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Climate Change Vulnerability Assessment in Jalisco: A Comprehensive Analysis

Ramírez-Sánchez Hermes Ulises [a,b*], Fajardo-Montiel Aida Lucia [b], García-Guadalupe Mario Enrique [a] and Ulloa-Godínez Héctor Hugo [a]

[a] *Instituto de Astronomía y Meteorología CUCEI, University of Guadalajara, Av. Vallarta 2602. Col. Arcos Vallarta, Guadalajara, Jalisco, México.*
[b] *University Center of Tonalá, University of Guadalajara, Av. Nuevo Periférico No. 555 Ejido San José Tateposco, C.P. 45425, Tonalá, Jalisco, México.*

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

The changes in temperatures and precipitation estimated for the different climate change scenarios will have an impact on all sectors in the world, Mexico and Jalisco. Variations in temperature, precipitation, relative humidity, melting glaciers, expansion of water bodies due to thermal expansion and the rise in sea level in recent decades in the intertropical zone are evidence of the country's high vulnerability to climate change. Significant increases in temperature, decreases in

**Corresponding author: E-mail: hermes.ramirez@academicos.udg.mx, ramirez@astro.iam.udg.mx;*

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precipitation and runoff will cause scarcity and pressure on water resources, health, agriculture, livestock, marine ecosystems, industry, biodiversity, urban development, energy, housing, mobility, economy, waste, among others.

Aims: The objective of this study is to present regional projections of temperature and precipitation in Jalisco, under the IPCC's AR6 climate change scenarios, improving the projections of the Oceanic-Atmospheric General Circulation Models and estimating the possible impacts of climate change in Jalisco.

Methodology: A total of 27 CLIMDEX climate change indices were calculated, using 197 stations distributed in the 125 municipalities of the State of Jalisco. For the regional modeling, the PRECIS (Providing Regional Climates for Impact Studies) model was used, developed by the Hadley Center of the United Kingdom, in a domain that covers the west of the Mexican Republic with a resolution of 25 km in the period 2020-2099.

Results: Regional models for Jalisco show temperature increase between 0.5 to 5°C, while % precipitation will range between -20.3 and 13.5% depending on the scenario and period of analysis. The increase in temperature will cause soil moisture deficits, water stress, sparse vegetation and semi-permanent meteorological drought. Under these scenarios, the entire country is expected to be subject to moderate to extremely severe droughts that will last and worsen between now and the end of the century. Regional modelling shows significant impacts on the water sector with low water availability; in the agricultural sector with a decline in the productivity of the state's crops, mainly affecting small landowners and subsistence farmers. As for livestock, the increase in temperatures will decrease the availability of water and feed; cattle will enter heat stress and increase respiratory and heart rate, which will decrease productivity and with the possible disappearance of livestock areas. In terms of biodiversity, it is estimated that between 20-30% of plant and animal species are at greater risk of migration and/or extinction due to temperature increase >3 ºC. The vulnerability of biodiversity will occur due to the weakening of ecosystems, forest fires, land use change and the decline of water resources. The energy sector will be affected by the increase in temperature, greater demand for energy, decrease in energy production, the main effects will be on its distribution. The health sector will be affected due to the presence of heat waves, heat stress and heat stroke; diseases due to high concentrations of pollutants, respiratory, cardio-vascular, vector-borne and contaminated water diseases, neurological and/or mental diseases, among others. Children, the elderly, and people with chronic and degenerative diseases will be the most vulnerable groups. All areas of the state will be impacted, although in a differentiated way, the lack of availability of water will occur throughout the state, agriculture and livestock in the area of Los Altos, floods and loss of biodiversity in coastal areas, the central area will concentrate most of the impacts due to the high population density.

Conclusion: it is estimated that Jalisco's vulnerability to climate change is high to very high in all sectors and in all regions of the State of Jalisco.

Keywords: Climate change; impacts; vulnerability; jalisco.

1. INTRODUCTION

One of the biggest concerns with climate change concerns its potential effects on water resources and consequently on all other sectors. In fact, a country's climate, hydrological cycle and development are intimately related and it is difficult to define the boundaries between them. Climate depends on relevant variables of the hydrological cycle, such as relative humidity, precipitation, evaporation, among others; and the productivity of crops, livestock, energy production and biodiversity depend on climate and water availability. The climate system and the hydrological cycle are closely linked to the oceans, as evidenced by the ENSO (El Niño-Southern Oscillation) phenomenon [1], on which the health of marine ecosystems and resources, as well as their biodiversity, depends. Of course, the dynamics of the oceans will also have important changes as a result of global warming, which will interact with the global climate system. Inland bodies of water are great regulators of the climate, creating microclimates. Thus, the increase in temperature in climate change scenarios will have repercussions on the global, regional and local hydrological cycle, and consequently, on the availability of water resources in the most vulnerable areas of Mexico, on which the country's other economic activities and development depend greatly.

In terms of urban development, the most vulnerable settlements are those in flood-prone coastal and river areas, climate-sensitive resource-related economies, and in extreme weather areas where rapid urbanization is taking place.

The sixth report of the Intergovernmental Panel on Climate Change (IPCC) has concluded that: "A.2 It is unequivocal that human influence has warmed the atmosphere, ocean and land. There have been widespread and rapid changes in the atmosphere, ocean, cryosphere, and biosphere; A.3 Human-induced climate change is already affecting extreme weather and climate events in all regions of the world. Evidence of observed changes in extremes such as heat waves, heavy rainfall, droughts, and tropical cyclones and, in particular, their attribution to human influence," [2,3,4,5].

The effects of global climate change are already being observed with greater or lesser intensity in different regions of the world. Fig. 1 shows the anomalies of a) temperature and b) global precipitation; Fig. 2 shows global sea level change [2].

The World Meteorological Organization (WMO) indicates that the global average temperature over the continents and oceans during 2020 has been one of the three warmest on record. This represented a positive anomaly of 1.2 °C, compared to the pre-industrial era (1880-1900), as shown in Fig. 3. The average surface temperature of the last ten years has been one of the warmest; thus, the decade 2011-2020 has been the warmest on a global scale.

According to AR6, compared to 1850-1900, global surface temperature during 2081-2100 is very likely to be higher by 1.0 to 1.8 °C in the very low greenhouse gas (GHG) emissions scenario (SSP1-1.9), 2.1 to 3.5 °C in the intermediate GHG scenario (SSP2-4.5), and 3.3 to 5.7 °C in the very high GHG scenario (SSP5-8, 5). The most likely scenarios by the end of the century are estimated to be SSP2-4.5 and SSP3-7.0 [2].

Temperature rise forecasts for these scenarios are shown in Table 1 [2]. In the SSP2-4.5 scenario ("intermediate scenario"), the expected global average temperature by the end of the century will increase from 2.1°C to 3.5°C. In the second most likely SSP3-7.0 scenario (critical scenario), the expected increase will be 2.8 to 4.6 °C. As GHG emissions continue to grow, even at a higher rate than expected, pessimistic forecasts seem to be coming true.

Mexico has a great variety of biomes, the North and Central zones are very arid and semi-arid and occupy 56% of the territory, the mountains and coastal plains of the Pacific, Gulf of Mexico and northeastern part of Yucatan represent the sub-humid area that represents 37% and the humid areas are located in the rest of the territory with 7%. Its location between two oceans and complex topography increases the country's exposure to extreme hydrometeorological events such as tropical cyclones, frost, heat waves, and floods.

Mexico's climate presents regional differences due to its topography and geographic location. The average temperature in the country varies from 15 to 20°C in the central highlands; 23 to 27°C in the coastal lowlands. Seasonal variations are minimal in the south, but range from 10°C to 30°C in summer in the northernmost parts of the country. Mexico's average annual temperature is 20.6 °C, with monthly averages ranging from 15 °C (January) to 25°C (June). The average annual rainfall is 725 mm, with constant rainfall mainly from June to October. In the far north, rainfall is less than 50 mm per month throughout the year, while the southern regions and central highlands have a wet season from June to October, with an average of 550 mm per month in the southernmost regions. From June to November, the Atlantic and Pacific coasts are vulnerable to hurricanes and the climate is strongly influenced by events such as El Niño-Southern Oscillation (ENSO), which provides wet, cool weather in winter and warmer, drier conditions in summer.

In Mexico, a pattern of temperature increase is observed, with values higher than the world average, the anomalies for the period 1950-2000 are shown in Fig. 4 [6], and the temperatures for the period 1901-2020 in Fig. 5 [7]. The average temperature growth rate in the country is 0.3 °C/decade in the last 20 years and 0.72 °C in the last decade, values that confirm Mexico's high vulnerability to climate change.

In terms of rainfall based on the period 1941-2020, 1943 is the driest year and 1958 is the wettest. The year 2020 is the second consecutive year with below-average rainfall and with it we complete 5 years with deficit rainfall between 2011-2020 (Fig. 6). The average annual and five-year rainfall in the period 1901-2020 is presented in Fig. 7.

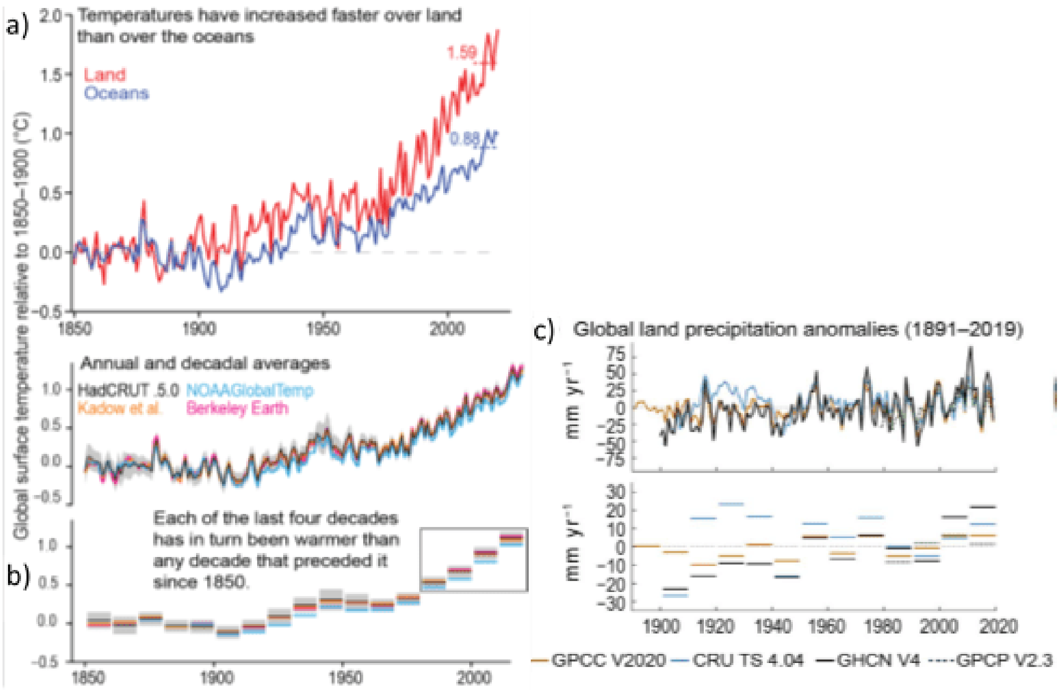

Fig. 1. Evolution of the Earth's surface temperature. (a) Temperature from instrumental data in the period 1850-2020, multi-product annual mean time series assessed for ocean temperature (blue line) and land temperature (red line) and indicating warming up to the last 10 years; and (b) annual and decadal averages for GMST data. Gray shading shows the uncertainty associated with the estimate [8]; (c) Changes in observed precipitation. Annual and decadal mean time series from 1891 to date relative to climatology 1981-2010 [9].

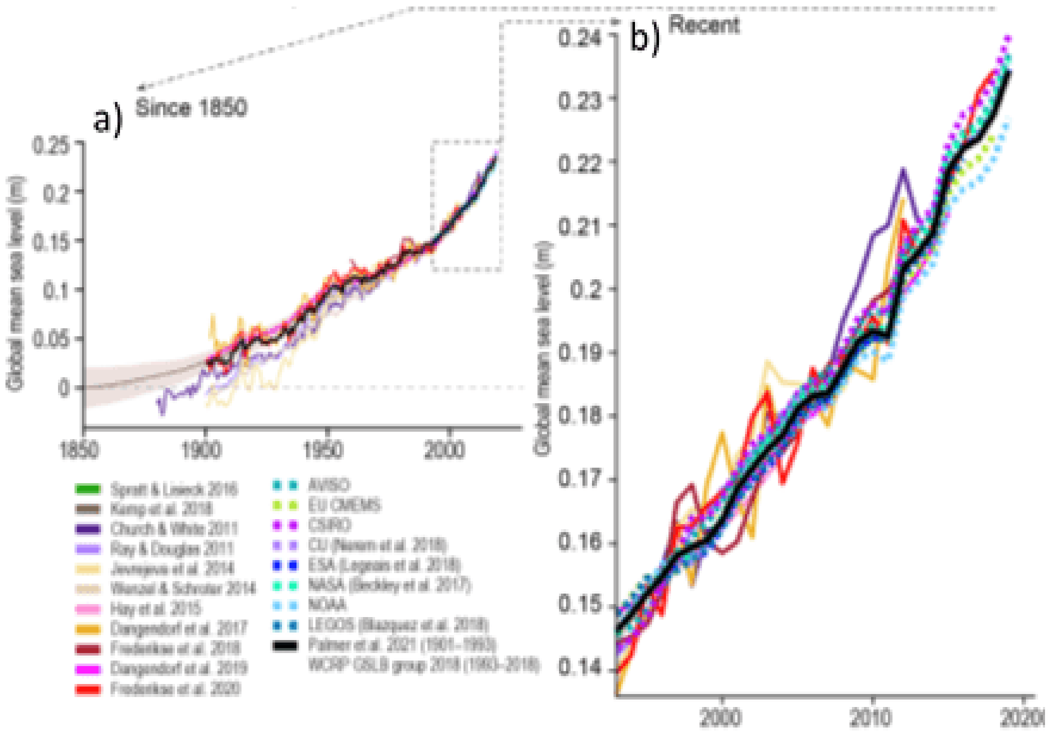

Fig. 2. Changes in global mean sea level a) Estimates based on tide gauges and altimeters since 1850b) The most recent recording period [9]

