emissions increased from 63.73 $MtCO_2e$ to 81.67 $MtCO_2e$. [5]. in places where there is a shortage of water, climate change may make things worse while creating new opportunities elsewhere. It is necessary to establish adaptation strategies for agricultural water management that capitalize on the identification of these concerns and Iglesias and Garrote [6].According to Ritchie and Roser [7], Among the most urgent problems facing the globe now is climate change. Because of greenhouse gas emissions created by humans, the global temperature has increased by about 1°C since pre-industrial times. Methane (CH4), carbon dioxide (CO2), and other gases are among them. Globally, CO2 emissions exceed 36 billion tons annually, and atmospheric CO2 concentrations are continuously higher than 400 parts per million. This is 800,000 years' greatest level. China already emits 25% more CO2 than the US does globally, overtaking the US in this regard. According to Kaini et al. [8], examined the limitations of earlier studies on the selection of global climate models (GCMs) and strategies for advancing the field's understanding of climate. They continued by saying that when assessing the consequences of climate change on different industries, choosing GCMs with high competency to reflect the past and forecast the future climate for a particular place is a crucial first step. It is anticipated that the annual average temperature will rise, although more quickly in the winter than in the monsoon season, according to the data. Schilling et al. [9], examined and contrasted the socioeconomic effects of climate change and vulnerability in Egypt, Algeria, Tunisia, Morocco, and Libya. The findings demonstrate that all countries are vulnerable to significant temperature increases and a high risk of droughts as a result of climate change. Climate change and the region's explosive population increase will continue to further exacerbate the already dangerous water situation in North Africa. It is expected to impact agriculture more in the years to come because of changes in the amount, intensity, and distribution of precipitation as well as changes in soil moisture content, water vapor content, and temperature, all of which will eventually increase evapotranspiration. This will have a major effect on the quantity of irrigation water required, particularly in semi-arid regions, [10, 11,12]. Climate change has been having a significant impact on the Middle East. to more adequately prepare their communities to withstand its shocks, policymakers must abandon top-down paradigms and incorporate a greater portion of the public in climate adaptation [13]. According to Schwartz [14], Because of the rise in carbon dioxide levels, experts predict that temperatures will climb by 1.5 to 4.5 °C in the next 40 years, tripling since preindustrial times. the temperature range has now been reduced by a team of experts to between 2.6 and 4.1 °C. According to the (W. M. O) [15], the globally average temperature in July 2023–June 2024 is 1.64°C higher than the pre-industrial average for 1850s–1900s, as will as in July and August of 2023 and 2024; the world's temperature exceeded all previous records.

This study also shows an increase in summertime temperatures and the number of hot days that occur each year, most likely as a result of a combination of rising summertime temperatures and decreasing summertime precipitation. El-Rawy, M et al. [16] in this analysis, the SSP5-8.5 scenario outperformed the SSP2-4.5 scenario in all climate change evaluation items. In the middle decades (2060s and 2080s), the annual rainfall (mm/year) fell marginally by 2.11% and 2.43% under SSP5-8.5, and by 2.48% and 1.06% under SSP2-4.5. These results indicated an increase in all scenarios. This decrease in rainfall is beneficial for crop development and raises the rate of evapotranspiration. As a result, the mean daily ETo foresaw a very modest decline from the current period in the future roughly -0.66% and -0.48% for SSP2-4.5 and SSP5-8.5, respectively. The results also demonstrated that, in the anticipated climate change scenario, crop production would significantly decline and GIWR would rise in the crop areas of dates, wheat, clover, and other crops.

Penman–Monteith [17], one of the methods commonly used to determine ETo is one that was proposed as an internationally recognized method for identifying and quantifying reference crop evapotranspiration. Several studies have used the Penman-Monteith-FAO system to examine the spatial dispersion of the measured ETo. However, different approaches to calculating ETo were used. [18,19,20]. Water management professionals globally use the Smith [21]-created CROPWAT 8.0 simulations, which are also based on the Penman-Monteith approach.

The objectives of this research examined the predicted detrimental effects of climate change on SOFULJEEN, one of Libya's most significant agricultural regions, using five different climate models. The average yearly temperature in the years 2040, 2060, 2080, and 2100. It's also critical to predict how climate change will affect the amount of irrigation water needed for the primary crops grown in Sofuljeen. The FAO CROPWAT 8.0 model was used to determine the ETo and net irrigation water requirement (NIWR) for the most significant cultivated crops.

As a way to reach these objectives, (1) I collected soil, wheat, tomato, and potato data for the current SOFULJEEN climate. (2) Change in temperature and precipitation data (current period) to simulate the climate in the years 2040, 2060, 2080, and 2100 using SSP2-4.5 and SSP5-8.5. (3) Based on soil, climate, and crop data, the CROPWAT 8.0 model was used to calculate crop water requirements and irrigation needs. (4) Studying multiple changes can help with future modeling for predicted climate conditions as well as irrigation strategies

2. Materials and methods:

2.1. Study Area Description

In Libya, the SOFULJEEN area is located coordinates at 31˚, 56’N latitude and 14˚, 46’E longitude, in Bani Walid city. Bani Walid is a city in Libya with a inhabitants and an area of 19710 km2, Bani Walid is located 123000population of in Northwest Libya in the Misurata District and has borders with Tarhuna and Msalata municipalities in North, Misratah in Northeast, Surt in the East, Mizdah in West and Gharyan in Northwest respectively (Figure1). Sofuljeen's agriculture predominantly depends on groundwater irrigation; however, the production of crops is severely constrained by scarce renewable water resources, unfavorable weather patterns, and poor soil. The average monthly temperature of Sofuljeen, which is dry, ranges from 5°C in the winter to 41°C in the summer. Based on a daily evapotranspiration rate of 6.5 mm, the yearly average rainfall is around 58 mm. The average wind speed is 3.88 to 5.07 m/s, and the humidity ranges from a minimum of 40.6% in the dry months to as high as 52% in the winter. [22]

With a cultivated area of 695 ha, the three main crops cultivated in the Sofuljeen area are wheat, tomatoes, and potatoes. This study determines the net irrigation water requirements (NIWR) and gross irrigation water requirements (GIWR) for the three main crops cultivated in Sofuljeen: wheat, tomato, and potato. Sprinkler and drip irrigation systems can be used Particle size distribution assigns the soil in the Sofuljeen-cultivated area to the soil textural class sandy loam. The soil's initial available moisture (FC-WP) is 140 mm/meter, its total available moisture (as% TAM) is 0%, its maximum rooting depth is 900 cm, and its maximum rate of rain infiltration is 30 mm/day. Summarizes the sofuljeen crop planting and harvesting dates: potatoes, wheat, and tomatoes planting dates are November 1, June 1, and September 1, in that order. Three harvests will be on June 28, October 23, and January 8, correspondingly.

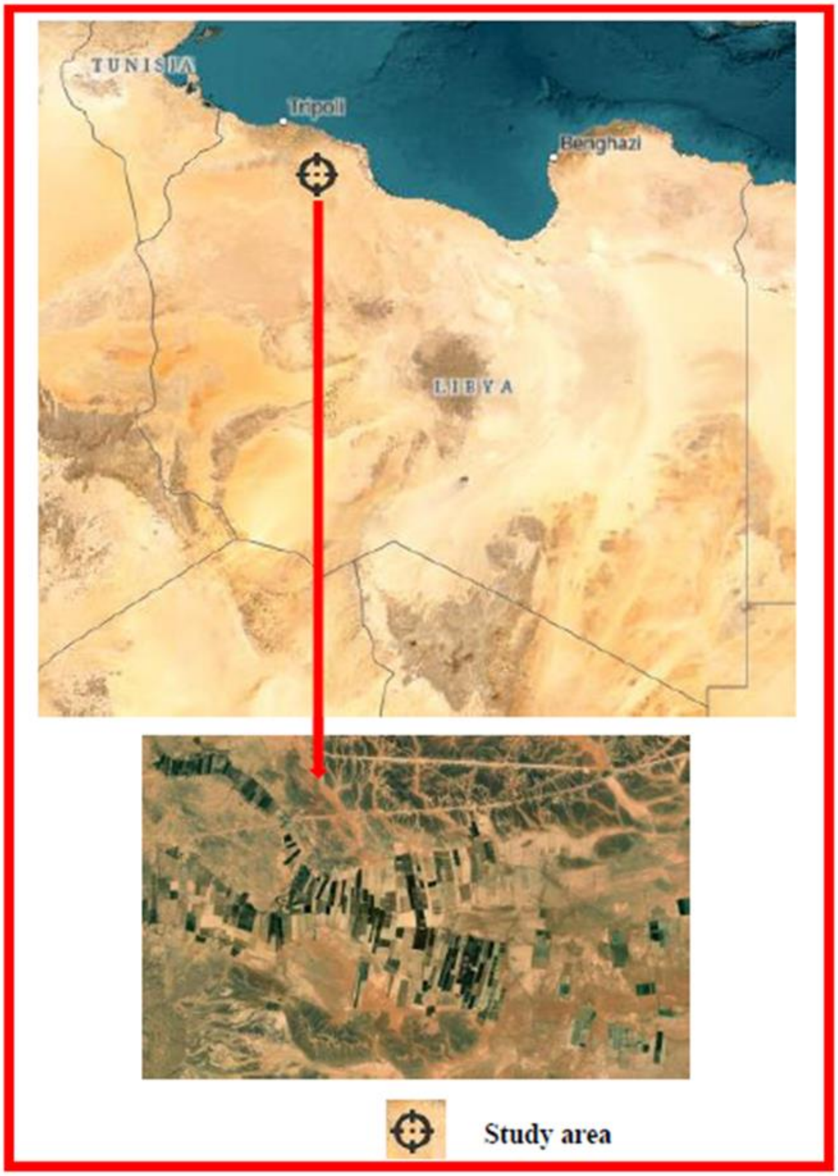


Figure 1. The study area sofuljeen

2.2. Climate Data

The database climateknowledgeportal.worldbank.org. provided the future climate data for the Sofuljeen area for the years 2040, 2060, 2080, and 2100 temperature (maximum, minimum) and rainfall for the four years under the SSP2-4.5 and SSP5-8.5 emission scenarios. Historical climatic data for the country of Libya accessed July 1, 2024. The temperature and rainfall data for the years 1990–2020 were collected at Sofuljeen Altitude, which is located at 177 m latitude (31.56° N) and 14.46° E longitude. As seen in Fig. 2, climate stations and average data were calculated to reflect Sofuljeen. To be employed in the Cropwat 8 model, additional climate data for the Sofuljeen area were gathered, including relative humidity, wind speed, sunlight, and solar radiation, for the years 1990–2020 (Table 1).

