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Current aptitude under climate change scenarios for three crops in Mexico

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Abstract

For the agricultural land area of Mexico, the areas with different degrees of aptitude for corn, sorghum and wheat were determined, all under temporary conditions, for the current conditions and with climate change scenarios estimated with the GFDL, HAGDEM and REA models; for the RCP of 4.5 and 8.5 W m^{-2}. The proportion of agricultural land with some degree of aptitude for current conditions is as follows: corn 81.59%, sorghum 61.54% and wheat 26.95%. Of the climatic variables that determine the lack of aptitude in corn and wheat in agricultural areas, it is mainly the annual mean temperature alone or in combination with the precipitation, in sorghum it is mainly the annual mean precipitation alone or in combination with the annual average temperature. For climate change scenarios, with the exception of sorghum, the other two crops considerably reduce the proportion of agricultural land area with some degree of aptitude for these. Increasing the annual mean temperature to values above the threshold at which corn and wheat crops are grown is the main cause of loss of aptitude. The determination of the degree of change associated with climate change can be used to develop public policies to address the problem of decreasing or losing the development capacity of crops.

Keywords: adaptation, agroecological zoning, mitigation, productive capacity, vulnerability.

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Introduction

Several studies have shown that climate change will differentially affect countries, with significant vulnerabilities in low-latitude regions (Smith, 2012). Mexico is one of the most vulnerable countries with respect to climate change, within the sectors with the greatest possible impact is agriculture, this associated with the fact that a large proportion of the activity takes place under temporary conditions (82%) and only 18% is from irrigation (Tinoco *et al*., 2010).

As the climatic variability increases, it is estimated that the temperature will increase and the humidity in the soil will decrease, and with this the production of consumer goods will be compromised by this activity, reducing the economic income on which the population involved in agricultural activities.

It is also estimated that there will be a decrease in the organic carbon content of the soil and with it a decrease in the productive capacity of agricultural systems as the physical, chemical and biological properties of the soils are negatively affected (Gómez *et al*., 2019). Likewise, climatic variations bring other negative consequences for crops, since pests, diseases and weeds proliferate (Monterroso-Rivas *et al*., 2018).

The foregoing encourages farmers and those involved in the sector to make higher investments to adapt crops to the new climate conditions manifested, in order to cope with the changes they must modify crop patterns, use of inputs, production level, among other actions (IFPRI, 2009). However, most farmers do not have sufficient income to meet new needs.

Thus, while developed countries have found a balance between performance and sustainability, developing countries resort to less balanced methods, deteriorating their natural resources by modifying ecosystems. Therefore, the challenge is to satisfy the demand for food while maintaining sustainable management of natural resources and include mitigation actions and sustainable management of agricultural land (Landeros and Pérez, 2009).

It is necessary to generate studies that obtain information to establish adaptive measures before the unfavorable events present more complications and with it reduce negative impacts, minimize socioeconomic problems related to hunger, poverty reduction, as well as generation of alerts to disasters natural (FAO, 2018). The objective was to analyze the current aptitude and climate change for three important crops in Mexico at the regional level and thus have technical elements to recommend adaptation actions in the national agricultural sector.

Material and methods

The process was divided into three stages: first, the matrices of environmental requirements for the crops under study were elaborated, then for all the agricultural areas of the country, files were created in shapefile format with databases of climatic variables and the classes of current aptitude. Finally, the climate change projections were applied and the changes in the degrees of aptitude associated with climate change in agricultural lands were estimated, better described below.

Crop requirements matrices

The matrices of environmental requirements of the three crops of the study, corn, sorghum, wheat, were elaborated, based on a bibliographic review in technical data sheets, FAO guides and articles related to the crops, emphasizing the climatic variables such as quantity and distribution of the annual average precipitation, water balances, monthly and annual average temperature, in addition to the soil and landscape conditions in which they have the best development, considering the areas where these crops are currently established. Four aptitude grade classes were used: suitable, moderately suitable, marginally suitable, and unsuitable.

Preparation of maps of degree of aptitude of crops

From the matrices of environmental requirements, the current aptitude maps were elaborated for each one of the crops of the study in the areas with agricultural use of the country, which were delimited from the map of series VI of the use of the soil and vegetation (INEGI, 2017), this with ArcGis 10.3 Software. For all the agricultural areas of the country, files were created in shapefile format with databases of climatic variables such as mean annual precipitation and mean annual temperature, duration of the growth period by available humidity, average temperature of the warmest month, average temperature of the coldest month, soil texture, terrain slope, drainage condition, pH, salinity and sodicity as well as soil depth.