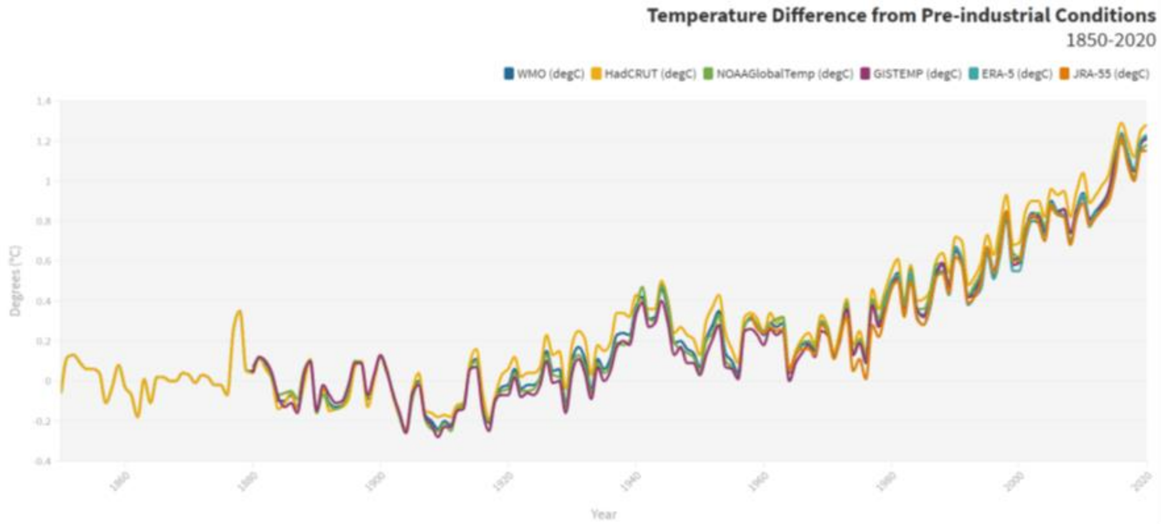

Fig. 3. Average air temperature anomaly of two meters globally in 2020, from different research centers such as: ERA5 (ECMWF Copernicus Climate Change Service, C3S); GISTEMPv4 (NASA); HadCRUT4 (Met Office Hadley Center); NOAA GlobalTemp (NOAA), JRA-55 (JMA) and WMO [10]

Table 1. Changes in global surface temperature over 20-year periods and in the five emission scenarios considered. Temperature differences relative to the global mean surface temperature for the period 1850-1900 are reported in °C. [2]

	Near term, 2021-2040		Mid-term, 2021-2040		Long term, 2021-2040	
Scenario	**Best estimate (°C)**	**Very likely range (°C)**	**Best estimate (°C)**	**Very likely range (°C)**	**Best estimate (°C)**	**Very likely range (°C)**
SSP1-1.9	1.5	1.2 to 1.7	1.6	1.2 to 2.0	1.4	1.0 to 1.8
SSP1-1.9	1.5	1.2 to 1.8	1.7	1.3 to 2.2	1.8	1.3 to 2.4
SSP1-1.9	1.5	1.2 to 1.8	2.0	1.6 to 2.5	2.7	2.1 to 3.5
SSP1-1.9	1.5	1.2 to 1.8	2.1	1.7 to 2.6	3.6	2.8 to 4.6
SSP1-1.9	1.6	1.3 to 1.9	2.4	1.9 to 3.0	4.4	3.3 to 5.7

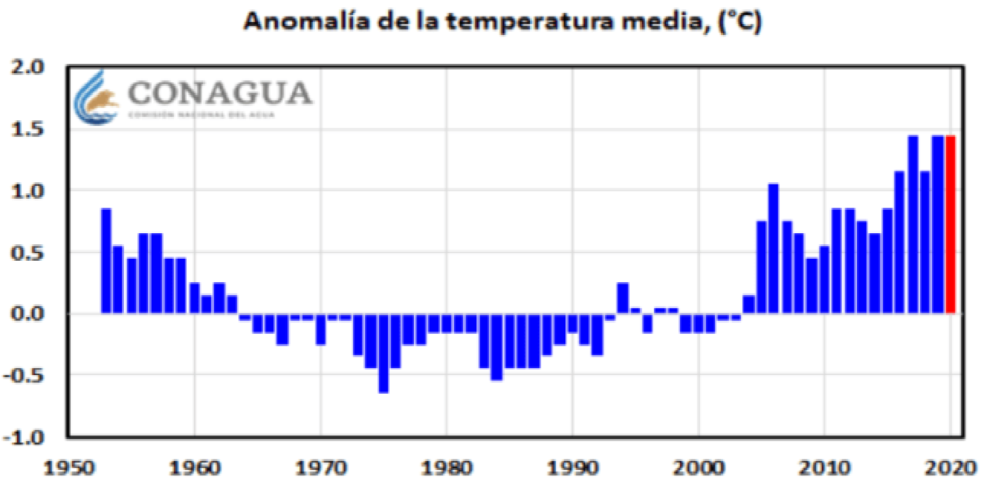

Fig. 4. Annual mean temperature anomaly (°C), the red bar corresponds to the estimated national anomaly in 2020. Based on measurements since 1953 by the National Weather Service [6]

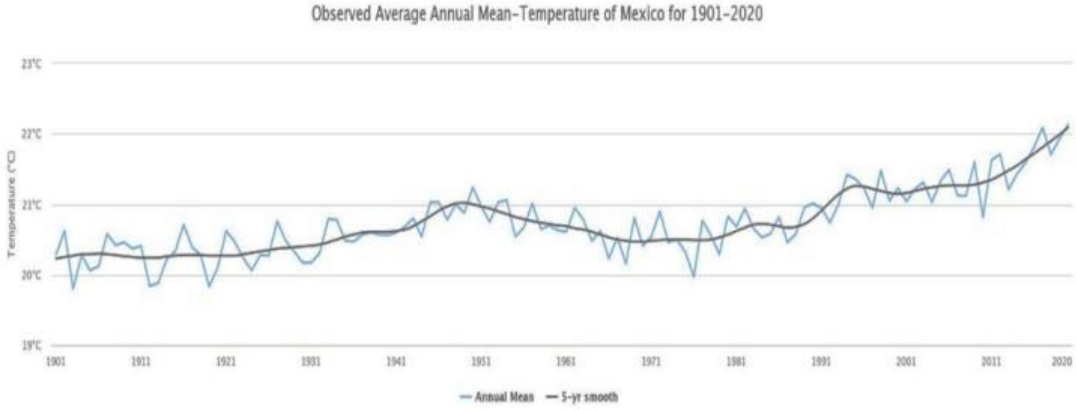

Fig. 5. Annual and five-year average temperature in the period 1901-2020 [7]

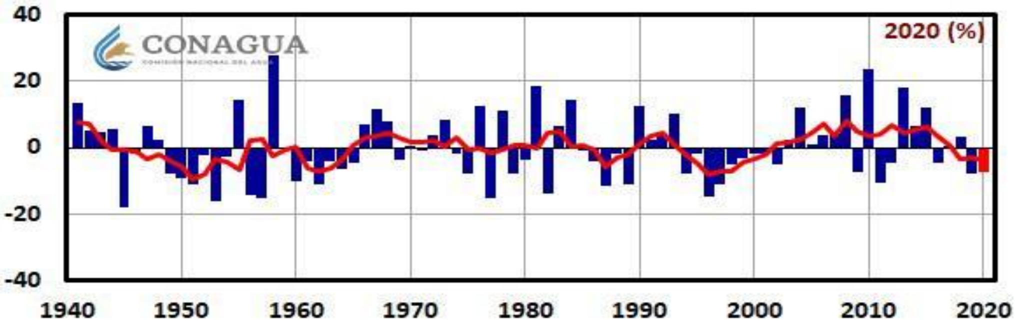

Fig. 6. Anomalies of annual national precipitation (Blue Bars), Five-Year Moving Average (Red Line) [6]

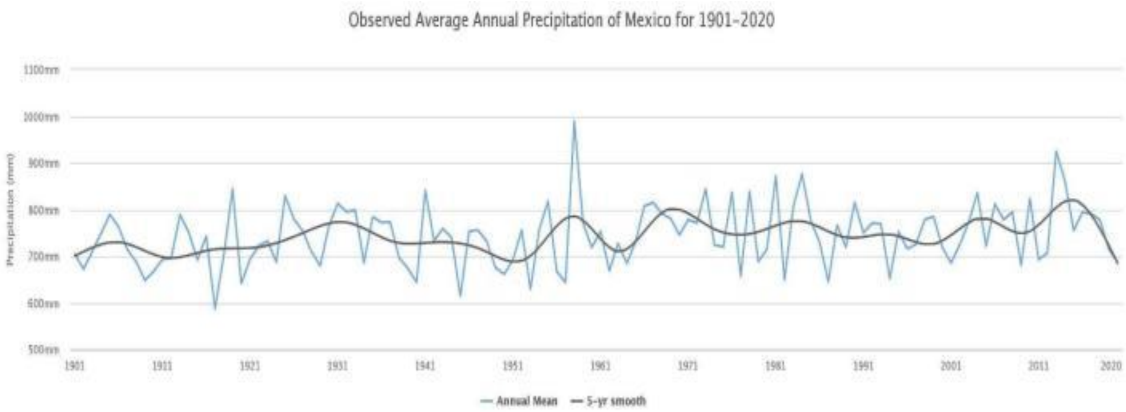

Fig. 7. Average annual and five-year rainfall in the period 1901-2020 [7]

Regarding sea level variations, a study by INE-SEMARNAT-UNAM [11] reported that sea level increases on the coasts of Mexico were highly variable: In Ciudad Madero 9.16 mm/year, Guaymas 4.23 mm/year, Ensenada 2.73 mm/year, Progreso 2.45 mm/year, Cd del Carmen 3.38 mm/year, Manzanillo 3.28 mm/year, Veracruz 1.89 mm/year, Salina Cruz 1.13 mm/year and Acapulco -2.44 mm/year. These differences are due to the increase in sea level due to thermal expansion and melting as a result of climate change, and geological phenomena such as subsidence due to tectonic plate collision or continental elevation due to sediment discharge in river deltas are added or subtracted.

Future weather conditions will depend on the amount of GHG emissions. Thus, scientific predictions are made in terms of scenarios, which will depend on the ability of civilization to control its GHG emissions, the protection of biomes, conservation of jungle and forest regions, which capture part of the CO_2 emitted into the atmosphere. The set of regional projections of temperature and precipitation under conditions of the IPCC AR6 climate change scenarios for Mexico will be used to describe the possible temperature and precipitation scenarios; and will allow assessing the vulnerability of Mexico and Jalisco to climate change by the end of the century [12-17].

2. MATERIALS AND METHODS

For the present study, modeled data from the global climate model compilations of the Coupled Model Intercomparison Projects (CMIP) of the World Climate Research Programme were used. The data presented are CMIP6, derived from the Sixth Phase of the CMIP and form the IPCC Assessment Reports database. This climate forecasting tool, used as a statistical method of downscaling, allows regional projections of climate change in temperature and precipitation. In this way, the changes in temperature and precipitation for the present century are obtained; and along with vulnerability projections, potential impacts are estimated. Projection data is presented with a resolution of 1.0º x 1.0º (100km x 100 km). In this way, a set of regional projections on climate change was made for the period 2020-2099, for Mexico and the state of Jalisco [12-17].

The ability to generate scenarios over a long period of time allowed the reproduction of climatic parameters, as well as the response of the regional climate to the increased radiative forcing resulting from increased GHG concentrations. Thus, the temperature and precipitation trend at the regional scale for Mexico in 2020-2099 was obtained [12-17].

Complementary data were used for impact analyses, such as the Normalized Difference Vegetation Index (NDVI) that was taken from the NASA data archive; which allowed to evaluate the impact of anomalous climatic conditions on vegetation, negative values indicate clouds and water, positive values close to zero, which indicate bare soil, and higher positive values ranging from sparse vegetation (0.1−0.5) to dense green vegetation (0.6 and above). Thus, positive anomalies correspond to healthy vegetation conditions and negative anomalies correspond to stressed vegetation. Standardized precipitation evapotranspiration indices (SPEI) were also used as a drought indicator. Positive values indicate a positive water balance (wet conditions) and negative values indicate a negative water balance (dry conditions). This indicator was assessed in 12-month accumulation periods, as an indicator of the risks associated with prolonged hydrological drought, such as reduced reservoir recharge and water availability. However, it excludes factors that influence drought, such as geology, soil type, flow, glacier melt and evapotranspiration. Soil moisture (m^3/m^3) was also estimated, which is the average water content of the topsoil (0 to 5 cm deep) and is used as an indicator of the extent and duration of drought. There is a strong interrelationship between soil moisture, vegetation and climate in the short and long term. Soil moisture influences vegetation type and condition and evapotranspiration. Change in soil moisture can have considerable impacts on crop and livestock productivity, ecosystem health, and food security. Soil moisture is used to anticipate and manage risks related to drought and secondary hazards (wildfires), support crop insurance models, and guide long-term agricultural resilience programming. Finally, this information was complemented with maps of drought episodes in Mexico over the last two decades [12-17].

The historical data to establish Mexico's baseline climatology were taken from the Climatic Research Unit (CRU) at the University of East Anglia. Fig. 8 presents the climatology for the period 1990-2020, the data present a resolution of 0.5º x 0.5º (50 km x 50 km) for a) the mean annual temperature, b) accumulated annual precipitation; minimum, maximum and mean monthly temperatures and precipitation monthly during the period 1991-2020. The trend of change in temperature and precipitation is a measure of the climate's sensitivity to increased radiative forcing. The latter has increased in recent years, leading to a warmer climate [2]. The linear trend over Mexico between 1991-2020 is captured by the CMIP6 regional set of climate change scenarios. For projections for this century, the sources of uncertainty on a global scale relate to GHG emission scenarios. The differences between climate change experiments have been used as a measure of uncertainty, concluding that the greater the dispersion between the models, the greater the uncertainty in the projection.

3. RESULTS AND DISCUSSION

3.1 Regional Climate Change Scenarios for Mexico

Most studies agree that the temperature will increase in the coming decades and that it will affect the hydrological cycle on a global and regional scale [2, 18, 19]. The impacts of climate change are expected to have a large number of socio-economic consequences, particularly in regions where several climate disasters have occurred in recent decades. The IPCC [2, 18] has concluded that Mexico will be among the regions where the water deficit will be exacerbated due to temperature increases and reduced rainfall. The regional climate change scenarios obtained through CMIP6 show the contrasts in projected climate changes between regions of Mexico. Temperature increases are expected to vary because the dynamic mechanisms that control climate variability are related to processes in the Pacific and Atlantic oceans [20-21].

Regional models for Mexico show that the annual mean surface temperature may experience increases ranging from 0.5 to 5 °C depending on the scenario and period, while the percentages of change in precipitation range from -20.3 to 13.5% depending on the scenario and period. It is considered unlikely to limit GHGs and radiative forcing to the SSP1-1.9 and SSP1-2.6 scenarios, on the other hand, it is expected that GHG emission mitigation actions will allow the worst scenario (SSP5-8.5) not to be reached, so it is estimated that the most likely scenarios are the SSP2-4.5 and SSP3-7.0. For the anomalies of temperature, precipitation and percentage of rainfall, the period 1991-2020 was taken as a reference.