Table 1 shows the Sofuljeen climate data for relative humidity, wind speed, sunshine, and solar radiation from (1991–2020) current.(Libyan Meteorological Center).

Month	Humidity	Wind	Sun	Rad
	%	km/day	hours	MJ/m²/day
January	56	372	8.1	13.2
February	51	389	8.6	16.1
March	44	406	9.8	20.6
April	39	432	11.1	25
May	38	406	12	27.6
June	36	380	12.4	28.6
July	38	363	12.3	28.1
August	43	337	11.5	25.9
September	48	363	10.5	22.3
October	49	328	9.7	18.2
November	51	380	8.8	14.4
December	56	415	8	12.3
Average	46	381	10.2	21

2.3. CROPWAT 8 program

The FAO's decision-support computer tool CROPWAT 8.0 calculates ETo, crop net irrigation water requirements, and irrigation schedules using data on soil, crops, rainfall, and climate. The USDA soil conservation approach was utilized to calculate the reference evapotranspiration (ETo), and Penman Montieth's 1998 method was employed to calculate the effective rainfall.. [23,18] . Fig. 2 displays the flow chart used to simulate the amount of water needed for crop irrigation. The main component utilized to calculate crop evapotranspiration (ETc) was ETo. [12,24]. Under normal conditions (unrestricted crop growth, sufficient water availability, and crops free of pests and diseases), ETc was estimated as the value of ETo and crop coefficient (*K*c) [25].

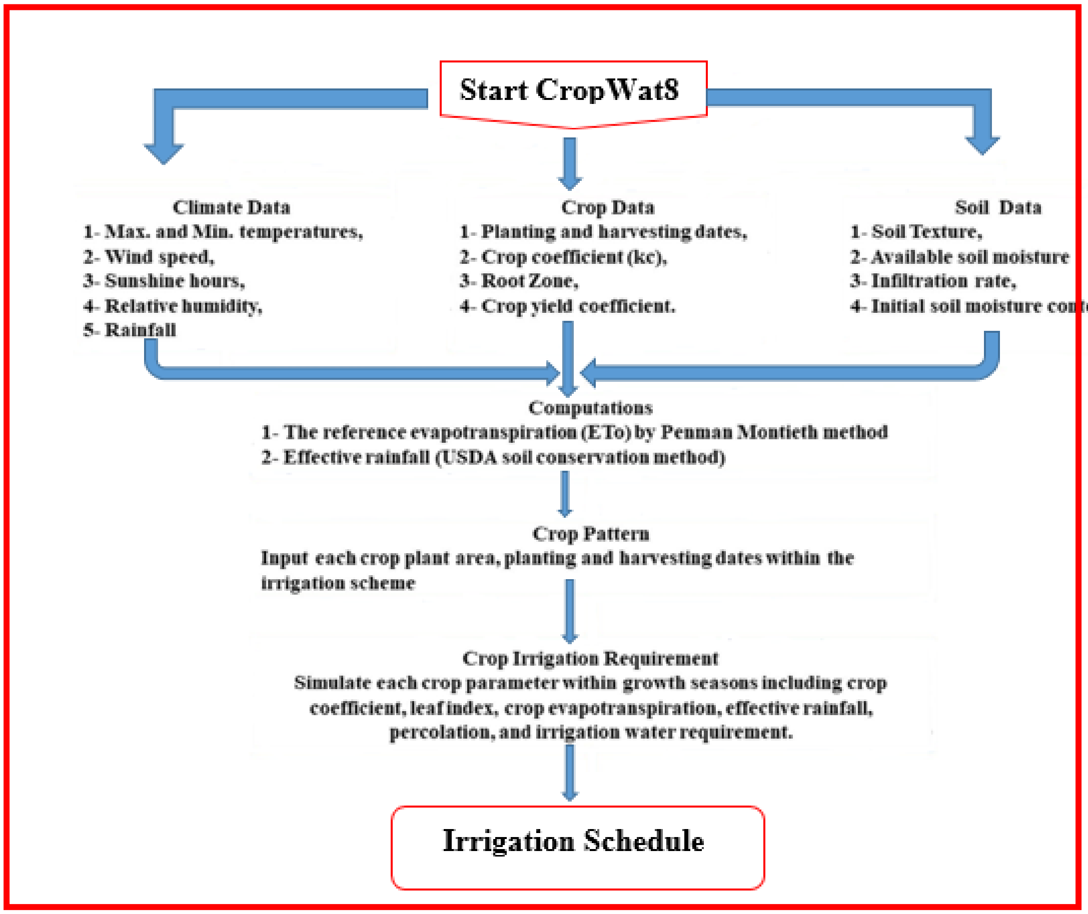


Fig. 2: Methods for simulating crop irrigation water requirements diagram [26].

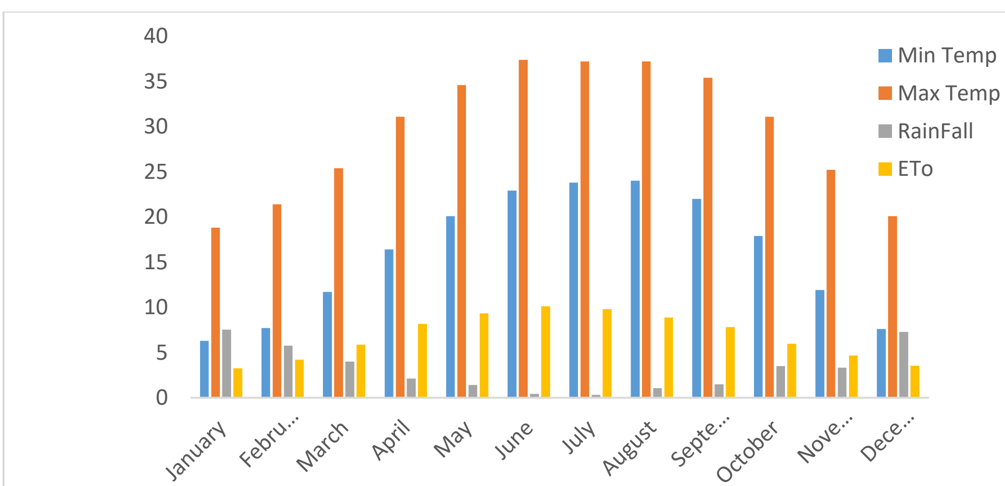


Fig. 3 Weather data (Tmin, Tmax, rainfall and ETo) for sofuljeen for the period 1991–2020.

2 Results and discussion:

Table 2 displays the rainfall, maximum temperature, minimum temperature, range, difference, and change for the SSP2-4.5 and SSP5-8.5 emission scenarios for the years 2040, 2060, 2080, and 2100. The average maximum temperature is 26.93 °C, with a range of 36.10 °C in July to 16.90 °C in January, compared to the current situation (2020). In contrast, SSP2-4.5 (2040) has an average maximum temperature of 28.14 °C and a maximum temperature range of 36.37 °C in August to 18.6 °C in January. SSP2-4.5 (2060) has an average maximum temperature of 28.70 °C and a range of 37.20 °C in August to 18.95 °C in January. in SSP2-4.5(2080) be the average maximum temperature is 29.23°C, with a range of 37.94 °C in August to 19.42 °C in January. in SSP2-4.5(2100) be the average maximum temperature is 29.58°C, with a range of 38.30 °C in August to 19.61 °C in January. The increases were as follows: 4.50%, 6.57%.8.54 % and 9.84% respectively, Compared to the current situation. However, according to SSP5-8.5, the maximum temperature changes for the years scenarios 2040, 2060, 2080 and 2100 are 5.13%,8.66%,13.15%, and 18.70% higher, respectively, than they are for the present scenario (2022). On the other hand, for the current scenario, SSP2-4.5 the average minimum temperature in 2020 is 13.96 °C, with a maximum value of 21 °C in August and a minimum value of 6.6 °C in January. For the scenario SSP2-4.5 (2040) is the average minimum temperature 16.49 °C, with a maximum value of 24 °C in August and a minimum value of 8.5 °C in January. in (2060) the average minimum temperature is 17.01 °C, with a maximum value of 24.80 °C in August and a minimum value of 9 °C in January. Moreover, the average minimum temperature for 2080 is 17.52°C with a maximum value of 25.40 °C in August and a minimum value of 9. 40 °C in January. In addition, the minimum temperature change for the scenario SSP2-4.5 (2100) is the average 17.80 °C , maximum and minimum 25.80°C in August and 9 °C in January. Respectively. Compared to the current situation, which represent increases of 18.12%, 21.84%.25.50 % and 27.50%. Respectively. However, according to SSP5-8.5, the minimum temperature changes for the years scenarios 2040, 2060, 2080 and 2100 are the average minimum temperature 13.96°C, 16.58°C,17.55°C,18.77°C and 20.28°C Respectively. Maximum and Minimum temperature change are 21(Aug) – 6.6(Jan), 24.30(Aug) -8.60(Jan) ,– 25.60(Aug) -9.30(Jan) , 27.10 (Aug)- 10.40(Jan) and 28.80(Aug) - 11.70(Jan). Respectively. Compared with the current situation (2020). However, according (SSP5-8.5%) be increases 18.76%, 25.82% , 34.46%

and 45.27%. higher. respectively. In SSP2-4.5, the average rainfall (mm/month) for 2040, 2060, 2080 and 2100 were in the ranges of 5.32, 5.11, 4.92 and 4.83 respectively. The change of rainfall percentage four-year as follows: -11.33,-14.83,-18 and -19.5 respectively .The change of rainfall was compared with the average (6 mm/month) of the current period 2020. While values were found in SSP5-8.5, being for rain fall(mm/month) as follows : 5.17,4.74,4.70 and 4.24 respectively. compared with period (2020) which was 6 mm/month). However, according The change of rainfall (SSP5-8.5%) for 2040, 2060, 2080 and 2100 which : - 29.33,- 21.6.- 21 and -13.83, respectively.

