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BELIZE
EFFECTS OF CLIMATE CHANGE ON AGRICULTURE

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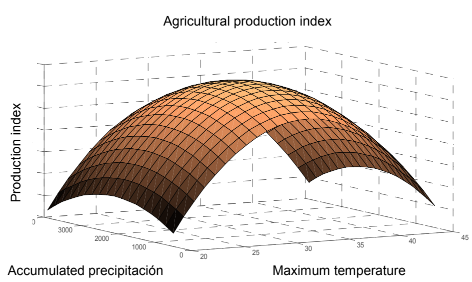

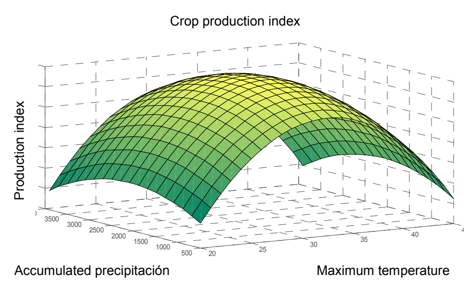

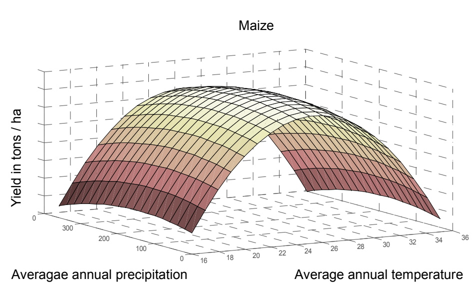

Economic Commission for Latin America and the Caribbean (ECLAC) • Subregional Headquarters in Mexico

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EXECUTIVE SUMMARY

Climate change poses a serious threat to Central American societies due to its foreseeable and multiple impacts on the population and productive sectors. In fiscal terms it constitutes a contingent public liability that will affect the public finance of governments for generations to come. It is estimated that by 2030, Central America will still produce less than 0.5% of greenhouse gas (GHG) emissions on the planet,[1] yet it is already one of the regions most vulnerable to the battering of climate change.

The increase in atmospheric and sea temperatures, the reduction and instability of rain patterns and the rise in sea levels, together with the intensification of extreme meteorological events —such as droughts and hurricanes— will impact the production, infrastructure, ways of life, health and safety of the population, and will also weaken the environment's capacity to provide vital resources and services.

In response to the mandate that emerged from the May 2008 Central American Presidential Summit on Climate Change, the ECLAC Subregional Headquarters in Mexico is implementing the project "The Economics of Climate Change in Central America" with the region's Authorities of Environment, Ministries of Finance/Treasury, the Central American Secretariat for Economic Integration (SIECA) and the Central American Commission for Environment and Development (CCAD). The project was approved by environmental authorities beginning in January 2009 with funding from the British government's Department for International Development (DFID).

Its goal is to alert decision makers and key players in Central America, particularly those from the social and economic fields, to the urgency of confronting the challenge of climate change and promoting a dialogue of policy options as well as national and regional actions. The specific objective is to conduct an economic evaluation of the impact of climate change in Central America with different development scenarios and emissions trajectories, while considering the costs and benefits of potential "business as usual" responses, and of options for vulnerability reduction and adaptation, as well as the transition toward an economy that is both sustainable and low in carbon.

The Project Steering Committee is comprised of the Ministers of Environment and Treasury/Finance of the seven countries of Central America. It has a Regional Technical Committee with delegates from those Ministries, CCAD/SICA and SIECA. The ECLAC Subregional Headquarters in Mexico acts as Project Coordinating Unit. The initiative works in coordination with other projects in Latin America, with the global network of projects on the economics of climate change and the British government's Stern team.

Throughout 2009, the project implemented the following components: Climate Scenarios, Macroeconomic and Demographic Scenarios, Land Use Change, Water Resources, Agriculture, Biodiversity, Energy, Economic Valuation of Impacts (initial stage), Poverty and Adaptation (initial stage), Mitigation, Policy Options in Adaptation and Mitigation (initial stage). The disasters component is being executed by ECLAC's Disaster Unit with financing from the Kingdom of Denmark. The pending components to be started in the coming months are Health, Ecosystems and Forest/Land Use Change. The Poverty, Economic Valuation of Impacts, Adaptation and Mitigation Options components and their costs will continue. Additionally, the project partners are considering options for responding to other needs that have become more evident in the past year, like a better analysis of funding and fiscal aspects, and the importance of strengthening national and regional capacities.

[1] Assuming emissions from land use change are maintained at 2000 levels.

The agricultural sector is sensitive to climatic variations and could be one of the most affected sectors as a result of global warming. The objective of this document is to analyse the possible impacts of climate modifications on Belize's agricultural sector; in particular, the results of temperature and precipitation variation effects are presented using two climate scenarios and different time horizons.

This current study is part of the series of documents created by ECLAC in the framework of the project: one for the Central American region and Belize as a whole and one for each of the seven countries (Belize, Costa Rica, El Salvador, Guatemala, Honduras, Nicaragua and Panama). The studies are based on the results of climate projections using production functions and a Ricardian model that measures the effect of climate change on land values. In Belize's case, however, the Ricardian model could not be used due to the lack of information available. To build the Ricardian model for the six remaining countries, household surveys were utilised, the relevant variables being the value of land rent or agricultural revenue. After learning of the existence of a survey entitled "2002 Belize Living Standards Measurement Survey (LSMS)," a request was made for a copy from the Statistical Institute, but the document has yet to be received.

For the sector as a whole, the results of the production functions show losses in production. According to the A2 climate scenario,[2] by the year 2100 the accumulated losses in the sector will range near 77% of 2007 GDP. Furthermore, the test of the impact on some of the most important crops (maize, beans, sugar cane and oranges) shows significant decreases in yield: by the year 2100 these decreases will be between 6% and 20% of 2007 GDP.[3]

Both temperature and precipitation in Belize during 2005 were very near the optimal level required by the function in order for agricultural production as a whole to maximize production. This indicates that alterations in climate conditions could have negative effects on production. Furthermore, if measures that strive to compensate the climatic tendencies are not taken, the economic losses could be significant, above all for small farmers, who are the most vulnerable to the battering of the climate.

2 At a discount rate of 0,5%.

3 Ibid.

INTRODUCTION

Human activity has caused worldwide atmospheric concentrations of greenhouse gases (CO_2, methane (CH_4) and nitrous oxide (N_2O)) to increase considerably. According to the IPCC report (2007), these concentrations are currently much higher than pre-industrial levels.

Because of variations in greenhouse gas (GHG) concentrations and a variety of factors such as changes in land use, the climate system is suffering alterations that include rising temperatures on the continents and in the oceans.

Eleven of the 12 years spanning 1995 and 2006 were among the hottest years of global surface temperature on record (since 1850). Land areas have heated up faster than oceans. Observations made since 1961 indicate that, on average, worldwide ocean temperatures have increased in depths down to at least 3000m because the oceans have absorbed more than 80% of the heat incorporated into the climate system.[4]

The increase in temperature has been projected for the next 100 years based on emissions scenarios. They are described in the IPCC's Special Report on Emissions Scenarios (SRES, 2000) and are grouped into four families (A1, A2, B1, B2), which explore alternative development paths by incorporating an entire series of demographic, economic and technological factors, in conjunction with the resulting GHG emissions. The SRES scenarios do not consider other climate policies apart from the existing ones. The projections generally show considerable warming of the planet as a result of the increase in emissions. Such an increase in temperature has never been recorded in human history and the resulting physical effects will seriously limit development (IPCC, 2007). Table 1 summarises some of the possible impacts of global warming on the agricultural sector.

As the temperature increases, precipitation will vary and extreme climate events, droughts, floods and forest fires will be ever more frequent. Additionally, rising sea levels threaten densely populated costal areas. As a result, the poor population in developing countries faces crop failure, collapse of agricultural productivity, and risks to food security along with hunger, malnutrition and disease.

Climate change will affect every country, but is also expected to widen the gap between developed and developing countries. High income countries, even when suffering the consequences of climate change, are in better conditions to respond to its effects. Some evaluations (Mendelsohn and others, 2001) indicate that developing countries will be the ones to bear a large part of the burden of climate change effects. In these countries, climate change poses a serious threat and increases the vulnerability of the poor since they are the ones who are most dependent on ecosystems.

A large part of the population in developing countries lives in physically exposed places and in precarious economic conditions. Moreover, a significant percentage of these countries' revenue is directly dependent on climate-sensitive natural resources; most are located in tropical and subtropical regions already subject to a variable climate.

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[4] IPCC, 2007**:** Climate Change 2007**:** Synthesis Report**.** Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, IPCC, Geneva, Switzerland

TABLE 1
EXAMPLES OF POSSIBLE CLIMATE CHANGE EFFECTS FROM THE DISTURBANCE OF ATMOSPHERIC EVENTS AND EXTREME WEATHER, BASED ON PROJECTIONS FOR THE MID TO LATE 21st CENTURY

Events and trend direction	Probability of projected 21st century trends based on SRES scenarios	Projected impacts on agriculture, forestry and ecosystems
In the majority of land areas: days and nights that are hotter and less often cold; days and nights that are hotter and more often very hot	Practically certain [a]	Better harvests in colder places; worse harvests in warmer places; more frequent insect infestation
Hot periods/heat waves. Higher frequency in most land areas	Very likely	Impoverishment of crops in the warmest regions due to heat stress; higher risk of uncontrolled fires
Episodes of intense precipitation. Increased frequency in most regions	Very likely	Crop damage; soil erosion, inability to cultivate lands due to saturated soil
Area affected by an increase in droughts	Likely	Land degradation; smaller crop yield, crop deterioration and even crop failure; greater losses of heads of livestock; increase in the risk of uncontrolled fires
Increased intensity of tropical cyclones	Likely	Crop damage; uprooting of trees; coral reef damage
Increased incidence of extreme rises in sea level (except tsunamis) [b]	Likely [c]	Stalinisation of irrigation water, estuaries and fresh water systems

Source: IPCC, 2007: Climate Change 2007: Synthesis Report. Contribution of Working Groups I, II and III to the Fourth Assessment Report by the Intergovernmental Panel on Climate Change. IPCC, Geneva, Switzerland.
Note: These projections do not consider variations in adaptive capacity.

[a] Warming of the most extreme days and nights each year.

[b] Extreme rises in sea level depend on the average sea level and on regional atmospheric systems. It is defined as 1% higher than hourly sea level values observed in a season for a given reference period.

[c] In all scenarios, the projected average world sea level by 2100 is greater than that of the reference period. The effect of the alteration of regional atmospheric systems on extreme sea level values has not been evaluated.

According to some estimates, developing countries will absorb approximately 75% to 80% of the cost of the damages caused by climate variations. An increase of no more than 2° C above pre-industrial temperatures could bring about a permanent reduction of between 4% and 5% in the gross domestic product (GDP) of Africa and Southern Asia (World Bank, 2009).

As previously mentioned, developing countries are more exposed to, and less capable of resisting climatic risks. Based on this view, it is anticipated that the Millennium Development Goals may be more difficult to achieve and that the ability to guarantee a sustainable and safe future after 2015 may be in jeopardy. For example, according to the IPCC report in Latin America, towards the middle of the century, increases in temperatures and the decrease in soil water could cause major economic losses. The output of certain crops such as grains will decrease, influencing livestock output, with undesirable consequences for food security. When combined, all of these developments would increase the number of people threatened by hunger.

The rise in sea levels will intensify floods, storm surges, erosion and other costal hazards, which threaten infrastructure and settlements and affect the subsistence of insular communities. Deteriorating costal conditions in response to beach erosion or coral discoloration would affect local resources in countries like Belize.

With the intention of providing elements useful for decision making, this study analyses the potential impacts of climate change on the agricultural sector in Belize. The document is organised into six chapters. The first chapter contains a review of the literature related to the impact of climate change on the agricultural sector, emphasising the work in the region and Belize. The second chapter provides an overview of the current situation in the agricultural sector, as well as the strategies adopted by the Belizean government in light of climate change. The third chapter presents the methodology of the production functions used to analyse the future impacts of climate change. The fourth chapter gives the econometric results. The quantification of the economic impacts of climate change on the agricultural sector is presented in the fifth chapter, and chapter six contains the conclusions.

I. LITERATURE REVIEW

Various vulnerability studies exist that analyse the implications of climate change for the agricultural sector, the majority of which show the growing threat that this change poses to sustainable development for low-income countries and for global food security. In the IPCC's analysis (2007) of the impacts of climate change, a general reduction in potential crop yields and a decrease in water availability are expected for agriculture and for people in many parts of the developing world.

This section describes the literature that discusses the main efforts to analyse the effects of climate change on the agricultural sector as well as the methodological approaches that are used. Whenever possible, emphasis is placed on the studies carried out for the Central American region and Belize.

The methods adopted to calculate the effects of climate change on the agricultural sector can be classified into two approaches: structural and spatial (McCarl and others, 2001; Molua and Lambi*,* 2007, Schimmelpfennig and others, 1996). The first combines the physical responses of crops with the economic responses of agricultural producers, while the second is characterised by analysing agricultural production and the climate of the different regions and then, the differences are estimated.

1. Methodological approaches

The majority of the analyses use individual approaches, however, they can be considered complementary.

a) Structural approach

The structural approach uses interdisciplinary models to simulate crop response, and based on the estimated effects, production changes are simulated. The advantage of using this methodological approach is that it allows detailed information to be obtained regarding physical, biological and economic responses, as well as possible adjustments. Nevertheless, among its disadvantages is the need to make multiple inferences from relatively few sites and crops in relation to large extensions of land and a variety of production systems (Schimmelpfennig and others, 1996).

In general, the studies that use the structural approach employ an empirical production function as a starting point to predict climate effects on crops. The analysis takes into account that farmers minimize costs or maximize their well-being according to the climatic restrictions imposed on the model. This type of model measures crop responses to different climate scenarios, which contain data from a specific group of climatic attributes, often temperature and precipitation.

Once the effects are estimated, they are included in the agricultural sector's economic models in such a way so as to allow the simulation of changes in crop supply and market prices. Studies conducted by Warrick (1984) were among the first to use this methodology; Warrick used a regression to simulate temperature increases similar to those that occurred in the 30's and found that crop production decreased. Terjung and others (1984) deduced that the amounts of water for irrigation would have to be greater when faced with rising temperatures if no technological changes were made. In turn, Easterling and others (1993) found that climate change in the United States, in the absence of technological changes or increases in CO_2, would bring about reductions in production resulting in economic losses.

The greatest difficulty that this methodological approach faces is incorporating farmer adaptation into the models to reduce the possible overestimation of negative aspects.

b) Spatial approach

Using the spatial approach methodology, the effects of climate change on the agricultural sector can be determined through the differences between the type of land, agricultural production and other regional variables that relate the climate to the sector. The models that characterise this approach use statistical or programming methods to analyse changes in spatial production standards; the models used include Ricardian, (Mendelsohn and others, 1994), Computable General Equilibrium (CGE) models and Geographic Information System models.

In this way, spatial approach models identify production standards using a statistical technique. One hypothesis states that producers are willing and able to adopt new crop systems and crops from other regions. Another is the idea that the physical and economic adjustments needed for crops and by farmers are carried out automatically. The latter hypothesis makes it unnecessary to model the adaptation behaviours of farmers related to adjustment costs in the short and medium terms. The models included in the spatial approach have the disadvantage of being highly dependent on the availability of information.

i) Ricardian model. This approach is based on statistical relationships between climatic variables and economic indicators. An advantage of this approach is that producer adaptation to local climate conditions is implicitly considered. Among the disadvantages of using this model are that it regards the farm's food prices and production prices as constants, and it generally fails to consider key factors that determine agricultural production such as water availability and carbon fertilisation. The Ricardian model has gained popularity among economists and is based on the idea that land value, derived from efficient land use and the existence of competitive markets, represents the present value of expected net revenue. This model calculates the effects of variations in climatic, economic and non-economic variables on the value of arable land using disaggregated information.

The studies that are based on the Ricardian model and address the effects of the climate on the agricultural sector include one conducted by Mendelsohn and others (1994) that explored the effect of climate change on the net value of arable land in the United States. Using information from a county-level cross-section, they found that higher temperatures over the course of the year (except in the fall season) have a negative effect on average land values. Schlenker and others (2006), also using data from the county level in the United Status, along with climatic indicators, land characteristics and socioeconomic conditions, showed that global warming causes profit losses in different U.S. counties.

Similarly, Maddison and others (2007) built a Ricardian model using data from 11 African countries; they found that by 2050 some African countries will suffer considerable losses in agricultural production. Likewise, Molua and Lambi (2007) studied the relationship between the climate and farmers' net profit using data from 800 agricultural farms in Cameroon. They found that net profit decreases as precipitation decreases and temperature increases.

The Ricardian approach also allows for comparisons between the potential effects in developed and developing economies. For example, Mendelsohn and others (2001) compared sensitivity to climate change in the United States and India. The results were that India's Ricardian function was much more likely to suffer negative effects from global warming than that of the United States. They found that the level of development has a significant effect on sensitivity to climate change. Under the same analytical frameworks, Mendelsohn and others (2007) used data from Brazil and the United States and found evidence that when faced with an increase in temperature, Brazil will feel the most severe effects.

Most of these studies uncovered evidence suggesting that the strongest negative effects will be felt by developing countries, and emphasising that the group of countries most susceptible to suffer losses are those located close to the equator and at lower latitudes, where temperatures tend to be higher. Adams and others (1999) agree that the impacts on crops tend to be more negative in lower latitudes, particularly for wheat and maize yields.

With regard to the livestock sector, Seo and Mendelsohn (2008a) developed a structural Ricardian model that takes into account the adaptation decisions taken by producers. The results indicate significant contrasts by the year 2100, depending on the animal group in question. For example, net revenue from beef cattle will decrease between 10% and 50% (depending on the climate scenario), while net revenue from dairy cattle will increase from 30% to 50%. These results reveal that net livestock revenue will suffer losses in the future, but as producers adapt to more tolerant species, net livestock revenue will see considerable increases.

Seo and Mendelsohn (2006) conducted a study in 11 African countries whose results indicate that the net revenue of big producers will be reduced as the temperature rises, while that of small producers will increase. The authors explain that these results can be attributed to the fact that small producers deal with species that are more tolerant of high temperatures, while big livestock producers mainly depend on cattle livestock, which is less tolerant of increases in temperature.

ii) Computable General Equilibrium (CGE) models. Darwin and others (1995) show that there are two limitations not taken into account when conducting aggregate-level studies: 1) the effects of climate change on other regions as they assume that the climate outside the area being studied is kept constant, and 2) world trade. To correct these kinds of restrictions, the CGE approach offers the possibility to model agriculture in relation to other economic sectors, allowing for resource mobility among regions when the economic incentives to do so exist. While a CGE model has the advantage of taking prices as endogenous and accounting for intersectoral links, a crucial limitation is that they come at the cost of considerable aggregations (Schlenker and others, 2006).

The study conducted by Rosenzweig and Parry (1994) employed this approach. They examined climate change effects on worldwide grain production and the distribution of these effects between developed and developing countries up to 2060. The scenario that was used predicted that worldwide grain production could decrease between 1% and 8% and prices would go up between 24% and 145%. The inclusion of farmer adaptations at the farm level helped to mitigate these impacts to the extent that the projected change in world grain production varied between -2.5% to 1%, and that of global prices fluctuated between -5% to 3.5%.

2. Previous studies of the region and Belize

a) Previous studies of the region

Climate is an essential determinant for agriculture. In regions like Central America, the climate is quite variable and there are problems related to droughts and floods that directly affect food production.

Also, climate related insect infestations, weeds and diseases tend to cause damage in developing countries such as those in Central America.

The specific case of South America was addressed by Mendelsohn and Seo (2007). Using data from 2,000 farmers, they found empirical evidence of the effect of climate change on agricultural activities. In the study, the producers' choices (to work in agriculture or animal husbandry or install irrigation) were modeled, and they tested whether their decisions were influenced by climatic variables like temperature or precipitation. The results show that both the choice of activity and the use of irrigation are climate sensitive. Farmers are more likely to choose to work in agriculture in colder temperatures, while those in dry areas opt to work in animal husbandry. In hot places, they have more opportunities to choose a combination of work in agriculture and animal husbandry. Farmers tend to use irrigation in areas that are both cool and dry. The conclusion is that a colder than average temperature and increases in precipitation raise the land value for all types of farms. With a future scenario in which the climate is very hot and dry, land value is expected to drop by one third by the year 2100.

In a study in which they also used information from 2000 farmers from South America, Seo and Mendelsohn (2008b), found that the value of arable land will decrease as temperature and precipitation increase, except in cases where there is irrigation. In the extreme climate scenario farmers will lose 14% of their revenue by the year 2020, 20% by 2060, and 53% by 2100. They point out that small pieces of land are highly vulnerable, and large ones are more sensitive to an increase in precipitation. The study predicts that both dry and irrigated lands will lose more than 50% of their revenue by 2100.

Mendelsohn and others (2009) applied the Ricardian model to a study of Mexico. They found similar results to those of the South American region; predicted losses for 2100 are between 42% and 54%, depending on the severity of the climate scenario used. The segment of producers most seriously affected would be the seasonal ones. Nevertheless, there was not sufficient evidence to distinguish the differentiating effects between small and large producers, but the losses farmers will suffer from climate change are negative.

