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Climate Change and Agriculture – A Review of Some Global and Caribbean Concerns

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Abstract

This paper presents a review of the impact if climate change on agriculture as well as the contribution that agriculture can make to the reduction of climate change mainly by lowering the emission of green house gases (GHG). The paper also presents available evidence for temperature rise in the Caribbean sine it is argued that such evidence could help galvanize public support in the Caribbean for the policies that maybe necessary for mitigating the effects of climate change. Several mitigation strategies for Caribbean agriculture are also discussed in the paper.

Keywords: climate change, Caribbean, agriculture, mitigation strategies

Introduction

Climate change is very topical nowadays and the severe warning of the need to do something about climate change now, before it is too late to reverse its possible detrimental effects, echoed from the presentations from the recent Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) held in Geneva in May 2007 (IPCC, 2007). These severe warnings have been given since the Third Assessment Report (IPCC 2001b), which stated for example that:

> "if there were no significant adaptive responses (to climate change), a 1-m sea-level rise would decrease the area of Bangladesh by 17.5% or that of the Majuro Atoll in the Marshall Islands by 80%. Human health impacts of global climatic change include changes in the geographic range and seasonality of various infectious diseases …, increases in mortality and morbidity associated with heat waves, and effects on malnutrition and starvation in some regions as a result of redistribution of food and water resources… The frequency and severity of extreme events such as heat waves, high rainfall intensity events, summer droughts, tropical cyclones, windstorms, storm surges, and possibly El Niño-like conditions are likely to increase in a warmer world…"

However even given these scenarios, many still wonder if climate change is real, when it will start to occur, and whether it will really have an effect on the Caribbean in general and on agriculture in particular. This paper will simply try to examine the evidence for temperature rise in the Caribbean. The paper will then consider the impact of climate change on agriculture. Finally after considering the ways in which agriculture can help to mitigate climate change, the paper will consider the measures that can be taken to minimize the impact of climate change on Caribbean agriculture.

Global Evidence with Respect to Climate Change

The evidence seems overwhelming that current climate change may not be due to any long term variation in climate patterns. As IPCC 2001 stated:

> "New palaeoclimate analyses for the last 1,000 years over the Northern Hemisphere indicate that the magnitude of 20th century warming is likely to have been the largest of any century during this period."(IPCC, 2001a) There has been broad scientific agreement that continued accumulations of "greenhouse" gases in the atmosphere are leading to changes in the global climate, as well as to changes in the climates of regions around the world. (Crosson, 1997)

Temperature Changes

In examining evidence for climate change scientists generally focus on temperature changes in the near surface and variables related to such temperature changes. According to Crosson, the 1996 IPCC Report stated that an increase in atmospheric concentrations of greenhouse gases equivalent to a doubling of carbon dioxide (CO_2) will force a rise in global surface temperature by 1.0 to 3.5 degrees Celsius by 2100.
By 2001, the Third IPCC report stated inter alia as follows:

- Average global surface temperature has increased by approximately 0.6°C since the late 19th century, with 95% confidence limits of close to 0.4 and 0.8°C.
- Most of this increase has occurred in two periods, from about 1910 to 1945 and since 1976, and the largest recent warming is in the winter extra-tropical Northern Hemisphere.
- The warming rate since 1976, 0.17°C/decade, has been slightly larger than the rate of warming during the 1910 to 1945 period (0.14°C/decade).
- The most recent warming period also has a faster rate of warming over land compared with the oceans.
- Twentieth century temperature trends show a broad pattern of tropical warming, while extra-tropical trends have been more variable.
- Warming from 1910 to 1945 was initially concentrated in the North Atlantic and nearby regions. The Northern Hemisphere shows cooling during the period 1946 to 1975 while the Southern Hemisphere shows warming.
- The recent 1976 to 2000 warming was largely globally synchronous, but was pronounced in the Northern Hemisphere continents during winter and spring.
- There was year-round cooling from 1976 to 2000 in parts of the Southern Hemisphere oceans and Antarctica. North Atlantic cooling between about 1960 and 1985 has recently reversed.
- Overall, warming over the Southern Hemisphere has been more uniform during the instrumental record than that over the Northern Hemisphere.
- Analyses of mean daily maximum and minimum land surface air temperatures continue to support a reduction in the diurnal temperature range in many parts of the world, with, global minimum temperatures increasing at nearly twice the rate of maximum temperatures between about 1950 and 1993. The rate of temperature increase during this time has been 0.1°C and 0.2°C/decade for the maximum and minimum, respectively.

Changes in Temperature Related Variables

Rainfall: One of the variables

that is expected to experience major change due to temperature rise is rainfall. According to Crosson, IPCC (1996) predicted that average precipitation would rise by 2100 by as much as 10 to 15% because a warmer atmosphere holds more water. IPCC (2001) has stated that: "Over the last twenty-five years, it is likely that atmospheric water vapour has increased over the Northern Hemisphere in many regions."