Table 2 displays the average, range, difference, and change of monthly maximum and minimum temperatures and the rainfall variations for the next four years (2040 and 2100) by SSP2-4.5 and SSP5-8 using the current situation as of (2020).

	Current (2020)	2040	2060	2080	2100
Monthly maximum temperature. (°C) SSP2-4.5					
Average	26.93	28.14	28.70	29.23	29.58
Range	16.9(January) - 36.1 (July)	18.6(Jan) – 36.37(Augu)	18.95(Jan) – 37.2(Aug)	19.42(Jan) – 37.94(Aug)	19.61(Jan) - 38.30
Difference (ΔT) %	-	1.21 4.50	1.77 6.57	2.30 8.54	2.65 9.84
SSP5-8.5					
Average	26.93	28.28	29.23	30.44	31.93
Range	16.9(January) - 36.1 (July)	59.6 – 347.81	19.25 – 38.03	39.67 – 20.41	21.62 – 41.42
Difference (ΔT)		1.38	2.33	3.54	5.03
%	-	5.13	8.66	13.15	18.70
Monthly min. temperature. (°C) SSP2-4.5.					
Average	13.96	16.49	17.01	17.52	17.80
Range	6.6(Jan) – 21(Aug)	8.5(Jan) – 24.1(Aug)	9(Jan) – 24.80(Aug)	9.40(Jan) – 25.40(Aug)	9(Jan) – 25.80(Aug)
Difference (ΔT)	-	2.53	3.05	3.56	3.84
%	-	18.12	21.84	25.50	27.50
SSP5-8.5					
Average	13.96	16.58	17.55	18.77	20.28
Range	6.6(Jan) – 21(Aug)	8.60(Jan) – 24.30(Aug)	9.30(Jan) – 25.60(Aug)	10.40(Jan) – 27.10 (Aug)	11.70(Jan) – 28.80(Aug)
Difference (ΔT)	-	2.62	3.59	4.81	6.32
%	-	18.76	25.82	34.46	45.27

Monthly rainfall (mm/month)SSP2-4.5					
Average	6	5.32	5.11	4.92	4.83
Range	0(Jul)- 12(March)	0.3(Jul)- 9.08 (Oct)	0.23(Jul)- 9.71(Jan)	0.18(Jul)- 9.37 (Oct)	0.18(Jul)- 8.22 (Oct)
Difference (ΔT)	-	-0.68	-0.89	-1.08	-1.17
%		-11.33	-14.83	-18	-19.5
SSP5-8.5					
Average	6	5. 17	4.74	4.70	4.24
Range	0(Jul)- 12(Mar)	0.24(Jul)- 9.15(Jan)	0.20(Jul)- 8.41(Jan)	0.18(Jul)- 8.58 (Oct)	0.11(Jul)- 7.52 (Oct)
Difference (ΔT)	-	-0.83	-1.26	-1.3	-1.76
%		-13.83	- 21	- 21.6	- 29.33

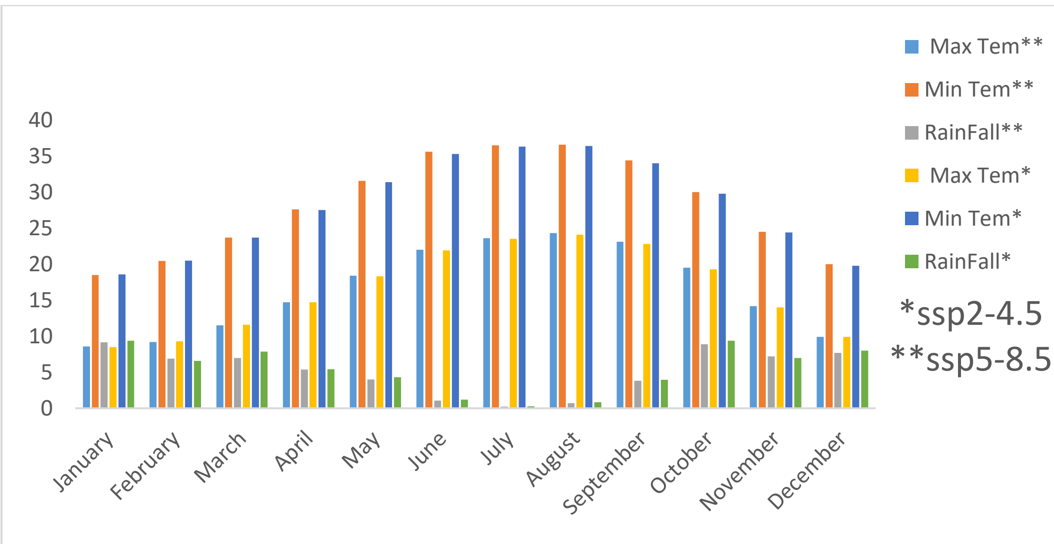


Fig4. Climate data (Tmin, Tmax and rainfall) for sofuljeen for the for the SSP2-4.5 and SSP5-8.5 emission scenarios 2040

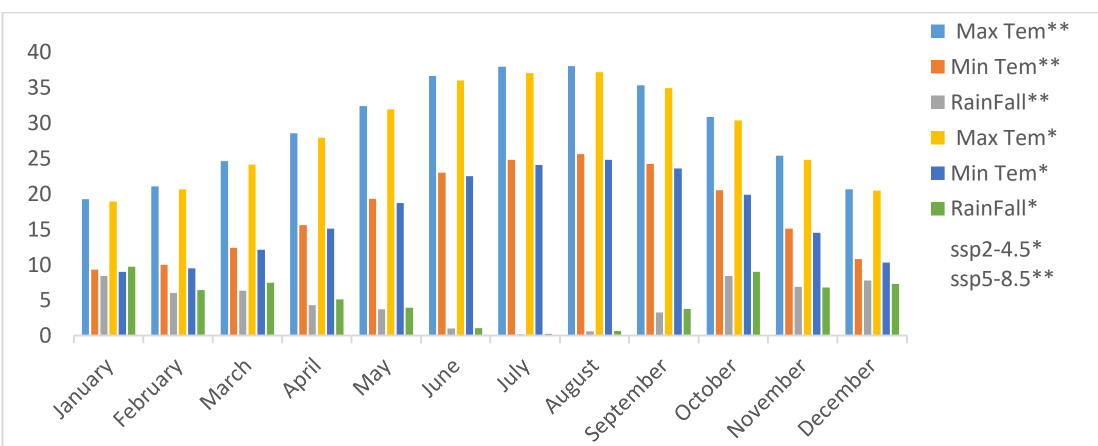


Fig5. Climate data (Tmin, Tmax, and rainfall) for sofuljeen for the for the SSP2-4.5 and SSP5-8.5 emission scenarios 2060.

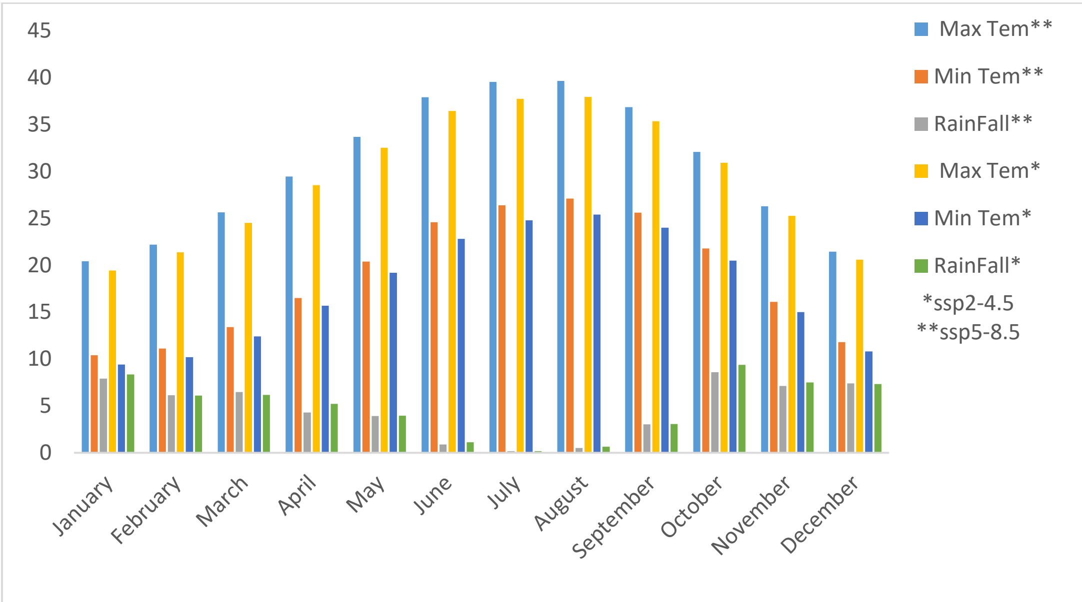


Fig6. Climate data (Tmin, Tmax, and rainfall) for sofuljeen for the for the SSP2-4.5 and SSP5-8.5 emission scenarios 2080.