A recent study on Latin American countries by de la Torre, Fajnzylber and Nash (2009) concluded that the gravity of the effects would vary between countries and also from region to region within countries. For example, in Mexico some regions would benefit from climate change. However, the findings suggest that negative effects tend to increase as analyses get closer to the equator, and there may be potential benefits in the southern part of the continent.

Gay and others (2004) applied an econometric model to explore the sensitivity of coffee production in the state of Veracruz, Mexico to changes in climatic and economic variables. Estimates of future coffee production indicate that by 2050 output will decrease significantly (by between 73% and 78%). The economic implications of this fall in production could be devastating, in particular for small producers, whose revenue would fail to cover production costs.

Another important study developed for the countries of Mesoamerica is that of Magrin and Gay (in Alfaro and Rivera, 2008). They assert that if no attention is paid to the effects of CO_2, grain yields could decrease by up to 30% by 2080 when a relatively hot scenario is considered. This study also forecasts that demand for water for irrigation will notably increase in hotter climates and lead to more competition between household and agricultural use. Furthermore, the authors show that climate change will cause the salinisation and desertification of arable lands and that by 2050, these events will affect 50% of such land.

The studies conducted offer estimates of how climate change could affect agricultural markets. The results have generally shown that the effects can be quite severe if adaptation mechanisms are not put into place.

b) Previous studies of Belize

The negative effects of climate change are worse in countries like Belize where there are particularly vulnerable regions as well as groups that are relatively more exposed to climate changes, have few adaptation capacities and little potential for recovery.

The economy in Belize depends on the climate. Good performance in activities like agriculture, fishing, logging and tourism are largely dependent on a stable and predictable climate. The devastating effects of hurricanes have shown how fragile Belize is against the whims of climate.

In 1995, the US Country Studies Program (Belize First National Communication to the Conference of the Parties of the United Nations Framework Convention on Climate Change 2002) conducted an agricultural vulnerability study. In it they simulated the yields of rice, beans and maize under climate scenarios that considered increases of 1° C and 2° C and a change of +/- 20% in precipitation. The model predicted production shortfalls of between 14% and 19% in the case of beans, 10% to 14% for rice, and 17% to 22% for maize. The study demonstrated that the increase in temperature shortened the crops' growth period, resulting in a decrease in their yield. It also showed that a change in precipitation did not affect the growth period, but it did affect the yield, especially that of maize.

The study did not incorporate the carbon dioxide fertilization effect into the yield, which could compensate for some losses; however, neither did it incorporate the effects of a rising sea level, which is anticipated to have a negative effect on Belize. The study recommends some adaptation measures, like developing more heat resistant varieties as well as promoting an infrastructure appropriate for efficient irrigation systems and improving crop management.

The US Country Studies Program (cited in Belize First National Communication to the Conference of the Parties of the United Nations Framework Convention on Climate Change 2002) also funded a vulnerability study for costal areas that predicts a 50 cm increase in sea level by 2075. This would give rise to saltwater intrusion and would affect agriculture, especially sugar cane and bananas. Costal flooding would stimulate a need to use new arable land and search for new sources of potable water in the country's interior, placing more pressure on scarce arable lands and forcing farmers to use marginal land and hillsides, thus increasing the need for intensive farming. Sugar cane is not expected to be significantly affected by climate change since it tolerates a wide range of temperatures and prospers in chalky soils. It is also a crop that could benefit from carbon dioxide fertilisation.

In the study by Santos and Garcia (2008), crop yield simulations were made based on different scenarios. It was found that the possible effects of climate change on Belize's agricultural sector varied depending on production systems and the area studied. However, climate change in general affects the conditions necessary for crops and as a result, their cycles are affected. Some crops are more vulnerable to changes in the climate than others. Nevertheless, a considerable decrease in yield could occur due to an increase in temperature. Some crops require low temperatures at some point during their growth cycle, like the flowering stage, and high temperatures reduce the duration of this cycle, affecting the plants' development. Maize produced in Belize using the rain-fed farming technique will be affected by a lack of water in the summer. The environmental conditions for maize crops are worse when climate projections predict a decrease in precipitation. Similarly, a potential increase in temperature can cause a decrease in yield due to a reduction in the duration of the crop cycle. Climate change could favour maize production only if the amount of rain during the summer rose, provided that nitrogen deficiencies are controlled.

In this same study, sugar cane yields were simulated based on two climate scenarios that predict increases between 1º C and 2.5° C, along with +/- 12% in precipitation by the year 2028 and +/- 20% by 2050. An 11.9% reduction was noted in sugar cane yield by 2028, and a 17.4% reduction by 2050. An increase in temperature shortens the growth periods of the crops, and therefore decreases their yields. Changes in precipitation did not affect the growth season, but they did affect the yield, especially when there are periods of high or low precipitation. Sugar cane is a crop that tolerates a wide range of temperatures and increases its yields with CO_2 as long as there are favourable conditions for the development of irrigation systems.

Simulations of citrus yields predicted a reduction of 3.4% by 2028 and of 5% by 2050. The increase in temperature shortens the vegetative period of the crops, which decreased their yield. In their research, really and others (2002) (taken from Santos and Garcia (2008)) concluded that citrus production benefited from higher temperatures in all the projected scenarios.

II. THE AGRICULTURAL SECTOR AND CLIMATE CHANGE

Agriculture is facing serious problems worldwide such as soil degradation and the pollution of water resources. The situation worsens when considering phenomena like climate change. One of the direct consequences of climate change (including rising temperature and variations in precipitation), and of soil degradation is the pressure they create and exert on food security, causing a reduction in the world food supply and leading to higher prices. The description given in this chapter is meant to provide an overview of Belize's agricultural sector.

1. The importance of the agricultural sector

Belize is located in Central America and forms part of the Yucatan Peninsula. It borders Mexico to the north, Guatemala to the south and west, and the Caribbean Sea to the east. The total surface area of the country is 22 965 square kilometres (see table 2); 95% of the area is on the mainland and 5% is divided into more than 1,060 islands.[5] Most of Belize's territory is at sea level. Costal areas and small islands are vulnerable to natural disasters and floods. Furthermore, it is a country with fragile ecosystems–tropical rainforests and coral reefs–and is very susceptible to natural disasters, like hurricanes.

TABLE 2

BELIZE: LAND USE, 2009

	Thousands of hectares	Percentages [a]
Total	2 297	
Land area	2 281	100.00
Agricultural area	152	6.66
Arable land and permanent crops	102	4.47
Arable land	70	3.07
Permanent crops	32	1.40
Permanent grasslands and pastures	50	2.19
Forest area	1 412	61.91
Other lands	717	31.42
Internal waters	16	0.70

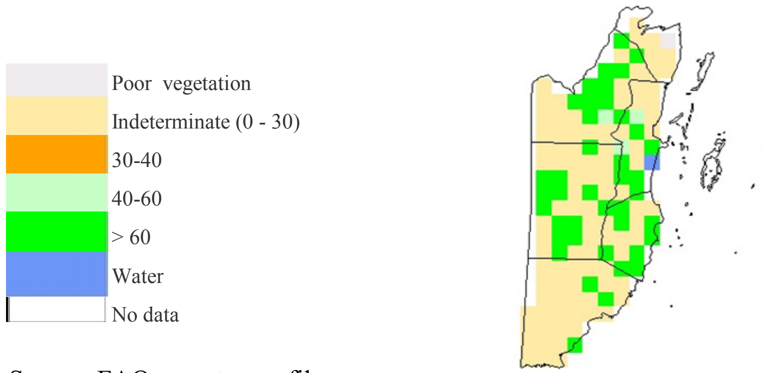
Source: FAOSTAT.

[a] Percentages based on land area.

The statistics on land use varied depending on the source consulted. Looking at the data presented in the "First National Communication to the Conference of the Parties to the United Nations Framework Convention on Climate Change," more than 70% of the territory is covered by vegetation, but only 33% is considered apt for agriculture (see map 1).

5 First National Communication to the Conference of the Parties to the United Nations Framework Convention on Climate Change; most recent update, February 1, 2003.

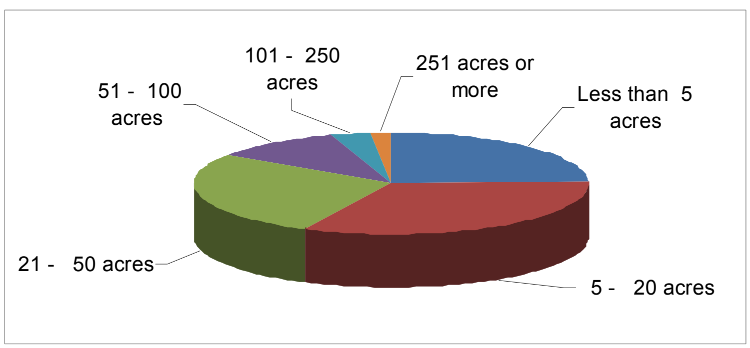
MAP 1
BELIZE: PERMANENT CROPS AND ARABLE LANDS
(Intensity percentages)



Source: FAO, country profiles.

Climate change directly affects production and agricultural productivity. The most vulnerable are small producers, who will face significant adaptation problems. Belize has 9,696 registered farmers in the "Belize Farm Registry,"[6] 60% of whom are "small farmers" that own less than 20 acres (see figure 1).

FIGURE 1
BELIZE: AGRICULTURAL UNITS REGISTERED BY SIZE



Source: Belize Farm Registry (BFR), Ministry of Agriculture and Fisheries.

a) Economic overview

Belize's economy greatly depends on climatic conditions. Agriculture, animal husbandry, forestry, fishing and tourism are all activities that rely heavily on the climate. Table 3 shows the percentage of GDP that these activities represent.

[6] Updated 1 February 2003.

TABLE 3
BELIZE: CONTRIBUTION TO GROSS DOMESTIC PRODUCT BY ACTIVITY, 2000-2010

(In percentages)

	2002	2003	2004	2005	2006	2007	2008	2009	2010
Agriculture, hunting & forestry	10.0	10.6	11.3	10.9	10.3	10.1	9.8	9.3	9.0
Fishing	3.3	6.3	6.4	6.8	5.5	2.3	2.2	2.4	2.3
Hotels and restaurants	3.7	3.9	4.0	4.1	3.9	4.0	3.7	3.5	3.6

Source: Statistical Institute of Belize.

Table 4 depicts the principal economic indicators in Belize for the 2000-2010 period. In 2010, the agricultural sector represented about 11% of total GDP.

For that same period, growth in agricultural output 1.3% average annual rate, lagged that of the economy as a whole -4% average annual rate-.

The agricultural sector's participation in foreign trade is important for the economy. According to the figures in table 4, agricultural exports in relation to total exports have dropped significantly from 62% in the year 2000 to 42% in 2009. However, the participation of agricultural imports remained steady at about 15% of the total.

Table 4 also shows population-related indicators. About half of the population lives in rural areas, a figure that has remained constant during the study period. The rural economically active population (EAP) as a percentage of total EAP, has also remained constant at about 24%. The percentage of women in the rural EAP is low, and it decreased between 2000 and 2010, showing very little participation of women in the country's workforce. Unemployment remained at about 13% on average.

b) Productive dynamic and structure

Citrus crops were the segment that account for the greatest share of gross agricultural production value (see table 5) at about 14% of the total agricultural output in 2008. Bananas were the second most important commodity. Livestock products comprised close to 25% of agricultural output in 2008.

Sugar cane, bananas and citrus are the most important export crops and constitute a substantial part of national revenue. The data on agricultural land use (shown in table 6) suggest that the majority of the agricultural area planted —approximately 68,660 acres—is used for sugar cane, mainly in the Corozal and Orange Walk districts. Also, 46,133 acres are used to grow oranges, mainly in the Stann Creek valley. The most important basic grains are beans, sorghum, maize and rice. Maize (yellow and white) takes up the greatest area of cultivated land at about 17,300 acres.

TABLE 4
BELIZE: PRINCIPAL INDICATORS, 2000-2010

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009 [a]	2010 [a]
Sectoral indicators	Growth rates										
Agricultural gross domestic product at market prices (in 2000 dollars)	9.5	-0.4	0.5	38.9	9.5	3	-6.4	-20.7	0.1	-2.2	-0.2
Agricultural gross domestic product, per capita (in 2000 dollars)	6.8	-2.8	-1.8	35.7	7	0.03	-8.4	-22.1	-2	-11.3	-6.8
	Percentages										
Agricultural GDP/GDP total	14.7	13.9	13.3	16.9	17.7	17.7	15.8	12.4	11.9	11.7	11.4
Agribusiness GDP	7.6	6.9	6.5	6.1	6.1	6.0	6.1	6.0	5.9	…	…
Extended agri-food GDP [b]	22.3	20.8	19.8	23.0	23.8	23.7	21.9	18.4	17.8	…	…
Agricultural exports/total exports of goods	62.4	53.3	44.3	54.2	58.3	55.9	46.4	39.3	33.0	42.5	…
Agricultural imports/total imports of goods	12.3	13.6	13.3	12.1	16.3	12.4	12.9	12.3	11.5	15.4	…
Agricultural expense/total central government expense	…	…	…	…	…	…	…	…	1.6	…	…
Agricultural credit/total credit	11	11.6	11.6	11.3	10.5	9.3	8.9	9.4	9.5	9.4	9.7
Implicit prices in the agricultural sector [c]	50	53.2	51.6	59.8	61.8	64.9	58.3	52.4	…	…	…
	Index (2000 = 100)										
FNAB/CPI [d]	99.6	100.3	101.3	101.4	101.9	100.9	100.9	98.1	92.2	89.7	93.3
Principal agricultural export prices	100	81.4	88.3	66.9	61.8	57.4	66.2	83.9	77.6	…	…
Social indicators	Percentages										
Rural population/total population	49.4	49.4	49.4	49.4	49.4	49.6	49.6	49.5	49.5	52.6	54.9
EAP in crop activities/total EAP	30.1	30.2	30.3	29.3	29.5	29.6	28.7	28.5	28.2	24	23.7
Female EAP in crop activities/total rural EAP	4	3.8	3.7	3.7	3.6	3.4	3.4	3.4	3.4	3.3	3.2
Rural sector labour force/total labour force	…	…	…	…	…	…	…	…	40	…	…

Table 4 (concluded)

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009 [a]	2010 [a]
Total open unemployment rate	11.1	9.1	10.0	12.9	11.6	11.0	9.4	8.5	8.2	13.1	…
Rural open unemployment rate	…	…	…	…	…	…	…	…	…	…	…
Rural average for years of education	…	…	…	…	…	…	…	…	…	…	…
National illiteracy	9.0	…	…	…	…	9.0	…	…	…	…	7.0
Rural illiteracy	…	…	…	…	…	…	…	…	…	…	…
Public expenditure on education in relation to GDP	5.0	5.8	5.5	5.2	5.3	…	…	…	5.7	6.1	…
Macroeconomic indicators						Growth rates					
Gross domestic product at market prices	12.3	5.0	5.1	9.3	4.6	3.0	4.6	1.2	3.8	0.0	2.7
Consumer Price Index (annual average)	0.5	1.2	2.2	2.6	3.1	3.6	4.3	2.3	6.4	-1.1	0.9
						Percentages					
Fiscal deficit/GDP	8.4	11.3	5.8	10.9	6.3	6.8	1.9	1.2	-1.5	2.8	1.5
Current account/GDP	…	…	…	…	…	…	…	…	…	…	…
Real interest rates											
Average	16.0	15.3	14.3	13.5	12.7	12.6	12.0	11.9	11.0	11.1	10.8
Construction	14.7	13.8	12.9	11.7	11.5	11.6	11.1	10.8	10.0	10.1	9.9
Commercial	15.5	14.6	13.8	13.1	12.8	12.5	11.7	11.4	10.6	10.6	10.5
Real adjusted exchange rate	2.0	2.0	1.9	1.9	1.8	1.8	1.7	1.7	1.6	1.6	1.6
Nominal exchange rate (Belizean dollars per dollar)	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0

Source: Based on official figures from ECLAC, the Central Bank of Belize, Ministry of Finance, Ministry of Agriculture and Animal Husbandry and National Institute of Statistics.

[a] Preliminary figures.

[b] Includes primary agricultural GDP and manufacturing GDP at basic prices in the food, beverage and tobacco segment.

[d] Referring to the Consumer Price Index (CPI) divided by the Food and Non-Alcoholic Beverages price index (FNAB).

[e] Deflated by the CPI.

TABLE 5
BELIZE: GROSS AGRICULTURAL PRODUCTION VALUE, 2006-2008
(*In percentages*)

	2006	2007	2008
Agricultural total	100	100	100
Citrus	16.17	19.83	14.35
Sugar cane	15.84	15.6	13.10
Bananas	11.68	10.24	16.24
Fruit	8.2	7.45	6.03
Grains/legumes	6.86	11.97	10.04
Vegetables	4.7	3.75	4.56
Livestock	16.67	20.63	24.53
Fishing	19.88	10.52	11.15

Source: Belize, Ministry of Agriculture and Fisheries. Annual report, 2007.

As a result of the rise in sea level, floods and the salinisation of farmlands (filtration of salt water into rivers where irrigation water is obtained) have created potential threats to farmlands. For example, saltwater intrusion is a big concern for most of the islands and for many communities in the costal plains. Farmland in the costal plains could experience salinity problems as the sea level goes up, as well as a drop in the availability of fresh water for irrigation. Sea level also has effects on erosion. The floods in northern Belize in 1998 affected sugar cane quality and net sugar production. [7]

TABLE 6
BELIZE: PRINCIPAL CROPS, TOTAL CULTIVATED AREA
(*In acres*)

	Corozal	Orange Walk	Belize	Cayo	Stann Creek	Toledo	Total
				Permanent crops			
Sugar cane	33 290	35 227	99	17	5	21	68 660
Orange	247	1 250	2 800	14 303	23 222	3 310	46 133
Grapefruit	2	50	76	1 236	5 739	6	7 109
Banana	26	24	37	26	5 193	743	6 049
				Cyclical crops			
Red beans	6 744	2 958	13	1 993	149	243	12 100
Sorghum	1 221	8 043	0	526	0	0	9 790
Yellow maize	585	5 482	113	2 195	211	344	8 931
White maize	327	425	4	1 634	540	5 475	8 407
Rice	1	5 284	6	193	278	752	6 513

Source: Belize Farm Registry (BFR), Ministry of Agriculture and Fisheries.

In Belize, many farmers are dependent on rain for a good harvest (according to the "Belize Farm Registry," nearly 76% of farmers depend on rainfall alone). At the same time, use of irrigation is limited

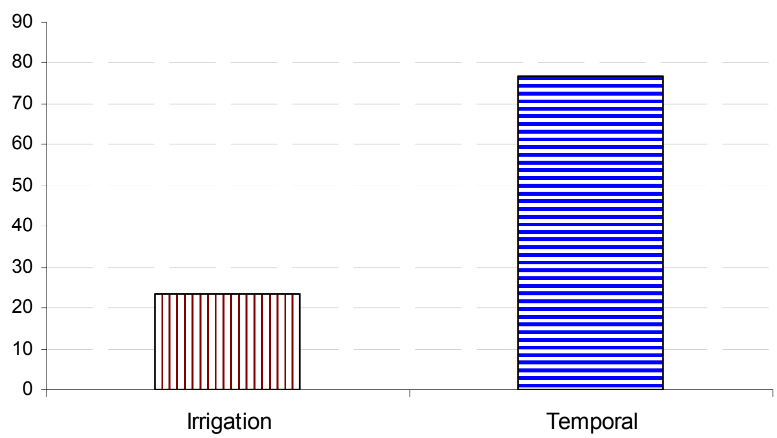
[7] See: First National Communication to the Conference of the Parties to the United Nations Framework Convention on Climate Change.

even on large plantations. In recent years, banana and papaya farms and a considerable number of rice fields have installed irrigation systems to compensate for the lack of humidity in the soil during the dry season.[8]

c) Trade insertion and international competitiveness

Belize has a little-diversified foreign market (see table 7). The principal export destinations are the markets of the United States and the United Kingdom. However, these markets have been decreasing in importance, especially those directed towards the United Kingdom. Furthermore, Central American countries have acquired greater significance as export destinations, particularly since 2006. The percentage that Central American countries represented went from 0.24% in the year 2000 to 18.45% in 2009.

FIGURE 2
Belize: Irrigated and non irrigated land
(*In percentages*)



Source: Belize Farm Registry (BFR), Ministry of Agriculture and Fisheries.

Belize's main exports are citric (orange and grapefruit) concentrates and sugar. Even though both products have lost importance in comparison to other exports, in 2010 they added up to about 30% of total exports (see table 8). The importance of seafood, in turn, decreased from 16.74% of all exports in 2000 to only 11% in 2010. The same occurred with bananas, whose importance decreased from 15.64% in 2000 to 12.7% in 2010. Oil exports have assumed greater importance, making up close to 37% in 2010.

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8 Ibid.