Agricultural areas with similar soil and climatic attributes were generated with the superimposition of the values of the indicated parameters. For each polygon with values of the climatic and soil variables, the ranges of the climatic and soil variables for each crop that define each aptitude class were included, and for each, their current aptitude label was generated.

For this work in the estimation of the degree of aptitude under climate change scenarios, it was decided to include only mean annual precipitation (PMA) and mean annual temperature (TMA), these considering the monthly mean rainfall and temperatures. The aptitude class was defined by the most limiting climatic parameters under the following combination described in Table 1.

Once the aptitude classes were defined, the ArcGis 10.3 Software generated the dynamic tables detailing the surface for each combination of the parameters that define the aptitude degree and the regional scale maps were prepared (1: 250 000) for each crop.

Table 1. Combination of climatic parameters that determine the land aptitude class for a particular crop.

Parameters that determine aptitude	Criterion
Precipitation and Temperature	PMA and TMA same aptitude level
Precipitation	PMA at a lower aptitude level than TMA
Temperature	TMA at a lower aptitude level than PMA
Without limits	PMA and TMA without aptitude restrictions, all in suitable class

PMA= mean annual precipitation; TMA= mean annual temperature.

Climate change scenarios

The climate change scenarios obtained from Fernández *et al*. (2015) for three models: GFDL_CM3, HadGEM2-ES and REA; for the distant time horizon (2070-2099), in addition to two RCPs: 4.5 and 8.5 W m^{-2}. The models were taken from the page of the Center for Atmospheric Sciences of UNAM (UNIATMOS, 2018). The rates of change for the monthly mean rainfall and the mean monthly temperatures for each agricultural area of the country were obtained and the mean annual precipitation and mean annual temperature were calculated from the monthly values for each of the climate change scenarios.

The procedure described under current conditions was applied to define the aptitude degree classes of agricultural land for each crop, obtaining the databases and their respective maps for each crop, that is, with each model, two dynamic tables were generated with the databases and their maps, one for RCP 4.5 and the other for RCP 8.5. With this information, the current aptitude changes in each climate change scenario for each crop were analyzed.

Results

Grain corn (*Zea mays* L.) current conditions

Of the 32 429 966 ha delimited as for agricultural use (INEGI, 2017), 81.59% have some degree of aptitude for corn under temporary conditions (Table 2), of which 10.91% have no limitations (suitable), 35.67% as moderately suitable and 35% as marginally suitable. The climatic parameters that represent restrictions for this crop and that define the agricultural areas as unsuitable, are in the first place the temperature.

Table 2. Percentage of agricultural land by aptitude for growing seasonal corn under current climatic conditions.

Parameters that determine aptitude	Area in percentage by current aptitude level			
	Suitable	Moderately Suitable	Marginally Suitable	Unsuitable
Precipitation and temperature	10.91	5.68	5.23	1.26
Precipitation		16.17	7.92	7.59
Temperature		13.83	21.85	9.56
Total	10.91	35.67	35	18.41

As the only limitation or in combination with other variables with 10.82% of the total agricultural land, most of these areas have annual average temperatures below 12 °C and are located in the high areas of the Eje Transversal Mexicano and high areas of the Sierra Madre Occidental. Precipitation as a limitation for agricultural land to be suitable for this cultivation under temporary conditions, either alone or in combination with other variables represents 8.85% of total agricultural land.

These areas are associated with agricultural areas with rainfall less than 350 mm annually and some areas with average annual rainfall greater than 4 000 mm. Within agricultural areas with average annual rainfall of less than 350 mm, they correspond mostly to irrigated areas, although there are some seasonal agricultural areas that have this condition of low rainfall where, in addition to other crops, corn is also planted but with high accident rate.

Climate change scenarios

Table 3 shows the results of the degree of aptitude of the country's agricultural land for seasonal maize under climate change scenarios for a RCP of 4.5 and 8.5 for the distant time horizon (2 070 to 2 099) and applying the rates of change for the three general models of atmospheric circulation (MGCA).

Table 3. Degree of aptitude of agricultural land in Mexico for corn under climate change scenarios estimated with the GFDL, HADGEM and REA models for a RCP of 4.5 and 8.5.