Glaciers and Sea ice Extent and Thickness: IPCC (2001a) reports as follows:

- Alpine and continental glaciers have extensively retreated in response to 20th century warming. Glaciers in a few maritime regions are advancing, mainly due to increases in precipitation related to atmospheric circulation changes, e.g., Norway, New Zealand.
- The duration of Northern Hemisphere lake-ice and river-ice cover over the past century, or more, shows widespread decreases averaging to about two fewer weeks of ice cover.
- A 10 to 15% reduction in sea-ice extent in the Arctic spring and summer since the 1950s is consistent with an increase in spring, and to a lesser extent, summer temperatures in the high latitudes. There is little indication of reduced Arctic sea-ice extent during winter.
- New data from submarines indicate that there has been about a 40% decline in Arctic sea-ice thickness in summer or early autumn between the period 1958 to 1976 and the mid-1990s, an average of near 4 cm per year. Other independent observations show a much slower decrease in winter sea-ice thickness of about 1 cm per year.
- Satellite data indicate that after a possible initial decrease in the mid-1970s, Antarctic sea-ice extent has stayed almost stable or even increased since 1978.

The major concern about the retreat of glaciers and the reduction of sea ice extent and thickness is that the water released into the oceans from such developments will lead to seal level rise and flooding of especially low-lying areas of the world, such as coastal wetlands and habitations, as well as small island states.

Extreme Events: There is the concern that higher land and sea temperatures could cause a greater frequency of extreme precipitation and wind events such as hurricanes and tornadoes. IPCC 2001 reports that: "Widespread increases are likely to have occurred in the proportion of total precipitation derived from heavy and extreme precipitation events over land in the mid- and high latitudes of the Northern Hemisphere." (IPCC, 2001a)

Temperature Rise in the Caribbean Region

Crosson points out that while the

models used by the IPCC give "reasonably good agreement with respect to global temperature rise", with respect to regional changes "agreement among the models is poor". An attempt will therefore be made to review the evidence can be easily put forward for temperature rise in the Caribbean. The following graphs from Daly (undated) provide pictorially historical temperature series for selected sites in the Caribbean.

The first point that is noticeable about the Figures 1 to 4 is the absence of observations in the data series on annual temperature for some years in even quite recent times like around 1985 for Barbados at Grantley Adams and even for around 1995 for Nassau. The general picture that emerges however is an increase in temperature in the Caribbean from around 1957. Specifically, Nassau in the Bahamas showed its highest temperature around 1900, but from around 1956 there has been a fairly steady upward climb in the annual temperature from around 24^0 to just below 26^0.

San Juan, Puerto Rico showed a rise in annual temperature from around 25.2^0 in 1949 to just below 28^0 by 1980, almost a three degree rise in temperature. However, the annual temperature had moderated to around 27^0 by 2002. San Fernando, Venezuela (7.9^0 N) just south of the Caribbean (Trinidad and Tobago is 10^0 N) demonstrates a much more uniform temperature as was alluded to above. Temperature in the early 1960's, late 1970's and early 1980's averaged just below 27^0, the period since 1995 has seen temperature generally above 27^0 , with a high for the period of above 28^0 in 1998.

The picture for Lamentin in Martinique shows the temperature increasing from below 25^0 in the period 1974 to 1977 to a high of above 27^0 around 1998. In general the temperature moved from around 25.5^0 in the period 1963-1979 to 26.5^0 for the period 19860-2000.

The information for Grantley Adams in Barbados is short and the high of above 27.5^0 for 1951 and 1952 is not shared at Codrington, which recorded a temperature of around 26.2^0 in those two years. From 1954, the temperature at Grantley Adams fluctuated around 26.5^0. However, from 1995 to 1998 the temperature was above 27^0, after not attaining that annual temperature from 1953 to 1977. In general evidence for temperature rise in Barbados is weak for in 1999 and 2000, the annual temperature was again below 27^0.

Trinidad and Tobago

Data on the minimum and maximum temperature for Piarco airport in Trinidad and Tobago was available from 1946 to 2000. These data were plotted in Figures 5 and 6 and also linear trend lines were estimated.

The data for the maximum temperature showed variability, but a pattern of a mean temperature of 30.9^0 from 1946-1986 and an increase to a mean of 31.8^0 from 1987 to 2000. While the data for the minimum temperature again showed variability, the upward trend in temperature is more strongly linear moving from below 21.5^0 in 1946 – 1947 to being consistently above 23^0 from 1997 – 2000. The minimum temperature thus seems to have risen from an average of 21.8^0 from 1946 – 1955 to 23.2^0 from 1991 – 2000 a rise of 1.4^0 C. This pattern is consistent with the IPCC 2001 statement referred to earlier of a greater increase in minimum temperature than in maximum temperature.

The estimate for the linear trend line for the maximum temperature at Piarco, Trinidad using Genstat (2006) was[1]:

$$MaxTemp = -2.34 + 0.0170Year$$

$$p - values = (0.753)(< .001)$$

This implies that every ten years, the maximum temperature at Piarco increased by 0.17^0C over the period 1946 to 2000.

The estimate for the linear trend for the minimum temperature at Piarco, Trinidad was:

$$MinTemp = -35.73 + 0.0294Year$$

$$p - value = (< 0.001)(< 0.001)$$

This implies that every ten years the minimum temperature at Piarco increased by 0.29^0 over the period 1946 to 2000, which is 1.7 times the increase of the maximum temperature. These results therefore point to a definite pattern of temperature rise in Trinidad.