TABLE 7
BELIZE: EXPORTS BY MAIN DESTINATIONS, 2000-2009
(*In percentages)*)

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
United States	48.73	52.04	53.12	55.49	54.97	51.32	41.84	26.55	42.42	32.43
Central America	0.24	0.80	0.84	0.30	0.54	0.72	12.67	28.45	20.56	18.45
United Kingdom	28.76	24.22	24.61	24.52	19.51	21.11	16.50	18.04	19.80	31.71
Other European Union countries	10.63	6.94	9.36	5.40	10.11	7.54	14.94	14.37	7.24	5.01
CARICOM countries	4.66	6.71	7.09	9.18	11.33	10.96	8.28	7.03	5.24	5.36
Other countries	4.93	8.25	3.04	3.51	1.80	2.61	2.46	3.52	2.69	4.38
Mexico	0.65	0.63	1.20	1.45	1.53	5.69	3.22	1.94	1.68	2.21
Canada	1.40	0.41	0.74	0.16	0.21	0.06	0.10	0.11	0.37	0.44

Source: Statistical Institute of Belize.

As part of this study, the competitiveness of Belizean products in international markets was analysed based on the percentage change in market share and the amount of products exported to the United States during the 2002-2007 period (using data from the Module to Analyse the Growth of International Commerce, MAGIC). The results of the analysis of 25 groups of agribusiness and agricultural products are shown in table 9.

TABLE 8
BELIZE: PRINCIPAL EXPORT PRODUCERS, 2000-2010
(*In percentages*)

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Seafood	16.7	20.4	22.2	28.9	26.2	23.0	16.0	8.3	11.9	13.1	10.9
Sugar	17.7	18.2	20.8	18.7	19.9	16.4	18.7	17.4	12.2	18.2	10.4
Orange concentrate	25.8	26.0	21.3	20.5	19.7	25.2	20.3	23.1	15.3	15.1	16.6
Bananas	15.6	13.2	10.6	13.8	12.8	11.5	9.4	8.2	11.4	13.7	12.7
Papayas	2.7	3.2	4.9	4.4	5.6	6.3	5.8	5.1	3.8	4.5	4.6
Oil	-	-	-	-	-	-	16.5	28.1	39.5	24.7	36.5

Source: Statistical Institute of Belize.

Of the 25 groups that comprise the agribusiness and agricultural sector, only the sectors of seeds and oil fruits, and vegetable and animal fats and oils, constitute a growing market thanks to its relative importance in trade flows and increased market share. In contrast, live fish, other animal products, and beverages and alcoholic liquids are products that have remained stagnant and have lost relative share.

Although products like legumes and vegetables, edible fruits, unroasted coffee, tea, yerba mate and spices, sugars and sweets, cacao, grain-based products, and legume, fruit and vegetable products, are gaining share, their markets are stagnant.

TABLE 9
BELIZE: COMPETITIVENESS OF AGRI-FOOD EXPORTS TO THE UNITED STATES, 2002-2010

Tariff code [a]	Product	Typology [a]
	Agricultural	
1	Live animals	Undefined
2	Fresh and refrigerated beef	Undefined
3	Live fish	Retreat
4	Dairy and honey	Undefined
5	Other animal products	Retreat
6	Plants and flowers	Declining star
7	Legumes and vegetables	Missed opportunity
8	Edible fruits	Missed opportunity
9	Unroasted coffee, tea, yerba mate and spices	Missed opportunity
10	Grains	Undefined
12	Seeds and oily fruits	Rising star
	Agribusiness	
11	Milling products	Undefined
13	Gums and resins	Undefined
14	Weaving materials and other products	Undefined
15	Vegetable or animal fats and oils	Rising star
16	Meat	Declining star
17	Sugars and sweets	Missed opportunity
18	Cacao and cacao products	Missed opportunity
19	Grain-based products	Undefined
20	Legume, fruit and vegetable products	Missed opportunity
21	Various food products	Missed opportunity
22	Beverages, alcoholic liquids	Retreat
23	Animal feed and waste	Undefined
24	Tobacco and tobacco substitutes	Undefined
44	Wood and wood products	Declining star

Source: MAGIC, 2011.
Note: Rising stars: dynamic markets and products gain share. Declining stars: dynamic markets and products lose share. Missed opportunities: stagnant markets and products gain share. Retreat: stagnant markets and products lose share. Undefined: does not participate in trade with the United States. Dynamic sectors are those that increase their relative importance in trade flows from a base year to a final year. Stagnant sectors are those that decrease their relative importance in trade flows from a base year to a final year. Competitive sectors are those that increase their market share, contribution or specialisation from a base year to a final year. Non-competitive sectors are those that decrease their market share, contribution or specialisation from a base year to a final year.
[a] Of the harmonized system (MS).

d) Trade agreements [9]

Belize is not an RD-CAFTA member, but it does have an agreement with the WTO member countries, signed in 1995 as a GATT contracting party; Belize joined GATT in 1983. The country also signed a trade agreement with the CARICOM countries on 4 July 1973 that was revised in 2001. It has a partial tariff agreement with Colombia dating back to 1994, and one with Venezuela, signed in 1992.

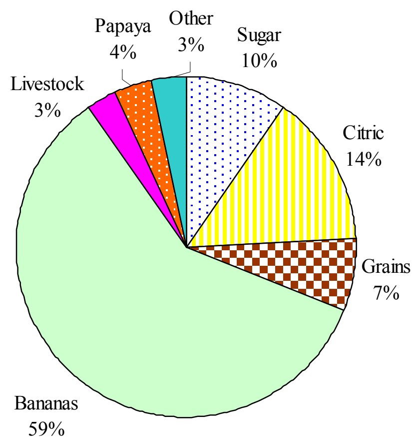
[9] Source: Foreign Trade Information System (SICE) <http://www.sice.oas.org/default_s.asp>.

e) Credit in the agricultural sector

According to data from the Central Bank of Belize, agricultural credit in Belize constituted 9.7% of total credit in 2010. Although agricultural credit grew 108% over the 2000-2010 period, its share of total credit narrowed from 11% in 2000 to 97% by 2008.

Most agricultural credit in 2010 corresponded to banana farming, accounting for 59% of the total (see figure 3). However, credit for growing sugar cane saw the greatest increase between 2004 and 2008, while support for citrus decreased in the same period.

FIGURE 3
BELIZE: AGRICULTURAL CREDIT DISTRIBUTION, 2010
(*In percentages*)



Source: Central Bank of Belize, Statistical Digest, 2010.

2. Belize and climate change

a) Effects of climate change on agriculture in the last few years

Over the last few years, extreme weather events have intensified, causing repercussions in the form of economic losses for countries. Central American countries have been among the most affected by climatic events. Table 10 lists the Central American countries and their place in the Climate Risk Index (CRI). The CRI shows countries that have been affected by extreme weather events over the 1998-2007 decade and takes into account the total number of deaths per 100,000 inhabitants, the absolute losses in millions of U.S. dollars and losses as a percentage of GDP. These indicators imply the development and vulnerability levels of the countries at risk. This index reflects both the physical effects of extreme weather events and the national circumstances that determine the adaptation capacity of each country and its population (Harmeling, Sven, 2008).

Belize ranks 34th on the index, however, losses as a percentage of GDP stand at 5.5%, the highest in Central America.

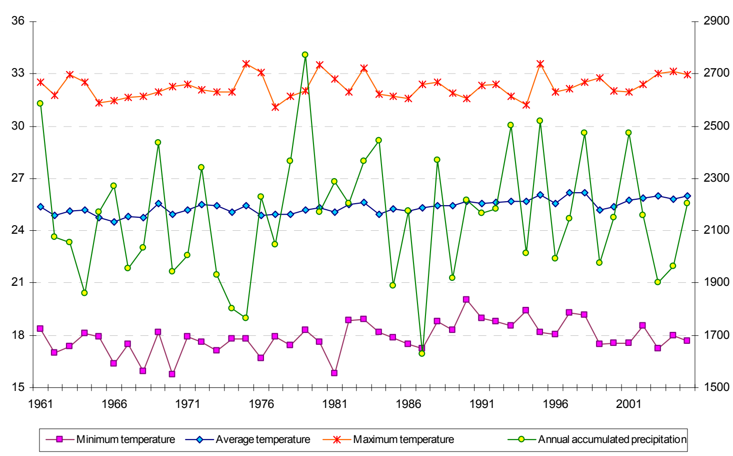
In the last few decades, the average annual temperature in Belize has shown a slight tendency to increase. The annual accumulated amount of precipitation has varied greatly from year to year (see figure 4).

TABLE 10
CLIMATE RISK INDEX (CRI): RESULTS OF SPECIFIC INDICATORS FOR COUNTRIES OF THE CENTRAL AMERICAN ISTHMUS AFFECTED BY EXTREME WEATHER EVENTS, 1998-2007

CRI ranking (1998-2007)	Country	CRI	Average deaths	Average annual number of deaths per 100,000 inhabitants	Total average losses (millions of U.S. dollars PPP)	Average GDP losses (% of GDP)
1	Honduras	6.75	579.00	8.50	1,166	5.15
3	Nicaragua	11.67	308.00	5.70	528	4.30
4	Dominican Republic	14.83	414.00	5.00	503	0.98
11	Guatemala	26.67	132.10	1.14	243	0.50
30	El Salvador	43.25	38.00	0.58	103	0.32
34	Belize	49.33	3.40	0.41	98	5.51
84	Costa Rica	80.00	5.80	0.14	33	0.10
100	Panama	90.42	13.70	0.45	2	0.01

Source: Harmeling Sven (2008).

FIGURE 4
BELIZE TEMPERATURE AND PRECIPITATION, 1961-2001



Source: Prepared by report authors based on data from the Climate Change and Solar Radiation Group, part of the Center of Atmospheric Sciences at the National Autonomous University of Mexico (UNAM).

Due to its geographic position, Belize is strongly affected by hurricanes, which cause both human and material losses as well as serious damage to infrastructure that has a considerable impact on the agricultural sector. Furthermore, it must be kept in mind that small producers, who do not have any kind of insurance against these events, are the ones who suffer the greatest negative effects from these kinds of natural dangers. Table 11 lists the natural disasters that have occurred in the last few years. Hurricane Keith in 2002, inflicted economic losses totalling approximately 30% of GDP. Hurricane Dan, which struck in 2007, caused losses equivalent to 90 million dollars (7% of GDP), 64% of which corresponded to the agricultural sector.

TABLE 11
BELIZE: DAMAGES AND LOSSES IN THE AGRICULTURAL SECTOR PER DISASTER, 2002 AND 2007
(In millions of dollars)

Year	Event	Total damages and losses	Agriculture			Percentages			Current GDP	Total damages and losses /GDP
			Total	Damages [a]	Losses [b]	Agriculture/ Total	Damages/ Agriculture	Losses/ Agriculture		
2002	Hurricane Keith - Belize	280.1	62.2	38.7	23.4	22.2	62.3	37.7	932.2	30.0
2007	Hurricane Dean - Belize	89.9	57.9	21.2	36.7	64.4	36.7	63.3	1 276.8	7.0

Source: ECLAC, based on official figures from the Disaster Unit database.
[a] Refers to the total or partial destruction of heritage or capital.
[b] Refers to losses or alterations in flows.

b) Strategies, policies and programs for facing climate change

In 1992, Belize signed the United Nations Framework Convention on Climate Change (UNFCCC), and ratified it in 1994. The Government of Belize designated its National Meteorological Service (NMS) as the focal point for matters related to climate change.

Belize presented its First National Communication to the UNFCCC in 2002, and the Second National Communication (preliminary version) in 2007. At the same time, GHG emissions inventories were compiled (1994, 1997 and 2000) and the first mitigation and adaptation strategy was outlined, reflecting national circumstances and problems, primarily in the Agricultural and Water Resource sectors.

Thanks to its participation in CARICOM, Belize is a partner in the Alliance of Small Island States. Its UNFCCC negotiating position is coordinated within this organisation. Belize is also a member of the Central American Commission on Environment and Development (CACED) and collaborates on the “Caribbean Community Climate Change Center.”

The preparation of national greenhouse gas inventories is part of the international response to climate change. These are used to try and document the net amount of greenhouse gases that are produced or eliminated (via sinks), as well as the sectoral activity and the gases that are present in each sector. In accordance with the UNFCCC, Belize used 1994, 1997 and 2000 for their national inventories of GHG sources and sinks. The results of the first inventory show that Belize is a net GHG sink; that is, it absorbs more than it emits.

Belize is vulnerable to adverse climate change impacts. Therefore, the national goal should be to identify viable adaptation options to confront climate change.

According to the first communication, the Ministry of Agriculture has the following mandate:

i) Conduct studies about climate change vulnerability for all main crops.
ii) Prepare adaptation options for threatened crops.
iii) Promote the use of new crop varieties and practices in the community.
iv) Include a report on activities related to climate change in the Ministry's annual report.
v) Provide a report regarding its climate change activities.

3. Reflections on the land market in Belize

As it was not possible to employ a Ricardian model, some reflections on the land market were made in order to give an idea of how the sector is currently doing.

As previously stated, the country of Belize covers a total area of 22,960 km^2, 5% of which is distributed over more than 1,060 islands. Privately owned land comprises 54% (about 12,400 km^2) of the total national land area.

More than 10,000 km^2 of these private lands are distributed as rural parcels of more than 0.4 km^2 (40 ha), while small, private, urban parcels account for less than 0.1% of the total national land area. Public lands make up 46% (approximately 10.560 km^2) of the total area of Belize. Those lands are further divided in the following way: (a) protected areas and forest reserves that comprise more than 30% of the total national land area; and (b) other "national lands" (16% of the national total), which consist of both lands that are allocated under lease contracts from the State, and unleased public lands. It is estimated that there are between 200,000 and 225,000 parcels (100,000 in rural areas) that could become part of the national land registry and contribute to a dynamic market of investments (Barnes, 2001).

The Ministry of Natural Resources and the Environment (MNRE) is responsible for administrating renewable and non-renewable natural resources, including land, as well as regulating the environment with the intention of promoting sustainable development in Belize. As part of the MNRE, the Department of Lands and Surveys (DLS) is responsible for supervising the registration of land ownership rights, valuation of lands to determine the amounts charged for lease and taxes, allotment of public lands via lease contracts or individual sales, mapmaking and land information management.

This section is organised into three parts: a historical review about the evolution of land ownership patterns, a description of the current situation regarding land management and administration, and a review of the main international initiatives regarding land use planning in Belize.

a) Patterns and initiatives in land ownership: an historical perspective

During the colonial period, land management in Belize was marked by a high degree of concentration in land ownership that benefitted a small group of people and excluded the rest of the population. Through the years, government has taken on a more active management role focused on making changes that stimulate productive activity and with it, the participation of the private sector. Land management has evolved in response to changes in the legal framework and in the way public lands are used.

Although land management and the functions of the DLS date back to 1862, land use planning, data collection and the development of resource information capacities were not established until 1992 (Iyo and others, 2003).

i) Principal land use patterns. Currently, Belize is characterised by a large variety of land ownership practices ranging from freehold titles to leasehold titles, both in rural and urban areas. A total of 8% of available rural lands are National Estate lands that are available for lease or currently in a lease application process. There are estimates indicating that close to 1% of available national parcels are involved in some kind of lease process, and in the majority of cases, those who lease have applied for full ownership of the land. In 2001, it was reported that an estimated 90,000 to 100,000 parcels had yet to be assigned, but more recent studies suggest that this might be a considerable underestimate (Iyo and others 2003).

The Government of Belize and various NGO's have begun to notice a combination of increased land use near forest reserves involving the *milpa* crop-growing technique (shifting cultivation), and greater soil loss (erosion) mainly caused by shortened fallow periods (Barnes, 2001).

In different periods throughout Belizean history, the distribution and ownership of land have been determined by state policies, race and ethnicity, among other factors. In contrast to other Caribbean countries that were dominated by plantations, land use in pre-colonial and colonial Belize was largely determined by forest resource exploitation. Furthermore, state policies regarding land were influenced by the fact that settlements in Belize operated without colonial status from the 17th to mid-19th centuries. Up to the mid-1700's, there were practically no laws regarding land tenure in the area; since the number of British colonists was very low, there was no need to regulate land ownership. Hence, the way to acquire land was simply to claim an area for a certain activity and when someone wished to start something new, it was simply a question of taking control of another section of land (Belize, 1988).

The State's influence over land ownership patterns after the establishment of colonial status was restricted by previous arrangements. Specifically, land policies in Belize before 1871 were characterised by private control of all lands.

The Crown Lands Act (CLA) of 1872 marked the process of acquisition of usufructary rights for public lands, the acquisition of ownership rights for public lands, as well as the establishment of reservations for the native and Caribbean peoples and rules for their operation. This Act also called for the process of delineating forest reserves and arable lands. Above all, it successfully deprived the Maya and Garifuna of the right to own land and only gave them a small portion of land previously determined by the Crown (Bollan, 1988).

A major change in land policies occurred between 1920 and 1968. This was influenced first and foremost by displacement of the labour force due to the mechanisation of forestry operations (Barnett, 1991).

Since the arrival of the British in the 17th century, land use in Belize has been linked to the means of production. Land acquisition and accumulation of land took into account the nature and character of its distribution and ownership. Before 1862, agricultural activities were secondary to those of forestry. The people consistently involved in agricultural production were the elderly, the infirm and women. The rest of the population worked on their small plantations only when mahogany could not be harvested (Bolland and Assad, 1977). In a sign of the secondary role agriculture played, it is not possible today to determine how much land was allotted to crops during this period. However, just after 1871 (the start of the Crown period), State promotion of agriculture and the decline in forestry resources changed the situation so that by 1889, there were more than 60,000 acres of cultivated land (the main crops were maize, sugar cane and banana). By 1911, 15% of the population of Belize was involved in agriculture, 50% of whom were classified as agricultural workers with the other half consisting of small farmers and *milperos* (Iyo, 1998).

The creation of the Registered Land Act simplified the law and the procedures related to land tenure. The effectiveness of this regulation in particular was enhanced by the introduction of the Strata Titles Registration Act of 1990 and the Land Acquisition Act of 1992. The latter helped to clarify property rights in the event that property was disputed, and it also made the land registration system more efficient and effective. The Strata Titles Registration Act provides elements for the registry and assurance of common ownership titles (Iyo and others, 2003).

By the period immediately following independence, some types of land tenure systems (including agricultural reserves) had been discontinued, replaced by leases and purchases of national land. At the same time, the volume of private properties for sale increased dramatically. These changes in land ownership patterns prompted the decision to introduce the Land Use Act (LUA) in 1981. The central goal of this act was to ensure the best use of the land and to reduce or prevent fragmentation and under utilisation.

Management of national lands (lands that are property of the government, excluding forest reserves and national parks) was transformed after the National Lands Act (NLA) was passed in 1992, which repealed and replaced the Crown Lands Act. The NLA established a land advisory committee to provide pertinent advice related to land, and it also made provisions for a system in which local committees could make the necessary recommendations for a new system for land distribution.

It is worth noting that the period just before and just after independence produced the most significant efforts at changing land ownership patterns through passage of laws to regulate land acquisition within Belize. This period was characterised by progressive land distribution involving both lands previously owned by the state and private lands acquired by the government for the purpose of breaking up vast land holdings into to smaller-scale properties. Another notable characteristic of post-independence land tenure was the rise of plantation agriculture, giving way to a mix of small-farmer lands alongside large company landholdings. This period was also characterised by a decrease in land purchases by the government, as well as an increase in land lease contracts. Despite these attempts, in 1986 almost 85% of private landowners controlled 4% of freehold land while a mere 3% of private landowners controlled almost 90% of freehold land (Iyo and others, 2003).

b) Current framework in land ownership management

During the colonial period (1871-1964), the State had emerged as the mediator in land distribution in Belize, influencing land policies that included access and equity in terms of distribution. The state also acted as facilitator for, and competitor to private owners for two reasons: first, it served as the financial institution that was promoting the sale of land, and second, political power was employed to accumulate large tracts of land.

As a result, the State went from playing a passive role, creating policies regarding land management, to an active and participative one in changing land policy. All that notwithstanding, the government's efforts have been focused on attracting foreign investors, paying little attention to local citizens who still have no land and whose only possibility of accessing land through the lease system (in the North) or by squatting in the Central areas and reserves (in the South). More than 75% of all productive land remains in the hands of large land owners that have benefitted since colonial times. Suffice it to say that the unequal distribution of private land property still affects current land market activity (Barnes, 2001).

Beginning with the Land Reform Programme of 1968-1977 and later marked by the right to "a piece of land for every citizen", each government declared the land redistribution issue the cornerstone of its development strategy. However, up to now, the successive administrations have not been able to effectively translate their campaign promises into a real policy framework, even when facing strong demands and pressure to follow through.

Government efforts at redistribution have significantly affected the current state of the land market, and there is a general consensus that such endeavours have affected the market's dynamics. But despite this intervention, as discussed above, the government's participation has been criticised, especially in matters of equity. A comparison of the prices charged for lands purchased from the public sector and those sold by private sector agents and individuals is the clearest indicator. Evidence shows that an average tract sold on the private sector (secondary) market sells for between five and seven times the value of a property of equivalent size sold by the Government of Belize (Iyo and others, 2003). This discrepancy has led to a continuous demand for national estate lands, even on the part of clients who are neither first-time buyers nor low-income wage earners. The effect of government intervention on the redistribution effort, from a historical perspective, and the recognition of the need to provide access to the disadvantaged underscore the need for a fair, comprehensive pricing policy.