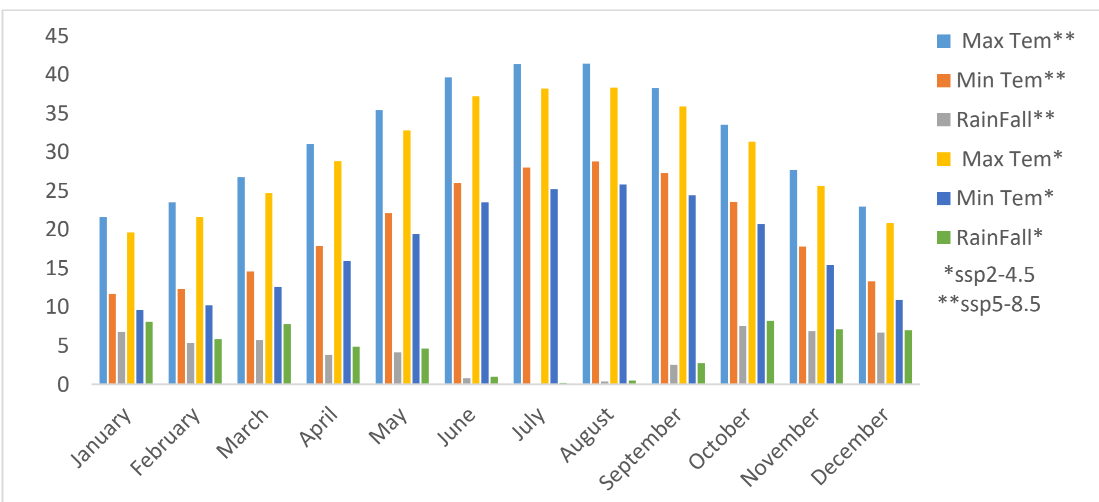


Fig7. Climate data (Tmin, Tmax, and rainfall) for sofuljeen for the SSP2-4.5 and SSP5-8.5 emission scenarios 2100.

Reference Evapotranspiration (ET_o)

Table 3 showing the daily (ETo) for the sofuljeen area for the four years (2040s, 2060s, 2080s and 2100s) the SSP2-4.5 and SSP5-8.5 scenarios, with the current situation (2022). Therefore, SSP2-4.5: 2022,2040,2060,2080 and 20100 are ETo Average from 6.78, 7.03, 7.45, 7.60 and 7.68 mm/day, respectively. ETo range in (January – June)3.24 (Jan)- 10.12(Jun), 3.46 (Jan) – 10.54 (Jun) ,3.51(Jan)-

10.97(Jun) ,3.58(Jan) – 11.20(Jun) and 3.67(Jan) – 11.43(Jun) mm/day, respectively. Moreover, the average ETo for SSP5-8.5 for years 2022,2040,2060,2080 and 20100 which was 6.78, 7.12, 7.61, 7.94 and 8.37 mm/day, respectively. as will is for ETo range in (January – June) for years SSP5-8.5 are : 3.24(Jan)- 10.12(Jun) , 3.40 (Jan) – 10.51(Jul) , 3.57 (Jan) – 11.36 (Jul) , 3.73(Jan) – 11.83(Jul) and 3.91(Jan) – 12.62(Jul) mm/day, respectively . Change predicted by SSP2-4.5: shows a rise of 3.68, 9.89, 12.09 and 13.27 %, respectively. The ETo changes for the years 2040, 2060, 2080 and 2100, as compared to the current scenario (2022), are 5.01, 12.24, 17.11 and 23.45% higher, respectively, according to SSP5-8.5.

Table 3 shows the average, range, difference, and change for the SSP2-4.5 and SSP5-8.5 scenarios for the four years (2040, 2060, 2080, and 2100) with the current situation (2022) for the Sofuljeen region

	2020	2040	2060	2080	2100
					ETo (mm/day) SSP2-4.5
Average	6.78	7.03	7.45	7.60	7.68
Range	3.24 (Jan)- 10.12(Jun)	3.46 (Jan) – 10.54 (Jun)	3.51(Jan)- 10.97(Jun)	3.58(Jan) – 11.20(Jun)	3.67(Jan) – 11.43(Jun)
Difference (ΔT)	-	0.25	0.67	0.82	0.9
%	-	3.68	9.88	12.09	13.27
					ETo (mm/day) SSP5-8.5
Average	6.78	7.12	7.61	7.94	8.37
Range	3.24(Jan)- 10.12(Jun)	3.40 (Jan) – 10.51(Jul)	3.57 (Jan) – 11.36 (Jul)	3.73(Jan) – 11.83 (Jul)	3.91(Jan) – 12.62(Jul)
Difference (ΔT)	-	0.34	0.83	1.16	1.59
%	-	5.01	12.24	17.11	23.45

Crop Water Requirement

The dates of agricultural planting and harvesting for Sofuljeen are summarized in Tables 4. and 5. For large-area crops such as wheat, tomatoes, and potatoes in Sofuljeen, the Net Irrigation Water Requirement (NIWR) and Gross Irrigation Water Requirement (GIWR) were calculated under SSP2-4.5 and SSP5-8.5 scenarios for 2040, 2060, 2080, and 2100. The results were expressed in million m3 (MCM) for the four years under SSP2-4.5 and SSP5-8.5 scenarios and the current case (2020). The average for the present period of 2020 was compared to the changes in NIWR and GIWR. El-Rawy, M et al. [16]. Table 4and 5 summarizes NIWR and GIWR in million m^3 (MCM) for the four models under SSP2-4.5 and SSP5-8.5 scenarios and the current case (2020). The values of increases in NIWR and GIWR for wheat, tomato summer, and potatoes in scenario SSP5-8.5 compared to SSP2-4.5 show a substantial difference; after 2040, the variability increased by (NIWR) 1.79, 10.27, and 8.17%, respectively, nearly doubling. (GIWR) 11.33, 5.77, and 3.16% respectively. SSP5-8.5(NIWR AND GIWR): 5.79, 19.27 and 17.96 respectively. 8.20, 16.62 and 10.52 respectively. For 2040 According to SSP2-4.5 and SSP5-8.5, the (NIWR AND GIWR): is anticipated to rise by 7.09, 21.4, and 19.4%, and 7.27, 18.37 and 15.12% respectively and 9.09, 23.93 and 21.57 and 15.64, 23.72 and 14.59 respectively, in 2060. Addition to 2080 are values of changes of NIWR 9.33, 23.50 and 21.47 and GIWR 17.06,18.62 and 14.34 in scenario SSP2-4.5 , changes of NIWR 13.35, 30.78 and 25.22 too GIWR 28.19,29.64 and 21.84 in scenario SSP5-8.5. Moreover in 2100 changes of NIWR are the values 10.35,25.26 and 23.18 , however GIWR are 15.01 ,22.66 and 23.29 in scenario SSP2-4.5.while scenario SSP5-8.5 be (NIWR AND GIWR) 18.85,37.65 and 32.26 and 33.42 , 31.93and 33.20 respectively. Compared to the current 2020 NIWR AND GIWR 6050.94, 2457.94 and 1287.09 and 7381.50, 3495.43 and 1783.32 respectively.as show table .4.

Table 4 Crop Water Requirement for sofuljeen (2020)

Crop	Planting	Harvest	Crop growing period (days)	Crop area (ha)	NIWR (mm)	GIWR (mm)	Overall NIWR (MCM)	Overall GIWR (MCM)
Wheat	1st Nov	28Jun	240	420	1440.7	1757.5	6050.94	7381.50
Tomato-S.	1st Jun	23rd. Oct	145	211	1164.9	1656.6	2457.94	3495.43
Potatoes	1st Sep	8th. Jan	130	210	612.9	849.2	1287.09	1783.32

Table 5 Crop Net Irrigation Water Requirement (NIWR) and Gross Irrigation Water Requirement (GIWR) (MCM) for the four years (2040, 2060, 2080, and 2100) under SSP2-4.5 and SSP5-8.5 for the study area (sofuljeen).

Crop	Crop area (ha)	NIWR (mm)	GIWR (mm)	Overall NIWR (MCM)	Overall GIWR (MCM)	ΔNIWR (MCM)	Change (%)	ΔGIWR (MCM)	Change (%)
									SSP2-4.5-2040
Wheat	420	1466.5	1956.7	6159.3	8218.14	108.36	1.79	836.64	11.33
Tomato S	211	1284.5	1752.2	2710.29	3697.14	252.35	10.27	201.71	5.77
Potatoes	210	663.0	876.0	1392.3	1839.6	105.21	8.17	56.28	3.16
									SSP5-8.5-2040
Wheat	420	1524.1	1901.6	6401.22	7986.72	350.28	5.79	605.22	8.20
Tomato S	211	1389.4	1932	2931.634	4076.52	473.694	19.27	581.09	16.62
Potatoes	210	723	938.5	1518.3	1970.85	231.21	17.96	187.53	10.52
									SSP2-4.5-2060
Wheat	420	1542.9	1885.2	6480.18	7917.84	429.24	7.09	536.34	7.27
Tomato S	211	1410.0	1961.0	2975.1	4137.71	517.16	21.04	642.28	18.37
Potatoes	210	732.7	977.6	1538.67	2052.96	251.58	19.55	269.64	15.12
									SSP5-8.5-2060
Wheat	420	1571.6	2032.4	6600.72	8536.08	549.78	9.09	1154.58	15.64
Tomato S	211	1443.7	2049.5	3046.21	4324.45	588.27	23.93	829.02	23.72
Potatoes	210	745.1	973.1	1564.71	2043.51	277.62	21.57	260.19	14.59
									SSP2-4.5-2080
Wheat	420	1575.1	2057.4	6615.42	8641.08	564.48	9.33	1259.58	17.06
Tomato S	211	1438.6	1965.1	3035.45	4146.36	577.51	23.50	650.93	18.62
Potatoes	210	744.5	971.0	1563.45	2039.1	276.36	21.47	255.78	14.34
									SSP5-8.5-2080
Wheat	420	1633.1	2253.0	6859.02	9462.6	808.08	13.35	2081.1	28.19
Tomato S	211	1523.5	2147.6	3214.585	4531.44	756.645	30.78	1036.01	29.64
Potatoes	210	767.5	1034.7	1611.75	2172.87	324.66	25.22	389.55	21.84
									SSP2-4.5-2100
Wheat	420	1589.8	2021.3	6677.16	8489.46	626.22	10.35	1107.96	15.01
Tomato S	211	1459.2	2032	3078.91	4287.52	620.97	25.26	792.09	22.66
Potatoes	210	755.0	1047.0	1585.5	2198.7	298.41	23.18	415.38	23.29
									SSP5-8.5-2100