Impact of Climate Change on Agriculture

The Consultative Group on International Agricultural Research (CGIAR, 2001), summarized the IPCC 2001's findings on the impact of climate change on agriculture as follows:

- Severe water stress in the arid and semiarid land areas in southern Africa, the Middle East and southern Europe;
- Increased risk from flooding and landslides, driven by projected increases in rainfall intensity and, in coastal areas, rising sea levels;
- Decreased agricultural production in many tropical and subtropical countries, especially countries in Africa and Latin America, which would lead to;
- Higher worldwide food prices as food supplies fail to keep up with the demand of an increasing world population.

The CGIAR statement also noted that climate change would cause major changes in the productivity and composition of critical ecological systems, particularly coral reefs and forests. These changes could be expected to affect fishing and forestry industries especially again in developing countries.

The CGIAR also made an interesting observation that with its low per capita fossil energy use, Sub-Saharan Africa has the lowest emissions of the greenhouse gases that are the major cause of climate change. Yet Sub-Saharan Africa and

[1] Further information on these regressions are given in Appendix 1.

low-lying small island states are the most vulnerable to climate change because wide-spread poverty limits their capabilities to adapt to a continuing changing climate. "Particularly at risk are the arid and semi-arid regions and the grassland areas of eastern and southern Africa, and the areas already threatened by land degradation and desertification." (CGIAR, 2001)

According to IPCC 2001, climate change is likely to present opportunities for agriculture to expand into regions where it currently is limited by low temperatures, if adequate soils are present. Also Crosson (1997) points out that while increased carbon dioxide concentrations are a major cause of global warming such increased concentrations can also stimulate plant growth and thus crop yields. This can have a positive impact on grain production. This effect is called in this paper the CO_2 fertilization effect.

In summarizing the total impact of climate change on grain production therefore, Crosson (1997) states that in the worse case scenario (in Table 1), world grain production will fall between 11 and 20% because of climate change and between 14 and 16% in the developing countries. If the CO_2 fertilization effect is taken into account, grain production in developing countries will fall by 9 to 11%. However modest adjustments that farmers in developing countries can make by making use of current technology and practices will generally not affect the drop in production in grain production in these countries. In fact the figures suggest that some developing country farmers may even make the wrong adjustments and cause even a further drop in grain production to a maximum drop of 13%.

If farmers throughout the world are able to adjust to different crops and technology including increased irrigation, along with the CO_2 fertilization effect, world grain production is likely to fall by just about 2% or may even rise while the grain production in developing countries is forecast to drop by 6 to 7%.

In addition, IPCC 2001 pointed out that climate change can have some not so often mentioned effects. Livestock (e.g., cattle, swine, and poultry) are all susceptible to heat stress and drought and are likely to suffer productivity loss with global warming. Cooked rice grain from plants grown in high-CO_2 environments would be firmer than that from today's plants. However, concentrations of iron and zinc, which are important for human nutrition, would be lower. With wheat, elevated CO_2 reduces the protein content of grain and flour by 9-13%, and for bread-making, the quality of flour produced from wheat grain developed at high temperatures and in elevated CO_2 is degraded.

Caribbean Case Study

Homer and Ramsook (2005) reviewed one study which attempted to assess the impact of climate change on agriculture in the

Caribbean. This was a case study of the sugar industry in Trinidad carried out as part of the Initial National Communication of Trinidad and Tobago prepared in 2001 and executed by the Environmental Management Authority (EMA) and the Ministry of the Environment under the United Nations Framework Convention on Climate Change (UNFCCC).

Homer and Ramsook report that the study looked at the performance of the sugar cane industry in Trinidad for the period 1970 to 1995 "in relation to climatic circumstances for the same period". The major finding of the study was that for every 1^0 C rise in temperature, sugar cane yield was reduced by approximately three tones per acre. Therefore they concluded that the current trend of temperature rise, which is consistent with climate change models could result in significantly reduced sugar cane yields.

Agricultural Measures to Mitigate Climate Change

The IPCC Fourth Assessment Report (Smith et al, 2007) in its discussion on agriculture stated that agricultural lands (lands used for agricultural production, consisting of cropland, managed grassland and permanent crops including agro-forestry and bio-energy crops) now occupy about 40-50% of the Earth's land surface. Also agriculture accounted for in 2005, 10-12 % of total global emissions of greenhouse gases (GHGs): about 60% of N2O (nitrous oxide) and about 50% of CH4 (methane). Globally, agricultural CH4 and N2O emissions have increased by nearly 17% from 1990 to 2005.

Smith et al (2007) stated that many measures exist for mitigation of GHG emissions in agriculture. The most prominent options are: improved crop and grazing land management (e.g., improved agronomic practices, nutrient use, tillage, and residue management), restoration of organic soils that are drained for crop production and restoration of degraded lands.