In addition to the negative effect the lack of a fair pricing policy has on the growth of the land market, there is evidence of a parallel market where the secondary sale of land operates largely on an international level. It has been difficult for this market to be effectively implemented and consolidated owing to the reticence of real estate agents, the breadth of the trade and the extent of the market's value added. Nevertheless, the entrance of accredited companies like Century 21 and REMAX suggest that this market continues to expand. Furthermore, this growth has left regulatory regimens behind, particularly in regard to investor protections (Barnes, 2001).

Over the last decade, the MNRE has been carrying out an extensive process of modernising its land organisation services with the goal of promoting investments in key economic sectors like agriculture, through the protection of property rights. These efforts are an attempt to respond to an important problem related to diminished security of land ownership due in part to the use of two property registry systems, of which only one (in compliance with the Registered Land Act) allows for effective administration of land documentation and the attainment of more secure property titles by assigning a unique identification number to each parcel registered. Other problems that needed to be addressed were the inefficiencies and delays resulting from the use of physical files that had to be consulted manually. This takes a lot of time and complicates the task of linking the property title with its value and location, goals that have been reached based on the implementation of a series of international initiative programs, which are described next.

c) International initiatives and the development of a national land policy

The demand for land and the development of the land market are on the rise, and the methods related to land management are changing both for the public and private sectors. Consequently, the question of information management and dissemination and the creation of planning policies becomes a central topic in all issues related to land management, sale and distribution.

The Land Management Programme provides this support and is the underpinning for the institutional planning effort for land use. Its goal is to further the improvements necessary in national structure for planning and development in the physical requirements of this resource. Work prior to the implementation of the Land Management Programme began in 1999/2000, negotiations were conducted in 2001, and in March 2002 it was launched. In its first stage, the programme was approved for disbursement in July 2002. The Interamerican Development Bank (IDB) funded the program, along with support from the Government of Belize.

In order to build on the achievements of the first phase of the Land Management Programme, the second phase of the Land Management Programme (LMP II) was designed to support the transition of a significant portion of the country to a single Land Registry for rural and urban areas alike, with pilot activities in the countryside. Additional efforts were made to strengthen capacities to carry out more complex land management functions. These include the valuation of parcels of land, land use planning and the application of national land policy. A key concept of the strategy was to organize investments and activities in tandem with a process of institutional strengthening that would allow the changes produced by the Land Management Programme to be adequately integrated into the MNRE, the Programme's executing body.

The loan given by the IDB achieved its main goals: owners of more than 16,000 parcels of rural land located in the Corozal, Orange Walk and Belize districts received secure titles to the lands they were on. Surveys were conducted on another 7,000 rural parcels declared to be registry sections (which means it is mandatory to register land transactions). With the LMP II, the Land Registry Act regulations are now applied to all rural lands in the Corozal and Orange Walk districts. The Programme allowed tenure clarification and the registration of more than 3,000 km^2 of lands (13% of the country's total area), and another 550 km^2 were declared. The activities performed in urban areas were somewhat less successful. Applications for 380 parcels in Belize City were received, short of the original goal of 500 parcels surveyed and registered during the pilot stage of urban titling.

The resources provided also allowed the financing to improve land transaction processing services with the creation of a land registry information system based on units that link the data of four of the seven sections of the Department of Lands and Surveys (Land Registry, Surveys and Mapping, Valuation and the Land Information Center). This parcel-based land information system normalised cadastral information into four sections by assigning a Parcel Identification Number (PIN), which for the first time links data on the ownership, location, parcel size and property value. As a result of carrying out the LMP II, the MNRE now effectively administers a digital land registry that covers 50% of all parcels in Belize.

At the same time, the system: a) has eliminated the need for the physical files containing the documents on the properties to be maintained, stored and moved to different sites, along with the inherent risk in such a system of the documents being damaged or misplaced; b) has considerably reduced the chances of fraud; c) allows the MNRE to respond quickly to the inquiries of property owners, lawyers, real estate agents and bank representatives regarding the status of transactions; and d) has improved quality assurance now that transactions have to follow a specific and uniform set of steps and automated processes. The installation of the land registry information system in four of the seven sections of the Department of Lands and Surveys has had a major impact on its operations, the most important being that it has greatly increased the capacity to register parcels, thus resolving bottlenecks created by massive adjudication programmes in urban and rural areas.

Although the framework of the parcel-based information system has already been designed and tested, there is still a need to extend it to all sections of the Department of Lands and Surveys and to the six district offices, in an effort to establish complete coverage. There are three sections yet to be integrated into the system:

i) National properties, which provide services to some 100,000 owners that periodically want to convert their leased property parcels into freehold property, apply for, sell or pay leases. The clients that do not live in districts have to travel to the MNRE offices in Belmopan to conduct these transactions, because the district offices lack the communications tools necessary to offer these services in their areas.

ii) Physical planning, which currently processes approximately 30 subdivision applications monthly, each one of which represents multimillion dollar investments.

iii) Real estate revenue (taxes), from real estate commissions, leases and taxes (in rural areas) generate between 5 million and 7 million dollars annually, making this is one of the government's main revenue sources.

These three sections continue to make transactions by manually consulting the physical documents, which causes significant delays and risks the loss of, or damage to the files. Such land transactions are also subject to ad hoc procedures that result in incongruity, errors and potentially fraudulent practices. The resulting lack of transparency, the inability to offer land-use organization services from the district offices, the lack of online access through which to follow up on transactions, and the precarious physical state of the offices where clients go create inconveniences for the owners and leasers, reduce revenues and, in general terms, undermine the credibility of the MNRE.

Also needed are ways to accelerate the initial registry in urban areas in which titling is obligatory, and an extension of this registry to urban areas that the LMP did not originally cover. These improvements could increase the revenues collected by the MNRE, which would allow investments in land organization to continue.

The MNRE recognizes that the sustainability of the improvements made with the LMP I and the LMP II is fundamental in order to preserve the quality of land organization services. Even though the application of the Land Registry Act across the country is still a priority, it is necessary to conduct strategic planning and establish medium-term priorities for urban and rural land allocation, the strengthening of capacities and the gradual implementation of a strategy for charging the user in tandem with improved service provision.

In order to make the most of the benefits that the modernization of land organization services that began with the LMP II entails for agriculture and rural areas, it will be necessary to implement a new phase of the Programme that will complete the transition from manual land transaction processing and document maintenance to the use of automated and simplified procedures in a parcel-based information system that will: i) improve transparency and considerably decrease the possibilities of errors, fraud and title loss;

ii) provide easy access to reports and files; and iii) create additional revenue flows as a result of the improved services and increased transactions.

There is also an urgent need to improve information on rural lands while expanding land organization services to the entire country. The nine most important urban areas of Belize account for most land transactions each year (and, consequently, the majority of collections from transactions). Great precision in the data for urban parcels and their improvements greatly benefit the calculation of tax valuations and public works planning. The combination of the expansion of the parcel-based information system with improved information on urban lots will translate into quantifiable benefits in access, efficiency and quality of the land-use regulation services and an increase in real-estate related collections.

The objective of the Programme (LMP III) is to consolidate the land administration services and extend them to the whole country in order to improve access to said services, as well as their quality and efficiency. This will also contribute to the goal of improving land tenure security and create a dynamic land market. This new phase of the Programme has three components: i) the expansion of the parcel-based information system; ii) improvement of information about urban lands; and iii) support in offering modern land administration services. The total cost of this Programme is an equivalent of 2.729 million dollars: the IDB will finance 2.5 million and the government of Belize will provide 229,000 dollars.

It is hoped that by the end of the LMP III that the MNRE will have added 50,000 urban parcels to the digital cadastre, reaching a total of 158,000 parcels. This would be the equivalent of 70% of all the parcels in the country.

III. METHODOLOGIES

The importance of conducting ever-more comprehensive studies, as well as the need to have more robust results from a meteorological point of view makes it necessary to combine various methods. With that in mind, the present study initially sought a combination of structural and spatial approaches involving production functions and the Ricardian model, however it proved impossible to apply the Ricardian approach due to the lack of information available. Next, we describe the methodology of the production functions used.

There are different tools that can be used to study the economic impacts of climate change on agriculture. One of the approaches that traditionally has been used to estimate the physical and economic effects of climate change on agriculture is the production function, which estimates impacts by altering one or more variables, such as precipitation or temperature.

Mendelsohn and others (1994) considered that the production function approach could overestimate negative climate effects by not taking into account the adaptations that producers adopt in response to changes in environmental conditions. Hence, in evaluating the consequences of climate change, the results often overestimated reductions in crop yields. However, when based on climate scenarios, the production function approach makes it possible to directly estimate the effects on specific crops. At the same time, it allows temperature and precipitation thresholds to be identified, as well as the points of inflection beyond which climate conditions become harmful.

In this study, the production function will serve to examine the effects of climate change on the production and yields of different crops. Table 12 describes its principal characteristics.

TABLE 12
CHARACTERISTICS OF THE PRODUCTION FUNCTION MODEL

Model	Description	Advantages	Weaknesses
Production function	Based on empirical relationships between yields and climatic variables (temperature and precipitation)	Carried out using ordinary least squares (OLS) Allows effects on specific crops to be analyzed. Identifies temperature and precipitation thresholds beyond which the effects can be beneficial or harmful.	Only based on the relationship between weather and production Negative effects of weather can be overestimated Does not consider possible adaptations Can create collinearity problems in the estimates

Source: Prepared by report authors.

1. Production function approach

A production function relates factors (X) and an obtained product (Y).

$$Y = f(X) \quad (1)$$

Fleischer and others (2007) assert that a crop production function (Q) can be expressed based on endogenous and exogenous variables and on variables that represent the ability or capacity of farmers. Endogenous variables (x) include work, capital, fertilizers and other inputs. The exogenous ones include climatic variables. Farmer characteristics (m) include human capital variables.

In formal terms, the crop production function is illustrated in the following way:

$$Q_t = f(m_t, z_t, x_t) \quad (2)$$

where Q_t represents agricultural production or per hectare yields of a specific product and the sub index *t* the time or the year observed.

The benefits function of a farmer who produces *n* crops in time *t* is expressed in the following way:

$$\pi_t = \sum_{j=1}^{n} \left[p_{jt} Q_{jt}(m_t, z_t, x_{jt}) - w_t x_{jt} \right], \qquad j=1,2,...n \text{ crops} \quad (3)$$

where p_j represents the prices of product *j* and *w* the prices of the product inputs *j*.

One hypothesis in this approach is that farmers try to maximize their benefits and, therefore, choose the amount of inputs (*x*) that allow them to achieve that goal; exogenous variables like the weather as given. The optimal amount of inputs should satisfy the following condition of prime order in each one of the periods looked at:

$$p_j \frac{\partial Q}{\partial x_t} = w, \qquad j=1,2,...n \quad (4)$$

In this study, and based on the production function approach previously described, the effects of climate change on agricultural output are analyzed first (through production indices) in large groups: agricultural, crop and livestock production. Secondly, the effects of climate change on maize, bean, sugar cane and orange production are analyzed.

Climatic variables, considered exogenous, play an important role in determining crop yields. Plants develop depending on their exposure to moisture and temperature during their growing stage. That is, the climatic factors are related to important stages in the phonology of plants: for example, precipitation with germination and flowering; and temperature with development and maturation of the fruit.

In order to execute the econometric estimation of the equation (2) for each one of the production indices, it is possible to represent said function by the following equations:

$$Agriculture_t = f(m_t, z_t, x_t), \qquad t=1,\ldots T \qquad (5)$$

$$Crops_t = f(m_t, z_t, x_t), \qquad t=1,\ldots T \qquad (6)$$

$$Livestock_t = f(m_t, z_t, x_t), \qquad t=1,\ldots T \qquad (7)$$

Furthermore, this study presents an analysis of the effects of climate change on the yield of four crops: maize, beans, sugar cane and oranges. For these crops, the equations to be estimated are represented as follows:

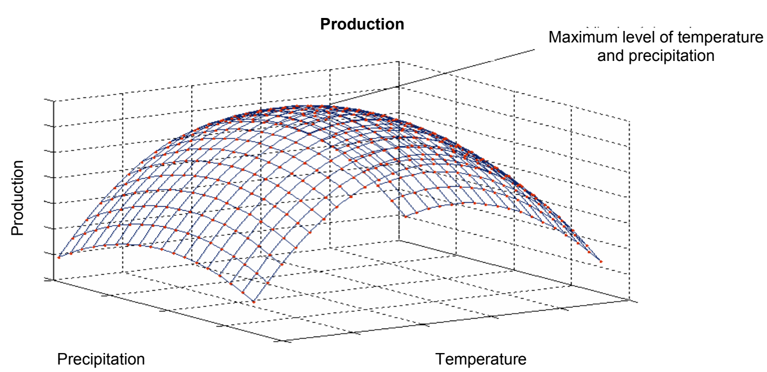
$$Maize_t = f(m_t, z_t, x_t), \qquad t=1,\ldots T \qquad (8)$$

$$Beans_t = f(m_t, z_t, x_t), \qquad t=1,\ldots T \qquad (9)$$

$$Sugar\ cane_t = f(m_t, z_t, x_t), \qquad t=1,\ldots T \qquad (10)$$

$$Oranges_t = f(m_t, z_t, x_t), \qquad t=1,\ldots T \qquad (11)$$

To estimate the production function, generally a functional quadratic form is chosen in order to be able to identify the temperature and precipitation levels that have positive or negative effects on production, as shown in the following figure.



Once the production functions are estimated, it is possible to calculate the impact on the different dependent variables (indices of production or crop yields) in light of variations in one or more factors, like temperature and precipitation, for example. In this way, it is possible to obtain estimations of the maximum production or yield per crop.

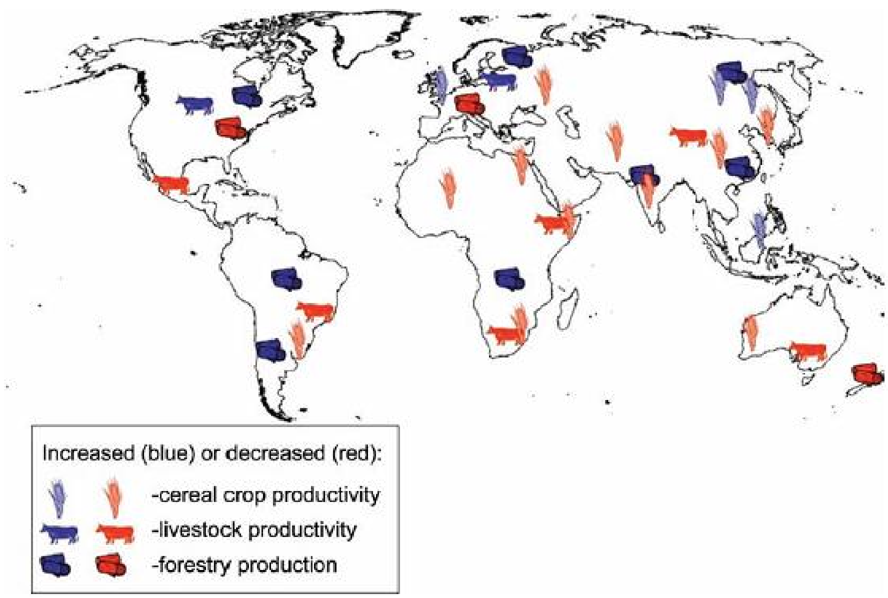
The production function estimates were carried out using the Ordinary Least Squares method (OLS).

Even if the production function does not capture the adaptation and mitigation strategies producers adopt in response to climate change, it has the advantage of showing results in terms of the relationship between yields and climate conditions, one that is of interest for purposes of this research. Furthermore, another advantage is that by being based directly on observed variables, the relationship between climatic variables and crop yields can be directly estimated.

IV. IMPACT OF CLIMATE CHANGE ON THE AGRICULTURAL SECTOR

Agricultural production is sensitive to climate changes, but the effects will depend on the region and the crop systems used. Map 2 shows a projection of world production up to 2050, as wells as the regions that will experience an increase or decrease in production; apparently the regions near the equator are the ones that will suffer the greatest decreases in production.

MAP 2
BELIZE: PRINCIPAL IMPACTS OF CLIMATE CHANGE ON AGRICULTURAL PRODUCTION AND FORESTRY PRODUCTION BY 2050



Source: IPCC, based on the literature and the views of the main authors of chapter 5.
Adaptation is not taken into account.

1. Impact on the agricultural production functions

Crop development is directly influenced by temperature and precipitation. Livestock production is directly and indirectly influenced by climate. For example, increases in temperature affect animal mortality, directly, and the availability of food and grain price increases due to droughts, indirectly.

Through the construction of production functions, this section examines the impact of changes in climatic variables (temperature and precipitation) on the agricultural sector. This analysis affords a general overview of the possible effects of climate change on agricultural production and a quantification of related economic costs, derived from estimates and the A2 and B2 climate models.[10]

The climatic projections predict that both temperature and precipitation will undergo serious variations in the future (the descriptive statistics for these variables can be found in annex I). Knowing the impacts on the sector is important in order to anticipate actions and deal with the possible effects. The IPCC report (2007) points out that according to projections for lower latitudes, especially in seasonally dry and tropical regions, crop productivity will drop due to increases in local temperature, which will in turn increase the risk of hunger.

a) Data

Agricultural production functions were built based on information from the 1961-2005 period. Forty-five years of annual data was used. The descriptive statistics are shown in table 13. The data used consists of the Laspeyres indices of agricultural production, constructed by the FAO,[11] meteorological data (precipitation and temperature) that were provided by the Climate Change and Solar Radiation Group of the Atmospheric Science Centre of the Universidad Nacional Autónoma de México (UNAM). The following were used as control variables: cultivated areas, irrigated areas, the economically active population (EAP), the rural EAP, and the general population. These variables come from the FAOSTAT database[12] and from CELADE (Latin American Center for Development).

b) Results

Different production functions were estimated based on the production indices (agricultural, crop and livestock production) with the intention of showing the sensitivity of the agricultural sector to climatic variations. The indices were divided among cultivated areas for the purposes of controlling production by land variety, an important factor in agricultural production. Similarly, labour-force related control variables were included: the EAP, the rural EAP and the general population. The climatic variables used in the specifications are: maximum annual temperature and annual accumulated precipitation, with their quadratic terms.

The estimates were made using the Ordinary Least Squares (OLS) method; different combinations of variables were used, and only those that were the most consistent were reported. For each production function, the dependent variable is the production index divided by the cultivated area.

The calculations present certain limitations since the scenarios do not take into account possible farmer adaptations to climate change or technological innovation. Because the information needed was not

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[10] Scenario A2 describes a very heterogeneous world with strong population growth, slow economic development and slow technological change. Scenario B2 describes a planet with a medium population and medium economic growth, more oriented toward local solutions to reach economic, social and environmental sustainability. Annex I contains the descriptive statistics of these models.

[11] The FAO agricultural production indices show the relative level of world agricultural production volume for each year, compared to the 1999-2001 base period. They are based on the sum of price-weighted quantities of different agricultural commodities produced, after deducting quantities used for seed and animal feed, weighted in the same way. The aggregate result constitutes the production available for any use (except for seed or animal feed). All indices are calculated by the Laspeyres formula. The production amounts of each commodity are weighted by the average international commodity prices for the 1999-2001 base period and summed for each year.

[12] FAO, Statistics Division.

available, it was not possible to incorporate the potential adaptability of farmers to climate change in the estimates. When not controlling for adaptation, it is possible to produce a certain overestimation of the effects of climate change, as stated in the literature review of this document.

TABLE 13
BELIZE: DESCRIPTIVE STATISTICS, 1961-2005 [a]

	Observations	Average	Standard deviation	Value	
				Minimum	Maximum
Agricultural production index [b]	45	51.87	29.50	13.00	115.00
Crop production index	45	49.49	28.75	12.00	108.00
Livestock production index [c]	45	62.91	36.72	19.00	154.00
Rural EAP (thousands of inhabitants)	45	18.64	4.69	12.00	29.00
Total EAP (thousands of inhabitants)	45	53.56	20.05	29.00	98.00
Population (thousands of inhabitants)	45	168.47	52.59	96.00	276.00
Irrigated area (thousands of hectares)	45	1.98	1.03	1.00	4.00
Maximum temperature (° C)	45	32.35	0.63	31.07	33.57
Annual accumulated precipitation	45	2 158.49	240.57	1 627.18	2 773.43

Source: Prepared by report authors.
[a] In reference to annual observations corresponding to the 1961-2005 period.
[b] The products included in the calculation of the agricultural production indices are all crops and animal husbandry products produced in the country. Practically all products are covered, with the exception of forage crops.
[c] The livestock production indices are calculated based on domestic animal production data, which includes the equivalent in meat of exported live animals, but excludes the equivalent in meat of imported live animals. For the purposes of the indices calculations, the annual changes in numbers of animals and birds or their live-weight average are not taken into consideration.

i) Agricultural production. The estimated regressions for the agricultural production function are shown in table 14. The variables' signs are as expected: the linear terms are positive and the quadratic terms are negative. The introduction of the quadratic terms allows the inflection points to be identified; based on these, the climatic variables have adverse effects on production (see figures 5 and 6). With the intention of showing the strength of the specifications, both the explanatory variables related to the labour force (rural EAP, total EAP and population), and the functional form (linear or logarithmic) were modified.

