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AN ASSESSMENT OF THE ECONOMIC IMPACT OF CLIMATE CHANGE ON THE AGRICULTURE SECTOR IN SAINT LUCIA

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Executive Summary

This study looks at the economic impacts of rainfall and temperature on the key agricultural sub-sectors in Saint Lucia: bananas, other crops (a wide mix of 24 tree, root and vegetable crops) and fisheries. A production function approach is used, largely due to data scarcity at the farm level. A Baseline case was constructed which assumed that the mean rainfall and temperature for the base period of 1980 – 2000 would exist through to 2050 under a "no climate change" case. This was compared to the IPCC A2 and B2 scenarios, using data derived from downscaled, regional PRECIS climate model. There were mixed results overall, with temperature generally having the larger unit effect on output.

For the A2 scenarios, rainfall is expected to change greatly through to 2020, increasing slightly initially, ending with a 17% reduction by the 2040s. The B2 scenario exhibited similar swings, and by the 2040s, rainfall is expected to fall by approximately 22% under this scenario. Over the same period, temperature is expected to increase by 1.53°C and 1.52°C under A2 and b2 respectively.

The mean annual rainfall of 1546.44 mm is well below the optimal rainfall range for bananas, and the mean temperature was below, the upper temperature limit for bananas of 30 °C. For bananas, a 1% increase in rainfall is expected to cause an approximate 0.27% increase in the growth of banana exports. A 1% increase in temperature is expected to cause an approximate 5.1% decrease in the growth of banana exports. There is an expected rapid fall-off in expected banana exports, so that by 2050, banana exports are minimal. By 2050, the value of cumulative yield losses (2008$) for banana, is expected to be $165.36 mil under the A2 scenario and $165.54 mil under the B2 scenario. In addition to the potential climate impacts, it should be noted that is the loss of preferential prices in the EU market by Caribbean exporters, is a key non-climate factors that have contributed, perhaps overwhelmingly, to the decline in the banana sector.

By 2050, the root crops are expected to lose $61.37 mil and $58.04 mil under the A2 and B2 scenarios (2008$), respectively. For tree crops, for all decades the production values are lowest under the baseline case, with A2 having the highest values in all decades. By 2050, the tree crops are expected to gain $345.35 mil under the A2 scenario and $251.63 mil under the B2 scenario (2008$). For vegetable crops, for all decades the production values are lowest under the baseline, with A2 having the highest values in all decades, so by 2050, gains of $333.31 mil under the A2 scenario and $313.82 mil under the B2 scenario (2008$) are expected.

Relative to the 2005 catch for fish, there will be a decrease in catch potential of 10 - 20% by 2050 relative to 2005 catch potentials, other things remaining constant. By 2050 under the A2 and B2 scenarios, losses in real terms were estimated to be $62.59 mil and $31.29 mil respectively, at a 1% discount rate.

Relative to the Baseline case, the key subsectors in agriculture are expected to have mixed impacts under the A2 and B2 scenarios. In aggregate, in every decade up to 2050, these sub-sectors combined are expected to experience a gain under climate change, all scenarios, with the highest gains under A2. By 2050, the cumulative gain under A2 is calculated as approximately $389.35 mil and approximately $310.58 mil under B2, which represents 17.93% and 14.30% of the 2008 GDP.

Sea-level rise is not expected to have any significant effect on agricultural land loss in Saint Lucia. Further, by 2050, additional losses due to an increased intensity of tropical cyclones is expected to be $6.9 mil under the A2 scenario and $6.2 mil under the B2 scenario, with a 1% discount rate.

The most attractive adaptation options, based on the Benefit-Cost Ratio are: (1) Design and implement holistic water management plans (2) Establish systems of food storage and (3) On-farm water

harvesting systems. However, the options with the highest net benefits are, (in order of priority): (1) Use of Drip Irrigation, (2) Mainstreaming climate change issues into agricultural management and (3) Establish systems of food storage. Therefore, government policy should focus on the development of these adaption options.

I. INTRODUCTION

More and more, there is increasing evidence that anthropogenic effects are already having a negative effect on the world's climate. As a result, all countries are now seeking to determine the likely impact of joint and interrelated actions on the global commons, and more importantly, to find ways to reduce the potential negative impacts, while preparing local communities for change in order to cope and/or even benefit from the projected changes. Fortunately, many countries are already making changes to reduce their emissions of greenhouse gases (GHG) in some sectors, through policy and legislative changes. However, other countries are vigorously trying to maintain their status quo, or are achieving very little changes in their contribution to climate change, as the final output relies heavily on individuals and firms making changes to their economic behavior, which may come at a personal cost, even though the aggregate benefit to society may vastly outweigh the sum of the individual costs.