Lower but still significant mitigation is possible with improved water and rice management; set-asides, land use change (e.g., conversion of cropland to grassland) and agro-forestry; as well as improved livestock and manure management.[2]

They go on to state that many mitigation opportunities use current technologies and can be implemented immediately, but technological development will be a key driver to ensure the efficacy of additional mitigation measures. They also state that agricultural GHG mitigation measures are generally cost competitive with non-agricultural options (e.g., energy, transportation, forestry).

An interesting conclusion of Smith et al (2007) is that GHG emissions

[2] These measures are summarized in Appendix 2 which includes the particular green house gas emission that will be affected by each measure.

could also be reduced by substituting fossil fuels with energy produced from agricultural feed stocks (bio-energy or bio-fuels e.g., crop residues, dung, energy crops). Where these bio-fuels are used by non- agricultural sectors this will reduce their emissions of GHG. However it is also possible for agriculture to increase its mitigation potential by itself using bio-fuels. The use of such bio-fuels in agriculture will however depend on relative prices of the fossil fuels and bio-fuels.

They also point out that agricultural mitigation measures often have synergy with sustainable development policies, and many explicitly influence social, economic, and environmental aspects of sustainability. Many of these measures also have co-benefits (improved efficiency, reduced cost, environmental co-benefits) as well as trade-offs (e.g., increasing other forms of pollution), and balancing these effects will be necessary for their successful implementation.

Finally, Smith et al (2007) note that, despite significant technical potential for mitigation in agriculture, there is evidence that little progress has been made in the implementation of mitigation measures at the global scale. Barriers to implementation are not likely to be overcome without policy/economic incentives and other programmes, such as those promoting global sharing of innovative technologies.

Measures to Minimize the Impact of Climate Change on Agriculture in the Caribbean

This final section will consider the measures that may be taken to reduce the impact of climate change on agriculture in the Caribbean. These measures will be based on those suggested in the INC for Trinidad and Tobago referred to earlier. (Homer and Ramsook, 1995).

Vulnerability Studies

One of the leading ways to minimize the impact of climate change on agriculture in the Caribbean is to discover areas of vulnerability of agriculture to climate change and then to devise ways and means of overcoming these areas of vulnerability. Once these measures have been put in place, assessment should be on-going to determine how well they are allowing agriculture to adapt to the new environment of climate change.

It has been suggested that vulnerability can be determine by using an Environmental Vulnerability Index. In the index used in the case of Trinidad and Tobago, indicators are scored on a 1 – 7 vulnerability scale, where scores in the range 5 -7, indicate above average vulnerability. Vulnerability indicators and vulnerability scores for agriculture in Trinidad and Tobago are given in Table 2. In this table it is seen that agriculture in Trinidad and Tobago is in general very vulnerable to climate change. In particular the rate of loss of natural cover is so great that climate change with its increased frequency of extreme events is likely to cause increased flooding of plains due to faster run off from denuded areas The loss of forests will also lead to less carbon sequestration and therefore a greater contribution of Trinidad and Tobago to the net emission of green house gases (carbon dioxide). Removal of commercial forest species for wood also will cause the remaining forests to lose natural cover and make them more vulnerable to higher temperatures and more intense droughts that may accompany climate change.

Also, the very high demand on the water resources of the state will mean that climate change with its higher temperatures and drought may increase the need for rationing of the available water resources, meaning higher prices and less availability of water for agricultural purposes. This more limited and expensive supply of water will have a major impact on irrigated agriculture, as well as intensive livestock production, especially broiler and pig production.

Construction of Protective Structures

In addition to the determination of vulnerability scores, measures will have to be taken to adapt the agricultural sector to the new scenarios of climate change and if possible reduce the level of vulnerability to these scenarios. One set of such measures will be investment in physical structures for:

- coastal protection, such as sea walls, as well as
- the provision of water in periods of drought, as well as to store water run off from extreme rainfall events to minimize flooding of agricultural holdings, such as dams, ponds etc .

Such investment could require large sums of money and would normally be carried out by the state. In general therefore such investment would usually be justified if it has a large set of primary beneficiaries, which would be expected to include residential households. In other words, such investment would be more easily justified to protect or serve large urban populations, rather than dispersed rural and agricultural communities.

Development of Policies to Restrict Development in Vulnerable Areas

Physical development for both agricultural and non-agricultural pursuits in areas known to be vulnerable to adverse natural events may have to be restricted, especially given that climate change may increase the likelihood of occurrence of these events. Such restrictions on development should be based on the measurement of the vulnerability of the area to adverse natural events. This measurement would require an adequate information base (an issue we will return to shortly) as well as transparency and honesty in the administration and operations of the relevant statal and parastatal institutions.

Implementation and Enforcement of Existing Policies with Respect to Resource Use

It is generally true in the Caribbean that adequate policies, laws and regulations exist with respect to the sustainable use of natural resources including those with respect to land use, water resources, biodiversity and forestry. Caribbean countries are signatories to most of the United Nations conventions on the conservation and wise use of natural resources as well. However, it is with respect to the implementation of these policies, laws and regulations that the Caribbean countries are deficient.