Suitable			Moderately suitable			Marginally suitable			Unsuitable		
GFDL	HADGEM	REA	GFDL	HADGEM	REA	GFDL	HADGEM	REA	GFDL	HADGEM	REA
Area in percentage by degree of aptitude for a RCP of 4.5 W m^{-2}											
11.52	10.03	8.91	1.18	2.35	2.89	2.75	4.94	7.88	6.86	9.16	5.64
-	-	-	17.63	9.38	10.75	8.19	9.63	9.42	7.16	16.23	15.9
-	-	-	7.98	5.89	6.07	11.97	11.59	14.58	24.76	20.8	17.96
11.52	10.03	8.91	26.79	17.62	19.71	22.91	26.16	31.88	38.78	46.19	39.5
Area in percentage by degree of aptitude for a RCP of 8.5 W m^{-2}											
10.79	12.14	9.13	2.51	1.08	3.03	4.45	1.03	7.09	7.64	7.62	5.73
			14.96	14.61	11.29	12.38	9.95	9.5	6.09	9.1	14.7
			7.42	7.42	6.29	10.81	14.43	14.9	22.96	22.62	18.34
10.79	12.14	9.13	24.89	23.11	20.61	27.65	25.41	31.49	36.68	39.34	38.77

P= mean annual precipitation; T= mean annual temperature.

In both RCP, the decrease in the surface with some degree of aptitude for this crop is considerable, going from 81.59% of the total agricultural land to 61.22%, 53.81% and 60.50% in the RCP 4.5 and to 63.32%, 60.66% and 61.23% in the RCP 8.5, for the GFDL, HADGEM and REA models, respectively. As can be seen, there are no major changes in the two RCP, even the surface is slightly larger with some degree of aptitude in the RCP 8.5 associated with the fact that a smaller decrease in precipitation is forecast than in the RCP 4.5.

The increase in the temperature estimated in the three models is the dominant factor in the exclusion of agricultural areas for this crop, where it is estimated that the average annual temperature in areas with some degree of aptitude under current conditions will be higher than 26 °C which is the limit to consider some degree of aptitude, the proportion of agricultural areas without aptitude for this crop associated with temperature alone or in combination.

With other variables such as precipitation less than 350 mm per year, it changes from 10.82% to 31.62%, 29.96% and 23.6% for the RCP 4.5 and 30.6%, 30.24% and 24.07% for the RCP 8.5 in the GFDL, HADGEM and REA, respectively. It is important to point out that, although some agricultural areas of the country that in current conditions have annual average temperatures below 12 °C and that in these scenarios their temperature will be higher than this threshold, so they will present some degree of aptitude for this crop.

However, the area that increases its annual average temperature to values above 26 °C is considerably larger. As can be seen, the proportion of the surface that becomes unsuitable is similar in the two RCP in each model. The proportion of the country's agricultural areas that will not be suitable for this crop under temporary conditions derived mainly from the decrease in precipitation to values less than 350 mm per year, goes from 8.85% to 14.02%, 25.39% and 21.54% in the RCP 4.5 and 12.05%, 14.96% and 18.69% in the RCP 8.5, for the GFDL, HADGEM and REA models, respectively. In the three models in RCP 8.5 there is less affectation on the surface with some degree of aptitude, this associated with the fact that it is estimated that the decrease in precipitation in different regions of Mexico will be less severe than for RCP 4.5.

Grain sorghum (*Sorghum bicolor* L.) current conditions

Of the total agricultural land, 61.54% have some degree of aptitude for grain sorghum under seasonal conditions (Table 4). The climatic parameters that represent restrictions for this crop and that define the agricultural areas as unsuitable, are firstly precipitation as the only limitation or in combination with other variables, 28.16% of the total agricultural land, these areas present average annual precipitation less than 400 mm or greater than 1 800 mm.

Table 4. Percentage of agricultural land by aptitude for seasonal grain sorghum under current climatic conditions.

Parameters that determine aptitude	Area in percentage by current fitness level			
	Suitable	Moderately suitable	Marginally suitable	Unsuitable
Precipitation and temperature	5.96	3.33	14.74	12.9
Precipitation		5.5	3.83	15.26
Temperature		10.6	17.58	10.3
Total	5.96	19.43	36.15	38.46

The temperature as a limitation for agricultural land to be suitable for this crop under temporary conditions, either alone or in combination with precipitation, represents 23.2% of total agricultural land, these areas are associated with agricultural areas with lower annual average temperatures at 15 °C or above 28 °C. In some regions of the country where this irrigated crop is established, the average annual rainfall condition is not necessarily met.