For the SSP2-4.5 scenario, the average annual temperature anomalies for Mexico in the period 2020-2039 are estimated at 0.83±0.06 °C, for 2040-2059 1.46±0.06 °C, for the period 2060-2069 1.96±0.09 °C and in 2080-2099 will reach a value of 2.35±0.12 °C with respect to the reference period 1991-2020 (Table 2 and Fig. 9). The values are differentiated according to the region, state and municipality. In the SSP3-7.0 scenario, the mean annual temperature (°C) anomaly in the period 2020-2039 is estimated at 0.75±0.04 °C, between 2040-2059 it will be 1.59±0.06 °C, and for 2060-2069 it will be 2.49±0.11 °C and in 2080-2099 it will reach 3.49±0.14 °C (Table 2 and Fig. 10).

Regional precipitation projections tend to produce negative and positive changes depending on the period analyzed and/or region of the country. The most important changes will be in the Northern, Central and Southern areas of Mexico. However, most of the changes are precipitation decreases in most of the country. For the SSP2-4.5 scenario, the mean annual precipitation anomalies in 2020-2039 are 0.12±3.71, for 2040-2059 -0.93±4.45, in 2060-2069 -2.12±5.00 and for 2080-2099 -3.40±6.31 (Table 2). In the SSP3-7.0 scenario, the mean annual precipitation anomalies for 2020-2039 are estimated at -0.97 ±2.13, in 2040-2059 -3.51±4.64, for 2060-2069 -5.92±8.35 and in 2080-2099 -7.77 ±11.18 (Table 2). The % precipitation change for the SSP2-4.5 scenario in 2020-2039 is -0.98± 4.48%, in 2040-2059 -3.10±6.71%, for 2060-2069 -5.1±6.49% and in 2080-2099 -5.81±7.59% (Table 2 and Fig. 11). In the SSP3-7.0 scenario, the % change in mean annual precipitation in 2020-2039 will be -1.46±3.60%, in 2040-2059 -4.94±6.15%, for 2060-2069 -8.78±8.94 and in 2080-2099 -10.59±12.66% (Table 2 and Fig. 12).

Mexico is located in one of the regions of the world where rainfall is most likely to decrease under climate change [18]. The reduction in rainfall together with increases in temperature implies an increase in potential evapotranspiration and a substantial reduction in the availability of water and soil moisture, affecting rainfed and irrigated agriculture; the agricultural productivity that could put food security, livestock and other economic sectors at risk. Thus, by the end of the century, the expected magnitude of negative changes in rainfall will be between -5 and -10%.

The temporal evolution of the projections indicates that decreases in rainfall are more likely to be significant during the second half of the 21st century, showing a clear negative trend in any of the CIMP6 scenarios. If we add to this the observations of soil moisture (mm), the 12-month Standard Precipitation Index SPEI12 Log (ERAS LAND), Normalized Difference Vegetation Index (NDVI) and drought events (Fig. 13) we get a more robust picture of how temperature and precipitation changes will affect Mexico's resources. Thus, the soil moisture map (mm) shows that the North, West and Bajio zones have the lowest soil moisture values with values below 0.1, which will be exacerbated with higher temperatures that will cause greater evaporation and with less rainfall, it will not allow the soil to recover its moisture. The South, Gulf, and Southeast, although they have a higher level of soil moisture (between 0.2-0.4 mm), will also be affected as a result of climate change (Fig. 13a). The SPEI is a standardized version of precipitation anomalies and has been used to characterize the severity of meteorological drought [21]. SPEI12 provides evidence of the effects of persistent precipitation anomalies and estimates the potential trend for more meteorological droughts. The SPEI12 map shows prolonged drought, with more intensity in the North (Fig. 13 b). The magnitude of SPEI12 during the 20th century ranged from -1 to −2 when prolonged droughts occurred, which corresponds to the category of extremely dry conditions. Regional-scale precipitation projections for 2000−2099 do not have the magnitude of observed natural variability. However, there is a definite trend towards negative SPEI12 values under the SSP3-7.0 scenario than under the SSP2-4.5 scenario, with average values of around -1, conditions considered as semi-permanent moderate meteorological drought.

NDVI (Fig. 13c) is closely related to soil temperature and moisture. Thus, the negative changes of the NDVI over Mexico are related to the reduction in precipitation and the increase in temperatures. The patterns projected for the second half of the 21st century correspond to a severe deficit of soil moisture and water stress in plants. NDVI values are considered sparse vegetation. The projected changes in soil moisture and NDVI in the SSP scenarios resemble the anomalies observed under intense ENSO event conditions (1982-1983, 1986-1993, 1997-1998, 2014-2016).

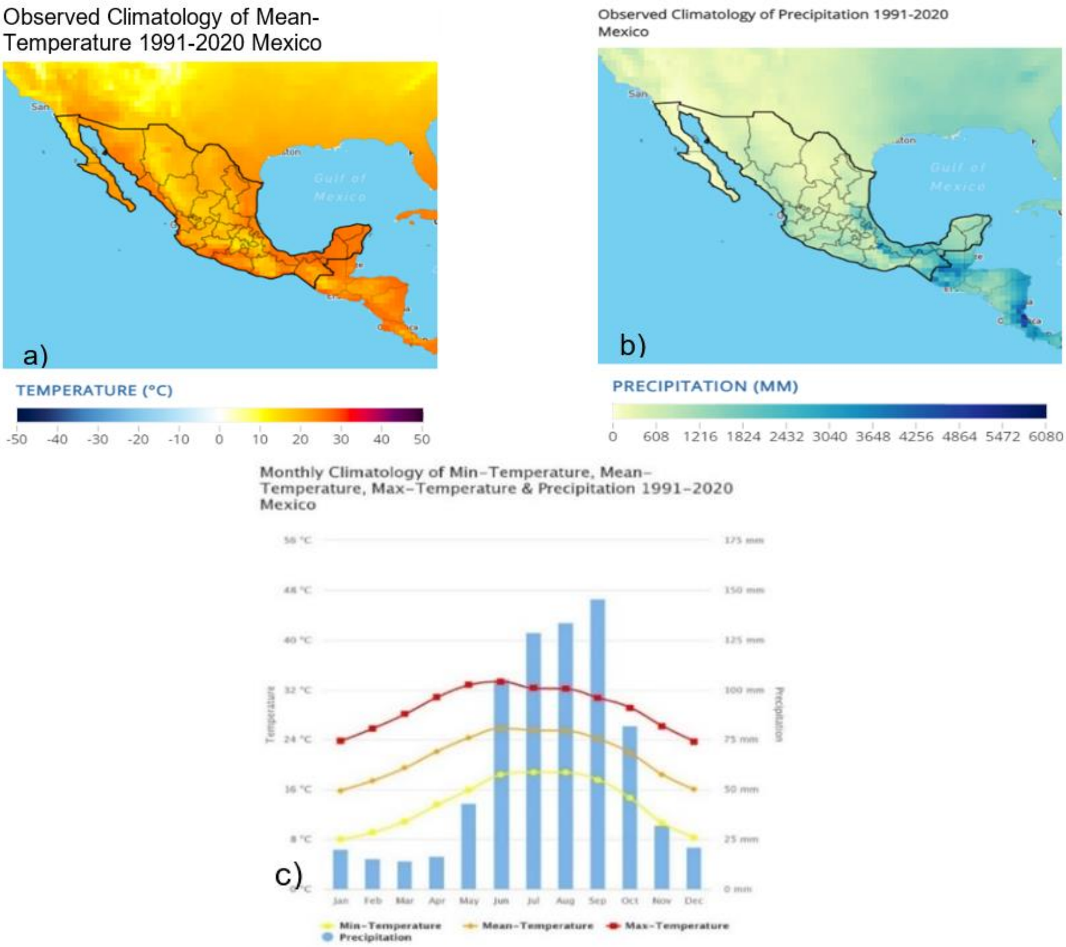

Fig. 8. Climatology at high spatial resolution with CRU data (50 × 50 km) (base period 1991-2020) observed from a) mean annual temperature (°C), (b) mean annual precipitation (mm) and (c) minimum, maximum, mean and monthly precipitation temperatures [7]

Table 2. Temperature, precipitation and % precipitation change anomalies for Mexico according to the regional models of the IPCC (2014) SSP1-1.9, SSP1-2.6, SSP2-4.5, SSP3-7.0, SSP5-8.5 scenarios during the current century (Authors, data from [7])

		Temperature anomalies in °C		
	2020-2039	2040-2059	2060-2079	2080-2089
SSP1-1.9	0.68±0.09	0.81±0.08	0.70±0.1	0.61±0.10
SSP1-2.6	0.82±0.06	1.19+±0.07	1.32±0.06	1.25±0.09
SSP2-4.5	0.83±0.06	1.46±0.06	1.96±0.09	2.35±0.12
SSP3-7.0	0.75±0.04	1.59±0.06	2.49±0.11	3.49±0.14
SSP5-8.5	0.94±0.04	1.93±0.05	3.14±0.08	4.54±0.15
		Precipitation anomalies in mm		
SSP1-1.9	1.57±5.41	2.58±5.83	2.27±5.98	1.58±5.28
SSP1-2.6	1.12±3.39	0.28±3.75	-0.65±3.38	0.08±3.75
SSP2-4.5	0.12±3.71	-0.93±4.45	-2.12±5.00	-3.40±6.31
SSP3-7.0	-0.97±2.13	-3.51±4.64	-5.92±8.35	-7.77±11.18
SSP5-8.5	-1.78±2.56	-3.32±5.82	-5.63±8.49	-9.38±14.07
		Changes in % precipitation in mm		
SSP1-1.9	-2.60±5.84	-1.64±5.57	-1.36±4.94	-2.90±3.84
SSP1-2.6	0.42±3.45	-0.21±3.62	-1.27±4.38	-0.35±4.54
SSP2-4.5	-0.98±4.48	-3.10±6.71	-5.1±6.49	-5.81±7.59
SSP3-7.0	-1.46±3.60	-4.94±6.15	-8.78±8.94	-10.59±12.66
SSP5-8.5	-1.65±4.76	-4.28±7.57	-7.63±11.18	-12.80±16.15

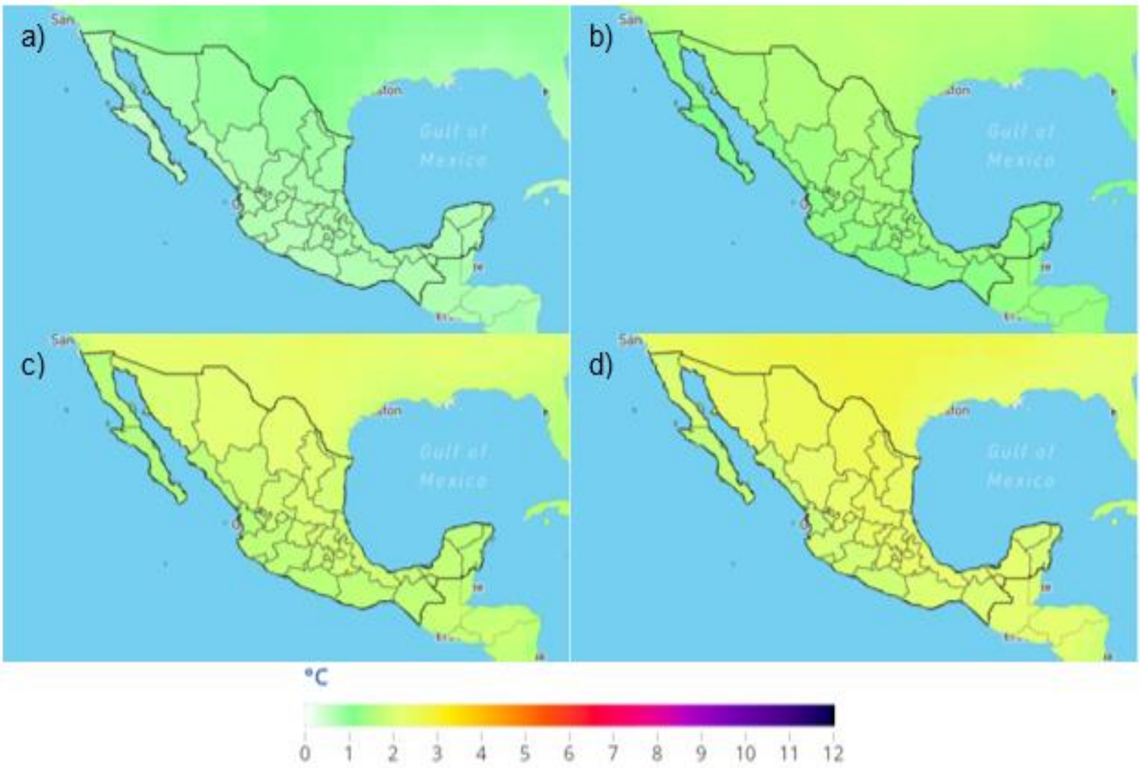

Fig. 9 Average (Annual) Temperature Anomaly projected for Mexico under the SSP2-4.5 scenario a) 2020-2039; (b) 2040-2059; (c) 2060-2079 and (d) 2080-2099 [7]

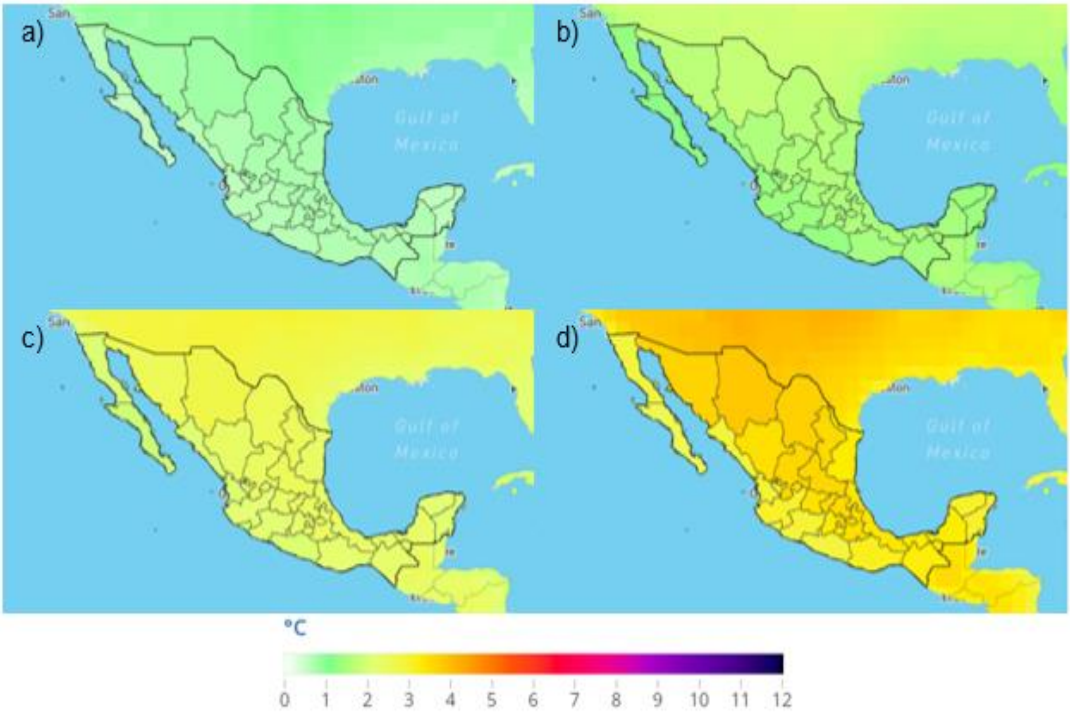

Fig. 10. Average (Annual) Temperature Anomaly projected for Mexico under the SSP3-7.0 a) 2020-2039 scenario; (b) 2040-2059; (c) 2060-2079 and (d) 2080-2099 [7]