However, the advent of climate change now means that the implementation of these legal instruments may be vital for the survival of agriculture in these countries and perhaps for the survival of the countries themselves. Policies and laws with respect to the removal of forests, especially on private land, will be of particular importance to the minimization of the impact of climate change on agriculture.

Research, Training and Information Dissemination in the Areas of Climate Change

There is a clear need for more research into all areas of climate change if further measures are to be formulated to minimize its impact on agriculture. This research is particularly needed at the regional and national level. We have seen for example the limited historical information that is readily available for temperature change assessment in Barbados. Much more research is now necessary to determine the impact that climate change can have on the Barbadian agricultural sector and also the measures that should be taken to minimize this impact. This situation is perhaps true for all the other CARICOM countries. For example many of the measures to reduce GHG emissions in agriculture in Appendix 2 require changes in farm management practices. However these new practices must be clearly defined, tested and shown to be economically feasible if they are to be adopted by the average farmer.

Therefore, a substantial research and development effort would be needed to create the information base which can bring about changed agricultural production and marketing systems to meet the demands of climate change. Clearly this type of development has not yet entered into the planning framework of most agricultural ministries in the region. There is also the need for extensive training and public education on issues of global warming, climate change and their effects on agriculture and mitigation measures for such effects. Again, the challenge in agriculture will be for the extension agents to have to deal with yet another pressing issue in its education and training programmes for farmers.

A further task exists in disseminating research information to key individuals, who are positioned to implement the findings to actually make a difference with respect to climate change. Such dissemination nowadays must include the availability of the information on-line. This information dissemination should in fact start with the most basic information. For example, the lack of on-line of basic historical data on rainfall, temperature and other climatic variables for CARICOM countries is regrettable.

Conclusion

All indications are that climate change could be having a major impact globally by the year 2100, but that even before that year the effects of climate change could be occurring. (IPCC, 2001) This paper has looked at the potential impacts of climate change on agriculture with particular reference to CARICOM countries. We have seen that a great deal of research, information dissemination and public education is necessary if the agricultural sector of the region is to be positioned to implement measures to deal with climate change.

However, the investments in human and financial resources necessary to deal with the issues of climate change in agriculture will not be forthcoming unless there is a consensus among the population that climate change is occurring and that the deleterious impacts commonly spoken about globally and seen on television can really occur in the Caribbean. There is therefore the need for a fairly substantial research effort to document whether in fact climate change is taking place in the Caribbean (and in Barbados for example) and its possible impact on Caribbean agriculture.

It is our hope that this review paper has been an initial contribution in this area and that it will be followed by a more substantial research programme on "Climate Change and Agriculture in the Caribbean". The School of Agriculture at the University of the West Indies is willing to take part in any such research with willing partners or collaborators.

REFERENCES

CGIAR "*Climate Change Poses Special Problems for Agriculture*" Consultative Group for International Agricultural Research, May 23, 2001. http://www.worldbank.org/html/cgiar/press/climate.pdf accessed 2007 06 23.

Crosson, Pierre, "*Impacts of Climate Change on Agriculture*", Climate Issues Brief No. 4, Resources for the Future, June 1997. http://www.rff.org/rff/Documents/RFF-CCIB-04.pdf accessed 2007 06 23.

Daly John L., "*Still Waiting for Climate Change, A Luke warm View of*

Global Warming: What the Stations Say” http://www.john-daly.com/stations/stations.htm accessed 2007 06 23.

Homer, Floyd and Ramsook, Nicole, “*Self-Assessment on Climate Change Activities in Trinidad and Tobago*.” 11th November 2005. http://www.sustrust.org/documents/Climate%20Change%20Self%20Assessment%20Trinidad%20Nov05.pdf accessed 2007 06 23.

GenStat Release 9.1 Lawes Agricultural Trust, Rothamsted Experimental Station, 2006.

Intergovernmental Panel on Climate Change, IPCC: Climate Change 2001, Working Group I: The Scientific Basis, 2001a. http://www.grida.no/climate/ipcc_tar/wg1/index.htm accessed 2007 06 23.

Intergovernmental Panel on Climate Change, IPCC: Climate Change 2001, Working Group II: Impacts, Adaptation and Vulnerability, 2001b. http://www.grida.no/climate/ipcc_tar/wg2/index.htm accessed 2007 06 23.

Intergovernmental Panel on Climate Change, IPCC: Climate Change 2001, Working Group II: Impacts, Adaptation and Vulnerability, Section 5.3, Agriculture 2001c. http://www.grida.no/climate/ipcc_tar/wg2/208.htm accessed 2007 06 23.

Smith, P., D. Martino, Z. Cai, D. Gwary, H. Janzen, P. Kumar, B. McCarl, S. Ogle, F. O’Mara, C. Rice, B. Scholes, O. Sirotenko, 2007: *“Agriculture.” in Climate Change 2007: Mitigation*. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [B. Metz, O.R. Davidson, P.R. Bosch, R. Dave, L.A. Meyer (eds)], Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA. http://www.ipcc.ch/pdf/assessment-report/ar4/wg3/ar4-wg3-chapter8.pdf accessed 2009 06 15.