The coefficients related to precipitation are significant in the majority of cases; those related to temperature are not significant independently. This could be due to the collinearity that is introduced when including the quadratic terms (Sergenson and Dixon, 1998). With the existence of collinearity, the explanatory power of the independent variables is limited, and it is possible that the t-statistic of the coefficients proves to be insignificant; however, the F statistic can be significant (Verbeek, 2005). In the lower part of table 14, the joint significance F-test is shown, which indicates that as a set, all the variables are relevant. Also, in accordance with different cointegrational statistical tests, the presence of false regressions was ruled out. The estimates seem to be robust in view of changes in the different control variables (rural EAP, total EAP, population).

To show the behaviour of production based on variations in climatic variables, the linear specification was chosen (specification (1) in table 14) with annual accumulated precipitation and maximum annual temperature. To build this function, rural EAP, total EAP and irrigated land were used as control variables, and dummy variables were included in the years when disasters occurred.

TABLE 14
BELIZE: AGRICULTURAL PRODUCTION INDEX

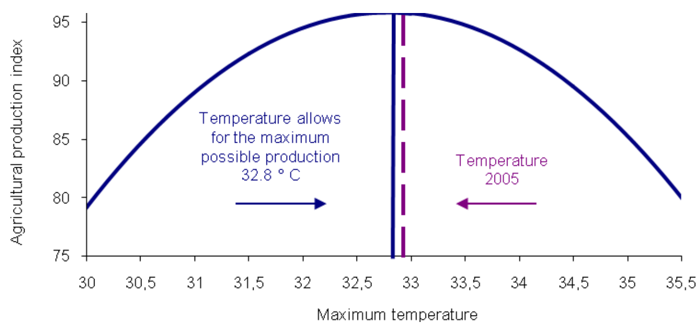
Equations	Rural EAP		Total EAP		Total population	
	Linear (1)	Logarithmic (2)	Linear (3)	Logarithmic (4)	Linear (5)	Logarithmic (6)
Annual accumulated precipitation	1.6284	1.5611	1.6623	1.5983	1.422	1.3734
	(1.844) *	(1.894) *	(1.899) *	(1.892) *	(1.52)	(1.61)
Annual accumulated precipitation^2	-0.0004	–0.0004	–0.0004	–0.0004	–0.0003	–0.0003
	(1.993) *	(2.057) **	(2.042) **	(2.047) **	(1.632)	(1.738) *
Maximum temperature	1,606.035	1,769.65	1,593.654	1,767.026	(1,286.642)	1,485.47
	(0.56)	(0.621)	(0.57)	(0.627)	(0.443)	(0.521)
Maximum temperature^2	-24.5869	-27.2458	-24.3862	-27.1981	-19.5552	22.7713
	(0.555)	(0.62)	(0.565)	(0.626)	(0.436)	(0.517)
Observations	44	44	44	44	44	44
R2	0.56	0.57	0.61	0.6	0.54	0.54
Joint significance tests of variables (F-statistics)						
Joint significance test of precipitation variables	3.64 **	4.36	3.6 **	4.22 **	2.23	2.75 *
Joint significance test of temperature variables	0.21	0.2	0.24	0.2	0.26	0.18
Joint significance test of precipitation and temperature variables	1.92	2.36 *	1.84	2.19 *	1.11	1.39
Joint significance test of the model	47.3 ***	38,108.72 ***	52.55 ***	107.27 ***	5.07 ***	5.20 ***
Johansen cointegration test						
Number of cointegration vectors. Trace statistic						
Number of cointegration vectors. Trace statistic	5 **	5 **	5 **	6 **	6 **	5 **
Number of cointegration vectors. Maximum eigenvalue	3 **	3 **	5 **	5 **	5 **	4 **

Source: Prepared by report authors.
Notes:
* Statistically significant at a 10% level;
** Statistically significant at a 5% level;
*** Statistically significant at a 1% level.
All equations were considered constants, with the projected irrigated area variable and dummy variables in the years when a natural disaster occurred.
Due to the size of the coefficients, they were multiplied by 1,000.

The impact of temperature and precipitation variations on agricultural production are presented in figures 5 and 6, respectively. In order to isolate the effect of the weather on agricultural production, the control variables are kept constant, using values from 2005.

The maximum temperature reached in Belize in 2005 was near 33° C. The following figure indicates that this temperature allows for the maximum possible production, however, climatic projections warn of an increase in temperature, which will in turn increase the risk of economic losses in the sector. It is likely, then, that this will provoke a decrease in agricultural production.

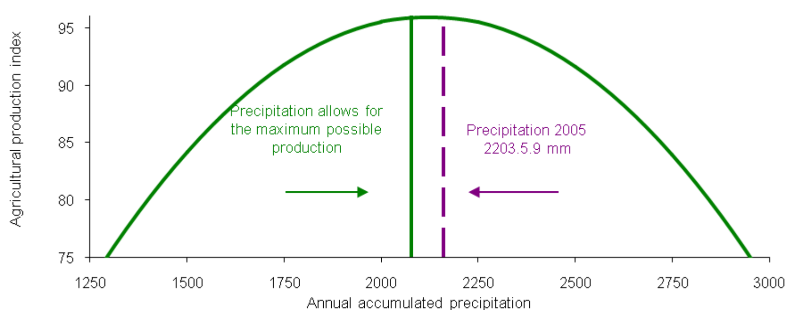
FIGURE 5
BELIZE: AGRICULTURAL PRODUCTION AND TEMPERATURE



Source: Prepared by report authors.

Figure 6 shows the behaviour of agricultural production according to variations in precipitation. This figure illustrates the level of precipitation that Belize had in 2005 (around 2,204 mm), which is slightly higher than the optimal level for production. According to these results, if precipitation increases or decreases significantly in the future, it will imply a lower level of production.

FIGURE 6
BELIZE: AGRICULTURAL PRODUCTION AND VARIATIONS IN PRECIPITATION



Source: Prepared by report authors.

i) Crop production. The results for the equations can be seen in table 15. Just as in the case of agricultural production, and with the intention to show the stability of the coefficients and robustness in the estimates, different variables and functional forms related to the labour force were used. The possibility of false regressions was ruled out using cointegration tests.

TABLE 15
BELIZE: CROP PRODUCTION INDEX

Equations	Rural EAP		Total EAP		Total population	
	Linear (1)	Logarithmic (2)	Linear (3)	Logarithmic (4)	Linear (5)	Logarithmic (6)
Annual accumulated precipitation	1.7737	1.7851	1.7752	1.7976	1.6521	1.6735
	(2.431)**	(2.517)**	(2.677)**	(2.682)**	(2.132)**	(2.296)**
Annual accumulated precipitation^2	-0.0004	-0.0004	-0.0004	-0.0004	-0.0004	-0.0004
	(2.603)**	(2.706)**	(2.855)***	(2.879)***	(2.269)**	(2.465)**
Maximum temperature	2345.436	2562.298	2288.226	2520.73	2067.119	2305.943
	(1.011)	(1.04)	(1.031)	(1.047)	(0.893)	(0.949)
Maximum temperature^2	-36.1329	-39.5616	-35.232	-38.9051	-31.7128	-35.4901
	(1.011)	(1.042)	(1.029)	(1.049)	(0.888	(0.947)
Observations	44	44	44	44	44	44
R2	0.65	0.65	0.7	0.7	0.62	0.62
Joint significance test of variables (F statistic)						
Joint significance test of precipitation variables	5.78***	6.67***	6.48***	7.58***	4.01***	5.39***
Joint significance test of temperature variables	0.51	0.56	0.54	0.56	0.48	0.46
Joint significance test of precipitation and temperature variables	3.3**	3.62**	3.52**	3.97***	2.12**	2.81**
Joint significance test of the model	26437.42***	149.8***	98.10***	208.59***	51.39***	116.59***
Johansen cointegration test						
Number of cointegration vectors. Trace statistic	4**	5**	5**	5**	4**	5**
Number of cointegration vectors. Maximum eigenvalue	3**	3**	4**	4**	4**	4**

Source: Prepared by report authors.

Notes:

* Statistically significant at a 10% level

**Statistically significant at a 5% level

*** Statistically significant at a 1% level.

All equations were considered constants, with the projected irrigated area variable and dummy variables in the years when a natural disaster occurred.

The coefficients relative to precipitation were significant in most of the cases, but those related to temperature were not significant individually. This, as stated before, could be a consequence of the collinearity that was created by including the quadratic terms. The quadratic terms are relevant when trying to show a non-linear effect of the climatic variables on production. The joint significance F-test, in the lower part of table 15, indicates that as a set, all the variables are relevant for the model.

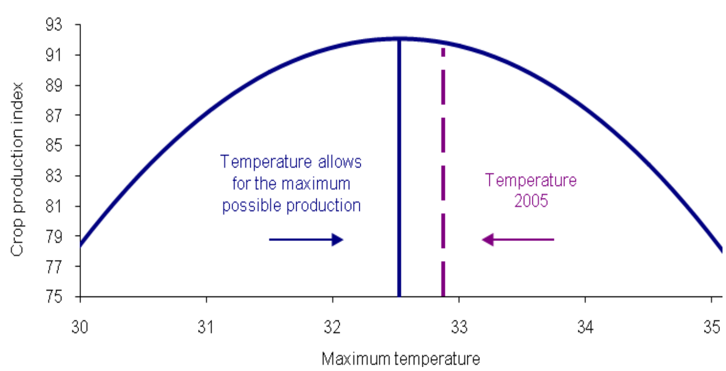
Due to the inclusion of the quadratic terms of the climatic variables, the production function form is concave. Production is stimulated as temperature or precipitation increases, but after a certain point, production decreases. Figures 5-11 depict this. Wanting to be consistent with the results given earlier, the linear specification (1') from table 15 was chosen to show the behaviour of crop production under climatic variations.

Figure 7 shows the variations in crop production as a result of the changes in the maximum annual temperature. The highest temperature in Belize in 2005 (33° C) was slightly higher than the temperature that allows maximum crop production to be achieved. Therefore, if the temperature continues to go up, serious losses are predicted for the crop sector.

Accumulated precipitation in Belize in 2005 was likewise slightly above the amount that allows optimal production levels to be reached. The projections that the scenarios provide show that precipitation will vary greatly, a sign that in the future crop production will be seriously affected (see figure 8).

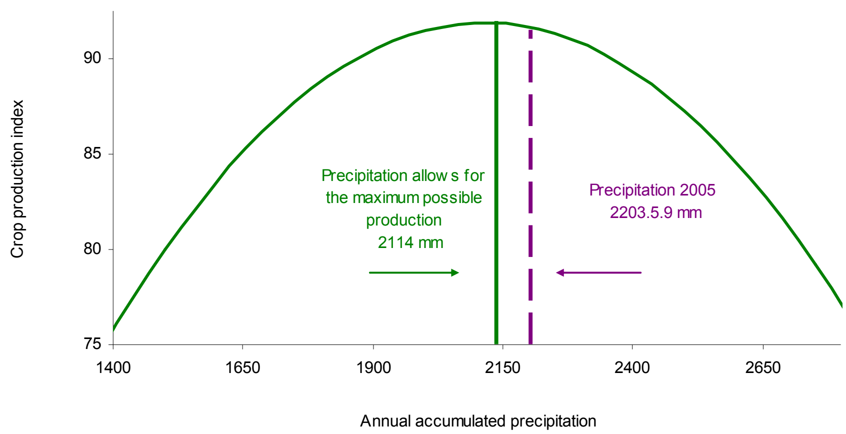
iii) Livestock production. The results of the estimated equations are displayed in table 16. The livestock production function was estimated with different control variables, however under no condition the climatic variables came out as significant, even when signs were as expected. This could be because the effect of the variables is indirect and lags behind. As a result, only the livestock production response was graphed for illustrative effects.

FIGURE 7
BELIZE: CROP PRODUCTION AND VARIATIONS IN TEMPERATURE



Source: Prepared by report authors.

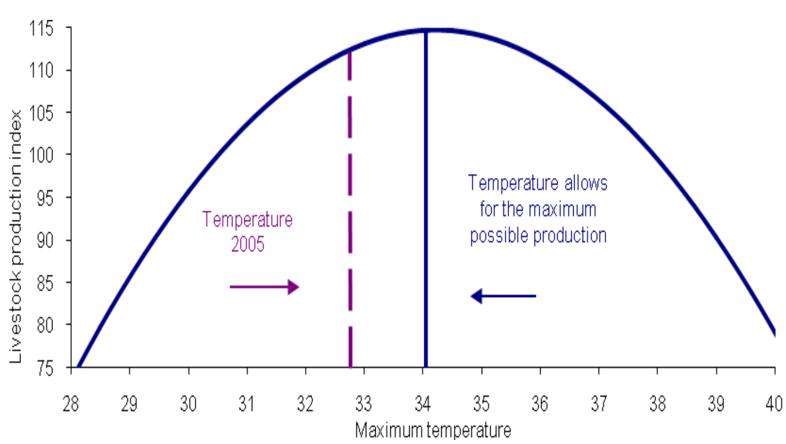
FIGURE 8
BELIZE: CROP PRODUCTION AND VARIATIONS IN PRECIPITATION



Source: Prepared by report authors.

In the case of livestock production, just as in the cases described above, the linear specification (1´´) from table 16 was chosen to show production behaviour under variations in temperature and precipitation. It can be seen that the 2005 temperature is lower than one which would allow for maximum production levels (see figure 9).

FIGURE 9
BELIZE: LIVESTOCK PRODUCTION AND VARIATIONS IN TEMPERATURE



Source: Prepared by report authors.

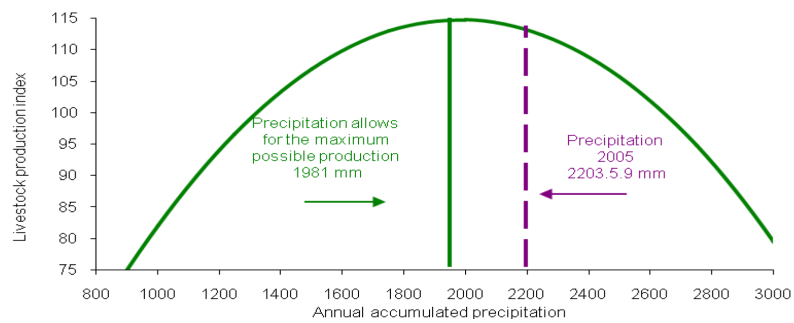
TABLE 16
BELIZE: LIVESTOCK PRODUCTION INDEX

Equations	Rural EAP		Total EAP		Total population	
	Linear (1)	Logarithmic (2)	Linear (3)	Logarithmic (4)	Linear (5)	Logarithmic (6)
Annual accumulated precipitation	1.833	1.372	1.747747	1.311	1.933	1.451
	(0.668)	(0.645)	(0.631)	(0.611)	(0.686)	(0.665)
Annual accumulated precipitation^2	-0.00046	-0.00034	-0.00044	-0.00033	-0.00048	-0.00036
	(0.737)	(0.701)	(0.699)	(0.665)	0.751)	(0.716)
Maximum temperature	998.723	766.209	931.129	721.2	1179.553	910.774
	(0.153)	(0.152)	(0.142)	(0.142)	(0.176)	(0.176)
Maximum temperature^2	-14.592	-11.465	-13.457	-10.7	-17.167	-13.531
	(0.145)	(0.147)	(0.133)	(0.136)	(0.166)	(0.169)
Observations						
R2	0.31	0.31	0.3	0.3	0.28	0.27
Joint significance tests of variables (F-statistics)						
Joint significance test of precipitation variables	0.72	0.52	0.67	0.48	0.66	0.49
Joint significance test of temperature variables	0.25	0.09	0.3	0.12	0.38	0.37
Joint significance test of precipitation and temperature variables	0.45	0.29	0.48	0.29	0.51	0.32
Joint significance test of the model	2.36**	2.41**	2.25*	2.21*	1.97*	1.95*
Johansen cointegration test						
Number of cointegration vectors. Trace statistic	4**	5**	6**	6**	5**	5**
Number of cointegration vectors. Trace statistic	3**	3**	4**	4**	4**	4**

Source: Prepared by report authors.
* Statistically significant at a 10% level;
** Statistically significant at a 5% level;
*** Statistically significant at a 1% level.
All equations were considered constants.
Due to the size of the coefficients, they were multiplied by 1,000

Precipitation has an indirect effect on livestock production since droughts and flooding affect cereal and forage production, which in turn affects the availability of fodder for animals. The livestock production response to variations in precipitation are presented in figure 10. It can be seen that precipitation in 2005 was greater than that which would allow for the maximum level of production.

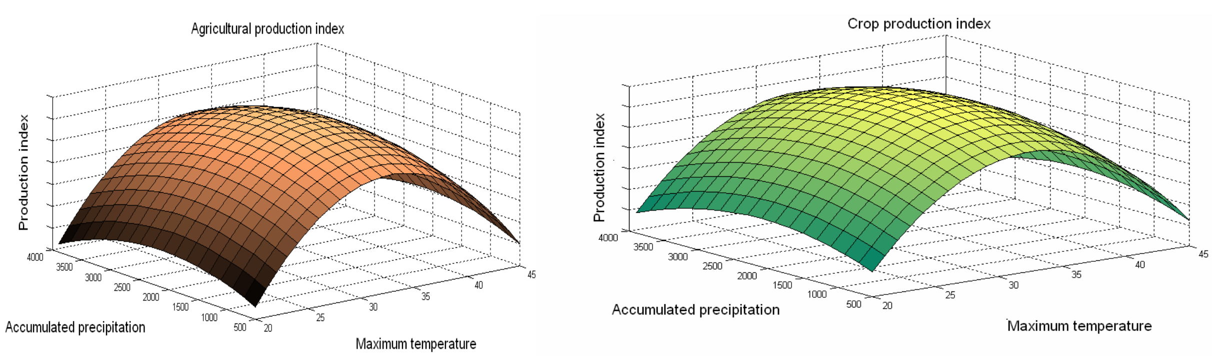
FIGURE 10
BELIZE: LIVESTOCK PRODUCTION AND VARIATIONS IN TEMPERATURE



Source: Prepared by report authors.

The crop and livestock production functions were built based on a concave functional form. Output trends higher up to a certain point, and then recedes (see figure 11). The figures were created keeping the control variables constant and not considering the possibility of technological changes or adaptation measures farmers might take in light of climate change.

FIGURE 11
BELIZE: IMPACTS OF CHANGES ON PRECIPITATION AND TEMPERATURE ON AGRICULTURAL PRODUCTION



Source: Prepared by report authors.

2. Impact on maize, bean, sugar cane and orange production

In this section, the potential effects of climate change are analyzed on four major crops produced by the people of Belize: maize, beans, sugar cane and oranges, as stated in the second chapter of this report. Just as in the previous section, the production function methodology was used, specifically using the MCO method.

a) Data

In all the crops that were studied, the variable of interest is performance, measured in tons produced per hectare. In order to study the effects of climate change on these crops, the procedure followed consists of finding a model that is methodologically robust to explain yield behaviour; to that end, information from climatic variables (temperature and precipitation) and other control variables related to the labour force for the 1961-2006 period were used.

b) Results

In looking for a relationship used to project climate change effects, different expressions of each climatic variable are valued and those that show the highest correlation with yields are considered. Precipitation expressions that were the most appropriate in the different models of this section were: average annual precipitation and average precipitation from November through April; for temperature, the following were used: average annual temperature, maximum temperature during the year and the temperature from November through April. In all cases, the squares of said climatic variables were included in order to identify the points from which the weather may have adverse effects. The descriptive statistics are shown in table 17.

TABLE 17
BELIZE: DESCRIPTIVE STATISTS OF THE YIELDS MODELS, 1961-2006 [a]

	Observations	Average	Standard deviation	Minimum Value	Maximum Value
Maize yields [b]	46	1.70	0.68	0.49	3.00
Bean yields [b]	46	0.713	0.14	0.45	1.10
Sugar yields [b]	46	45.93	5.88	28.80	57.00
Orange yields [b]		12.17	3.71	2.95	19.20
Average annual precipitation (mm)	46	181.03	21.32	135.59	233.20
Average precipitation from November through April (mm)	46	109.68	22.05	75.81	172.60
Average annual temperature (° C)	46	25.37	0.40	24.51	260.20
Maximum temperature (° C)	46	32.24	0.62	31.07	33.60
Average temperature from November through April (° C)	46	23.99	0.48	22.80	25.00
Rural EAP (thousands of inhabitants)	46	18.869	4.87	13.00	29.00
Population (thousands of inhabitants)	49	170.93	54.62	96.00	282.00

Source: Prepared by report authors.
[a] In reference to 46 annual observations corresponding to the 1961-2006 period.
[b] Tons per hectare.

In all the crops that were analyzed, four linear and logarithmic specifications that take into account the rural EAP and the total population were used to estimate the yields.

c) The case of maize

Table 18 shows the estimate results for maize yields. The climatic variables that were used in this case are the average annual precipitation and the average annual temperature. As can be seen, the temperature and precipitation seem to boost production at relatively low levels, and deter it at relatively high levels because both variables have positive coefficients but negative squares.