Climate change scenarios

Table 5 shows the results of the degree of aptitude of the country's agricultural land for grain sorghum in storm conditions for climate change scenarios for RCPs 4.5 and 8.5 for the distant time horizon (2070 to 2099) and applying the reasons for change for the three General Atmospheric Circulation Models (MGCA) of this study.

Table 5. Degree of aptitude of Mexican agricultural land for temporary low grain sorghum for the climate change scenarios estimated with the GFDL, HADGEM and REA models for a RCP of 4.5 and 8.5.

Suitable			Moderately suitable			Marginally suitable			Unsuitable		
GFDL	HADGEM	REA	GFDL	HADGEM	REA	GFDL	HADGEM	REA	GFDL	HADGEM	REA
Area in percentage by degree of aptitude for a RCP of 4.5 W m^{-2}											
6.70	6.12	5.09	2.81	4.32	2.29	11.43	12.23	10.87	12.24	16.05	16.68
			5.55	4.06	6.55	12.43	5.6	3.9	13.47	22.26	21.71
			5.84	3.61	4.43	20.82	17.12	20.85	8.71	8.63	7.63
6.70	6.12	5.09	14.2	11.99	13.27	44.68	34.95	35.62	34.42	46.94	46.02
Area in percentage by degree of aptitude for a RCP of 8.5 W m^{-2}											
6.46	6.31	5.29	3.79	3.37	2.16	14.05	11.11	11	12.55	13.1	15.78
			6.27	4.82	6.56	9.55	10.25	3.76	14.63	16.28	21.09
			4.97	6.28	4.55	18.15	20	21.84	9.59	8.48	7.97
6.46	6.31	5.29	15.03	14.47	13.27	41.75	41.36	36.6	36.77	37.86	44.84

In RCP 4.5, it is highlighted that in the GFDL model, the surface with some degree of aptitude for this crop will increase, going from 61.54% to 65.58%, while for HADGEM and REA models, the surface with some degree of aptitude for the development of this crop decreases to 53.06% and 53.98%, respectively.

For RCP 8.5 the proportion of the surface of agricultural land with some degree of aptitude increases slightly with respect to the current conditions in the GFDL and HADGEM models with 63.23% and 62.14%, respectively, and decreases to 55.16% in the REA model. With respect to the results of RCP 4.5, the greatest change is estimated with the HADGEM model, which increases by almost 10% of the total agricultural area, while in the other two models the changes are less.

The proportion of the country's agricultural areas that will not be suitable for this crop under temporary conditions derived mainly from the decrease in precipitation to values less than 400 mm per year, goes from 28.16% under current conditions to 23.9%, 38.31% and 38.39% in RCP 4.5 and 27.18%, 29.38% and 35.87% in RCP 8.5 for the GFDL, HADGEM and REA models, respectively.

In the GFDL model in the RCP 4.5 an increase in the surface that is in the precipitation range with some degree of aptitude is estimated, mainly due to the increase in the surface with annual average rainfall less than 1800 mm, while in the RCP 8.5 changing the surface within the precipitation range with some degree of aptitude is similar to current conditions.

In the HADGEM model for the RCP 4.5 there is a considerable decrease in the surface with the precipitation range with some degree of aptitude, while in the RCP 8.5 the precipitation increases with respect to the previous RCP, mainly in the areas that had lower values at 400 mm per year, to have a surface similar to current conditions. In the REA model in both RCPs there is a decrease in the surface with some degree of aptitude in the precipitation range defined for this crop.

The increase in temperature estimated in the three models reports an increase in areas with an average annual temperature greater than 15 °C, as well as an increase in areas with temperatures greater than 28 °C, so the proportion of agricultural areas without aptitude for this crop associated with temperature alone or in combination with other variables such as precipitation less than 400 mm per year or greater than 1 800 mm per year, it changes slightly from 23.2% in current conditions to 20.94%, 24.68% and 24.31% for the RCP 4.5 and 22.14%, 21.58% and 23.75% for the RCP 8.5, in the GFDL, HADGEM and REA models, respectively.

In the GFDL model there is an increase in the surface with some degree of aptitude for this parameter in the two RCPs, being higher in the RCP 4.5. For the HADGEM model, a slight reduction of the surface with some degree of aptitude is estimated in the RCP 4.5, while a slight increase is reported for the RCP 8.5. For the REA model the values for both RCPs are similar in the proportion of surface with some degree of aptitude.