In order to determine the impact of climate change on the agricultural sector in the Caribbean, a baseline period would first be established. The IPCC Special Report on Emissions Scenarios (SRES) A2[1] and B2[2] scenarios would then be used as the projected future climate for the Caribbean (IPCC 2000). Using Atmosphere-Ocean General Circulation and Earth System Models, the IPCC (2007) projects that global temperatures will rise. Under the A2 and B2 scenarios, it is expected that relative to temperatures during 1980-1992, temperatures will rise globally by 3.4°C and 2.4°C, respectively, with a likely range of 2.0 – 5.4 °C, and 1.4 – 3.8°C, respectively, by 2090-2099. Furthermore, global sea levels are expected to rise by 0.23 – 0.51 m under the A2 scenario and between 0.2 – 0.43 m for the B2 scenario for the same period. While climate projections have been made for a number of regions worldwide, the IPCC (1997) indicated that the potential change in many climate variables, including rainfall, for the Caribbean has had very little consistency among the Global Climate Models. From a small island perspective, one of the key concerns is the intensity, frequency and distribution of extreme events such as hurricanes, but model projections to date have not provided conclusive evidence of the patterns of these events that may occur in the future (IPCC 1997).

In the Caribbean, the tropical climate of most countries reflects an annual rainfall regime that is often characterized by pronounced wet and dry seasons. In the tropics and low-latitude regions of the Southern Hemisphere, the El Niño Southern Oscillation (ENSO) is a major factor in year-to-year climate variability, with a marked effect on rainfall patterns (IPCC 1997). This study econometrically analyses the projected impact of climate change on the agricultural sector of Saint Lucia.

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[1] The A2 storyline and scenario family describes a very heterogeneous world. The underlying theme is self reliance and preservation of local identities. Fertility patterns across regions converge very slowly, which results in continuously increasing population. Economic development is primarily regionally oriented and per capita economic growth and technological change more fragmented and slower than other storylines.

[2] The B2 storyline and scenario family describes a world in which the emphasis is on local solutions to economic, social and environmental sustainability. It is a world with continuously increasing global population, at a rate lower than A2 and intermediate levels of economic development. While the scenario is also oriented towards environmental protection and social equity, it focuses on local and regional levels.

A. MAIN OBJECTIVES

The main objective of this study is to determine the key climatic and economic factors that impact on agricultural output in Saint Lucia for the A2 and B2 scenarios, relative to a Baseline Case, which represents a “no climate change” case where the mean temperature and rainfall for the 1980 – 2000 period were assumed to exist for all future years. This was done for the sub-sectors which currently have the largest contribution to GDP. The specific objectives are:

1. To collect relevant data on the socioeconomic status of Saint Lucia, including the level and trends in the key economic drivers, livelihood characteristics, and drivers of development.
2. Evaluate the size and potential changes in the main factors that the economy is most at risk from in relation to climate change.
3. To forecast the losses in agricultural output for key subsectors under the A2 and B2 scenarios, to 2050.
4. Prioritize the key threats, based on established research and expert opinion.
5. Determine the timeframe over which the climate change-related events are projected to occur.
6. To create a detailed list of possible mitigation and adaptation strategies suitable for Saint Lucia.
7. To calculate the discounted costs of selected mitigation and adaptation strategies in Saint Lucia, which have been identified by the local government.
8. Calculate expected losses from extreme events.

In the early part of the 20th century, agriculture was the mainstay of all Caribbean economies, but over the last 20 years, the contribution of agriculture to total GDP fell dramatically in all of the Caribbean countries. Despite this, Guyana is the only country in CARICOM for which agriculture’s allocation to GDP exceeds 20%. For Saint Lucia, agriculture’s contribution to GDP fell from 2.5% in 1990 to 1.5% in 1998 and then to 0.4% by 2006.

The agricultural sector in the Caribbean is not only important in terms of the contribution of the sector to GDP, but also since it also is a significant employer, and by extension supports directly and indirectly, many farm families and communities. In 2000, the agricultural sector employed 15,000 persons in Saint Lucia, which represented 23.4% of total persons employed (FAO 2007).