Wheat	420	1712.2	2344.8	7191.24	9848.16	1140.3	18.85	2466.66	33.42
Tomato S	211	1603.5	2185.5	3383.39	4611.41	925.45	37.65	1115.98	31.93
Potatoes	210	810.6	1131.1	1702.26	2375.31	415.17	32.26	591.99	33.20

4. Discussion

4.1. Changes of climate for study area

4.1.1The maximum temperature changes in SSP2-4.5 emission were found to be higher than the current temperature (36.10°C), rising in the ranges of 36.37, 37.20, 37.94, and 38.30 °C, as seen in Figure 8. Difference (ΔT) of Temperature Changes in SSP2-4.5 for 2040, 2060, 2080 and 2100 are 1.21, 1.77, 2.30 and 2.65, respectively.as show Figure.10. However. Changes in SSP5-8.5 for four years 36.59, 38.03 , 39.67 and 41.42 respectively.as show Figure.9. Conversely, the data of SSP5-8.5 as show Figure.11. Showed more change in the maximum temperature, which as Difference (ΔT) of Temperature Changes as follows: 1.38, 2.33 3.54 and 5.03 for 2040 to 2100 respectively.

4.1.2. Minimum Temperature Changes in SSP2-4.5 during for four years were found to be rising in the ranges of 8.5, 9.0, 9.40 and 9.60 C^0, respectively, which is higher than the current (2020) temperature (6.30 C). Figure .12. Shows the minimum temperature for 2020,2040,2060,2080 and 2100. This is also evident in the Difference (ΔT) of Temperature Changes of 2.53, 3.05, 3.56 and 3.84 for the years 2040, 2060, 2080, and 2100, respectively, as shown in Figure 14.in SSP5-8.5 showed more change in Minimum Temperature for years four to be in the range of 8.60 ,9.30,10.40 and 11.70, respectively.as shown in Figure .13. Moreover were find the Difference (ΔT) of Temperature Changes of 2.62, 3.59, 4.81 and 6.32. Respectively, as shown Figure .15.

4.1.3.. Rainfall Changes: Figure 16 and 17 depicts the annual of rainfall (mm/year) in sofuljeen region for the future periods 2040, 2060, 2080, and 2100 under the SSP2-4.5 and SSP5-8.5, which are 64.18, 61.31, 58.98 and 58. mm/year for SSP2-4.5. respectively And SSP5-8.5 for years 62.08, 56.84, 56.47 and 50.82. mm/year. Respectively. The highest annual of rainfall (mm/year) in sofuljeen region in year 2040 are 64.18 and 62.08 mm/year. For SSP2-4.5 and SSP5-8.5. Moreover. The Difference (ΔT) of the amount of rainfall in four years that be under the two scenarios: -0.68,-0.89,-1.08 and -1.17 for SSP2-4.5 Respectively.as showing figure

18.in SSP5-8.5 were found to be rising :-0.83,-1.26.-1.3 and -1.76 Respectively.as showing figure 19.

4.1.4. Variation ETo

ETo values for study area are during 2020,2040,2060,2080 and 2100 presented in figure .20.ETo would range between 10.12 in June, 10.54 in June, 10.97 in June, 11.20 July and 11.43 in June.mm/day, Respectively. According for SSP2-4.5. As for SSP5-8.5 Change found for five years as showing figure 21. ETo would range 10.12 in June, 10.84 in June, 11.36 in July, 11.83 and 12.62 in July.mm/day, Respectively. with the latter being the highest.

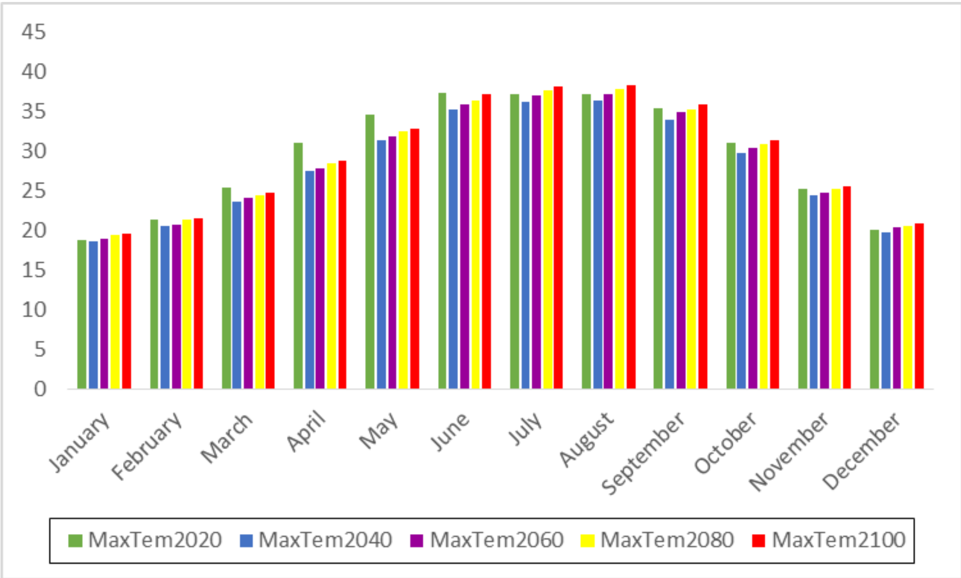


Figure 8. Maximum Temperature Changes in SSP2-4.5 for the five climate years

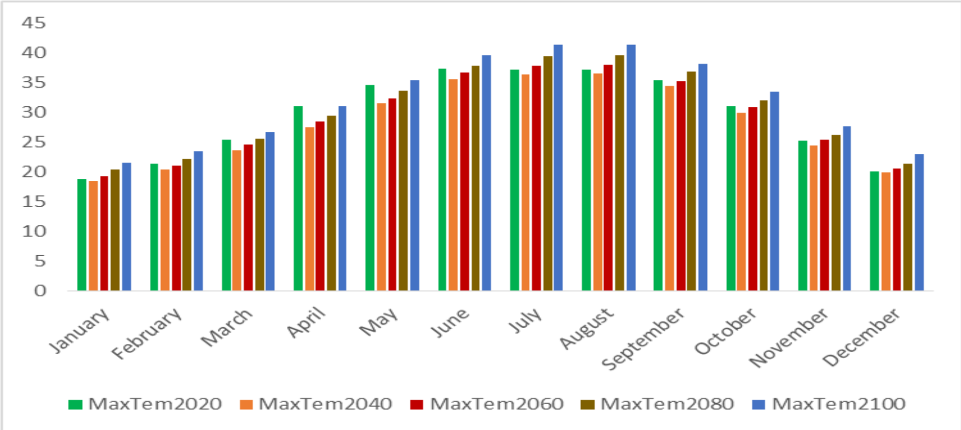


Figure 9. Maximum Temperature Changes in SSP5-8.5 for the five climate years

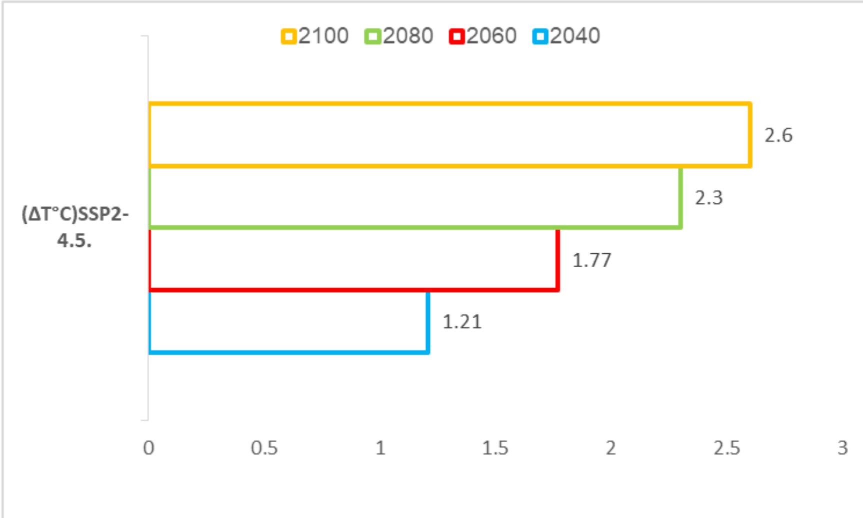


Figure 10. Difference (ΔT) of Maximum Temperature Changes in SSP2-4.5 for climate years