TABLE 18
BELIZE: ESTIMATE FOR YIELD PER HECTARE OF MAIZE

Equations	Rural EAP		Total population	
	Linear	Logarithmic	Linear	Logarithmic
Average annual precipitation	0.0268	0.025	0.0459 *	0.0372
	(0.82)	(0.78)	(1.69)	(1.49)
Average annual precipitation^2	-0.00007	-0.00007	-0.0001 *	-0.0001
	(0.84)	(0.79)	(1.71)	(1.5)
Average temperature	1.5702	0.7864	29.817 **	21.527 *
	(0.11)	(0.05)	(2.38)	(1.88)
Average temperature^2	(0.024)	(0.008)	(0.588) **	(0.425) **
	(0.08)	(0.03)	(2.38)	(1.88)
R2	0.82	0.82	0.87	0.89
Joint significance tests of variables (F statistic)				
Joint significance test of precipitation variables	0.36	0.33	1.48	1.13
Joint significance test of temperature variables	2.53 *	2.72 *	2.84 *	1.98 *
Joint significance test of precipitation and temperature variables	1.42	1.5	1.72	1.16
Joint significance test of entire model	17.76 ***	18.51 ***	27.88 ***	33.29 ***
Johansen cointegration test				
Number of cointegration vectors. Trace statistic	2 **	2 **	4 ***	3 ***
Number of cointegration vectors. Maximum eigenvalue	0 ***	0 ***	0 ***	1 ***

Source: Prepared by report authors.
Notes:
Absolute values of the t-statistic in parenthesis.
* Significant at 10%;
** Significant at 5%;
***Significant at 1%.
All models were estimated with a constant and with dummy variables that identified effects of natural disasters.
The cointegration test was conducted with a constant term in the cointegration equation and in the dynamic model.

Individually, the climatic variables were not statistically significant in all cases; however, as a set, there was statistical significance in most cases. As previously stated, the lack of statistical significance that occasionally occurs can follow the relationship between the linear and quadratic terms of the climatic variables. This can create a certain collinearity in the models. Nevertheless, it is preferable to include the squares of the climatic variables in order to identify the non-linear effects. In accordance with the cointegration tests, the presence of spurious regressions was ruled out.

Specification (4) in table 18 was used as a base for analyzing the effects of climate change; it includes the population as a logarithmic form. Based on this, projections were made about variations in temperature and precipitation, maintaining the other terms constant with the 2006 values.

In figure 12, the results for temperature appear, and figure 13 contains those for precipitation. According to these results, it is probable that the temperature that allows for the best yields in maize production has already been surpassed. The level of precipitation in 2006 was slightly higher than that which allows for the best yields; even levels slightly lower than those of 2006 could be beneficial. Therefore, it is probable that climate change is already having a negative effect on maize production.

FIGURE 12
BELIZE: MAIZE YIELDS AND VARIATIONS IN TEMPERATURE

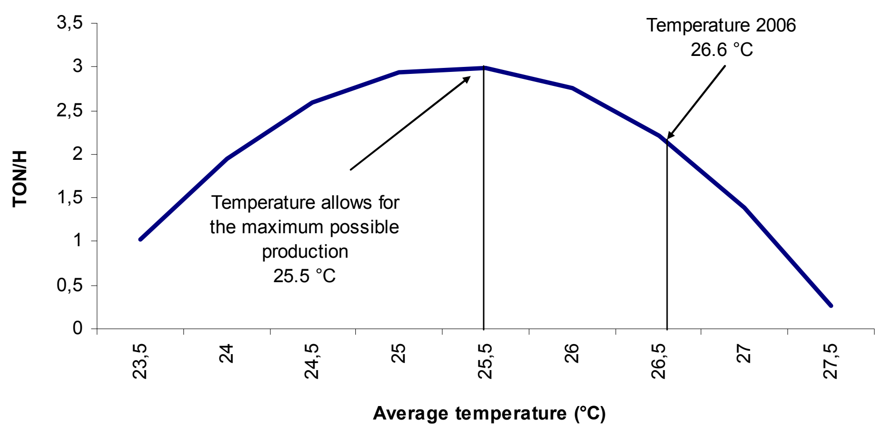
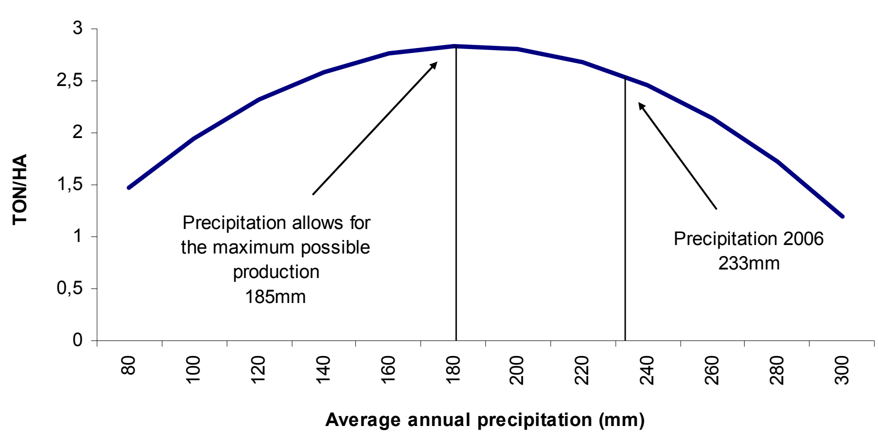


FIGURE 13
BELIZE: MAIZE YIELDS AND VARIATIONS IN PRECIPITATION



Source: Prepared by report authors.

d) The case of beans

In table 19, the results of the estimate for bean yields are shown. The climatic variables that were used in this case are the average annual precipitation from November through April and the highest temperature during the year. Both the linear and squared terms were used.

Although individually, precipitation and temperature did not show statistical significance in all cases; as a set, they did, which suggests that both variables could be relevant in explaining bean production behaviour. The climatic variables seem to show a concave behaviour regarding bean yields. This implies that at relatively low levels and up to a certain point, they tend to stimulate production; after that point, they do the opposite. The cointegration tests made it possible to rule out the possibility of spurious regressions.

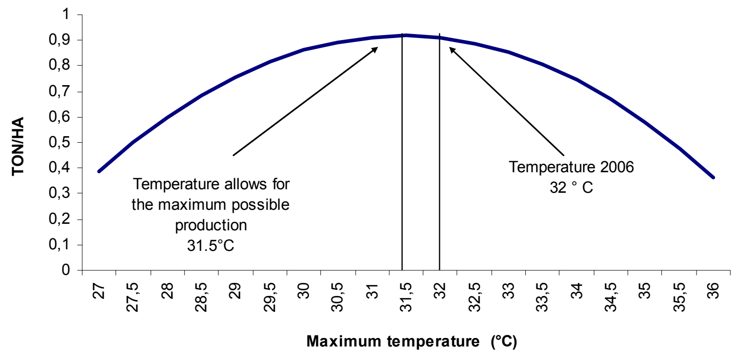
Bean yields projections reflecting changes in temperature are shown in figure 14; they were generated using the estimated coefficients based on the chosen specification (3´) from table 19. According to said figure, it is likely that the temperature allowing for the greatest yields of this crop has been surpassed, and consequently climate change could already be showing negative effects.

TABLE 19
BELIZE: ESTIMATE FOR YIELDS PER HECTARE OF BEANS

Equations	Rural EAP				Total population			
	Linear (1´)		Logarithmic (2´)		Linear (3´)		Logarithmic (4´)	
Average annual precipitation from November through April	0.0157 (2.06)	**	0.0157 (2.06)	**	0.0144 (2.03)	**	0.0146 (2.04)	*
Average annual precipitation from November to April	-0.00007 (2.23)	**	-0.00007 (2.22)	**	-0.00007 (2.20)	**	-0.00007 (2.22)	*
Maximum temperature	1.9061 (0.55)		1.9911 (0.57)		1.691 (0.52)		1.8135 (0.56)	**
Maximum temperature ^{2}	-0.03 (0.56)		-0.031 (0.58)		-0.027 (0.54)		-0.029 (0.57)	**
R2	0.26		0.25		0.35		0.34	
Joint significance test of variables (F statistic)								
Joint significance test of precipitation variables	3.05	**	3.05	**	3.07	**	3.18	**
Joint significance test of temperature variables	0.59		0.59		1.14		1.05	
Joint significance test of precipitation and temperature variables	1.65		1.65		1.89		1.89	
Joint significance test of entire model	1.62		1.59		2.5	**	2.44	**
Johansen cointegration test								
Number of cointegration vectors per trace statistic	1	**	1	**	2	***	2	***
Number of cointegration vectors per maximum eigenvalue	1	***	1	***	2	***	2	***

Source: Prepared by report authors.
Notes: Absolute values of the t-statistic in parenthesis.
* Significant at 10%.
** Significant at 5%.
*** Significant at 1%.
All models were estimated with a constant and with dummy variables that identified effects of natural disasters.
The cointegration test was conducted with a constant term in the cointegration equation and in the dynamic model.

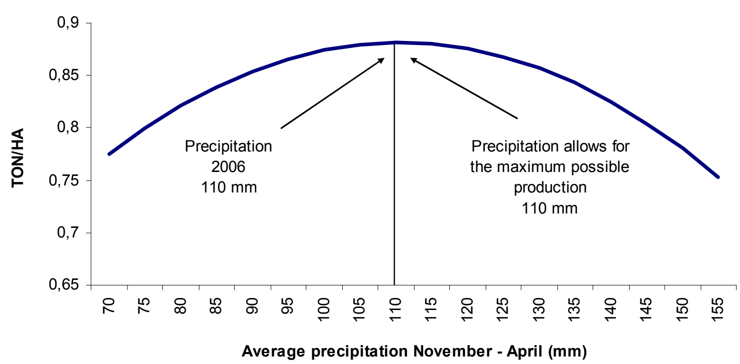
FIGURE 14
BELIZE: BEAN YIELDS AND VARIATIONS IN TEMPERATURE



Source: Prepared by report authors.

Also based on the same specification, projections were made for the possible bean yields reflecting different precipitation levels. These projections are displayed in figure 15. The results indicate that 2006 precipitation may have been close to that which maximizes yields, so precipitation levels that are either higher or lower than those of that year could bring with them lower than optimal yields.

FIGURE 15
BELIZE: BEAN YIELDS AND VARIATIONS IN PRECIPITATION



Source: Prepared by report authors.

e) The case for sugar cane

In order to estimate the production function for sugar cane, the relevant climatic variables were the average annual precipitation and the maximum annual temperature. Table 20 shows the estimated coefficients for the four specifications that consider the rural EAP and the total population. As shown, the temperature and precipitation seem to show a concave behaviour regarding sugar cane yields, since the linear terms have negative signs and their squares are positive. Although individually, the climatic variables were not statistically significant in all cases, as a set they do have statistical significance.

TABLE 20
BELIZE: ESTIMATE FOR THE YIELDS PER HECTARE OF SUGAR CANE

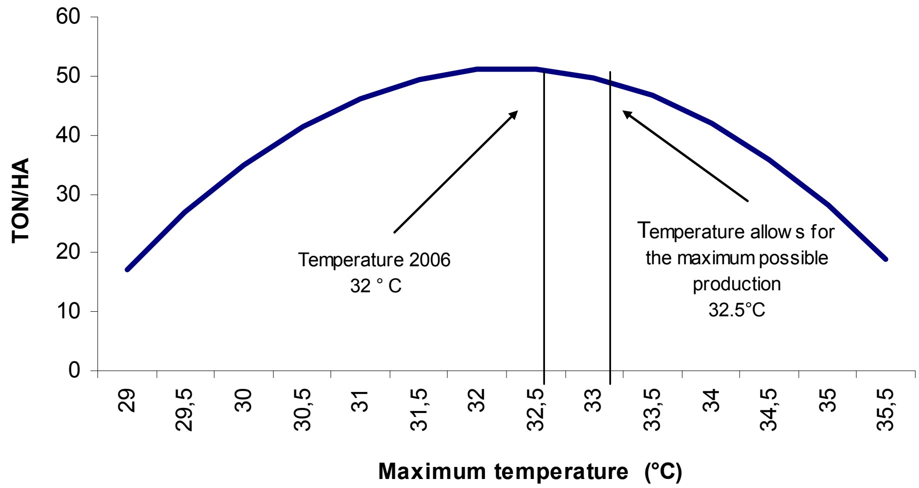
Equations	Rural EAP				Total population			
	Linear (1´´)		Logarithmic (2´´)		Linear (3´´)		Logarithmic (4´´)	
Average annual precipitation	0.7468		0.7452	*	0.7588		0.763	
	(1.69)		(1.7)		(1.58)		(1.62)	
Average annual precipitation^2	-0.002		-0.002		-0.002		-0.002	
	(1.67)		(1.68)		(1.57)		(1.6)	
Maximum temperature	213.39	**	209.46	**	204.12	*	205.75	*
	(2.1)		(2.08)		(1.85)		(1.91)	
Maximum temperature^2	-3.304	**	-3.243	**	-3.161	*	-3.185	*
	(2.11)		(2.09)		(1.86)		(1.91)	
R2	0.48		0.49		0.39		0.41	
Joint significance tests of variables (F statistic)								
Joint significance test of precipitation variables	1.45		1.46		1.26		1.33	
Joint significance test of temperature variables	2.41	*	2.37	*	1.89		1.96	
Joint significance test of precipitation and temperature variables	1.79		1.78		1.46		1.52	
Joint significance test of entire model	5.16	***	5.33	***	3.58	***	3.93	***
Johansen cointegration test								
Number of cointegration vectors. Trace statistic	1	**	1	**	2	**	2	**
Number of cointegration vectors. Maximum eigenvalue	1	***	1	***	2	**	2	**

Source: Prepared by report authors.
Notes:
Absolute values of the t-statistic in parenthesis.
* Significant at 10%.
** Significant at 5%.
*** Significant at 1%.
All models were estimated with a constant, using the irrigated land variable and dummy variables that identify the effects of natural disasters.
The cointegration test was conducted with a constant term in the cointegration equation and in the dynamic model.

In this case, specification (3´´) from table 20 looks at the population in a linear way. Based on this, production behaviour projections were made at different levels of temperature and precipitation.

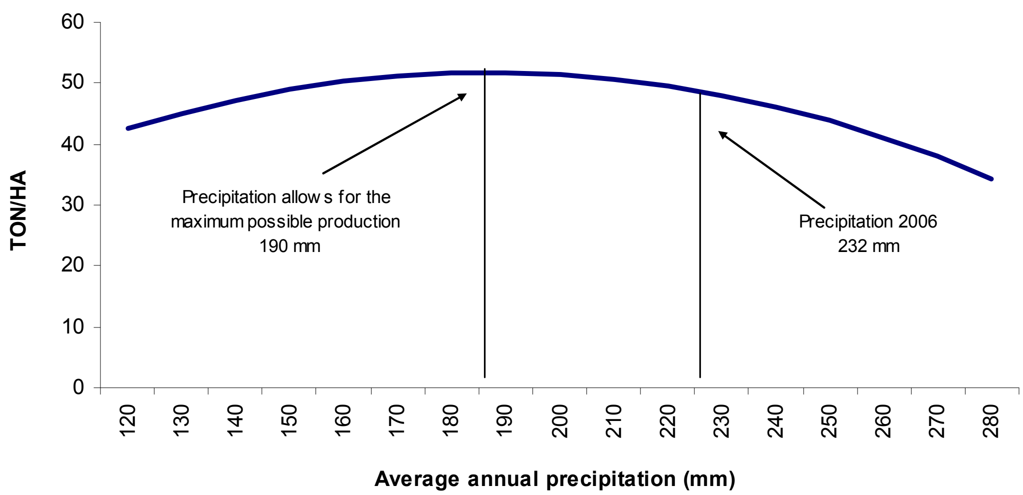
Figure 16 shows that it is probable that temperature levels are approaching those most conducive to the best sugar cane yields, suggesting that that climate change could have positive effects on the output of this crop, but they could turn negative in the long term. Figure 17 suggests that the precipitation level in 2006 was slightly higher than that which would allow for the best yields; hence, precipitation levels just under those of 2006 could be beneficial to the sugar cane crop.

FIGURE 16
BELIZE: SUGAR CANE YIELDS AND VARIATIONS IN TEMPERATURE



Source: Prepared by report authors.

FIGURE 17
BELIZE: SUGAR CANE YIELDS AND VARIATIONS IN PRECIPITATION



Source: Prepared by report authors.

f) Oranges

The specifications for orange yields included temperature from November through April and its square, as well as the average precipitation during those months, along with its square. The rural EAP and the total population are included separately, both expressed in linear and logarithmic ways. Table 21 presents the results for these estimates. All estimates seem to show relationships in the long term; that is, they are not spurious regressions like the cointegration tests indicate. Furthermore, the regressions are robust in the sense that the coefficients always maintain their signs. Although precipitation does not seem to show statistical significance by itself, in a set it does.

TABLE 21
BELIZE: ESTIMATE FOR YIELDS PER HECTARE OF ORANGES

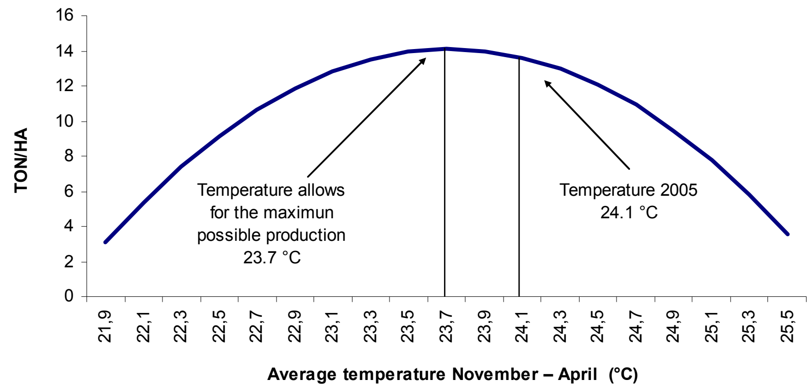
Equations	Rural EAP				Total population			
	Linear		Logarithmic		Linear		Logarithmic	
Average annual precipitation in the months of November through April	0.0559 (0.32)		0.0569 (0.33)		0.0569 (0.32)		0.0629 (0.36)	
Average annual precipitation in the months of November through April	-0.0005 (0.64)		-0.0005 (0.65)		-0.0005 (0.65)		-0.0005 (0.69)	
Average annual temperature in the months of November through April	156.34 (1.76)	*	157.98 (1.8)	*	142.43 1.57)		143.04 (1.61)	
Average annual temperature in the months of November through April	-3.288 (1.78)	*	-3.33 (1.82)	*	-3.015 (1.59)		-3.017 (1.62)	
R2	0.3578		0.3739		0.3264		0.3507	
Joint significance tests for variables (F statistics)								
Joint significance test for precipitation variables	3.02	**	3.01	**	3.12	**	3.18	**
Joint significance test for temperature variables	2.27		2.22		2.06		1.72	
Joint significance test for precipitation and temperature variables	2.73	**	2.69	**	2.74	**	2.52	*
Joint significance tests for entire model	2.58	**	2.76	**	2.24	**	2.5	**
Johansen cointegration test								
Number of cointegration vectors. Trace statistic	2	**	2	**	1	***	1	**
Number of cointegration variables. Maximum eigenvalue	0	***	0	***	1	**	1	**

Source: Prepared by report authors.
Notes:
Absolute values of the t-statistic in parenthesis.
* Significant at 10%.
** Significant at 5%.
*** Significant at 1%.
All models were estimated with a constant, using the irrigated land variable and dummy variables that identify the effects of natural disasters.
The cointegration test was conducted with a constant term in the cointegration equation and in the dynamic model

Of the four specifications, the one chosen controls for the rural EAP, which has a logarithmic form. Based on that, the possible values that orange yields would take in light of changes in temperature and precipitation were estimated. In figure 18, it can be seen that it is likely that the temperature allowing for the best yields has already been reached, so climate change could already be exerting adverse effects on this crop.

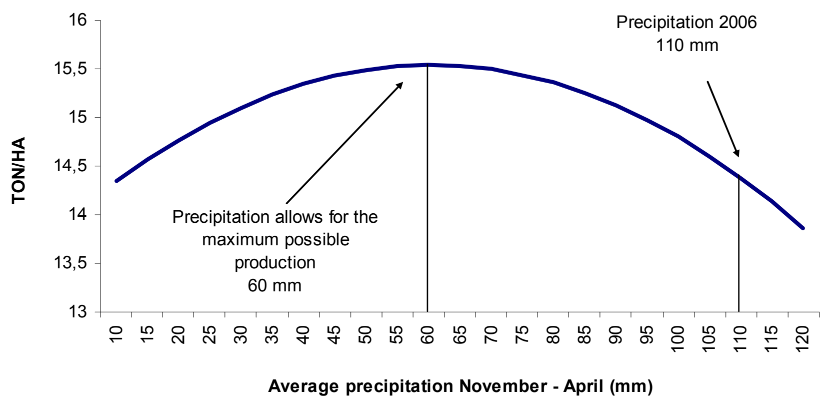
Furthermore, the projections for precipitation, shown in figure 19, indicate that orange production reaches its maximum yield at levels lower than those of 2006, indicating that precipitation levels lower than those of that year could be beneficial.