Table 1: Estimated Percentage Grain Production Changes Resulting from Climate Change Scenarios

Climate Change Scenario	% Change in World Grain Production	% Change in Developed Countries Grain Production	% Change in Developing Countries (Asia, Africa, Latin America) Grain Production
Climate change with no offsetting effects considered	-11 to -20	-4 to -24	-14 to -16
Climate change with the CO_2 fertilization effect	-1 to -8	-4 to +11	-9 to -11
I Climate change with the CO_2 fertilization effect and modest farmer adoption	0 to -5	+2 to +11	-9 to -13
Climate change with the CO_2 fertilization effect and more ambitious farmer adaptation	-2 to +1	+4 to +14	-6 to -7

Source: Crosson, 1997

Table 2: Vulnerability Scores for Agriculture in Trinidad and Tobago

Indicator	Vulnerability Score	Area of Agriculture Impacted
Sea Surface Temperature	5	Fisheries
Lowlands (% of land <10m above sea level)	Trinidad – 3 Tobago – 2	Coastal and Wetland Farming
Rate of loss of Natural Cover (net% of land area natural vegetation removed in last 5 years)	7	Forestry, flood plain farming
Renewable Water (Mean % water usage/year met from renewable and non-declining sources)	7	Irrigated cropping, Intensive livestock farming

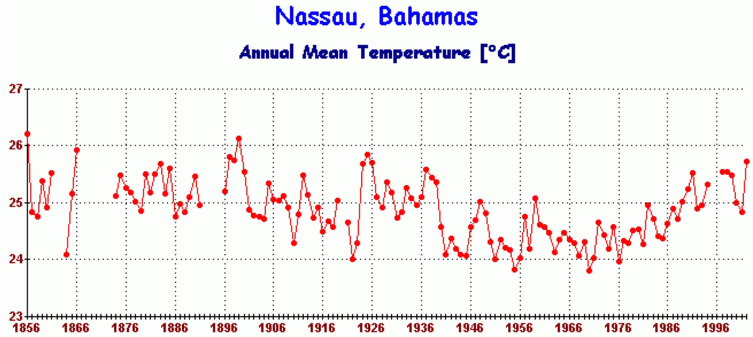


Figure 1: Annual Mean Temperature: Nassau, Bahamas

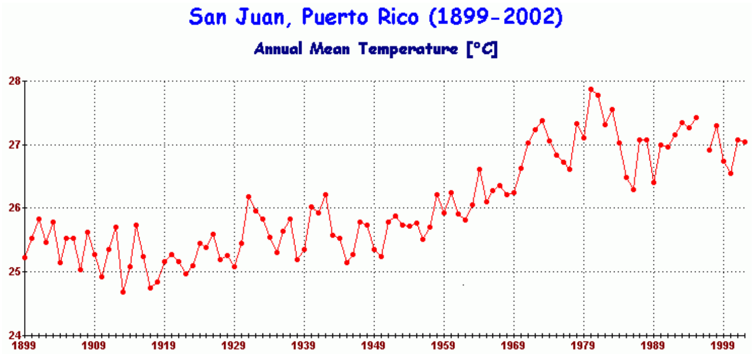


Figure 2: Annual Mean Temperature: San Juan, Puerto Rico (1899 – 2002)

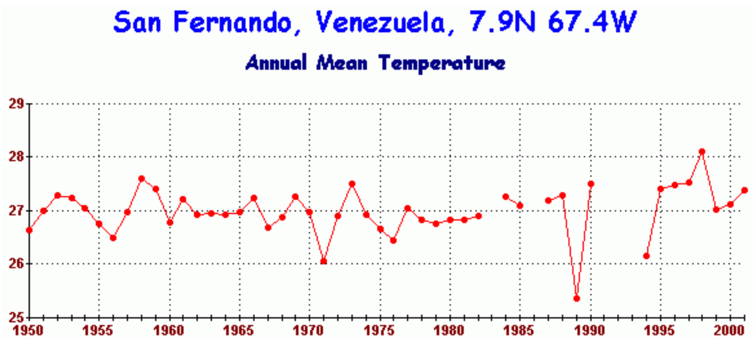


Figure 3: Annual Mean Temperature: San Fernando, Venezuela

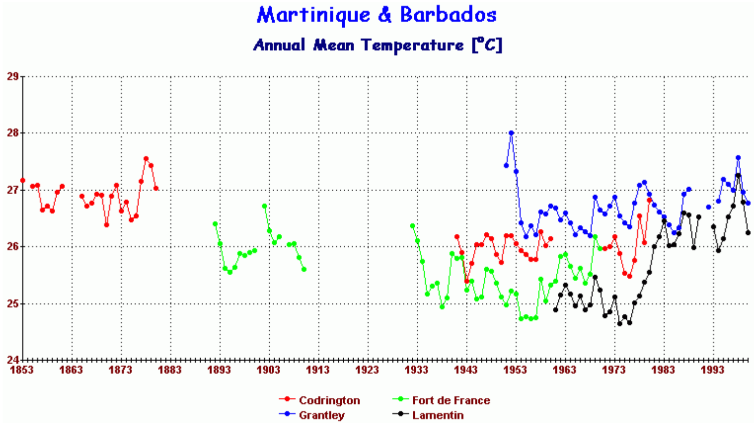


Figure 4: Annual Mean Temperature Four Reporting Stations, Martinique and Barbados