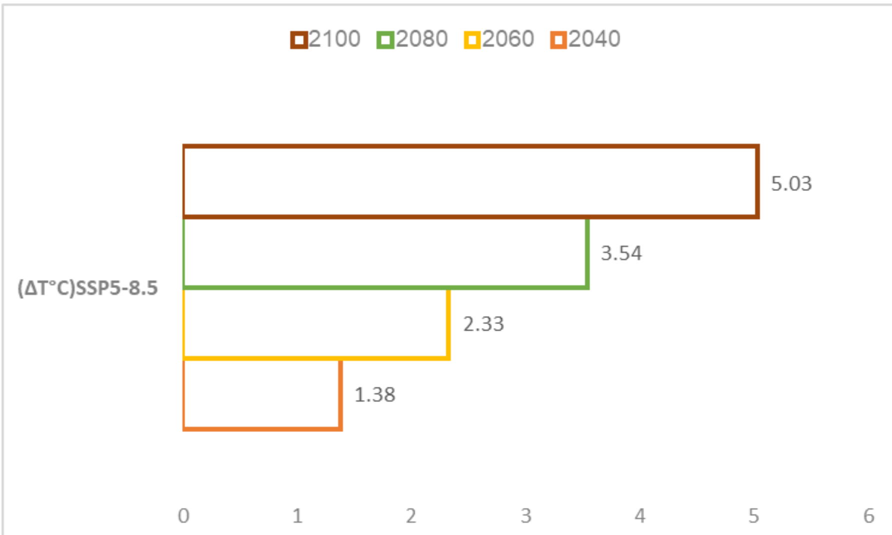


Figure 11. Difference (ΔT) of Maximum Temperature Changes in SSP5-8.5 for climate years

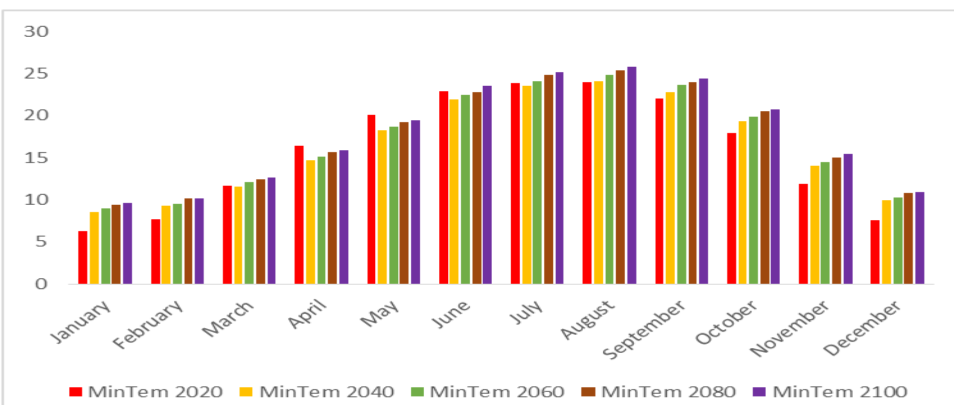


Figure 12. Minimum Temperature Changes in SSP2-4.5 for the five climate years

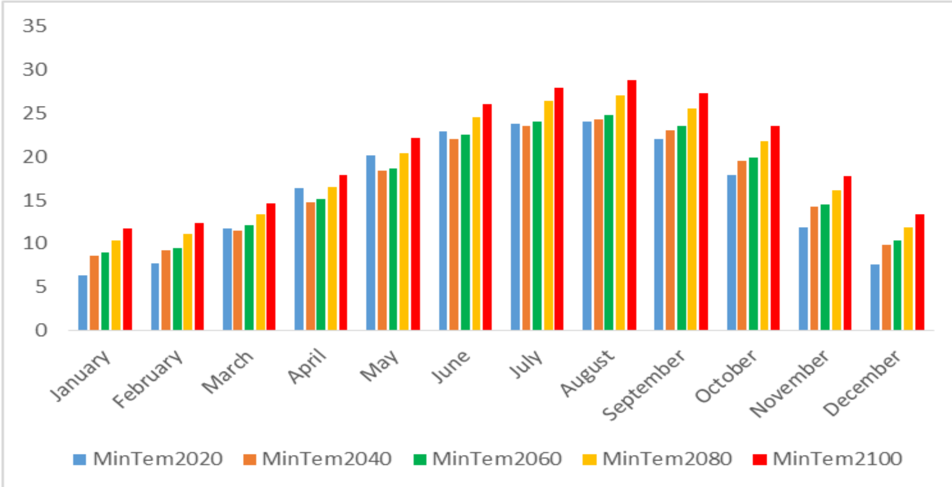


Figure **13.** Minimum Temperature Changes in SSP5-8.5 for the five climate years

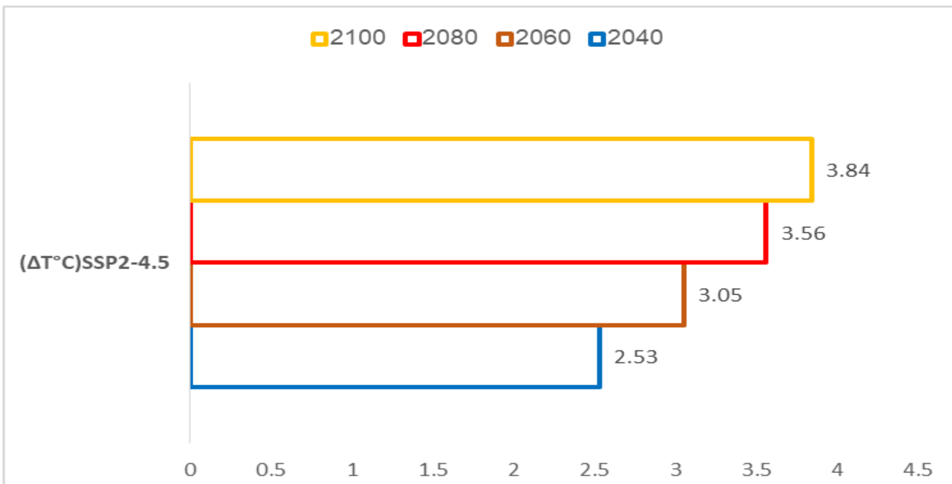


Figure 14. Difference (ΔT) of Minimum Temperature Changes in SSP2-4.5 for climate years.

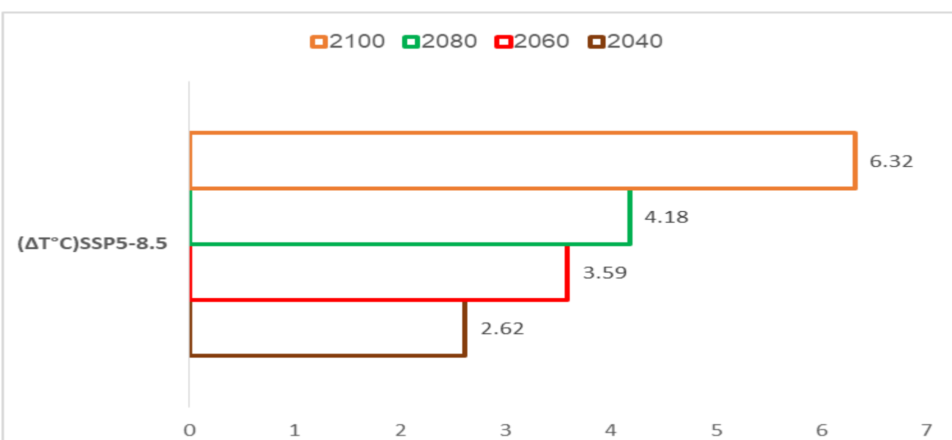


Figure 15. Difference (ΔT) of Minimum Temperature Changes in SSP5-8.5 for climate years.

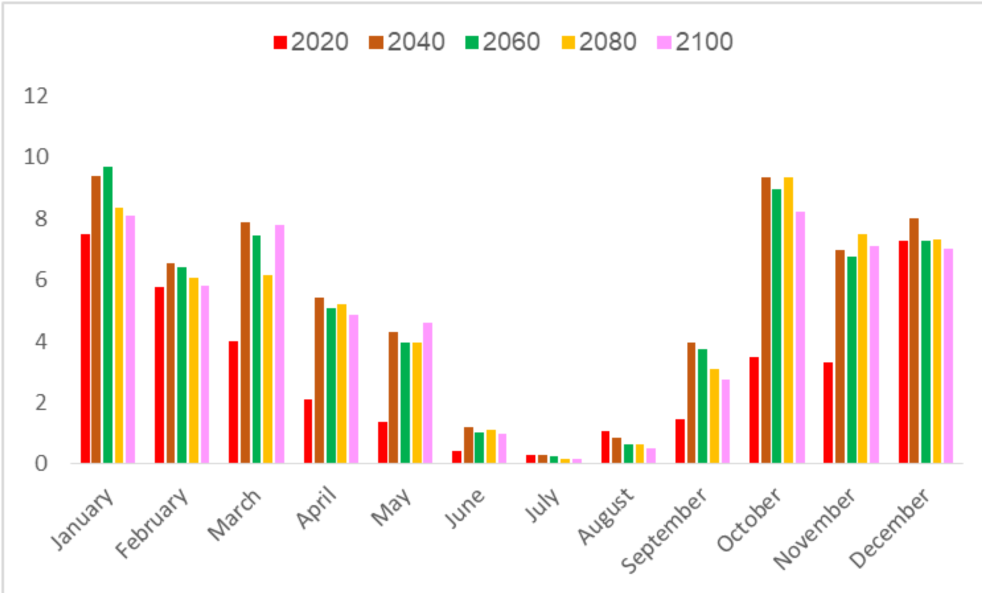


Figure 16. Rainfall for the five climate years under SSP2-4.5.