FIGURE 18
BELIZE: ORANGE YIELDS AND VARIATIONS IN TEMPERATURE



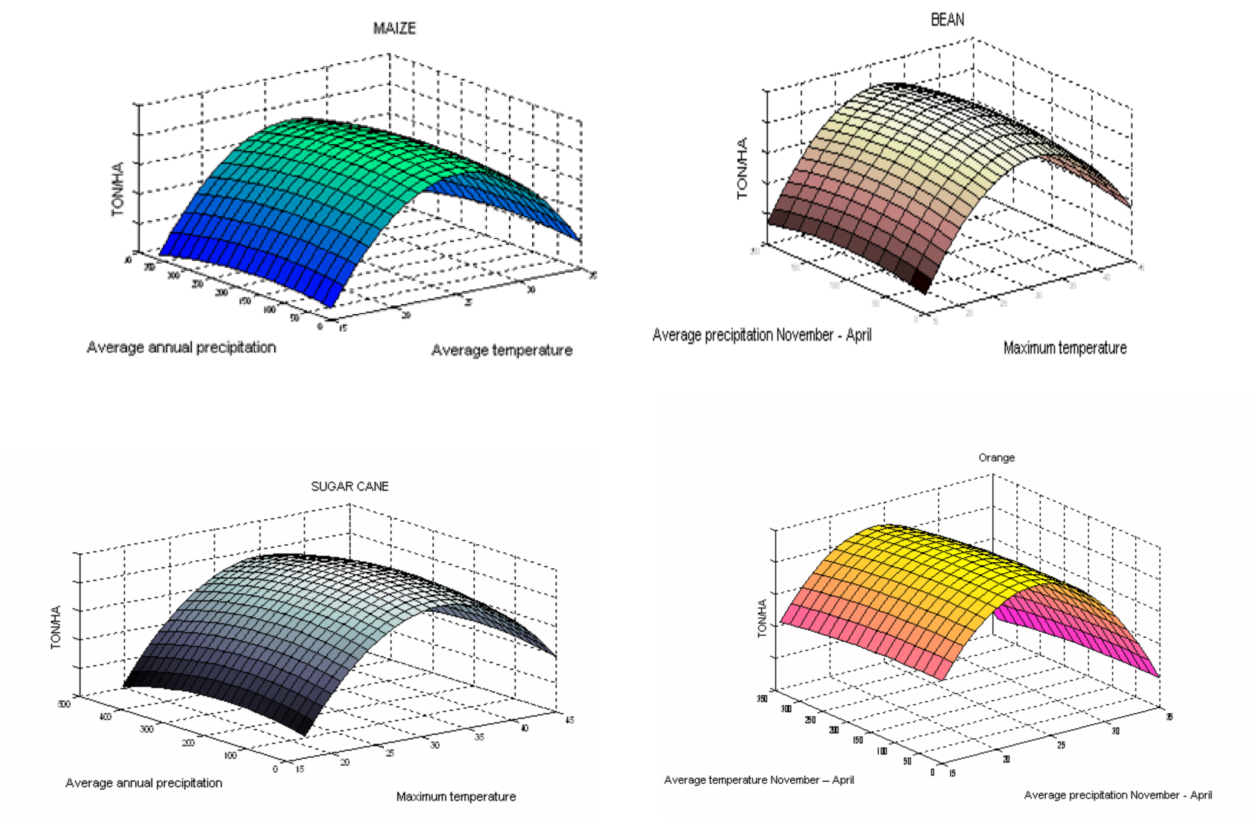
Source: Prepared by report authors.

FIGURE 19
BELIZE: ORANGE YIELDS AND VARIATIONS IN PRECIPITATION



Source: Prepared by report authors.

FIGURE 20
BELIZE: IMPACTS OF CHANGES IN PRECIPITATION AND TEMPERATURE ON MAIZE, BEAN, SUGAR CANE AND ORANGE YIELDS



Source: Prepared by report authors.

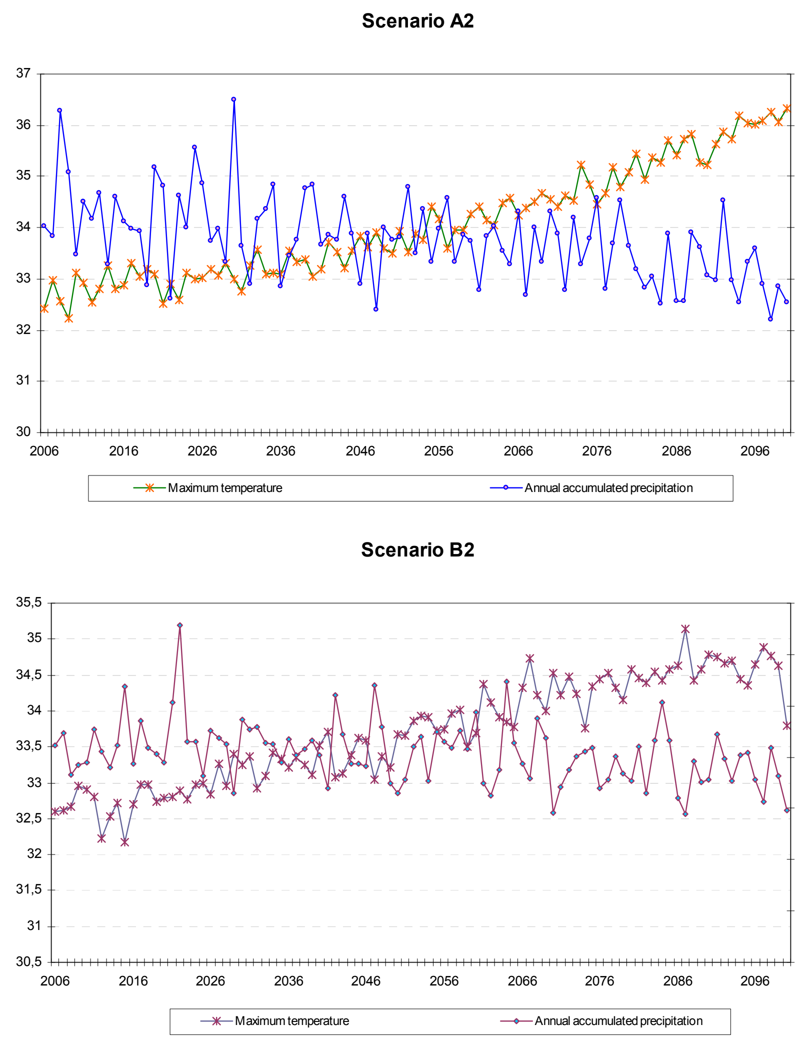
V. FUTURE SCENARIOS: ECONOMIC IMPACTS OF CLIMATE CHANGE ON THE AGRICULTURAL SECTOR

1. Impacts on agricultural production

Based on the coefficients of the specifications (1 and 1´) for the agricultural and crop production functions (refer back to tables 14 and 15) and in scenarios A2 and B2, the impacts on the sector caused by variations in precipitation and temperature were quantified.

The A2 and B2 climate change scenarios predict an increase in temperature and a decrease in precipitation, which will also be highly variable. These predictions can be seen in figure 21.

FIGURE 21
BELIZE: CLIMATE SCENARIOS A2 AND B2, 2006-2100



Source: Prepared by report authors.

The production function approach attempts to explore the magnitude of the impacts caused by climate changes in the agricultural sector in the next few years. The estimates assume that the rest of the conditions remain constant as this study looks to isolate only the effect of temperature and precipitation on agricultural production.

The results of the production function models show economic losses brought on by climate change. The economic impacts estimates are presented as a percentage of GDP in 2007, using discount rates of 0.5%, 2%, 4% and 8%.

The impacts on agricultural production until 2100 were posted in relation to 2007 GDP (see table 22).[13] Looking at scenarios A2 and B2 and a 4% discount rate accumulated until 2050, losses would be about 12% and 5% of the 2007 GDP, respectively. Counting the negative impacts until 2100 with the same discount rate, the accumulated economic losses will make up 16% and 7% of 2007 GDP, respectively. In view of a 2% discount rate, losses will increase to 35% in the A2 scenario and to 16% in the B2 scenario, up to the year 2100.

TABLE 22
BELIZE: IMPACTS OF CHANGES IN PRECIPITATION AND TEMPERATURE AS A PERCENTAGE OF THE 2007 GDP, 2020-2100
(In percentages of the 2007 GDP)

Year	Scenario A2 (ECHAM, GFDL, HADGEM) Discount rate (r)				Scenario B2 (ECHAM, GFDL, HADGEM) Discount rate (r)			
	0.005	0.02	0.04	0.08	0.005	0.02	0.04	0.08
Agricultural production								
2020	6.98	6.42	5.79	4.85	1.31	1.13	0.94	0.65
2030	14.92	12.25	9.71	6.67	6.59	5.20	3.84	2.16
2050	22.54	16.78	12.02	7.33	10.40	7.41	4.93	2.45
2070	33.11	21.40	13.60	7.53	18.18	10.80	6.09	2.60
2100	77.18	34.50	16.33	7.67	34.84	15.92	7.20	2.66
Crop production								
2020	5.50	5.02	4.49	3.70	1.38	1.21	1.03	0.76
2030	11.41	9.37	7.42	5.07	5.27	4.20	3.15	1.85
2050	18.86	13.80	9.69	5.71	8.98	6.37	4.23	2.14
2070	29.17	18.32	11.23	5.91	16.39	9.62	5.35	2.29
2100	68.16	29.94	13.67	6.04	32.46	14.57	6.43	2.35

Source: Prepared by report authors.

Figures 22 and 24 show agricultural production projections based on scenarios A2 and B2. Both scenarios exhibit decreases in production and, as a result, economic losses in production. Figures 23 and 25, then, show crop production based on scenarios A2 and B2. Scenario A2 projects the most extreme changes and therefore shows the most significant decreases in production. In all figures, an inevitable decline in production is seen.

[13] The costs as a percentage of GDP are found in annex II.

FIGURE 22
BELIZE: PROJECTIONS FROM THE AGRICULTURAL PRODUCTION INDEX
SCENARIO A2, 2006-2100

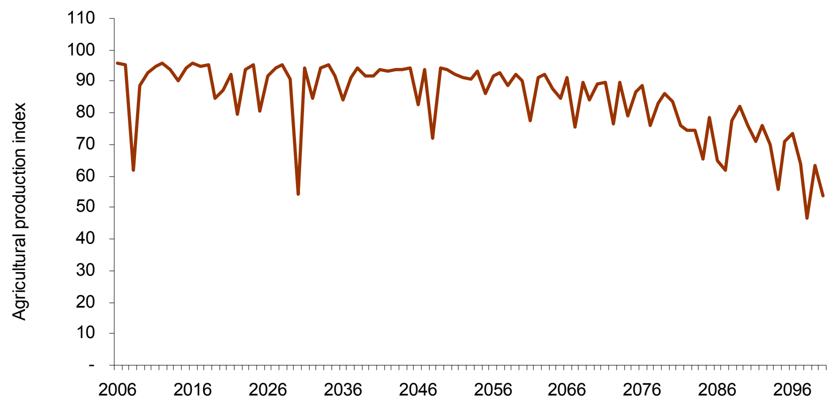
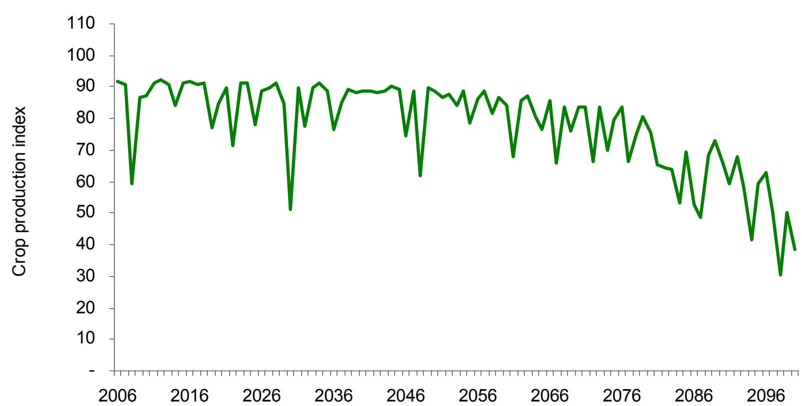


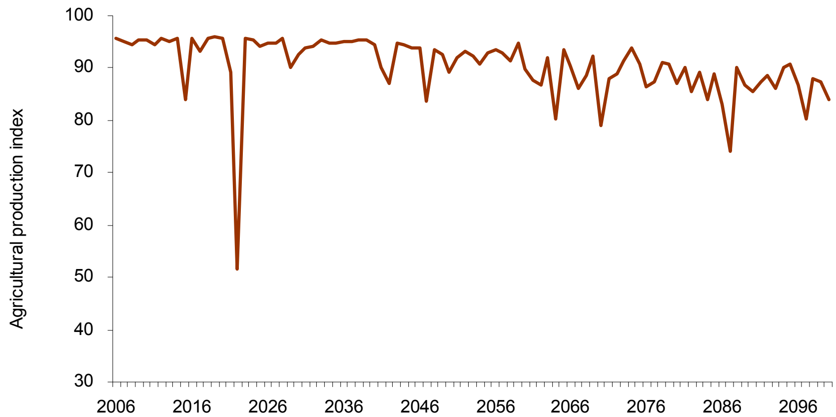
FIGURE 23
BELIZE: PROJECTIONS FROM THE CROP PRODUCTION INDEX
SCENARIO A2, 2006-2100



Source: Prepared by report authors.

FIGURE 24
BELIZE: PROJECTIONS FROM THE AGRICULTURAL PRODUCTION INDEX, 2006-2100

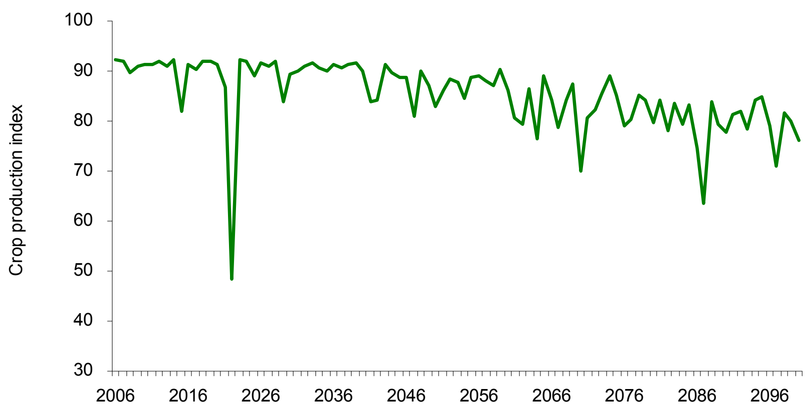
SCENARIO B2



Source: Prepared by report authors.

FIGURE 25
BELIZE: PROJECTIONS FROM THE CROP PRODUCTION INDEX, 2006-2100

SCENARIO B2



Source: Prepared by report authors.

In table 23, the distinction is made between the impact caused by temperature changes and by precipitation changes. The greatest negative impacts seem to be due to variations in precipitation. Increases in temperature until 2100, considering a discount rate of 2%, constitute a loss of almost 12% of 2007 GDP in the A2 scenario, and 7% for the B2 scenario. In the case of precipitation, losses amounted to 22% in the A2 scenario and 9% in the B2 scenario, when also considering a 2% discount rate.

TABLE 23
BELIZE: IMPACTS OF CLIMATE CHANGE, 2020-2100
(As a percentages of GDP of 2007)

Year	Scenario A2 (ECHAM, GFDL, HADGEM)				Scenario B2 (ECHAM, GFDL, HADGEM)			
	Discount rate (r)				Discount rate (r)			
	Agricultural production		Crop production		Agricultural production		Crop production	
	0.02	0.04	0.02	0.04	0.02	0.04	0.02	0.04
Changes in temperature and precipitation								
2020	6.42	5.79	5.02	4.49	1.13	0.94	1.21	1.03
2030	12.25	9.71	9.37	7.42	5.20	3.84	4.20	3.15
2050	16.78	12.02	13.80	9.69	7.41	4.93	6.37	4.23
2070	21.40	13.60	18.32	11.23	10.80	6.09	9.62	5.35
2100	34.50	16.33	29.94	13.67	15.92	7.20	14.57	6.43
Changes in temperature								
2020	0.08	0.06	0.31	0.26	-0.10	-0.09	0.10	0.09
2030	0.15	0.11	0.53	0.40	-0.01	-0.04	0.34	0.25
2050	1.03	0.54	1.63	0.95	0.69	0.32	1.29	0.73
2070	3.66	1.43	4.20	1.83	2.87	1.07	3.46	1.48
2100	11.85	3.14	11.42	3.34	6.67	1.89	7.01	2.25
Changes in precipitation								
2020	6.32	5.71	4.67	4.20	1.23	1.03	1.12	0.96
2030	12.09	9.58	8.81	6.98	5.27	3.91	3.92	2.95
2050	15.68	11.44	12.08	8.67	6.80	4.66	5.16	3.56
2070	17.47	12.05	13.86	9.28	8.15	5.12	6.37	3.97
2100	22.04	13.00	17.98	10.14	9.45	5.41	7.75	4.28

Source: Prepared by report authors.

The quantifications of the impacts based on climate scenarios give an overview of the performance of agricultural production under changes in precipitation and temperature, but it is necessary to consider that the estimates presented do not include any adaptation or external change, and that *ex ante* it is known that there could be overestimations of the effects.

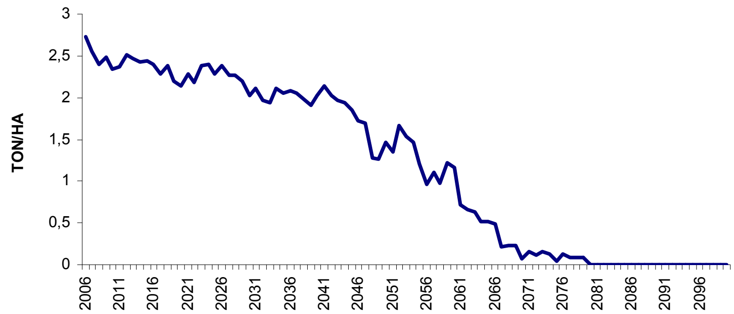
2. Impacts on maize, bean, sugar cane and orange yields

The A2 and B2 climate scenarios are also used in this section, and the estimates that were employed are now used to analyze the effects on the production of each of the four crops that are examined in this study: maize, beans, sugar cane and oranges. The projections are made between 2006 and 2100, and the following discount rates are used: 0.5%, 2%, 4%, and 8%. They are same as in the previous section and used to calculate the economic effects according to total 2007 GDP.[14]

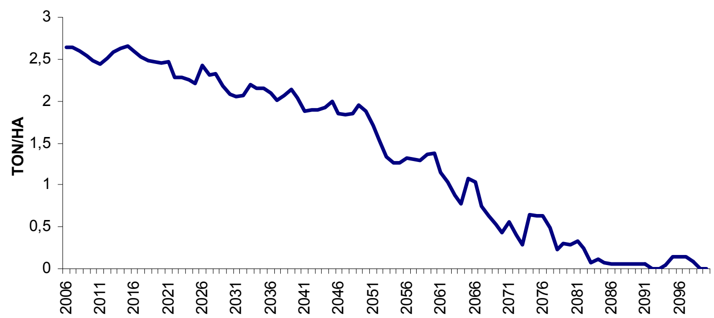
Figure 26 shows the possible path that maize production could take under both the A2 and B2 scenarios. In both cases, the production trajectories are decreasing. In the A2 scenario, this happened to a greater degree, showing that towards the end of the period, yields could be practically null. It is improbable that a situation like this would occur since farmers could adapt; however, if current production conditions remain unchanged, maize yields could be significantly affected by climate change.

[14] Costs as a percentage of agricultural GDP are found in annex II.

FIGURE 26
BELIZE: PROJECTIONS OF MAIZE YIELDS, 2006-2100
SCENARIO A2



SCENARIO B2



Source: Prepared by report authors.

The costs coming from the estimates shown in figure 26 are presented in table 24; they were calculated by comparing anticipated production levels based on scenarios A2, B2 and a scenario in which the weather remained at current levels. As shown, accumulated economic costs from climate change up to 2100 will be equivalent to losing about 2 percentage points of the 2007 GDP, based on a 4% discount rate, but at lower discount rates, losses could go up.

TABLE 24
BELIZE: ECONOMIC IMPACTS OF CLIMATE CHANGE ON CORN PRODUCTION, 2020-2100
(*In percentages of GDP of 2007*)

Year	Scenario A2 (ECHAM, GFDL, HADGEM)				Scenario B2 (ECHAM, GFDL, HADGEM)			
	Discount rate (r)				Discount rate (r)			
	0.005	0.02	0.04	0.08	0.005	0.02	0.04	0.08
2020	0.37	0.32	0.27	0.20	0.09	0.08	0.06	0.04
2030	0.78	0.63	0.48	0.30	0.48	0.37	0.26	0.14
2050	2.44	1.61	0.97	0.43	1.86	1.19	0.68	0.26
2070	6.09	3.21	1.52	0.50	4.99	2.57	1.16	0.32
2100	13.22	5.43	2.02	0.53	11.62	4.62	1.61	0.35

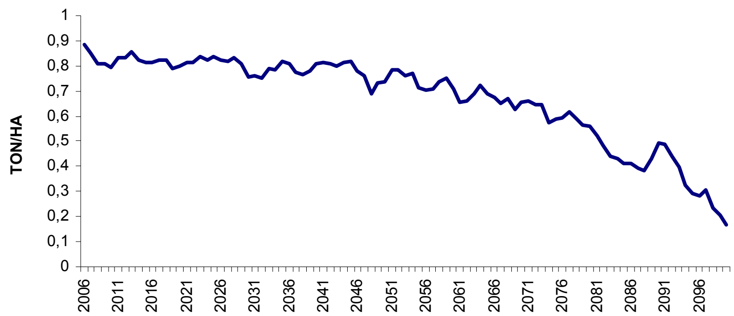
Source: Prepared by report authors.