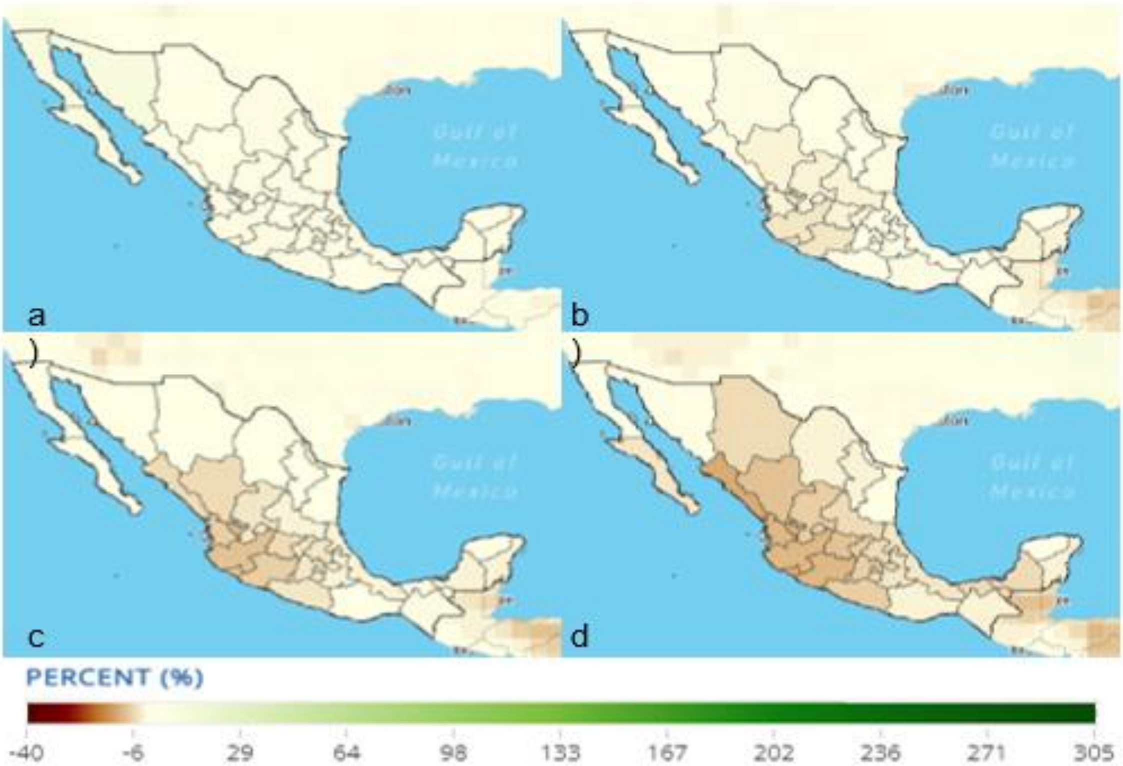

Fig. 11. Projected Precipitation Percentage Change Anomaly for Mexico under the SSP2-4.5 scenario a) 2020-2039; (b) 2040-2059; (c) 2060-2079 and (d) 2080-2099 [7]

Most of the affected regions are semi-arid areas, where natural vegetation is a niche of very rich biodiversity. Very low-frequency climate variability over Mexico with surface temperature anomalies of 5 °C and water stress has resulted in an increased number of forest fires, without considering the effect of climate change. If positive temperature anomalies and negative rainfall anomalies are added to these conditions, this will exacerbate the increasing presence of fires in forests and jungles in Mexico, a situation that could last until the end of the century.

Regional climate change scenarios suggest that, by the end of the 21st century, water availability in northern Mexico may be reduced by up to 30% due to global warming, due to possible reductions in precipitation and temperature increases. Historically, droughts have had serious consequences on primary activities such as agriculture, livestock, forestry and the environment. Anomalously high temperatures in northern Mexico persisted during the summers of 1998-2002 (around +2 °C) with below-normal rainfall (-20 to -30%), leading to prolonged drought. Such climatic anomalies resulted in a severe deficit of soil moisture and water stress on crops and vegetation that increased the potential for wildfires. The spring of 1998 turned out to be the season with the highest number of forest fires in Mexico in recent decades, not only because of hydrological stress on vegetation, but also because of slash-and-burn practices in the agricultural sector [22]. In northern Mexico, vulnerability has not been reduced [23] and the risk of a major environmental disaster is still present [24] and will be complicated by the effects of climate change (high temperatures and low precipitation).

The drought map (Fig. 13d) shows that virtually the entire country suffers from moderate (Central and Southern) to extremely severe (Northern) droughts. Under the climate change scenarios SSP2-4.5 and SSP3-7.0 with conditions of increasing temperatures and decreasing rainfall, the drought landscape in Mexico will be prolonged and worsen between now and the end of this century, with the associated social, economic, political and cultural implications.

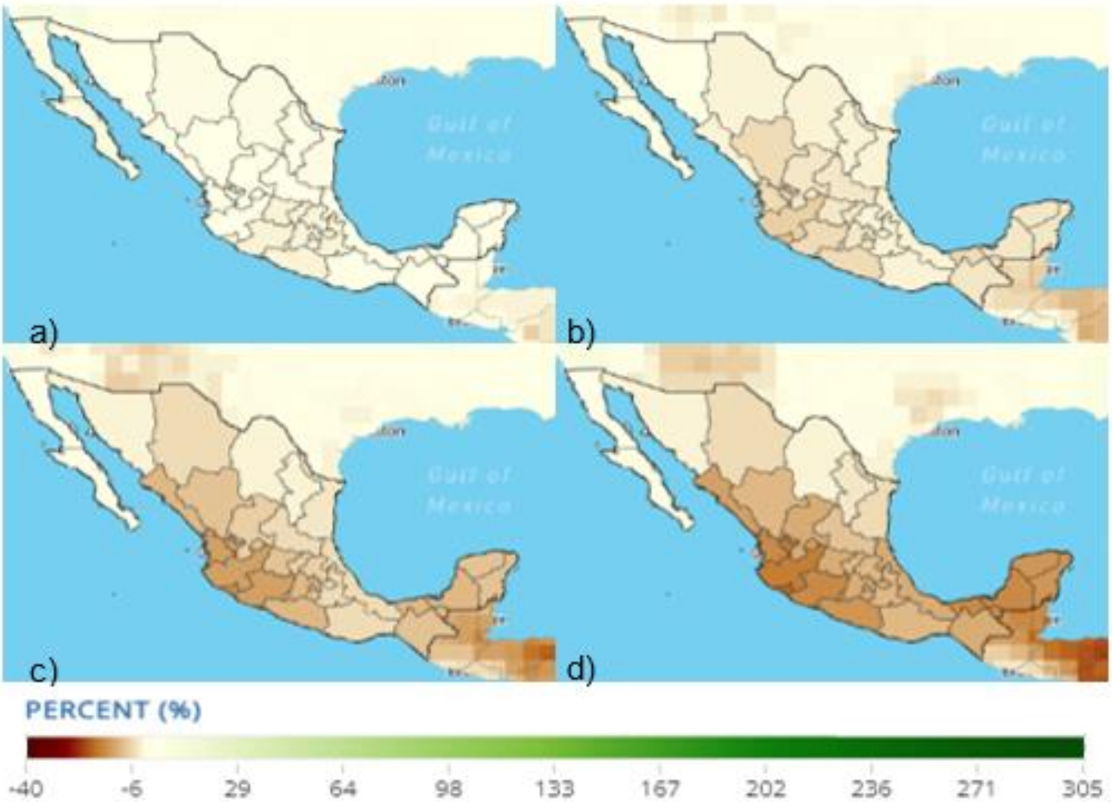

Fig. 12. Projected Precipitation Percentage Change Anomaly for Mexico under the SSP3-7.0 scenario a) 2020-2039; (b) 2040-2059; (c) 2060-2079 and (d) 2080-2099 [7]

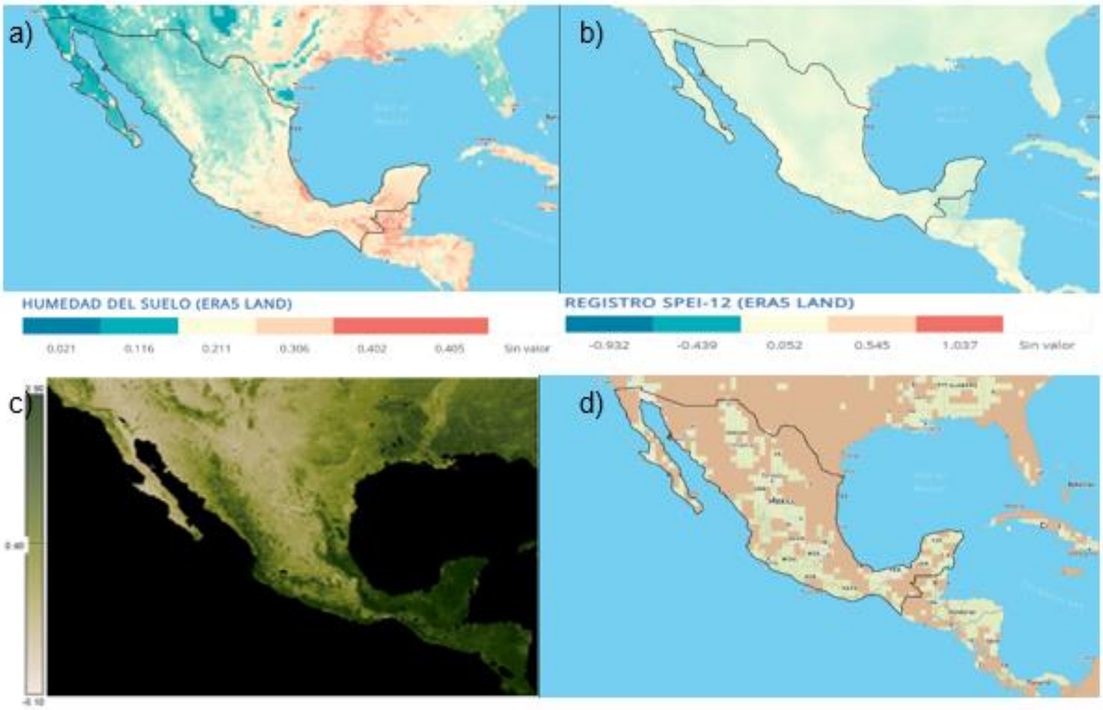

Fig. 13 (a) Soil moisture (mm) and (b) SPEI 12 Log (ERAS LAND), c) changes in the Normalized Difference Vegetation Index (NDVI) and d) Drought events in the SSP2-4.5 scenario for the second half of the 21st century [7]

3.2 Impacts of Climate Change in Mexico

Water sector: The results show a surface temperature increase of approximately 1.8 °C for the year 2020 compared to 1900, being above global values. CIMP6 regional models show that in most of Mexico, heat waves are more frequent and intense, while extreme cold events have decreased in frequency and intensity. This has led to very warm summers and less harsh winters. The regional scenarios projected for Mexico show that the surface temperature will continue to increase from 2020 to 2099 in all GHG emission scenarios considered, exceeding the threshold of 2 °C increase. Projections for the period 2081-2099 show an increase from 1.78 to 2.58 °C for the SSP2-4.5 intermediate scenario and 2.78 to 2.84 °C for the high SSP3-7.0.

In the regional projections for Mexico, this threshold in the period 2040-2059 would be exceeded by all global scenarios except for SSP1-1.9. It is estimated that, with the additional increase in global temperature, the changes in extremes continue to become larger, with greater intensity and frequency of heat waves, intense rainfall, meteorological, agricultural and ecological droughts in some regions, with more increases than decreases. In Mexico, the projected regional scenarios will reach higher temperatures than global temperatures (1.8°C), increasing the frequency and intensity of hot extremes (heat waves, intense rainfall, meteorological, agricultural and ecological droughts). Regional projections coincide with global projections, with temperature increases on hot days in the global ranges. Regional models for Mexico estimate that the frequency of such extreme events will increase in the current century.

The IPCC report estimates that heavy precipitation events will intensify by 7% for every °C of global warming. The proportion of intense tropical cyclones (category 4-5) and their maximum wind speeds are projected to increase with increasing global warming [2]. For Mexico, increases in rainfall are only estimated for the period 2020-2039 and in low scenarios. In the rest of the scenarios, the trend will be towards a decrease in precipitation; while the intensity of the rains will increase.

In Mexico, the period 2020-2039 will show an increase in precipitation, and from 2040 to 2099 there will be a decrease in wet events and an increase in dry events. The regional projections for Mexico coincide with the global forecasts of rainfall decrease in the SSP2-4.5 (-5.81±7.59%), SSP3-7.0 (-10.59±12.66%) and SSP5-8.5 (-12.80±16.15%) scenarios in the period 2080-2099. The decrease in soil moisture, the SPEI 12 index, NVDI and the large periods of drought in recent decades confirm for Mexico the global estimates of intensification of very dry weather and prolonged droughts.

Regional projections estimate that the North American monsoon will become increasingly delayed as the century progresses and, together with the decrease in precipitation, will cause storage problems in the country's northern water bodies. At 2°C or more of global warming, the magnitude of change in droughts and heavy and average rainfall is expected to increase. Thus, an increase in meteorological, hydrological and agricultural droughts are present in Mexico so far this century and are projected to intensify by the end of the century.