II. THE ECONOMY OF SAINT LUCIA

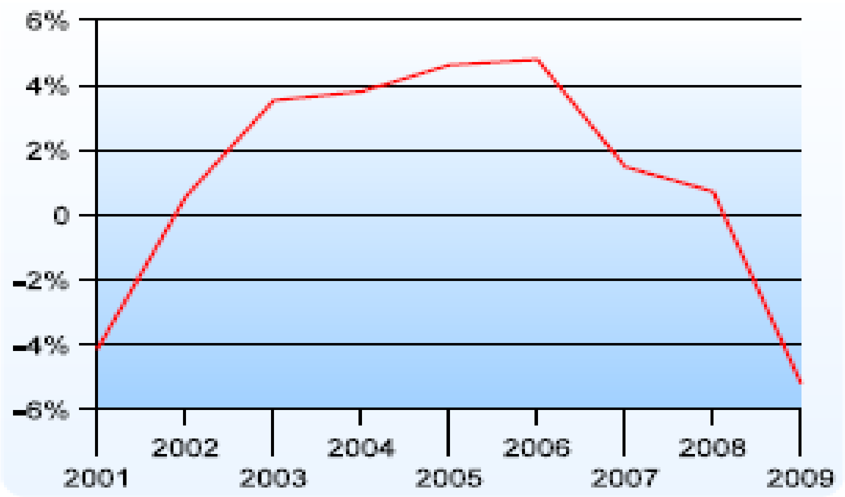
St Lucia is a volcanic and mountainous island (see Figure 1), with a total land area of 616 km^2 (CIA World Factbook). It had a population of 172,370 in 2009, which represented an increase of 1.2% from the 2008 level. Even though the agricultural sector has a significant role in the country’s economy, tourism is now the main source of income (CIA World Factbook). Saint Lucia is vulnerable to many external shock such as reduced tourism receipts (as occurred in 2009 following the worldwide recession), dependence on imported fuel, and hurricanes, which destroy banana plants (the main agricultural export) and which affects production exports for at least 9 months (CIA World Factbook). The public debt-to-GDP ratio was 71% in 2009 (Ministry of Finance, Economic Affairs & National Development 2010), which is high and would constrain the possibility of increased government direct investment in new capital projects. On the other hand, the economy remains stable, and had an inflation rate of only 1% in 2009, down from 7.2% the previous year.

Figure 1: Map of Saint Lucia

Source: CIA World Factbook

Saint Lucia's economy has suffered wide fluctuations in GDP growth (see Figure 2). In 2001, following the events of 9/11, its GDP growth rate was approximately -4%. The growth rate increased steadily thereafter and remained positive up to 2008, when it stood at 0.7%. In 2009, however, the economy contracted by 5.2% largely due to reductions in tourism receipts (following the worldwide economic decline) and a 24.4% reduction in private sector construction activity.

Figure 2: Real GDP Growth Rate of Saint Lucia



Source: (Ministry of Finance, Economic Affairs & National Development 2010)

The slowdown of the economy in 2009 was also attributed, based on preliminary data, to a reduction in banana output by 13.2% due to lower fertilizer application, and lower value added in the other crops and livestock sub-sectors. Despite the positive, but weak outlook for the economy in 2011, which is largely contingent on the rate of global economic growth and travel confidence, one of the identified risks is the incidence of drought and its impact on the agricultural sector, as experienced in the early months of 2010 (Ministry of Finance, Economic Affairs & National Development 2010).

III. SAINT LUCIA'S AGRICULTURAL SECTOR PERFORMANCE

Even though the forested area in Saint Lucia increased from 48.3 thousand hectares to 47 thousand hectares between 1990 and 2008 (Table 1), arable land availability fell by 40% over that time, and the available agricultural land fell by 45%, which would have a significant impact on total potential production.