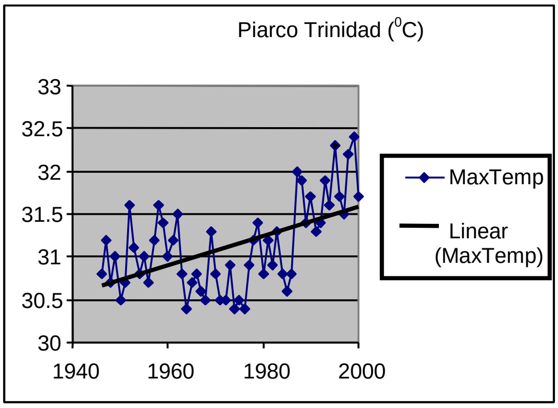


Figure 5: Annual Mean Maximum Temperature Piarco Airport, Trinidad: 1946-2000

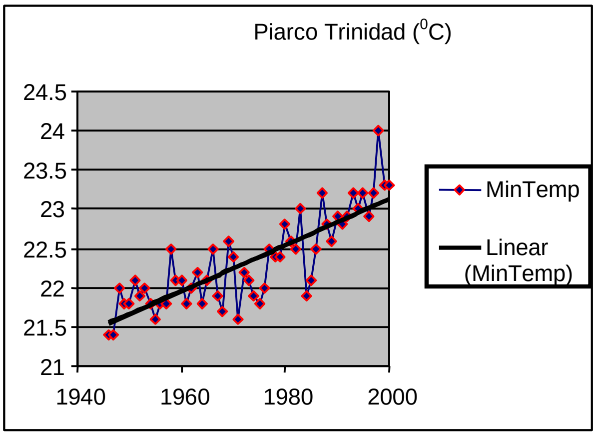
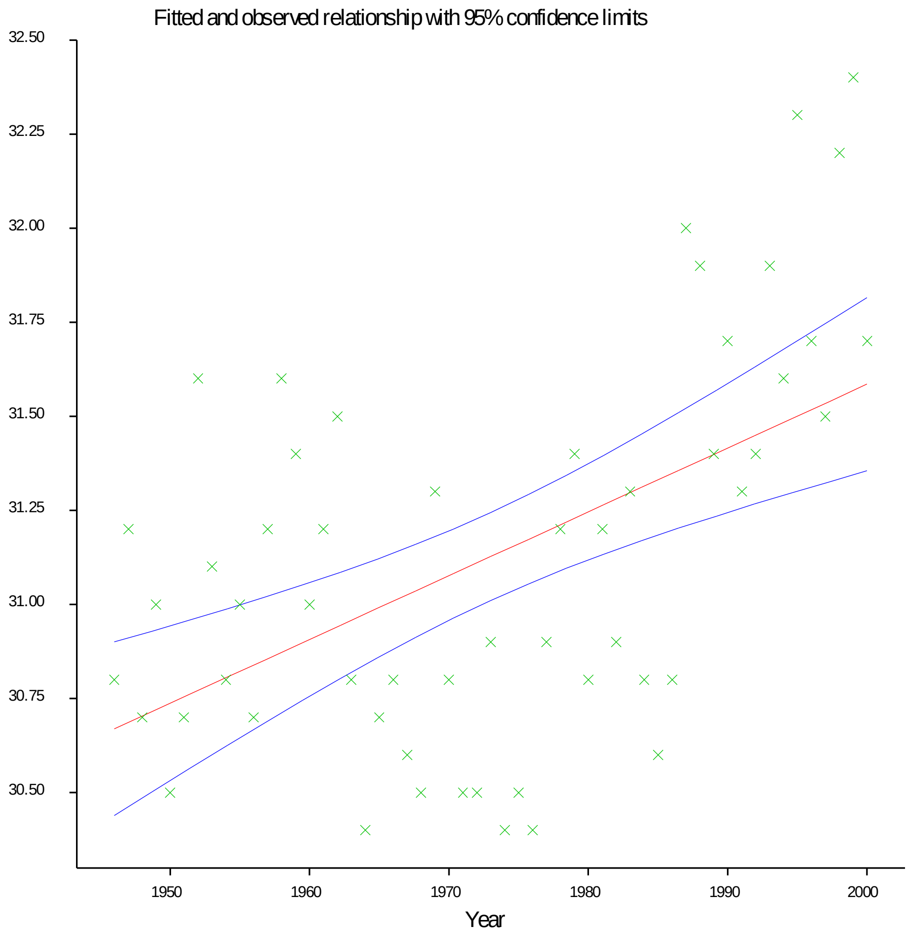
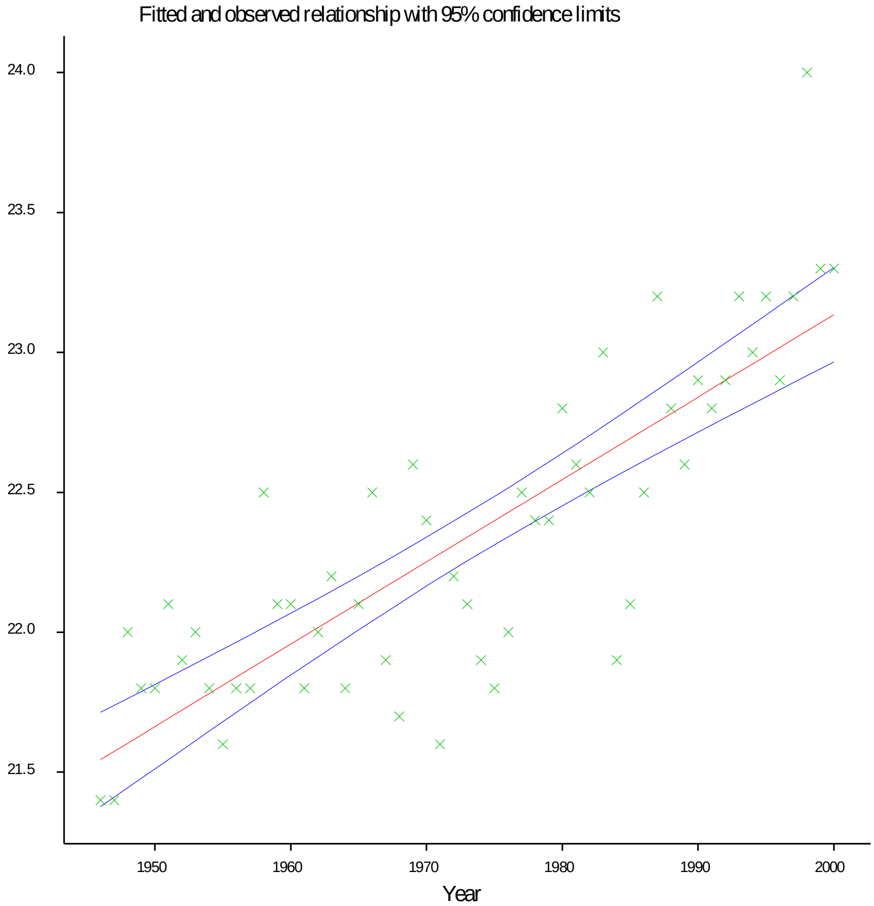