Likewise, many regions are projected to experience an increase in compound events such as heat waves and more frequent concurrent droughts, and in general, significant decreases in precipitation and runoff are expected for Mexico, which will cause an increase in conditions of scarcity and greater pressure on diversified water resources in the regions and with serious consequences problems in the economic sectors.

In various regions of Mexico, there are conditions of scarcity that are expected to increase, even without climate change, due to population growth, growing urban concentration, pollution of water bodies and overexploitation of resources. Added to this scenario are the effects of climate change, which in Mexico will be a reduction in water availability as a result of the increase in temperature and decrease in rainfall, which together pose very great challenges for the management and sustainable use of resources in Mexico.

Resource management practices in Mexico are not adequate or sufficient to address the challenges associated with climate change. The public resource management policies implemented are not, nor will they be, sufficient to address the impacts of climate change.

On the other hand, a warmer climate will lead to more intense precipitation events, even in places where the average annual rainfall will be lower, which is already happening and will continue to happen in the South and Southeast of Mexico. Indeed, the average annual rainfall may even decrease, but there will be heavier rainfall, which will make it more difficult to control flows through the current channels. It is expected that the impacts of climate change on runoff will be detected first in the occurrence of these extreme events than in annual availability, which itself has important natural variations. This effect of climate change will increase vulnerability in the south and southeast of Mexico, such as the Grijalva-Usumacinta systems in Chiapas and Tabasco, Papaloapan in Veracruz, to name a few examples that register flooding problems [25]. The existence of heavier rainfall coincides with the forecast of lower annual runoff. On the other hand, it is evident that the increase in droughts in the North coincides with predictions of decreased precipitation and runoff, which are expected to occur more frequently and intensely.

Healthcare sector: The IPCC's sixth report [2] mentions that climate change has negatively affected the physical and mental health of people around the world and in the regions assessed. In all regions, extreme heat events have led to human mortality and morbidity. The incidence of climate-related foodborne and waterborne illnesses has increased. The incidence of vector-borne diseases has increased due to range expansion and/or increased reproduction of disease vectors. Animal and human diseases, including zoonoses, are emerging in new areas. The risks of water- and food-borne diseases have increased regionally due to climate-sensitive aquatic pathogens and toxic substances from harmful freshwater cyanobacteria. Although diarrheal diseases have declined globally, higher temperatures, increased rainfall and flooding have increased diarrheal diseases, including cholera and other gastro-intestinal infections. Some mental health problems are also associated with rising temperatures, trauma from extreme weather events, and loss of livelihoods and culture. Increased exposure to wildfire smoke, atmospheric dust, and aero-allergens have been associated with climate-sensitive cardiovascular and respiratory distress. Health services have been disrupted by flood events [2].

The health sector in Mexico has fewer resources than other OECD countries. In 2020, Mexico spent 6.2% of GDP on health, equivalent to $1230 per capita per year (PPP), less than the

OECD average of 8.9%, equivalent to $4000 PPP. Out-of-pocket spending in Mexico makes up 45% of health system income and 4.0% of household spending. Both figures are among the highest in the OECD [26].

When categorizing deaths into three main groups, in 2019 the age-adjusted mortality rate for communicable diseases was 52.4 per 100,000 inhabitants, while for noncommunicable diseases it was 468.7 per 100,000 inhabitants. On the other hand, the rate for external causes was 58.8 per 100,000 inhabitants, in which case land transport accidents (12.9 per 100,000 inhabitants), homicides (25.3 per 100,000 inhabitants) and suicides (5.3 per 100,000 inhabitants) stand out. In 2000, the percentage distribution of causes was 70.2% for noncommunicable diseases, 17.9% for communicable diseases, and 11.9% for external causes, while for 2019 the percentages were 80.4%, 9.1%, and 10.5%, respectively.

The increase in deaths has been constant between 1998 and 2019 (from 400,000 to 700,000 deaths), and increased dramatically in 2019 and 2020 (1150,000) due to the emergence of the COVID-19 pandemic [26]. In the case of diseases caused by zoonoses, during 2020, there were a total of 1510795 cases of COVID-19 in Mexico, which represented 11928.8 per million inhabitants. In 2021, the identified cases amounted to 2536807, equivalent to 20016.5 per million inhabitants. Deaths directly caused by COVID-19 in 2020 were 199429 deaths of people diagnosed with COVID-19, that is, 1156 per million inhabitants, while in 2021 238070 were reported, representing 1846 deaths per million inhabitants. In the Americas, Mexico ranked 2nd in the number of deaths from COVID-19 in 2020, and for 2021 it ranked 17th, with a cumulative figure for both years of 3002 deaths per million inhabitants. According to the WHO, the total number of excess deaths in 2020 was 314596 cases, or 244 per 100,000 inhabitants. For 2021, 311327 deaths were estimated, representing an excess of 239 per 100,000 inhabitants. In the case of vector-borne diseases, there are records of dengue, which had 36742 cases in 2021 [27].

Fig. 14 shows the main causes of death in Mexico in the last 20 years, and the first places are occupied by diseases associated with climate change such as diabetes mellitus and malignant tumors, heart disease, cerebrovascular disease, pneumonia-influenza, chronic lung diseases, bronchitis, asthma and emphysema, intestinal infectious diseases, gastric and duodenal ulcers, malnutrition, anemias, suicides, among others.

Currently the population in Mexico is 128 million Mexicans (2020), and estimating population growth by 2050 of 25% (160 million Mexicans) and by 2100 of 20% (153 million). Under these scenarios, there would be a population of more than 50 million people over 60 years of age, with the respective increase in expenses in the preservation of their health. Estimating that health expenditures would grow in the same proportion without reducing poverty, or increasing total GDP and per capita, it would be necessary to triple the 6.2% of GDP (2020) health to more than 18% and increase spending from $1230 per capita per year (2020) to $3800 dollars in 2100, which would be unfeasible for the economy. Likewise, out-of-pocket spending in Mexico would constitute 65% of the income of the health system and more than 50% of household spending.

Since the regional models for Mexico show that temperature increases ranging from 0.5 to 5 °C, and % rainfall change will range from -20.3 to 13.5% depending on the scenario and period of analysis. The low soil moisture (mm), the negative changes in NDVI and SPEI 12 show that the entire country will present reductions in precipitation and temperature increase, flooding of lands due to sea level rise, disappearance of agricultural land and biodiversity, a large number of extreme events such as heat waves, intense rainfall, meteorological droughts, etc. A decrease in the number of wet events, a greater presence of dry periods, intensifying the moderate drought to prolonged drought, storage problems in reservoirs and moving from meteorological droughts to hydrological and agricultural droughts, a greater number of forest fires, a decrease in food productivity, malnutrition and greater vulnerability to the appearance and exacerbation of diseases typical of Mexicans (chronic-degenerative diseases, obesity, diabetes mellitus, among others) and increased vulnerability to diseases caused by climate change such as heat stress, heat islands, respiratory, vector-borne and contaminated water diseases, water and food shortages; mental illness, among others.

In Mexico, the aforementioned health disorders are already present and have increased in the last 20 years, such is the case of mortality and morbidity due to an increase in diseases caused by contaminated food, vectors such as dengue, Zika and Chikungunya; water-borne diseases such as cholera, red tide, mental illnesses such as anxiety and depression, respiratory, cardiovascular and allergic diseases resulting from fires and air pollution, and interruption and/or disappearance of health services due to extreme flooding events in southeastern Mexico. Likewise, migration phenomena, where communities leave their places of origin and migrate to large cities in search of opportunities, compromising their health and life in extreme weather events, malnutrition, anemia, food insecurity; malnutrition, stress, anxiety, and depression from extreme events or violent conflicts. Indigenous communities in Mexico suffer from high vulnerability that causes damage to their health. Mexico is already experiencing these ravages in many regions; the health of the population is compromised by food insecurity, malnutrition and the resulting diseases, along with the rest of the diseases associated with climate change; such as the increase in cases of dengue, Zika, Chikungunya, cholera, gastrointestinal problems, anxiety, depression and stress; and these are expected to increase significantly with the increase in temperature, decrease in precipitation and recurrent presence of extreme weather events.

In the case of Mexico, the most important risks are on the coasts of the Gulf of Mexico and the Caribbean Sea, where the greatest sea level rises are expected, cold regions will initially be favored, but perhaps by the end of the century they will begin to have health problems. Problems that are already occurring in communities in the North of Mexico (due to drought) and in the Southeast (due to floods), as well as problems of violence due to the availability of resources, incidence of physical and mental illnesses; and deaths from violence and suicides. In Mexico, due to poverty, there are problems of malnutrition, which will be aggravated by these factors, which will lead to serious health problems, with the corresponding expenses.

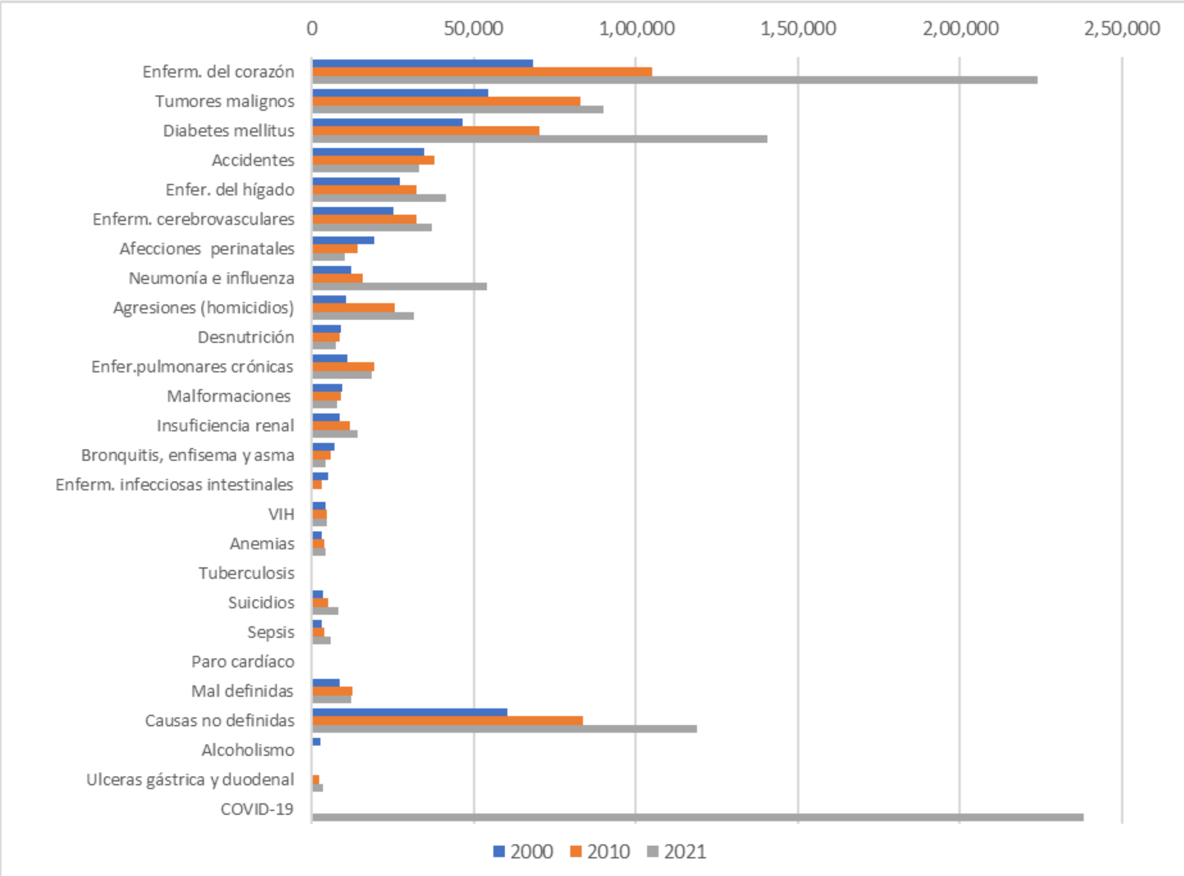

Fig.14. Main causes of mortality in Mexico in 2000, 2010 and 2021. Prepared by the authors with data from the Information System of the Ministry of Health

Agriculture and livestock: Over the course of this century, the effects of climate change and its impact on the agricultural sector will reduce economic growth, affect food security, and complicate efforts to reduce poverty [28]. In economic terms, the agricultural and livestock sectors are very likely to be the most affected by the negative effects of climate change [29-30]. According to the INECC, agriculture in Mexico can be affected by the presence of pests, insects and extreme weather events due to climate change. It has been shown that the increase in temperature will affect the growth of some crops and livestock development, especially if water consumption and the proliferation of pests and diseases increase [31].

Estimating that the demand for agriculture in Mexico would grow at the rate of the population (25%) without reducing poverty or increasing total and per capita GDP, 26 million hectares (ha) of crops would be needed instead of the 21 million planted in 2020. However, only 24.6 million hectares of land suitable for cultivation are available, with a deficit of 1.5 million hectares without considering climate change. Based on the 10 main crops grown in Mexico and their climatic requirements, estimates of possible changes in each of them were made. In the case of maize (grain and fodder), it is estimated that productivity could fall by 20-30% for the SSP2-4.5 and SSP3-7.0 scenarios; for the different varieties of beans grown in Mexico, productivity decreases are estimated between 30 and 50%, the productivity of sorghum will decrease between 5 and 10%, for sugarcane its yields will be reduced between 20 and 30%, for coffee productivity will decrease from 10 to 40%, wheat will decrease its productivity from 10 to 20%, for barley, its production will decrease between 5 and 15% compared to the current ones, oats would decrease its productivity between 10 and 30%, in the case of pastures and meadows, productivity could drop between 25 and 35% depending on the edaphic, climatic and sudden modification variables due to climate change.

Averaging all the decreases in the productivity of the 10 main crops, these would give -22%, which would represent a deficit due to low productivity of 4.84 million ha, which if we add the deficit due to lack of arable land of 1.5 million ha, would give a total deficit of 6.4 million ha of crops, which would represent a very significant decrease in food production putting at risk the food security of the country.

Regarding livestock production, estimating that the demand for cattle in Mexico would grow in the same proportion as the population (25%) without reducing poverty, or increases in total and per capita GDP, 137.25 million hectares would be needed dedicated to livestock (70.5% of the national territory), which is unfeasible. Taking the main species of cattle raised in Mexico and their optimal and critical temperatures, estimates of the effects on the agricultural sector in Mexico were elaborated. For cattle, conditions will not be conducive to their reproduction, development and maturity, with a reduction in milk and meat production. Pigs would reduce their reproduction and production of meat and its derivatives. A decrease in sheep and goat reproduction is estimated; and its production of meat and its derivatives. As for the breeding of birds, their reproduction will be affected, with the consequent reduction in the number of units raised, the production of eggs and poultry meat.