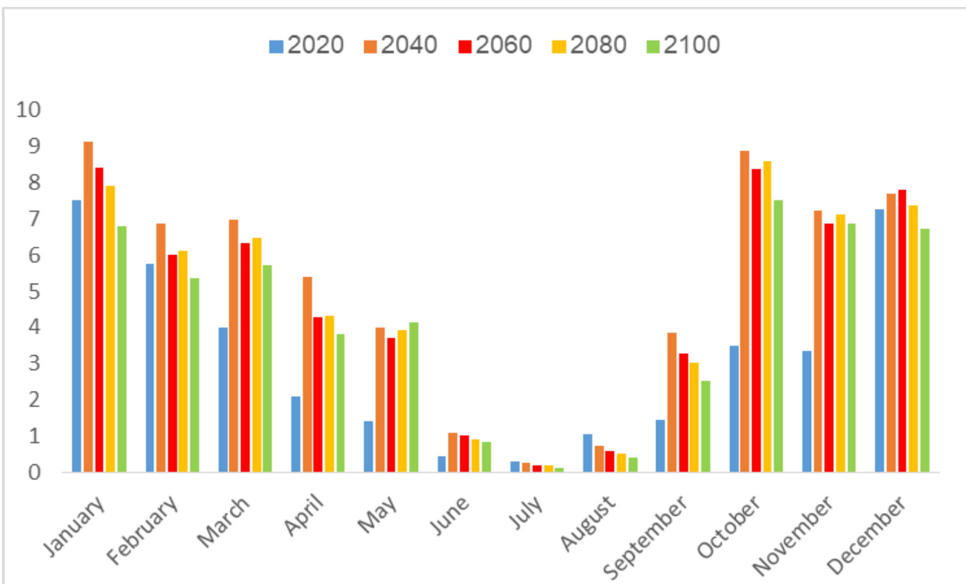


Figure 17. Rainfall for the five climate years under SSP5-8.5.

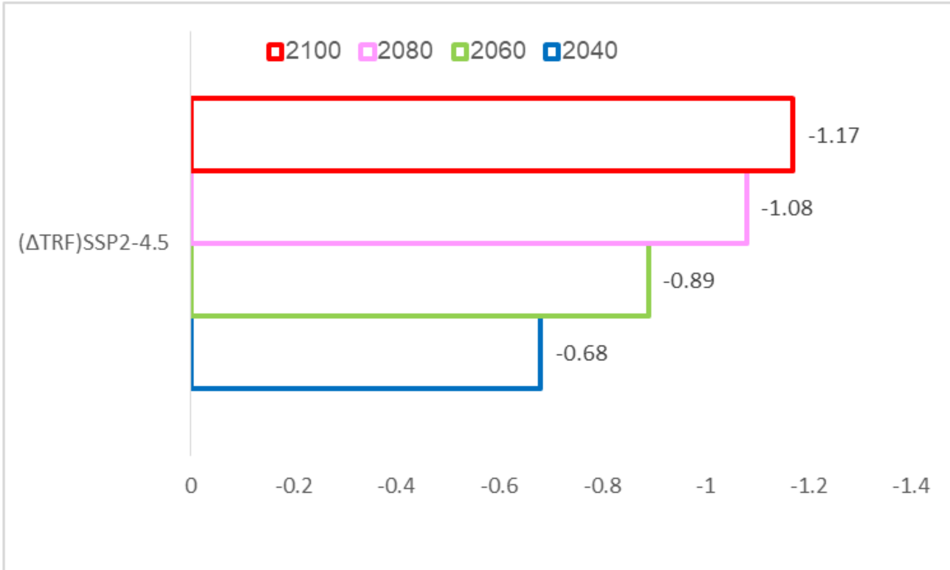


Figure 18. Difference (ΔT) of Rainfall for climate years under SSP2-4.5.

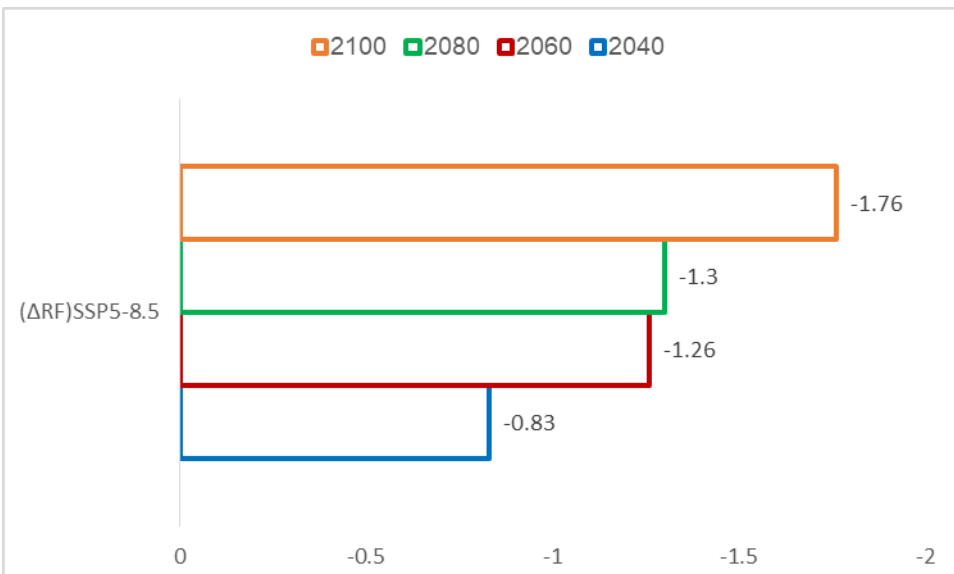


Figure 19. Difference (ΔT) of Rainfall for climate years under SSP5-8.5.

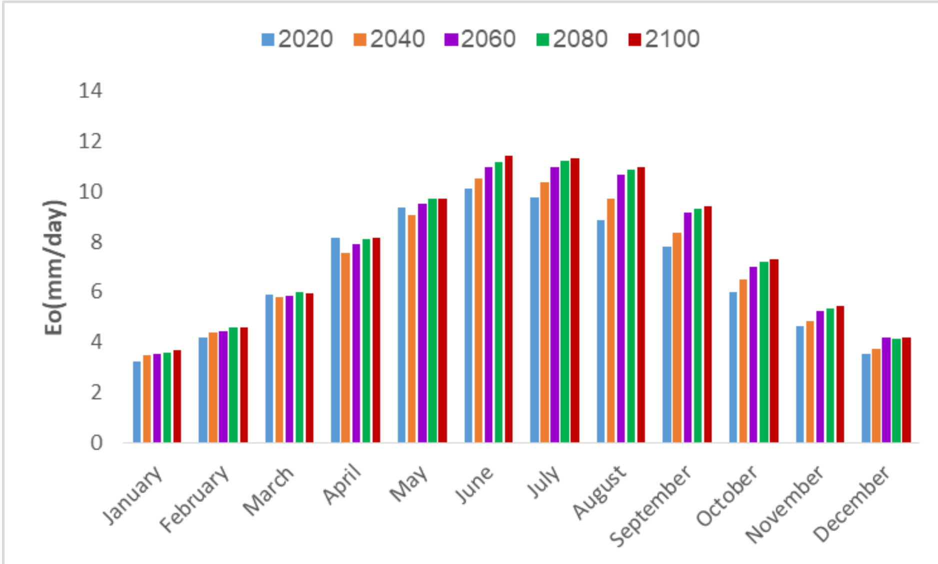


Figure **20.** Difference ETo on the five climate years under SSP2-4.5

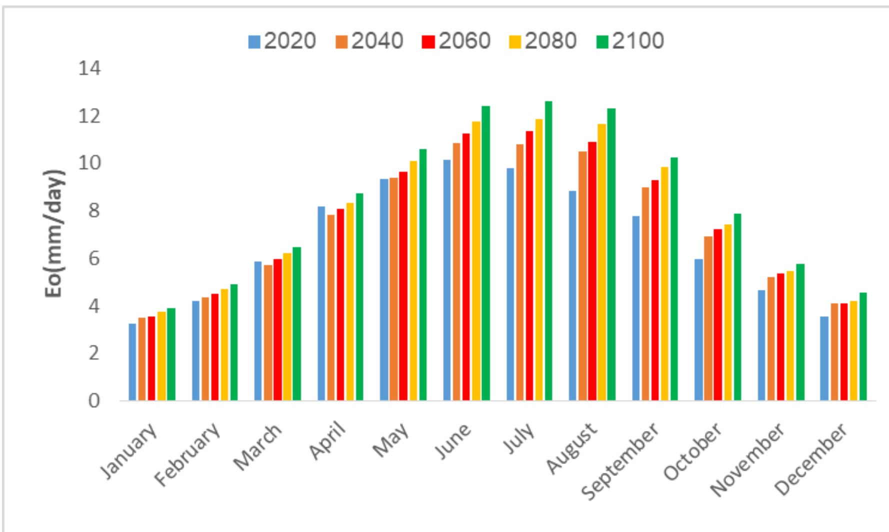


Figure 21**.** Difference ETo on the five climate years under SSP5-8.5.

4.5. ETc Variation

The ETc change in the Sofuljeen region for each of the two scenarios' five periods is displayed in Figure 22. For the crops of wheat, tomato S, and potatoes, the computed ETc for the current year, 2020, are 1440.7, 1164.9, and 612.9 mm/day, respectively.. According to available data SSP2-4.5 for the future 2100s, the values (ETc mm/day) are increased to 1589.8, 1459.2 and 755. For the crops wheat, Tomato S and Potatoes respectively. Additionally, in SSP5-8.5 for the future period 2100, ETc for the crops wheat, Tomato S and Potatoes, they increased to 1712.2,1603.5 and 810.6 respectively. As shown Figure .22. An increase in temperature during the growth season is the cause of this increase in ETc. Numerous past studies of areas with comparable semi-arid and dry climates, including India, have changed (Kaushika et al. [27]), Egypt (Makar et al. [28]), and Ethiopia (Hordofa et al. [29]) reached a similar conclusion: crop water requirements will eventually rise in response to a little increase or decrease in precipitation and a noticeable rise in temperature, especially if sowing dates are delayed..