Projected bean production between 2006 and 2100 is shown in figure 27. The results suggest that bean production will tend to decrease in the coming years, mostly in a warmer scenario like A2.

The economic effects that would result in this type of change in bean production are presented in table 25. Near 2100, the accumulated economic costs, in terms of 2007 GDP, will be close to one percentage point of GDP for a discount rate of 4%, but they could be greater if the discount rate is lower.

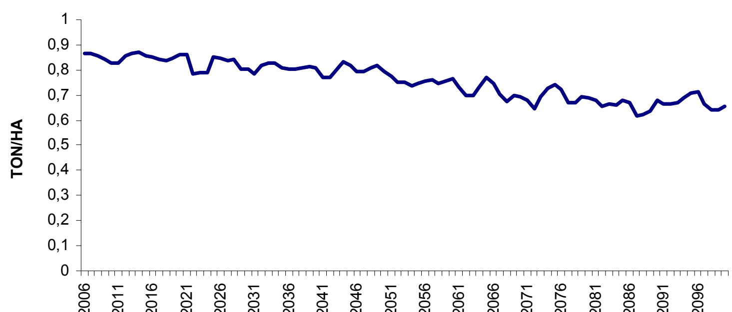
FIGURE 27
BELIZE: PROJECTIONS FOR BEAN YIELDS, 2006-2010

SCENARIO A2



BELIZE: PROJECTIONS FOR BEAN YIELDS, 2006-2010

SCENARIO B2



Source: Prepared by report authors.

Figure 28 displays sugar cane projections, which were made based on the two climate scenarios (A2 and B2). As shown, the production of this crop will tend to fall in the coming years. Just as in previous cases, scenario A2 predicts major declines, even dropping to zero towards the end of the period. This happens because, as mentioned, the possible adaptation by farmers due to climate change is not factored in.

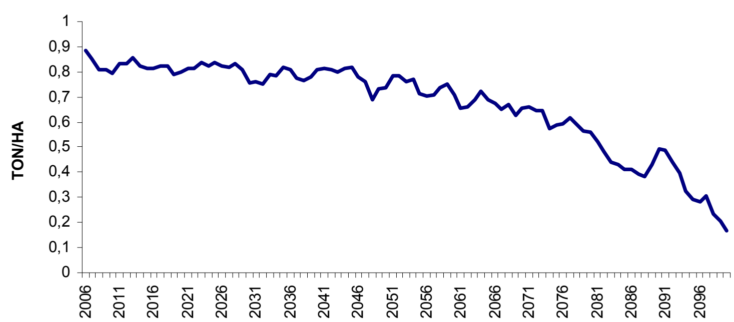
The accumulated economic effects up to 2100 predicted from the results are shown in table 26. It can be seen that the possible positive effects that climate change could bring to sugar cane production in the short term would reverse over the long term; in accumulated terms by 2100, the economic effects would be negative, reaching losses of between 2% and 5% of 2007 GDP. This would occur at a discount rate of 2%, but lower rates would produce greater adverse effects.

TABLE 25
BELIZE: ECONOMIC IMPACTS OF CLIMATE CHANGE ON BEAN PRODUCTION
(*In percentage of GDP of 2007*)

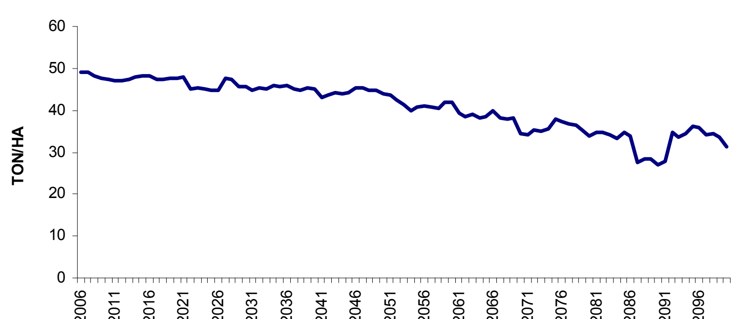
Year	Scenario A2 (ECHAM, GFDL, HADGEM)				Scenario B2 (ECHAM, GFDL, HADGEM)			
	Discount rate (r)				Discount rate (r)			
	0.005	0.02	0.04	0.08	0.005	0.02	0.04	0.08
2020	0.41	0.37	0.32	0.25	0.27	0.24	0.21	0.17
2030	0.69	0.57	0.46	0.32	0.54	0.44	0.35	0.24
2050	1.41	1.01	0.69	0.38	1.12	0.79	0.53	0.29
2070	2.45	1.46	0.84	0.40	2.01	1.19	0.67	0.31
2100	5.51	2.39	1.04	0.41	3.60	1.68	0.78	0.32

Source: Prepared by report authors.

FIGURE 28
BELIZE: PROJECTIONS FOR SUGAR CANEYIELDS, 2006-2100
SCENARIO A2



SCENARIO B2



Source: Prepared by report authors.

TABLE 26
BELIZE: ECONOMIC IMPACTS OF CLIMATE CHANGE ON SUGAR CANE PRODUCTIONS, 2020-2100
(*In percentage of GDP of 2007*)

Year	Scenario A2 (ECHAM, GFDL, HADGEM)				Scenario B2 (ECHAM, GFDL, HADGEM)			
	Discount rate (r)				Discount rate (r)			
	0.005	0.02	0.04	0.08	0.005	0.02	0.04	0.08
2020	-1.33	-1.20	-1.06	-0.86	-1.51	-1.37	-1.22	-0.99
2030	-1.88	-1.61	-1.34	-0.99	-1.79	-1.59	-1.37	-1.06
2050	-2.01	-1.70	-1.39	-1.00	-1.64	-1.50	-1.33	-1.06
2070	0.08	-0.83	-1.11	-0.97	1.38	-0.19	-0.88	-1.00
2100	19.65	4.93	0.07	-0.91	10.02	2.48	-0.30	-0.97

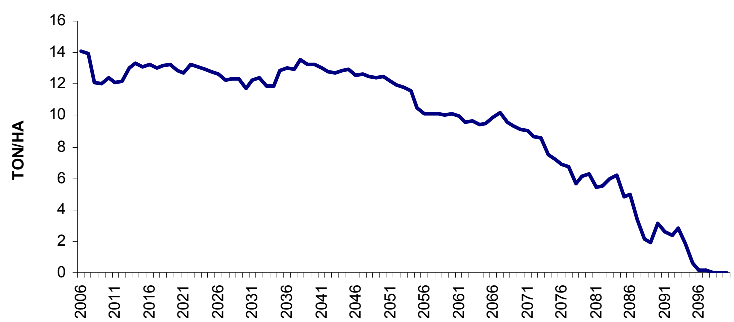
Source: Prepared by report authors.

Table 29 shows the projections for orange yields. Although in the short term, production of this crop might remain near current ones, climate change would cause orange yields to fall over the years implying a significant decrease in the long term.

The costs resulting from lower orange production caused by climate change are shown in table 27. As shown, the accumulated losses for this commodity up to the year 2100 could comprise between 4% and 6% of 2007 GDP at a discount rate of 2%, but the effects could be greater at lower discount rates.

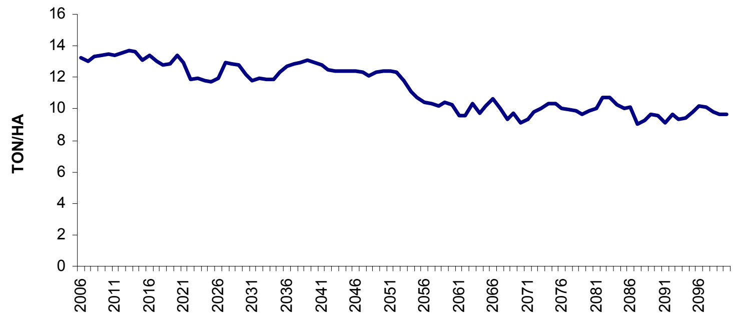
FIGURE 29
BELIZE: PROJECTIONS FOR ORANGE YIELDS, 2006-2100

SCENARIO A2



Source: Prepared by report authors.

SCENARIO B2



Source: Prepared by report authors.

TABLE 27
BELIZE: ECONOMIC IMPACTS OF CLIMATE CHANGE ON ORANGE PRODUCTIONS, 2020-2100
(*In percentage of GDP of 2007*)

Year	Scenario A2 (ECHAM, GFDL, HADGEM)				Scenario B2 (ECHAM, GFDL, HADGEM)			
	Discount rate (r)				Discount rate (r)			
	0.005	0.02	0.04	0.08	0.005	0.02	0.04	0.08
2020	0.65	0.59	0.52	0.41	0.36	0.32	0.28	0.22
2030	1.21	1.01	0.80	0.55	1.07	0.86	0.65	0.40
2050	2.17	1.59	1.11	0.64	2.28	1.59	1.04	0.52
2070	5.06	2.86	1.55	0.69	5.03	2.80	1.46	0.57
2100	15.40	5.97	2.20	0.73	9.31	4.13	1.75	0.59

Source: Prepared by report authors.

VI. CONCLUSIONS AND RECOMMENDATIONS

Climate change is one of the biggest challenges humanity faces in modern times. There is uncertainty about the effects that this phenomenon will have on economies. Nevertheless, it is clear that no country can face it alone. Decisions should be made as soon as possible to ensure that everyone involved acts and adapts in the best possible way. Projections warn that global climate change will directly affect productive sectors like agriculture, fishing, forestry, coastal area development, etc.

In this document, the potential effects of climate change on the agricultural sector in Belize were analyzed. In particular, the impacts on all agricultural production, as well as on the sub-sectors of crops and livestock, were studied. More specifically, it looked at some of the most important crops for this country's economy (maize, beans, sugar cane and oranges).

The results reveal that there could be severe repercussions in Belize's primary sector. Concretely, the analysis of the sectoral production functions show the negative effects that climate change will have on the agricultural sector due to variations in temperature and precipitation. Accumulated losses by 2100 in the agricultural sector as a whole could be approximately 35% of 2007 GDP.[15] Furthermore, it was determined that the greatest economic losses will be caused by variations in precipitation. The estimations also reveal that due to the importance that maize, bean, sugar cane and orange crops have to the economy, they will be the most affected by climate change.

The government of Belize is aware that the sector should be one of the priority areas to be tended to in terms of adaptation measures. Adaptation means responding to real or predicted damages caused by climate change. However, the capacity to adapt and to reduce the effects of the weather depend on environmental and socioeconomic circumstances, capital goods, human capital, social security, institutions, revenue, access to financing, information and technology availability, as well as development policies.

The challenge of adapting to climate changes implies knowing and confronting the risks and vulnerabilities that Belize faces. Therefore, the government has established the following main objectives of their adaptation policy:[16]

1. Explore and consent to the opportunities being developed through the climate change negotiation process.

2. Prepare all sectors in Belize to face the challenges of global climate change.

3. Promote the development of economic incentives that encourage public and private investment in adaptation measures.

4. Develop Belize's negotiating position at a regional and international level in order to promote its economic and environmental interests.

5. Encourage the development of adequate institutional systems for the planning and response to climate change.

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15 Using a discount rate of 2%.

16 Government of Belize Policy on Adaptation to Global Climate Change, National Meteorological Service.

The Government also recognizes that in order for the adaptation policy to be effective, an aggressive and innovative awareness programme should exist, directed at all sectors of the country.

While some regions could improve their agricultural production, others will face decreases in yield. It is very likely that in the next few years, there will be a reorganization of global agricultural production areas. However, reducing the negative consequences of climate change will depend on the adaptation strategies in each region and on the crop systems that use them.

In Belize, it is expected that the agricultural sector will be seriously affected, which poses the need to carry out adaptations in the sector, industry and markets, in producer strategies and in rural development strategies, with the objective of reducing social and economic costs.

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ANNEX I

TABLE AI-1
BELIZE: DESCRIPTIVE STATISTICS OF THE CLIMATE SCENARIOS, 2006-2100

		Observations	Average	Standard deviation	Minimum Value	Maximum Value
Temperature	A2	95	27.34	1.09	25.50	29.60
	B2	95	27.04	0.73	25.51	28.47
Precipitation	A2	95	1,312.25	285.58	768.66	2,260.22
	B2	95	1,416.69	208.32	1,005.95	2,287.57

ANNEX II
IMPACT ON AGRICULTURAL PRODUCTION FUNCTIONS

TABLE AII-1
BELIZE: IMPACTS OF CLIMATE CHANGE: 2020, 2030, 2050, 2070 AND 2100
SCENARIO A2 (ECHAM, GFDL, HADGEM)
(*In accumulated percentages of 2007 agricultural GDP*)

Year	Agricultural production Discount rate (r)				Crop production Discount rate (r)			
		0.02	0.04	0.08	0.005	0.02	0.04	0.08
	Changes in temperature and precipitation							
2020	45.10	41.47	37.43	31.31	35.51	32.43	29.01	23.89
2030	96.37	79.15	62.68	43.07	73.68	60.54	47.91	32.74
2050	145.58	108.39	77.65	47.32	121.78	89.13	62.56	36.90
2070	213.83	138.23	87.84	48.62	188.37	118.30	72.54	38.19
2100	498.44	222.79	105.49	49.53	440.20	193.35	88.27	39.00

Source: Prepared by report authors.

TABLE AII-2
BELIZE: IMPACTS OF CLIMATE CHANGE: 2020, 2030, 2050, 2070 AND 2100
SCENARIO B2 (ECHAM, GFDL, HADGEM)
(*In accumulated percentages of 2007 agricultural GDP*)

Year	Agricultural production Discount rate (r)				Crop production Discount rate (r)			
	0.005	0.02	0.04	0.08	0.005	0.02	0.04	0.08
	Changes in temperature and precipitation							
2020	8.46	7.32	6.07	4.21	8.88	7.83	6.67	4.94
2030	42.53	33.61	24.80	13.95	34.01	27.13	20.34	11.96
2050	67.19	47.87	31.85	15.82	58.02	41.13	27.32	13.85
2070	117.38	69.77	39.31	16.78	105.88	62.14	34.55	14.79
2100	224.98	102.83	46.52	17.18	209.66	94.09	41.54	15.19

Source: Prepared by report authors.

TABLE AII-3
BELIZE: IMPACTS OF CLIMATE CHANGE: 2006-2100
SCENARIO A2 (ECHAM, GFDL, HADGEM)
(In accumulated percentages of 2007 agricultural GDP)

Period	Agricultural production	Crop production
2001 - 2020	11.87	10.93
2021 - 2030	26.95	20.16
2031 - 2040	9.30	8.77
2041 - 2050	7.49	7.65
2051 - 2060	5.09	5.19
2061 - 2070	7.41	7.06
2071 - 2080	6.57	6.07
2081 - 2090	9.21	8.18
2091 - 2100	9.02	7.83

Source: Prepared by report authors.

TABLE AII-4
BELIZE: IMPACTS OF CLIMATE CHANGE: 2006-2100
SCENARIO B2 (ECHAM, GFDL, HADGEM)
(In accumulated percentages of 2007 agricultural GDP)

Period	Agricultural production	Crop production
2001 - 2020	5.94	5.34
2021 - 2030	19.78	14.44
2031 - 2040	2.18	2.69
2041 - 2050	5.78	5.19
2051 - 2060	3.60	3.81
2061 - 2070	5.57	5.05
2071 - 2080	3.69	3.72
2081 - 2090	3.84	3.57
2091 - 2100	2.48	2.40

Source: Prepared by report authors.

ANNEX III

IMPACT ON MAIZE, BEAN, SUGAR CANE AND ORANGE YIELDS, 2020-2100

TABLE AIII-1
BELIZE: ECONOMIC IMPACTS OF CLIMATE CHANGE ON MAIZE PRODUCTION, 2020-2100
(*In percentage of GDP of 2007*)

Year	Scenario A2 (ECHAM, GFDL, HADGEM)				Scenario B2 (ECHAM, GFDL, HADGEM)			
	Discount rate (r)				Discount rate (r)			
	0.005	0.02	0.04	0.08	0.005	0.02	0.04	0.08
2020	2.40	2.09	1.75	1.26	0.58	0.50	0.42	0.29
2030	5.04	4.06	3.10	1.91	3.10	2.38	1.69	0.90
2050	15.71	10.35	6.29	2.79	12.03	7.69	4.42	1.67
2070	39.27	20.69	9.84	3.25	32.16	16.57	7.49	2.07
2100	85.26	35.02	13.02	3.44	74.92	29.80	10.40	2.24

Source: Prepared by report authors.

TABLE AIII-2
BELIZE: ECONOMIC IMPACTS OF CLIMATE CHANGE ON BEAN PRODUCTION, 2020-2100
(*In percentage of GDP of 2007*)

Year	Scenario A2 (ECHAM, GFDL, HADGEM)				Scenario B2 (ECHAM, GFDL, HADGEM)			
	Discount rate (r)				Discount rate (r)			
	0.005	0.02	0.04	0.08	0.005	0.02	0.04	0.08
2020	2.64	2.36	2.06	1.60	1.74	1.57	1.38	1.10
2030	4.43	3.70	2.97	2.04	3.47	2.87	2.27	1.53
2050	9.10	6.50	4.42	2.46	7.21	5.12	3.45	1.87
2070	15.77	9.44	5.44	2.60	12.95	7.67	4.34	1.99
2100	35.57	15.40	6.71	2.66	23.23	10.86	5.04	2.03

Source: Prepared by report authors.

TABLE AIII-3
BELIZE: ECONOMIC IMPACTS OF CLIMATE CHANGE ON SUGAR CANE PRODUCTION, 2020-2100
(*In percentage of GDP of 2007*)

Year	Scenario A2 (ECHAM, GFDL, HADGEM)				Scenario B2 (ECHAM, GFDL, HADGEM)			
	Discount rate (r)				Discount rate (r)			
	0.005	0.02	0.04	0.08	0.005	0.02	0.04	0.08
2020	-8.55	-7.75	-6.85	-5.52	-9.72	-8.84	-7.86	-6.39
2030	-12.13	-10.40	-8.64	-6.36	-11.57	-10.23	-8.81	-6.86
2050	-12.97	-10.98	-8.98	-6.46	-10.55	-9.68	-8.58	-6.81
2070	0.55	-5.34	-7.18	-6.26	8.89	-1.20	-5.68	-6.44
2100	126.74	31.83	0.47	-5.88	64.65	15.98	-1.93	-6.23

Source: Prepared by report authors.

TABLE AIII-4
BELIZE: ECONOMIC IMPACTS OF CLIMATE CHANGE ON ORANGE PRODUCTION, 2020-2100
(*In percentage of GDP of 2007*)

Year	Scenario A2 (ECHAM, GFDL, HADGEM)				Scenario B2 (ECHAM, GFDL, HADGEM)			
	Discount rate (r)				Discount rate (r)			
	0.005	0.02	0.04	0.08	0.005	0.02	0.04	0.08
2020	4.20	3.81	3.36	2.66	2.30	2.06	1.80	1.42
2030	7.82	6.48	5.17	3.52	6.92	5.54	4.20	2.60
2050	13.98	10.22	7.14	4.11	14.72	10.28	6.70	3.35
2070	32.66	18.45	9.97	4.48	32.44	18.08	9.39	3.70
2100	99.35	38.49	14.22	4.70	60.06	26.67	11.29	3.81

Source: Prepared by report authors.

TABLE AIII-5
BELIZE: IMPACTS OF CLIMATE CHANGE: 2006-2100
SCENARIO A2
(In accumulated percentages of 2007 agricultural GDP)

Period	Maize	Beans	Sugar cane	Oranges
2011 - 2020	1.44	1.33	-4.34	2.14
2021 - 2030	1.43	0.97	-1.91	1.93
2031 - 2040	1.78	0.94	-0.19	1.30
2041 - 2050	1.82	0.69	-0.18	0.90
2051 - 2060	2.02	0.62	0.34	1.71
2061 - 2070	2.34	0.63	1.92	1.76
2071 - 2080	1.93	0.57	2.55	1.95
2081 - 2090	1.44	0.63	4.15	2.03
2091 - 2100	1.03	0.57	4.12	1.97

Source: Prepared by report authors.

TABLE AIII-6
BELIZE: IMPACTS OF CLIMATE CHANGE: 2006-2100
SCENARIO B2
(*In accumulated percentages of 2007 agricultural GDP*)

Period	Maize	Bean	Sugar cane	Orange
2006 - 2010	0.049	0.560	-3.619	0.773
2011- 2020	0.382	0.861	-4.451	1.080
2021 - 2030	1.357	0.950	-1.013	2.556
2031 - 2040	1.545	0.739	-0.194	1.657
2041 - 2050	1.519	0.576	0.470	1.132
2051 - 2060	1.859	0.575	1.533	1.621
2061 - 2070	1.901	0.512	2.024	1.675
2071 - 2080	1.668	0.407	1.969	1.171
2081 - 2090	1.389	0.338	1.994	0.822
2091 - 2100	1.011	0.230	1.253	0.641

Source: Prepared by report authors.

Note: Due to the overestimation that can occur in the calculations, the sum of the effects is not the total of the effects concerning the crops. Additionally, while these crops show losses, there could be some that show gains, as could be the case with tropical fruits.