On the other hand, livestock activities will demand on average between 11-15% more water for their development, going from the current 1.33-3.21 million m^3/day to consuming 1.53-3.69 million m^3/day, which are unlikely to be available due to the decrease in water resources as a result of climate change. The impacts of climate change on agricultural activities, through variations in temperature, relative humidity and precipitation that will be intensified by the presence of extreme weather events such as frosts, droughts, hurricanes and extreme rainfall in Mexico [31].

Biodiversity sector: Mexico is considered a "megadiverse" country (Table 3), as it is part of the select group of nations with the greatest diversity of animals and plants, almost 70% of the world's species diversity [32]. Mexico is home to more than 200,000 species of plants and animals, many of which are found nowhere else on Earth. However, it also faces challenges in trying to preserve its natural environment in the face of climate change. One of the most pressing issues is habitat loss due to deforestation and land-use change. Forests and jungles in Mexico are being cut down at an alarming rate, mainly due to the expansion of agriculture, cattle ranching, and urbanization. This destruction not only affects the species that inhabit these forests, but also contributes to climate change by releasing carbon dioxide into the atmosphere.

Mexico is facing a major impact of climate change on its marine ecosystems. Rising ocean temperatures, rising sea levels, and ocean acidification are putting pressure on the country's coastal communities and diversity of marine life. For Mexico, where increases of more than 2°C are projected between now and the end of the century in the two most likely scenarios SSP2-4.5 and SSP3-7.0, it is unlikely to minimize threats and extinctions of species. In the short term, climate-related risks to natural and human systems depend more on changes in their vulnerability and exposure than on climate hazards between emissions scenarios. There are regional differences, and risks are higher when species are close to their upper thermal limits and to the persistence of multiple non-climatic factors and where vulnerability is high. These risks are unavoidable in the short term, regardless of the emissions scenario.

Thus, in the case of Mexico, there are non-climatic factors that increase vulnerability to biodiversity loss, which will be difficult to stop and eliminate; and that together with the consequences of climate change, the number of threatened and endangered species will increase significantly, with no certainty as to how many will become irretrievably extinct. Based on the probable temperatures by the end of the century in Mexico (0.5 to 5 °C), it is estimated that the risk of extinction ranges from 3 to 48% in terrestrial ecosystems, while in ocean and coastal ecosystems the risk of biodiversity loss will go from moderate to very high; and for endemic species, the risk of extinction is estimated to be very high with the possibility of increasing by more than ten times. Regional model projections estimate that the dangers of crop failure, tree species die-off, will increase above global models, and floods will put animal and plant species at risk in flooded areas in the south and southeast of the country. Mexico presents a real risk of increasing forest fires due to climatic and non-climatic factors with the risk of threat and danger of extinction of plant, animal, fungal and chromist species that coexist in the biomes.

Inevitable sea level rise will bring cascading impacts resulting in losses of coastal ecosystems and ecosystem services, salinization of groundwater, flooding, and damage to coastal infrastructure that become risks to livelihoods, settlements, health, well-being, food and water security, and cultural values in the short and long term [2]. Events that have already been happening for decades in the Mexican territory in the jungles of the Southeast, in the forested and mountainous areas of the entire country and in the coastal areas of the Gulf of Mexico and the Pacific Ocean.

In Mexico, poor adaptation and mitigation strategies, instead of contributing to the reduction of climate change, have contributed to increasing the risk of threats to biodiversity in the country. In Mexico, it will be impossible to limit the temperature increase to 1.5 °C, and every tenth of a temperature increase and precipitation reduction will increase the loss of biodiversity. According to the Red List of Threatened and Endangered Species of the International Union for Conservation of Nature and Natural Resources [33], Mexico is one of the countries in Mesoamerica that presents the greatest risk of biodiversity loss. Mexico has 2437 threatened species. Plants are the largest group, followed by fish, amphibians, other invertebrates, reptiles, mammals, birds, and mollusks.

Table 3. Mexico's position with respect to the ten megadiverse countries [34]

Country	Vascular Plants	Mammals	Poultry	Reptiles	Amphibians
Place México	**5**	**3**	**11***	**2**	**5**
Brasil	56,215	648*	1,712	630	779
Colombia	48,000	456	1,815	520	634
China	32,200	502	1,221	387	334
Indonesia	29,375	670*	1,604	511	300
México	**21,989 - 23,424***	**564***	**1123-1150***	**864***	**376***
Venezuela	21,073	353	1,392	293	315
Ecuador	21,000	271	1,559	374	462
Perú	17,144	441	1,781	298	420
Australia	15,638	376	851	880	224
Madagascar	9,505	165	262	300	234

Declines in agricultural productivity would represent a significant decrease in food production for both human and livestock use; which would put at risk plant species that are not currently part of the food system. In addition, the decrease in livestock productivity is likely to lead to the use of non-traditional animal species, which would increase the risk of threat and extinction of these species. In Mexico, climate change puts increasing pressure on biodiversity, increases in the frequency, intensity and severity of droughts, floods and heat waves, continued sea level rise, will increase the risks of species loss in vulnerable regions from moderate to high between 1.5-2°C of global warming, with low or no levels of adaptation. With global warming of more than 2°C in the medium term, the risks to biodiversity will become more severe. Global warming will weaken soil health and pollination, increase disease and pest pressure, and reduce marine animal biomass. At a global warming of 3°C or more in the long term, areas exposed to climate-related hazards will expand, increasing the disparity in risks to biodiversity.

3.3 Regional Climate Change Scenarios for Jalisco

The climatology of the state of Jalisco was evaluated according to the 1981-2010 climatological normals of the National Meteorological Service (SMN). The results are based on the 208 stations that are distributed in the 125 municipalities of the state.

The state of Jalisco is located at an average latitude of 20.58º N, and an average longitude of 103.57º W. The average altitude is 1412 meters above sea level, with an average temperature of 20 ºC with extremes between 14 and 28 ºC. The average minimum temperature is 12 ºC with extremes between 6 and 21ºC. The average maximum temperature is 29 ºC with extremes between 21 and 37 ºC (Fig. 15). Average rainfall is 859 mm with extremes between 426 and 2003 mm (Fig. 16), average evaporation of 1766 mm between 70 and 2752 mm. During the year, there are an average of 73 days with rainfall and extremes of 2 to 122 days. The average number of foggy days per year is 23 between 0 and 23 days. The average day with hail is 1 day between 0 and 65 days. Thunderstorms occur in 19 days on average and extremes from 0 to 193 days, finally, the average relative humidity in the state is 54% with extremes between 39 and 69%.

This climatology is the one that was taken as a basis to make comparisons of CLIMDEX Indicators and regional model projections; to estimate variations from global models. In other words, the change of climate parameters from global to regional scale and to be able to assess vulnerability at the scale of states and municipalities.

A total of 27 CLIMDEX climate change indices were calculated using 208 stations distributed in the 125 municipalities of the State of Jalisco. The results for each region are as follows:

Northern Region: In this region, it was evident that changes in temperature patterns were reflected in the increase of 27 days of frost days and 25 days of summer days. An increase of 16 days with tropical nights and a decrease in the length of the growing season of 4.5 days was observed, the maximum-maximum temperature decreases 4 ºC, while the maximum-minimum 8 ºC, the minimum-maximum increased 3 ºC and minimum-minimum decreased 4 ºC, the diurnal temperature range has increases of up to 5.7 ºC. Increases in temperature are reflected in the conditions of the days and nights. The humidity and precipitation indicators show variations in precipitation presented in one and five days from -45 to 26 mm, in daily intensity from -2 to 6.5 mm/day, days of intense and very intense precipitation varied from -8 to 10 mm, increase in dry days and decrease in wet days, variations of very wet and extremely wet days between -150 to 300 mm and decrease of up to 250 mm in Total precipitation from wet days, indicating that the increase in temperature is associated with the decrease in humidity and precipitation over the last 30 years.

Altos Region: In this region, changes in temperature patterns are evident with a decrease in days with frost and an increase in summer days of up to 85 days. There was an increase of less than one day of tropical nights and a decrease in the length of the growing season from 3 to 4.5 days, the maximum-maximum temperature increased by 2.8 ºC, the maximum-minimum 1.8 ºC, the minimum-maximum decreased by 10 ºC and the minimum-minimum increased by 4.8 ºC, the diurnal temperature range varied from -2.5 to 1.2 ºC. Humidity and precipitation show increases in precipitation in one and five days, in daily intensity, however, on days of intense and very intense precipitation they present a decrease of up to 7 mm, an increase in dry days and a decrease in wet days, variations in very wet and extremely humid days and a decrease of up to 180 mm in the total precipitation of wet days. Thus, the increase in temperature is associated with the decrease in humidity and precipitation in the last 30 years.

North Coast Region: In this region there are changes in temperature patterns with a decrease in summer days by almost 55 days, a decrease of up to 14 days in tropical nights and the length of the growing season to less than a day, the maximum-maximum temperature increases by 0.8 ºC, the maximum-minimum 0.5 ºC, the minimum-maximum 0.1 ºC and the minimum-minimum of 1 ºC, which increases the daytime temperature range by 0.4 ºC. Precipitation decreased in one and five days, while daily intensity increased up to 3 mm/day, on days of intense and very intense precipitation there are increases of 3.5 and 2.2 mm, decrease in dry days and wet days, and increase in very wet days of 100 and 130 mm on extremely wet days and increase of 100 mm in total precipitation on wet days. This shows that this area is controlled by the high humidity that exists in the region, associated with the jungle and wooded area that surrounds it, which has limited temperature changes to moderate, with an increase in precipitation in a gradual way and not in a torrential and untimely manner.

South Coast Region: In this region there are changes in temperature patterns with an increase in frost days to 0.2 days, however, the increase in summer days is 5 days. A decrease of 80 days is observed in the tropical nights and the length of the growing season to less than one day, the maximum-maximum temperature increases by 1.5 ºC, the maximum-minimum decreases to 1.8 ºC, the minimum-maximum increases by up to 3ºC and the minimum-minimum decreases to 4 ºC, the diurnal temperature range varies from -3 to 2.2 ºC. Precipitation increased in one and five days by 40 and 80 mm respectively, in terms of daily intensity it showed increases of up to 4 mm/day, on days of intense and very intense precipitation there was an increase of 1 and 2 mm, there was a decrease in dry days and wet days, and an increase of 100 and 90 mm on very wet days and an increase of 150 mm in total precipitation of humid days. The region is controlled by the high humidity associated with the jungle and wooded areas that surround it and allows for moderate temperature changes, with an increase in precipitation gradually and not in a torrential and untimely manner during the last 30 years as in the North Coast.

Cienega Region: In this region, changes in temperature patterns were evidenced with a minimal increase in frost days and an increase in summer days of almost 140 days. A decrease of less than a day in tropical nights and in the length of the growing season is observed, the maximum-maximum temperature increased by 3 ºC, the maximum-minimum, minimum-maximum and minimum-minimum had a decrease, the diurnal temperature range will increase by 4.5 ºC. There is a decrease in the amount of precipitation presented in one and five days, in the daily intensity, in the days of intense and very intense precipitation; and increase in dry days; decrease in wet, very humid and extremely humid days and 210 mm decrease in total precipitation on wet days. This indicates that the increase in temperature is associated with a decrease in humidity and precipitation over the last 30 years.

Southern Region: In this region, temperature changes increase by 0.6 days of frost and 60 days in summer, decrease of five days of tropical nights without changes in the length of the growing season, the maximum-maximum, maximum-minimum and minimum-maximum temperatures decreased between 2 and 2.5 ºC, the minimum-minimum had an increase of 4 ºC, the daytime temperature range increased by 3.0 ºC. Precipitation increased by one and five days, and daily intensity decreased by 2 mm/day, as well as a decrease in days of intense and very intense precipitation, a decrease in dry days to 30 days and less than a day of wet days, increases in very wet and extremely wet days between 20 and 40 days, and a 50 mm increase in total precipitation on wet days. Rainfall has become less intense and longer. Temperature changes are associated with changes in precipitation in recent years.

Central Region: In this region there are no significant changes in the days of frost, there is a decrease in summer days, an increase of two days in tropical nights, the length of the growing season does not change, the maximum-maximum temperature decreases 3 ºC, the maximum-minimum, the minimum-maximum and minimum-minimum have increases that impact the diurnal temperature range with decreases of 4.0 ºC. There is an increase in precipitation in one and five days, in daily intensity, however, there is a decrease in the number of days of intense and very intense precipitation, an increase in dry days and a decrease in wet days, and increases in very wet and extremely wet days and an increase of 300 mm in the total precipitation of wet days. Thus, rainfall has become more intense and punctual, perhaps due to the influence of the high rate of urbanization in the ZMG. However, temperature changes are associated with changing precipitation patterns in the region over the past 30 years.