Grain wheat (*Triticum* spp. L.) current conditions

Of the total agricultural land in the country, only 26.95% have some degree of aptitude for growing wheat under temporary conditions (Table 6). The climatic parameters that represent restrictions for this crop and that define the agricultural areas as unsuitable, are in the first place the annual average temperature greater than 18 °C, which alone or in combination with precipitation represents 71.79% of the total agricultural land.

Table 6. Percentage of agricultural land by aptitude for growing temporary grain wheat under current climatic conditions.

Parameters that determine aptitude	Area in percentage by current fitness level			
	Suitable	Moderately suitable	Marginally suitable	Unsuitable
Precipitation and temperature	2.61	4.17	7.68	31.08
Precipitation	-	3.73	0.77	1.26
Temperature	-	3.53	4.46	40.71
Total	2.61	11.43	12.91	73.05

Precipitation as a limiting factor for agricultural land to be unsuitable for this crop due to having values greater than 2 000 mm per year or less than 300 mm per year, alone or in combination with other factors, represents 32.34% of the country’s agricultural area. It should be noted that some of the wheat-producing regions, such as the areas of the coastal plain of the northern Pacific in Sonora, cultivation takes place in winter and under irrigation.

Climate change scenarios

Table 7 shows the results of the degree of aptitude of the country’s agricultural land for wheat in temporary conditions for the climate change scenarios for the RCPs of 4.5 and 8.5 for the distant time horizon (2070 to 2099) and applying the rates of change for the three general models of atmospheric circulation (MGCA) in this study.

Table 7. Degree of aptitude of agricultural land in Mexico for the cultivation of seasonal wheat for the climate change scenarios estimated with the GFDL, HADGEM and REA models for a RCP of 4.5 and 8.5.

Suitable			Moderately suitable			Marginally suitable			Unsuitable		
GFDL	HADGEM	REA	GFDL	HADGEM	REA	GFDL	HADGEM	REA	GFDL	HADGEM	REA
Area in percentage by degree of aptitude for a RCP of 4.5 W m^{-2}											
2.08	1.77	1.7	2.27	2.81	2.51	3.33	4.51	4.6	39.19	45.33	43.91
			2.05	2.45	1.91	0.33	0.45	1.26	0.31	1.44	2.23
			3.13	3.31	2.64	2.42	1.95	2.02	44.91	35.98	37.23
2.08	1.77	1.7	7.45	8.57	7.04	6.06	6.91	7.88	84.41	82.75	83.37
Area in percentage by degree of aptitude for a RCP of 8.5 W/m^2											
2.25	2.28	1.69	2.45	2.89	2.52	4.09	2.91	4.66	40.57	41.16	42.83
			2.52	1.88	1.94	0.35	0.22	1.27	1.36	0.48	2.16
			2.89	3.53	2.57	2.56	3.5	1.96	40.96	41.16	38.41
2.25	2.28	1.69	7.86	8.3	7.04	7	6.63	7.89	82.89	82.8	83.4

In both RCP, the decrease in area with some degree of aptitude for this crop is considerable, going from current conditions of 26.95% of the total agricultural land to 15.59%, 17.25% and 16.62% in RCP 4.5 and 17.11%, 17.21% and 16.62% in the RCP 8.5, for the GFDL, HADGEM and REA models, respectively. As can be seen only in the GFDL model, there is a change between the two RCPs, with a smaller decrease in area with some degree of aptitude in RCP 8.5 compared to that of 4.5. In the other two models the results are similar for the two RCPs.

The increase in the temperature estimated in the three models is the dominant factor in the exclusion of agricultural areas for this crop, where it is estimated that the annual average temperature in areas with some degree of aptitude under current conditions will be higher than 18 °C, which is the limit to consider some degree of aptitude, the proportion of agricultural areas without aptitude for this crop associated with temperature alone or in combination with other variables such as precipitation less than 300 mm annually, changes from 71.79%.

In current conditions at 84.1%, 81.31% and 81.15% for RCP 4.5 and 81.53%, 82.31% and 81.22% for RCP 8.5, in the GFDL, HADGEM and REA models, respectively. As can be seen, the proportion of the surface that becomes unsuitable is similar in the two RCPs for the HADGEN and REA models, in the GFDL model it is greater in the RCP 4.5. The proportion of the country's agricultural areas that will not be suitable for this crop under storm conditions derived mainly from the decrease in precipitation to values less than 300 mm per year or increase.