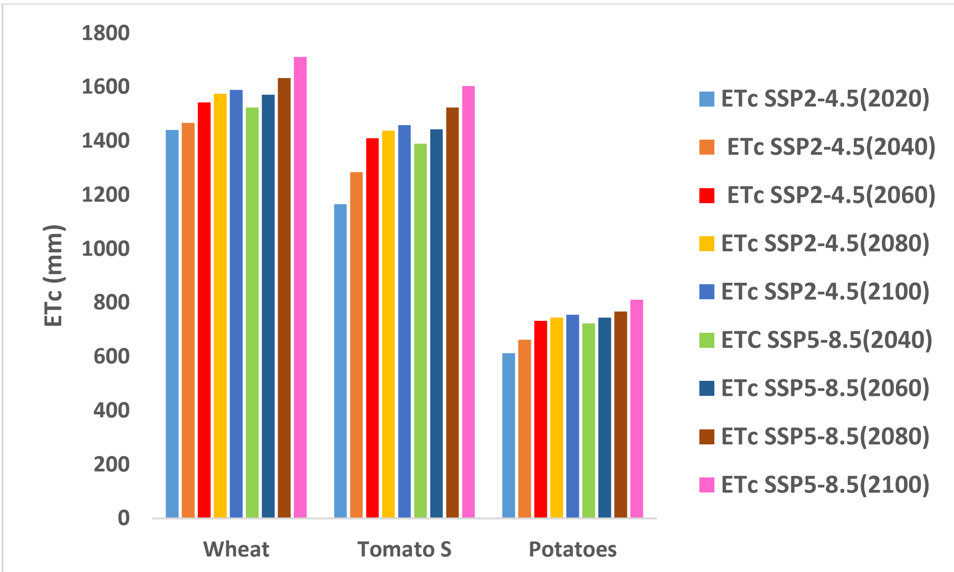
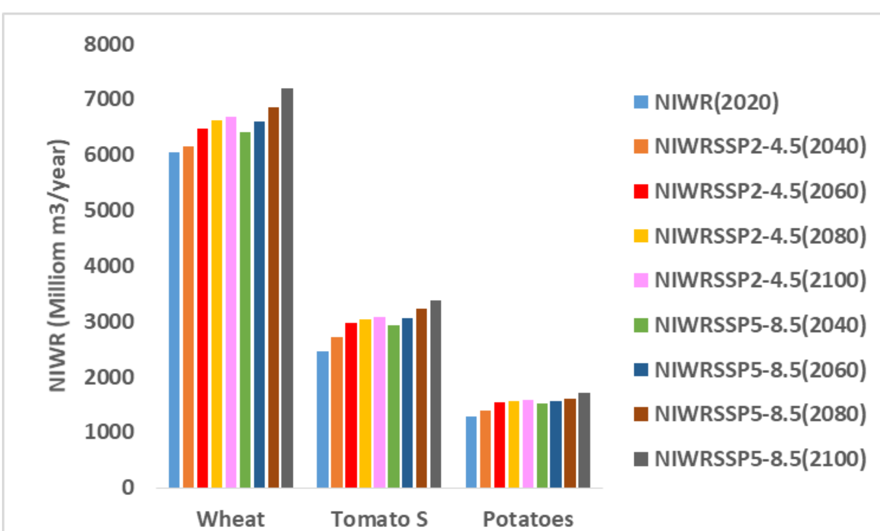
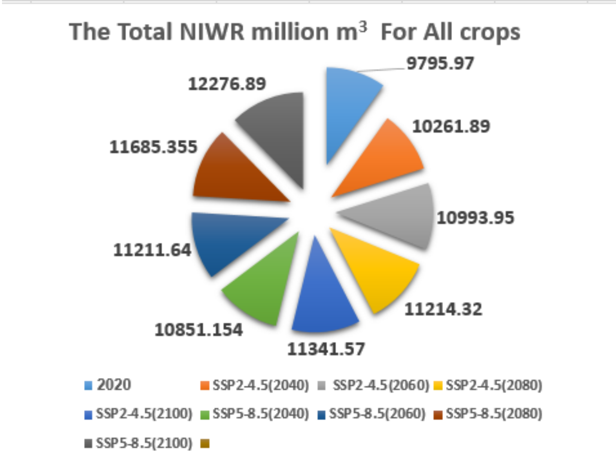


Figure 22. ETc difference for the current scenario (2020), SSP2-4.5, and SSP5- 8.5 for the period 2040–2100 for sofuljeen region.

4.6. The Requirement for Net Irrigation Water (NIWR) in the Scenarios of Climate Change

As compared to the current total NIWR for all crops, all examined crops' overall NIWR increases by 10.30, 11.03 11.26 and 11.38% under SSP2-4.5: 2040 to 2100, respectively. On the other hand, for the SSP5-8.5: 2040 to 2100, respectively, the total NIWR for all investigated crops increases by 10.89, 11.25, 11.73and 12.32 % in comparison to the current total NIWR for all crops (Fig. 23). According to available data SSP2-4.5 and SSP5- 8.5 to the period 2040–2100 for water needs .,the increase in agricultural water needs is expected to range from 10261.89 to 11341.57and from 10851.15 to 12276.89,respectively. Display in Fig. 23 However, It is crucial to take into account changes to the way that water resources are managed in the Sofuljeen region. Some of these modifications include the use of modern irrigation systems, crop rotation techniques that need less water, and crop calendars or modifications in the times and locations of cropping operations. In addition, the study results coincided with El-Rawy et al. [16] , who researched how Saudi Arabia's water irrigation system might be negatively impacted by climate change (arid region). The findings indicated that the annual average ETo rises over the 2100s were 0.35 mm/day (6%) and 0.7 mm/d (12.0%), respectively, as predicted by the Shared Socioeconomic Pathways (SSP)2–4.5 and SSP5-8.5 scenarios. The net irrigation water requirement (NIWR) and gross irrigation water requirement (GIWR) for the principal crops in the Al Quassim region were assessed under the current, SSP2-4.5, and SSP5-8.5 scenarios. SSP5-8.5 projects that, in comparison to the present situation (1584.7 million m3), the GIWR will increase by 2.7, 6.5, 8.5, and 12.4%, respectively, in the 2040s, 2060s, 2080s, and 2100s. As a result, under SSP5-8.5, main crops will experience larger deficits in2100, with deficits of15.1percentage, 10.7%, 8.3%, 13.9%, and10.7percentage, respectively, in the crop areas of wheat, clover, and maize, other vegetables, and dates. According to the results of the study with Gabr [26] who conducted research on how future agricultural water needs in the Red Sea (Egypt), Aswan, and Sohag Qena might be affected by climate change. indicates that, in comparison to the current (2022) overall NIWR for all crops, the results for the periods 2023–2080 and 2081-2100 under RCP 4.5 greenhouse gas emissions, respectively, demonstrate that the overall NIWR for all investigated crops increases by 5.1 and 5.9%. Compared to the current total NIWR for all crops, the total NIWR under the RCP 8.5 greenhouse emission scenario increases by 7.7 and 9.7% for the periods 2023–2080 and 2081–20100, respectively.





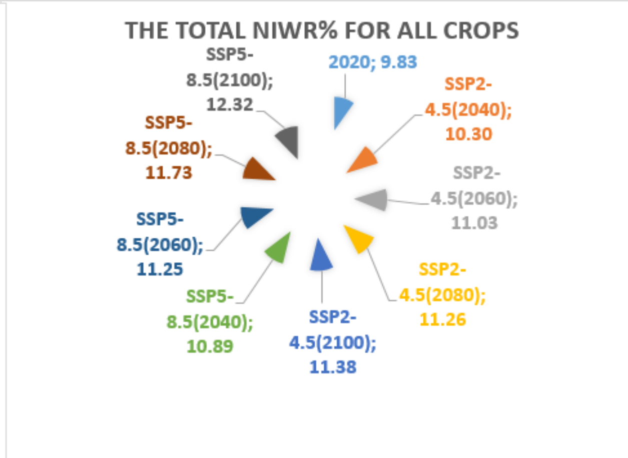


Figure 23. NIWR difference for the current scenario (2020), SSP2-4.5, and SSP5-8.5 for the period 2040–2100 for sofuljeen region.

5. Conclusions

As is clear from the results of the research that focused on studying climate change according to scenarios, the results were concluded that :Expected effects on sofuljeen region , Here is The importance of focusing on studying how climate change affects water demand For food crops: wheat, summer tomatoes, and potatoes. Changes During the projections for the current period 1991-2020, as well as in SSP2-4.5 and SSP5-8.5 scenarios for 2040, 2060, 2080, and 2100 based on five climate models. The current study's results align with previous research on North Africa (Egypt) and the Middle East, indicating a significant rise in temperatures. while the annual temperature is high by 6.57% and 8.54% under SSP2-4.5 and 8.66% and 13.15% under SSP5-8.5 in the middle years (2060s and 2080s), which is not advantageous for crop growth and causes a higher evapotranspiration rate. In the future years, the mean daily evapotranspiration rate (ETo) predicted a high of the present, to about 6.34% and 14.45% in SSP2-4.5 and SSP5-8.5, respectively. These results showed an Low rainfall in all scenarios, while the annual rainfall (mm/month), decreased According to SSP2-4.5 -14.83% and -18.0% in the middle periods (2060s and 2080s), also in SSP5-8.5 -21.0% and -21.6%, The period (2020) current ETc values in ascending order were 612.9, 1164.9, and 1440.7 mm/season for potatoes, summer tomato, and wheat respectively. The NIWR for all investigated crops rise need for water increases by were found to be rising in the ranges(%) 10.27 - 25.26 for Tomato S and Potatoes to the ranges(%) 8.17 - 23.18 and Wheat in ranges(%) 1.79 -10.35.under SSP2-4.5

for the periods , also in SSP5-8.5 for corps Tomato S , Potatoes and wheat is high By 19.27 – 37.65 , 17.96 – 32.26 and 5.79 – 18.85 , respectively. The crop that consumes the most water is tomatoes, then potatoes, and the least is wheat. Therefore, it is recommended to Wheat cultivation in the study area.

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