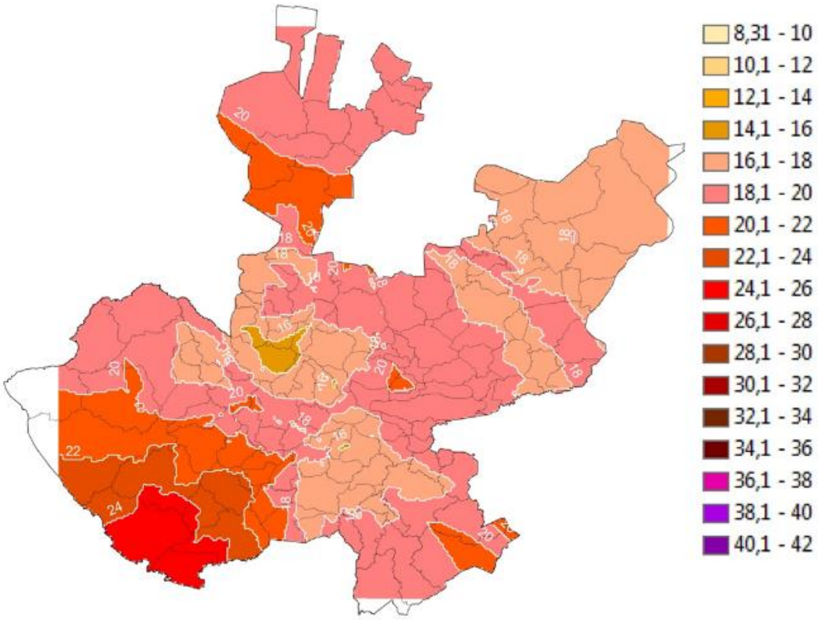

Fig. 15. Average temperatures of the State of Jalisco according to the Climatological Normals of the period 1981-2010

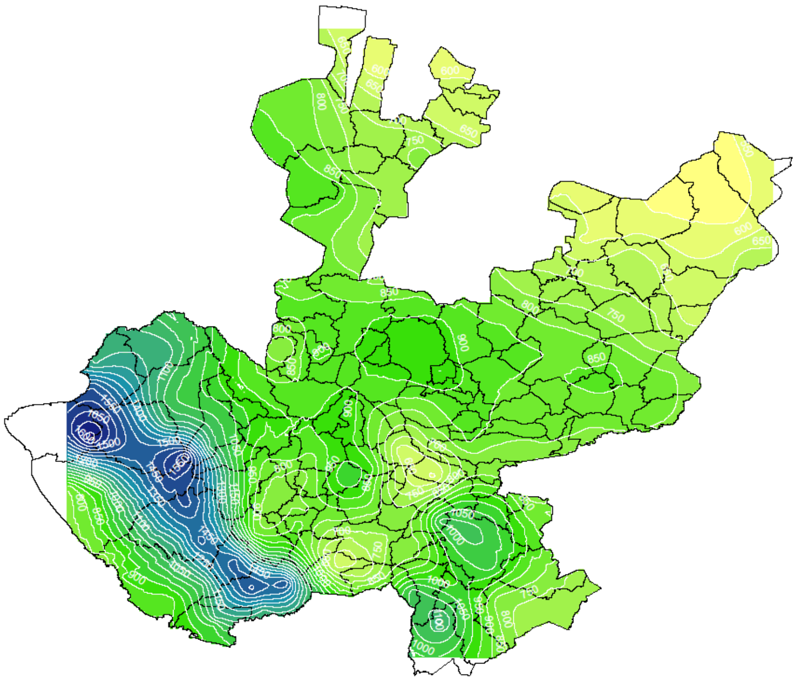

Fig. 16. Average precipitation in the State of Jalisco according to the Climatological Normals for the period 1981-2010

3.4 Regional Projections of Climate Change Scenarios in the State of Jalisco

The CLIMDEX indices show the changes that have already occurred due to climate change in the last 30 years in Jalisco, however, for the future the most important thing is to show what are the possible scenarios of climate change and their impacts on the State of Jalisco. Thus, for regional modeling, the PRECIS (Providing Regional Climates for Impact Studies) model, developed by the Hadley Center of the United Kingdom, was used in a domain that covers the west of the Mexican Republic with a resolution of 25 km in the period 2020-2099.

The results show changes in air and soil temperature; air and soil moisture and precipitation velocity, performing the monthly comparison throughout the year to identify the most significant features of the dry and rainy seasons in the two most likely scenarios SSP2-4.5 and SSP3-7.0. Based on this, it was determined that the most representative months of the year are January (low season) and July (stormy), December was included as a transition month between the two seasons. Subsequently, a comparative analysis was carried out between these months; and between the years 2030, 2050, 2080 (Fig. 17).

The air temperature in both scenarios will increase progressively. By 2080, temperatures of up to 42 ºC on the coasts and 32 ºC in the rest of the state are estimated in both scenarios SSP2-4.5 and SSP3-7.0. The soil temperature in both scenarios will increase progressively. By 2080, temperatures between 40-42 ºC on the coasts and 32 ºC in the rest of the state are estimated in both scenarios. Air and ground temperatures in the SSP3-7.0 scenario will increase across the board, while in the SSP2-4.5 scenario they will be fractional (Fig. 18).

Relative humidity (RH) will show a decrease from 2030 to 2080 in both scenarios. However, in coastal areas the RH will increase while in the rest of the state it will decrease. The increases in RH will occur in the stormy months and will decrease in the dry months. Soil moisture will show a more significant decrease than air moisture from 2030 to 2080 in both scenarios. Soil moisture by 2080 will be 40% in the Altos region, while the rest of the state will have values close to 0%, which represents extreme drought. Higher values will shift to unusual months such as January, while typically wetter July will have very low values (Fig. 18).

The rate of precipitation will decrease dramatically between 2030 and 2090. By 2030, speeds of 480mm/day will be reached in the Altos area. However, as we advance to 2050 and 2080, they will decrease significantly between 10 and 120mm/day in the stormy months in the coastal areas and the Altos; and very low values in the rest of the state (Fig. 18).

The conclusions of the analysis of the regional model projections for July and January in each region of the state of Jalisco in the SSP2-4.5 and SSP3-7.0 scenarios are as follows:

Central Region: The trend of air temperature is to increase; for the period 2000-2090 it is 3°C for the storm and 3.5 ºC for the low water in the SSP2-4.5 scenario and 4°C for the storm and 5.2 ºC in the low water in the SSP3-7.0 scenario. Relative humidity will show a moderate upward trend, with 10% in the storm and 6% in the dry season in the SSP2-4.5 scenario and decreases of 9% in the storm and low water in the SSP3-7.0. The intensity of rainfall increases and then decreases in the storm, the trend is downward in the SSP2-4.5 scenario and slight decreases in the storm and high decreases in the low water level in the SSP3-7.0 scenario. Soil temperature increases gradually to reach the end of the period to values between 3°C in the storm and 3.7 ºC in the dry season in the SSP2-4.5 scenario and 4°C in the storm and 6 ºC in the dry season in the SSP3-7.0 scenario.

Southern Region: The trend of air temperature is to increase; for the period 2000-2090 it is 3°C for the storm and 3.7 ºC in the dry season in the SSP2-4.5 scenario and 3.8°C for the storm and 6 ºC in the dry season in the SSP3-7.0 scenario. Relative humidity has a moderate increase trend, reaching 5% in the storm and a decrease of 6% for the dry season in the SSP2-4.5 scenario and decreases of 6% for the storm and up to 15% in the dry season in the SSP3-7.0 scenario. The intensity of rainfall increases and then decreases in the storm, while in the dry season the trend is downward in the SSP2-4.5 scenario and slight decreases in the storm and high in the low water in the SSP3-7.0 scenario. By 2099, soil temperatures will increase to 3°C in the storm and 3.7 °C in the dry season in the SSP2-4.5 scenario, 4°C in the storm and 6 ºC in the dry season in the SSP3-7.0 scenario.

Altos Region: The trend of air temperature is to increase for the period 2000-2090 of 3.5°C for the storm and 3.4 ºC in the dry season in the SSP2-4.5 scenario and 5°C for the storm and 5.5 ºC in the dry season in the SSP3-7.0 scenario. Relative humidity has a moderate increase trend, reaching 6% in the storm and a decrease of 6% for the dry season in the SSP2-4.5 scenario and decreases of 5% for the storm and up to 11% in the low water in the SSP3-7.0 scenario. Rainfall intensity decreases in the storm and low water in the SSP2-4.5 scenario and slight decreases for the storm and high for the low water level in the SSP3-7.0 scenario. Soil temperature increases gradually to reach the end of the period to values between 3.5°C for the storm and 3.6 ºC at low water in the SSP2-4.5 scenario and 5°C for the storm and 5 ºC at low water in the SSP3-7.0 scenario.

Northern Region: The trend of air temperature is to increase for the period 2000-2090 it is 3.0°C for the storm and 3.8 ºC for the low water in the SSP2-4.5 scenario and 5°C for the storm and low water in the SSP3-7.0 scenario. Relative humidity has a tendency of moderate increase of 7% in the storm and decrease of 7% in the low water level in the SSP2-4.5 scenario and decreases of 3% in the storm and 10% in the low water level in the SSP3-7.0 scenario. Rainfall intensity decreases in the storm and low water in the SSP2-4.5 scenario and slight decreases in the storm and high for the low water in the SSP3-7.0 scenario. By the end of the period, the soil temperature increases to 3°C in the storm and 4ºC in the dry season in the SSP2-4.5 0 scenario and 4.5°C in the storm and 5ºC in the dry season in the SSP3-7.0 scenario.

North Coast Region: The trend of air temperature is to increase for the period 2000-2090 of 3.0°C for the storm and 3.2 ºC in the dry season in the SSP2-4.5 scenario and of 2.5°C in the storm and 5 ºC in the low water in the SSP3-7.0 scenario. Relative humidity has increased moderately, reaching 3% in the storm and a decrease of 4% in the dry season in the SSP2-4.5 scenario and no changes for the storm and decreases of up to 10% in the low water level in the SSP3-7.0 scenario. Rainfall intensity increases in the storm and decreases in the dry season in the SSP2-4.5 scenario, and slight increases in the storm and high decreases in the low water level in the SSP3-7.0 scenario. Soil temperature gradually increases to reach the end of the period to values between 3.7 °C for the storm and 3.3 ºC for the dry season in the SSP2-4.5 scenario and 2.6 °C for the storm and 5.5 ºC in the dry season in the SSP3-7.0 scenario.

South Coast Region: The trend of air temperature is to increase for the period 2000-2090 of 3.0°C for the storm and 3.5 ºC in the dry season in the SSP2-4.5 scenario and 5°C for the storm and 5.2 ºC in the low water in the SSP3-7.0 scenario. Relative humidity has a moderate increase trend, reaching 6% for the storm and 8% in the dry season in the SSP2-4.5 scenario and no change for the storm and a decrease of up to 4% in the dry season in the SSP3-7.0 scenario. Rainfall intensity increases in the storm and decreases in the dry season in the SSP2-4.5 scenario and significant increases for the storm and high decreases in the low water level in the SSP3-7.0 scenario. Soil temperature increases gradually to reach values between 3.6 °C in the storm and low water in the SSP2-4.5 scenario and 3°C in the storm and 5.5 °C in the dry season in the SSP3-7.0 scenario.

Ciénega Region: The trend of air temperature is to increase for the period 2000-2090 it is 3.0°C for the storm and 3.3 ºC in the dry season in the SSP2-4.5 scenario and 5°C for the storm and 5.3 ºC in the low water in the SSP3-7.0 scenario. Relative humidity has a moderate increase trend, reaching 8% in the storm and a 5% decrease in the dry season in the SSP2-4.5 scenario and a decrease of up to 8% in the storm and up to 10% in the dry season in the SSP3-7.0 scenario. The intensity of rainfall increases significantly in the storm and decreases in the low water in the SSP2-4.5 scenario and a slight decrease in the storm and high in the low water in the SSP3-7.0 scenario. Soil temperature increases to reach the end of the period to values of 3 °C in the storm and 3.4 ºC in the dry season in the SSP2-4.5 scenario and 5.2 °C in the storm and 5.8 ºC in the dry season in the SSP3-7.0 scenario.

3.5 The Impact of Climate Change on Economic Sectors in Jalisco

Water: The impacts on the sector will be water depletion in water-stressed areas; surface water deficiencies (Altos and North Coast) and groundwater (Centro, Altos Norte and Ciénega). Heavy rainfall with risk of flooding in coastal and urban areas in the first decades, with the reverse effect for the rest of the century. As the century progresses, with the increase in temperature (0.5 to 5 °C) and decrease in relative humidity and precipitation (-20.3%), the extent of drought-affected areas will increase. It is estimated that there will be a 30% decrease in water reserves, which will reduce their availability by the end of the century.

Agriculture: Jalisco is first and second place nationally in 50% of the ten foods considered as basic and strategic products of Mexico: corn, eggs, milk and pork (1st place); sugar cane, beef and poultry (2nd place). The region with the highest food production is Altos Norte, followed by Ciénega, Valles, Sur and Altos Sur. In seasonally dry tropical regions (Mexico and Jalisco), crop yields are expected to decline even when the local temperature rises by only 1 to 2 °C, increasing the risk of famine. It is estimated that the increase in droughts and floods will affect crop production, mainly in the subsistence sectors (Altos, North, South and Central). The Altos Norte Region is considered the most vulnerable to climate change, in addition to being the region most affected by accidents in food-producing areas during 2005-2010 (Villafán, 2013), leading Jalisco to the second place in the country with the highest increase in accidents due to meteorological causes. It is estimated that in the first decades of the century a moderate warming will allow adaptations with the modification of crops and their planting period, maintaining or exceeding grain yields, to later decrease as we advance to 2100. Jalisco is the largest consumer of nitrogen fertilizers in the country, which causes water nitrification; and chemical degradation of soils by acidification (Curiel and Garibay, 2006). The impacts will affect smallholders and subsistence farmers, as cultivated species will experience heat stress and will not develop.

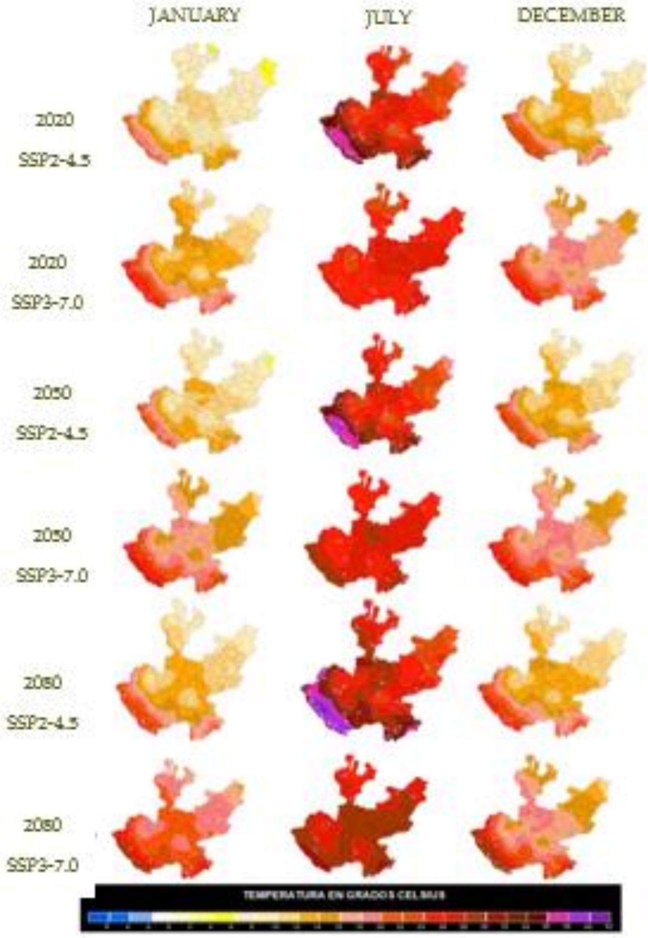

Fig. 17. Temperature projections using the PRECIS model for the months of January, July and December under the IPCC SSP2-4.5 and SSP3-7.0 scenarios; by 2020-2080

Table 4. Trend of Air and Soil Temperature, Relative Humidity and Precipitation Intensity for the different regions of the state of Jalisco in the IPCC SSP2-4.5 and SSP3-7.0 scenarios