In precipitation at more than 2 000 mm per year they go from 32.34% in current conditions to 39.50%, 46.77% and 46.15% in RCP 4.5 and to 41.93%, 41.64% and 44.98% in RCP 8.5, for the GFDL, HADGEM and REA, respectively. In the three models in the RCP 4.5 there is less affectation on the surface with some degree of aptitude.

Discussion

For the three general models of atmospheric circulation, the estimated climate change scenarios contemplate an increase in temperature that varies in the different regions of Mexico, as well as between each model, however, the expectations are that the entire country will have higher temperatures. Projected warming can exacerbate several existing vulnerabilities, including the suitability of land for different crops Sivakumar *et al.* (2005); Trenberth *et al.* (2007); Ojeda *et al.* (2011).

Higher temperatures can have negative and some positive impacts on crop development (Childress *et al.*, 2015), with negative ones prevailing in this study where corn and wheat show a reduction in surface area with some degree of aptitude associated with the increase in temperature, while for sorghum there is a slight increase in the surface with some degree of aptitude for the GFDL model and slight changes for the other two models.

Virtually every aspect of the agricultural sector is highly sensitive to climatic conditions and as indicated, changes in climate can have both positive and negative effects, depending on the region and the changes. Agriculture in Mexico is vulnerable in some of the predicted impacts of climate change, including increases in temperature, decrease in precipitation and less water supply, as well as increases in crop pests and diseases (Monterroso-Rivas *et al*., 2018).

Changes in the frequency and severity of droughts, in the amount and distribution of precipitation, floods, among others, also represent new challenges for farmers (Childress *et al*., 2015). It is estimated that the increase in temperatures, which will be more pronounced in the summer, will result in greater frequency and severity of droughts, reducing the available humidity Gornall *et al.* (2010); Hatfield *et al.* (2011).

For crops and also in the availability of water in dams and abatement in aquifers, these changes will have a significant impact on crop yield (Hatfield *et al*., 2011). The increase in temperatures can make various crops grow faster, which can make them more vulnerable to humidity stress in the most sensitive stages of the crop and with it greater uncertainty in yields (Islam *et al*., 2012).

For any particular crop, the effects of the increase in temperature will depend on the optimum temperature in which each crop is developed, so if it is outside the range in which growth, pollination and seed formation occurs, crop yield will be affected. Many crops show thermal threshold effects in which they can develop, so if warming exceeds the temperature of the range in which the crop develops, the yields can decrease considerably or be zero (Hatfield *et al*., 2011).

Seasonal crops, especially wheat, show reduced yields under various climate change scenarios due to increased temperature and water stress (Ko *et al*., 2012). Likewise, irrigated crops such as corn are sensitive to temperature increases even when the required irrigation is applied to them (Islam *et al*., 2012). The increase in temperature increases the demand for water for many crops.

Regardless of changes in precipitation, warmer temperatures during the growing season will increase the demand for evaporation, increasing evapotranspiration rates and thus the water demand of crops (Udall, 2013). Given this panorama, the agricultural sector is potentially vulnerable to climate change and to the decrease or loss of harvests (Childress *et al.*, 2015), which is why studies are needed to estimate how these crops are affected by climate change scenarios.

Conclusions

The degree of aptitude for current conditions varies considerably between crops, maize is the one with the highest proportion of agricultural land with some degree of aptitude with 81.59%, followed by sorghum with 61.54% and with a lower proportion are wheat that has 26.95%. Of the climatic variables that determine the lack of aptitude in corn and wheat in agricultural areas, it is mainly the mean annual temperature alone or in combination with the precipitation, sorghum is primarily the mean annual precipitation alone or in combination with the mean annual temperature

Particularly for corn, the area that is not suitable due to annual average temperatures with values lower than the lower limit in which the crop develops is considerably increased and that in the scenarios of climate change these areas will increase and will have aptitude, but it is considerably greater the surface that ceases to have aptitude as the temperature increases to values higher than the upper limit in which this crop develops.

The affectation in the degree of aptitude of agricultural land for the crops considered was determined and the geographical location of these affectations is known, which can be used to develop public policies to address the problem of diminishing or losing the development capacity of these crops, implementing mitigation programs and adaptation to the conditions that may arise under climate change scenarios and giving alternatives to producers in affected areas.

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