Figure 6: Annual Mean Minimum Temperature Piarco, Trinidad: 1946-2000


Fitted and observed relationship with 95% confidence limits
32.50
32.25
32.00
31.75
31.50
31.25
31.00
30.75
30.50
1950
1960
1970
1980
1990
2000
Year

[redacted]


Fitted and observed relationship with 95% confidence limits
24.0
23.5
23.0
22.5
22.0
21.5
1950
1960
1970
1980
1990
2000
Year

Appendix 2

Mitigation Measures

Table 8.3: Proposed measures for mitigating greenhouse gas emissions from agricultural ecosystems, their apparent effects on reducing emissions of individual gases where adopted (mitigative effect), and an estimate of scientific confidence that the proposed practice can reduce overall net emissions at the site of adoption

		Mitigative effects[1]			Net mitigation[2] (confidence)	
Measure	**Examples**	**CO_2**	**CH_4**	**N_2O**	**Agreement**	**Evidence**
Cropland management	Agronomy	+		+/-	***	**
	Nutrient management	+		+	***	**
	Tillage/residue management	+		+/-	**	**
	Water management (irrigation, drainage)	+/-		+	*	*
	Rice management	+/-	+	+/-	**	**
	Agro-forestry	+		+/-	***	*
	Set-aside, land-use change	+	+	+	***	***
Grazing land management/ pasture improvement	Grazing intensity	+/-	+/-	+/-	*	*
	Increased productivity (e.g., fertilization)	+		+/-	**	*
	Nutrient management	+		+/-	**	**
	Fire management	+	+	+/-	*	*
	Species introduction (including legumes)	+		+/-	*	**
Management of organic soils	Avoid drainage of wetlands	+	-	+/-	**	**
Restoration of degraded lands	Erosion control, organic amendments, nutrient amendments	+		+/-	***	**
Livestock management	Improved feeding practices		+	+	***	***
	Specific agents and dietary additives		+		**	***
	Longer term structural and management changes and animal breeding		+	+	**	*
Manure/biosolid management	Improved storage and handling		+	+/-	***	**
	Anaerobic digestion		+	+/-	***	*
	More efficient use as nutrient source	+		+	***	**
Bio-energy	Energy crops, solid, liquid, biogas, residues	+	+/-	+/-	***	**

Notes:

[1] *+ denotes reduced emissions or enhanced removal (positive mitigative effect);*

- denotes increased emissions or suppressed removal (negative mitigative effect);

+/- denotes uncertain or variable response

[2] *A qualitative estimate of the confidence in describing the proposed practice as a measure for reducing net emissions of greenhouse gases, expressed as CO_2-eq*

Agreement refers to the relative degree of consensus in the literature (the more asterisks, the higher the agreement); Evidence refers to the relative amount of data in support of the proposed effect (the more asterisks, the more evidence).

Source: Smith et al (2007).