Region	T Air (°C)		Relative humidity (%)		Precipitation Int (mm/a)		T Soil (°C)	
	SSP2-4.5	SSP3-7.0	SSP2-4.5	SSP3-7.0	SSP2-4.5	SSP3-7.0	SSP2-4.5	SSP3-7.0
Center	↑ 3-3.5	↑ 4-5.2	↑ 6-10	↓ 9	↓	↓	↑ 3-3.7	↑ 4-6
South	↑ 3-3.7	↑ 4-6	↑ 5 ↓ 6	↓ 6-15	↓	↓	↑ 3-3.7	↑ 4-6
Altos	↑ 3.5	↑ 5-5.5	↑ 6 ↓ 6	↓ 5-11	↓	↓	↑ 3.6	↑ 5
North	↑ 3-3.8	↑ 5	↑ 7 ↓ 7	↓ 3-10	↓	↓	↑ 3-4	↑ 4.5-5
North Coast	↑ 3-3.2	↑ 2.5-5	↑ 3 ↓ 4	↓ 10	↓	↓	↑ 3.7	↑ 2.6-5.5
South Coast	↑ 3-3.5	↑ 5-5.2	↑ 6 ↓ 8	↓ 4	↑ ↓	↑ ↓	↑ 3.6	↑ 5.5
Cienega	↑ 3-3.3	↑ 5-5.3	↑ 8 ↓ 5	↓ 8-10	↑ ↓	↓	↑ 3-3.4	↑ 5.2-5.8

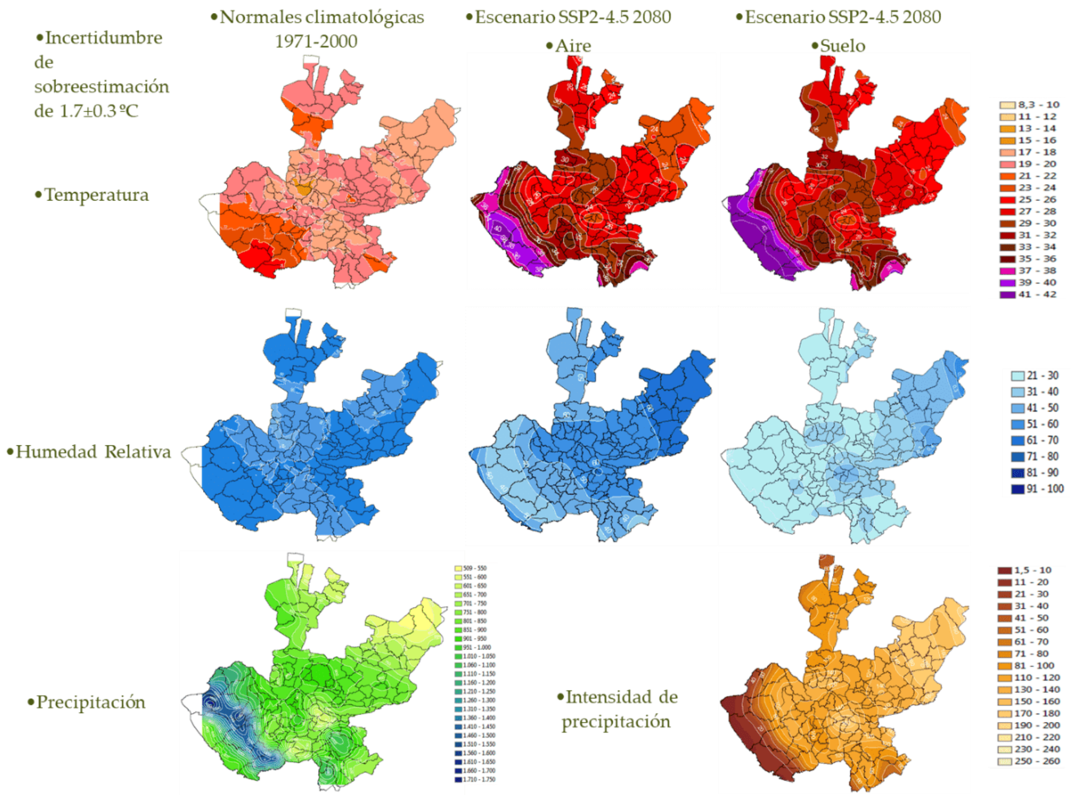

Fig. 18. Comparison of temperatures, relative humidity, precipitation and precipitation intensity in the state of Jalisco in the IPCC SSP2-4.5 scenario to 2080

Livestock: With the increase in temperatures, decrease in the availability of water and feed; livestock will enter heat stress and increase in respiratory and heart rate; in ecosystems with high deforestation, forest fires, introduction of invasive species, among others (Altos and North). Cattle at a temperature >26 ºC experience digestive disorders that lead to a decrease in productivity and reproductive capacity. By 2080 with temperatures > 42 ºC, the disappearance of livestock areas (Altos and Norte) will occur as a result of heat stress, lack of availability of water and food, which will cause Jalisco to lose its leadership in the production of dairy products and meat for human consumption.

Marine ecosystems: Coastlines are expected to be exposed to coastal erosion and sea level rise by 1 to 2 m by 2080, affecting coastal wetlands, marshes and mangroves that protect them from extreme events and sedimentation processes. Populations will be affected by flooding by 2080 in densely populated areas such as Puerto Vallarta, Riviera Nayarit, and Costa Alegre. Risks from tropical storms or local coastal subsidence are expected. Changes in fish distribution and production are expected with adverse effects on aquaculture and fisheries due to warming waters.

Urban development: The most vulnerable human settlements are those located in flood-prone coastal and river areas, resource-related climate-sensitive economies, and in extreme weather-prone areas where rapid urbanization is taking place. In Jalisco, the affected areas are Centro, Costa Norte, Ciénega, Sur, Altos and Norte; the ZMG, Puerto Vallarta, and Lagos de Moreno will have the highest frequency of disasters.

Biodiversity: Over the course of the century, it is estimated that between 20-30% of plant and animal species will be at greater risk of migration and/or extinction due to temperature increases >3 ºC. In Jalisco, the vulnerability of biodiversity will be significant in the North Coast, South Coast, South, North and Altos, followed by the Center, due to the weakening of ecosystems, forest fires, land use change, temperature increase > 3 °C and decrease in water resources. The vulnerability of vegetation will occur on the North Coast, South Coast; South, North and Altos. Ecosystems transform from permanent to seasonal and others will disappear.

Energy: The energy sector of Jalisco will be affected by the increase in temperature, greater demand for energy, decrease in water resources due to the decrease in rainfall and increase in its intensity, which will cause the decrease in the production of hydroelectric energy in the first decades of the century. Although Jalisco is not a major producer of energy, the main effects will be on its distribution. Storms and floods will affect oil and gas facilities, and heat will impact the electrical distribution system. Rising temperatures could overheat power lines, decreasing their ability to transmit and causing blackouts during heat waves. Stronger and more frequent storms will put infrastructure and sources of supply at risk. The more the temperature and lack of precipitation increase, along with the population growth of large cities, the greater the demand for energy to try to adapt to the new temperature conditions. The affected regions are the most populated and with the highest demand for energy (ZMG, Puerto Vallarta, Lagos de Moreno, Ocotlán and Ciudad Guzmán).

Health: In the extreme climate areas of the state such as the Altos and the North region, a reduction in deaths due to exposure to cold is expected in the first decades of the century. In the rest of the state, negative health effects are expected mainly in marginalized areas. Among the diseases resulting from climate change will be those caused by an increase in temperature: the presence of heat waves, heat stress and heat stroke; those induced by high concentrations of pollutants: respiratory, cardio-respiratory diseases; those transmitted by vectors such as dengue, malaria, Zika, Chikungunya, encephalitis, West Nile virus, among others; those transmitted by contaminated water: cholera, cyclospore, leptospirosis, among others; and neurological and/or mental diseases, among others. Also, increased morbidity and mortality of these diseases due to heat waves, floods and droughts. The most vulnerable groups will be children, the elderly, and people with chronic and degenerative diseases. The populations with the greatest health vulnerability are the densely populated and marginalized areas, such as the ZMG, Puerto Vallarta, and populations on the coasts and the northern zone.

Housing: According to the projections of temperature, relative humidity and intensity of rainfall for the present century and the trend of housing in Jalisco, the risks will be: inadequate ventilation; reduced indoor air quality; exposure to CO and insulating fibers harmful to health; airborne infectious diseases in rooms or air-conditioned spaces lacking fresh air; urban heat island; increased exposure to noise; bacterial growth in heating, ventilation and air conditioning systems; metabolic and psychological alterations due to lack of light and domestic accidents due to poor lighting.

Transportation: Motorized transport in Jalisco continues to grow uncontrollably, fueled by the policy that continues to prioritize private transport over public transport, and in particular, the most unsustainable means over the most efficient, which is the main cause of fragmentation of ecosystems and one of the responsible for the current chaos in territorial planning; urban planning and loss of quality of life. In the state, according to the accelerated urban development and mobility policies, it is estimated that private transport will predominate over public transport, with consequences beyond the current scenarios. The most affected areas will be the ZMG, Puerto Vallarta, Lagos de Moreno, Ocotlán and Ciudad Guzmán.

3.6 Vulnerability in the Regions of the State of Jalisco

North and South Coast Regions: The coastal population will be exposed to water stress, increased demand for water, reduced availability of water for human consumption and agriculture, decrease in agricultural and forestry production, increase in fires and droughts, decrease in arable areas and duration of vegetative growing seasons and productive potential, risk to food security, exacerbation of malnutrition, salinization and desertification of agricultural land, decrease and disappearance of livestock as a result of heat stress, lack of availability of water and feed for livestock, substitution of species by more resistant ones, low productivity of dairy products and meat for human consumption, risks of flooding in low-lying areas, presence of storm surges, erosion and other coastal hazards, loss of mangroves, coral reefs and change in location of fish stocks, decrease in fishery resources, significant loss of biodiversity in mangroves and virgin forests, loss of species in forests and grasslands, extinction or migration of species of endemic terrestrial and marine fauna, Through the extinction of endemic species and the proliferation of invasive species, arid vegetation will tend to replace semi-arid vegetation, increase endemic morbidity and mortality due to diarrheal diseases, dengue, influenza, cholera, among others, exacerbation of respiratory, cardiovascular, skin diseases, vector-borne diseases, contaminated waters, increase in the health budget that in the medium and long term would be unviable. increase in the demand for heating and air conditioning, concentration of the population in urban areas, increasing the risk of major impacts from extreme weather events, increased demand for energy, greater consumption of fossil fuels.

Altos Region: In the Altos region, it would be expected that the population would be exposed to risks similar to those described in the cases of the North and South Coast areas, with the difference that there are no problems of sea level rise, flooding of coastal areas, loss of species of marine flora and fauna, however there are other risks such as: water deficit with increased evapotranspiration and decreased rainfall, decrease and disappearance of livestock areas due to heat stress, lack of availability of water and feed for livestock, substitution of livestock species by more resistant ones, decrease in the production of meat and dairy products for human consumption, loss of forest and grassland species, with the consequent extinction or migration of endemic fauna species of the region, decrease in the productivity of crops such as corn, concentration of population in urban areas increasing the risk of impacts by extreme weather events.

Northern Region: For the Northern region, it is expected that the population will be exposed to the same problems described in the case of the Altos zone and some other risks such as: migration of the Wixárica population to other areas with less climatic rigor, loss of cultural identity of the region, extraordinary floods in the next two decades and subsequent extreme drought in the rest of the century. With the loss of grasslands, loss or migration of endemic fauna species, arid vegetation will tend to disappear with the consequent desertification.

Central Region: For the Central region, it is expected that the population will be exposed to the same problems as in the area of Los Altos, and other risks such as: decrease in the availability of water and food, problems of transportation, housing, energy demand, urban development and health more important than in the rest of the state due to the greater concentration of population increasing the risk of greater impacts by extreme weather events (floods during the first few weeks). decades, followed by water deficiencies in the rest of the century).

Southern Region: In this region, it is expected that the population will be exposed to the same problems described for the Altos area and other risks such as: decrease in the availability of water and food due to higher temperatures, greater problems in agricultural and livestock productivity due to higher temperatures and lower availability of water and food. critical health problems, with the presence of heat waves, heat stress and high evapotranspiration, dehydration, heat stroke and severe cardiovascular diseases.

Based on the results evidenced, it is important to design and prioritize climate change adaptation and mitigation actions in the most vulnerable regions of Jalisco, as well as public policies that allow future generations to have the minimum conditions of water sustainability and protect the economic, health, food security and social welfare conditions that are already compromised.

4. CONCLUSION

Regional models for Jalisco show temperature increase between 0.5 to 5°C, while % precipitation will range between -20.3 and 13.5% depending on the scenario and period of analysis. The increase in temperature will cause soil moisture deficits, water stress, sparse vegetation and semi-permanent meteorological drought. Under these scenarios, the country is expected to be subject to moderate to extremely severe droughts that will last and worsen between now and the end of the century. Regional modelling shows significant impacts on the water sector with low water availability; in the agricultural sector with a decline in the productivity of the state's crops, mainly affecting small landowners and subsistence farmers. As for livestock, the availability of water and feed will decrease; Cattle will enter heat stress and increase respiratory and heart rate, which will decrease productivity and with the possible disappearance of livestock areas. In terms of biodiversity, it is estimated that between 20-30% of plant and animal species are at greater risk of migration and/or extinction; The vulnerability of biodiversity will occur due to the weakening of ecosystems, forest fires, land use change and water depletion. The energy sector will be affected by the increase in temperature, decrease in energy production, greater demand for energy, the main effects will be on the distribution of energy. The health sector will be affected due to the presence of heat waves, heat stress and heat stroke; diseases due to high concentrations of pollutants, respiratory, cardio-vascular, vector-borne and contaminated water diseases, neurological and/or mental diseases, among others. Children, the elderly, and people with chronic and degenerative diseases will be the most vulnerable groups. All areas of the state will be impacted, although in a differentiated way, by water stress, reduced water availability, increased demand for water, decreased agricultural, livestock and forestry production, increased fires and droughts, food insecurity, exacerbation of malnutrition, desertification and salinization of soils, decrease and disappearance of livestock due to heat stress, substitution of species by more resistant ones, low productivity of dairy and meat products for human consumption, risks of flooding in low-lying areas, presence of storm surges, erosion, loss of mangroves, coral reefs, decrease in fishery resources, significant loss of biodiversity in mangroves, virgin forests, forests and grasslands, extinction or migration of species of endemic terrestrial and marine fauna; proliferation of invasive species, arid vegetation replacing semi-arid vegetation, increased morbidity and mortality due to diarrheal diseases, dengue, influenza, exacerbation of respiratory, cardiovascular, skin, vector-borne diseases, contaminated water, increase in the health budget that would be unfeasible in the medium and long term, increase in the demand for heating and air conditioning, concentration of the population in urban areas, increasing the risk of extreme weather events, increased energy demand, increased consumption of fossil fuels, among others. Jalisco's vulnerability to climate change is high to very high in all sectors and in all regions of the state.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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