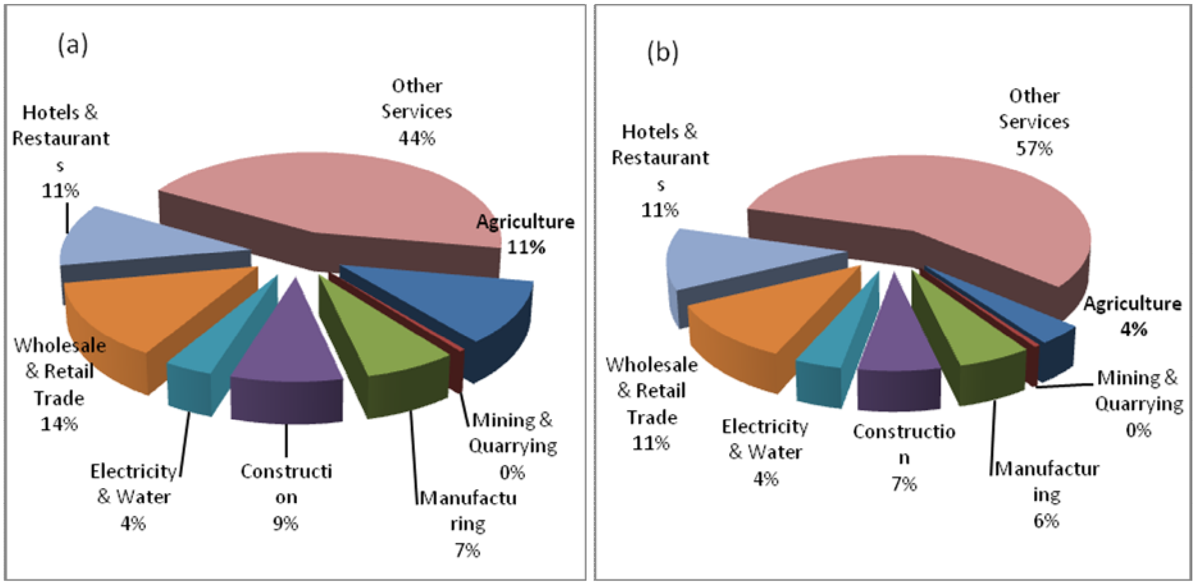
Table 1: Agricultural and Forest Land Area (1000 Hectares) and Tractor Use, Selected Years

	1980	1990	2000	2008
Agricultural area	20	20	16	11
Arable land	5	5	2	3
Permanent crops	12	13	12	7
Forest area		43.8	46.7	47
Total area equipped for irrigation	1	2	3	3
Total Agricultural Tractors	14	4	5	N/A

Source: FAOSTAT

Agriculture's total contribution to GDP fell significantly from 11% in 1995 (Figure 3) to 4% in 2009. It was replaced largely by the construction and Other Services sectors.

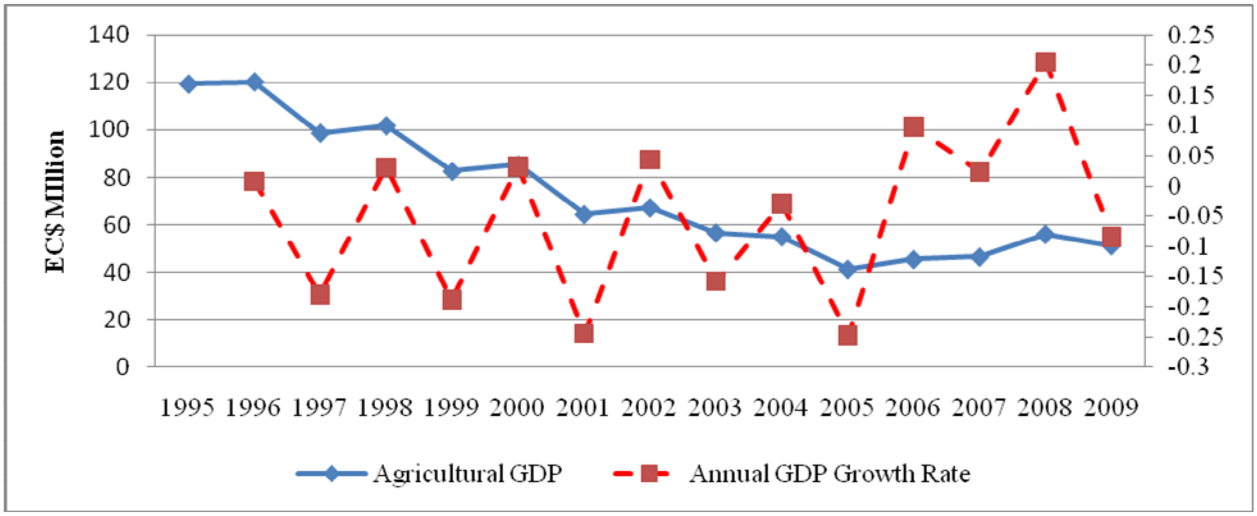
Figure 3: Contribution of Sectors to Total GDP in Saint Lucia in 1995 (a) and 2009 (b)



Source: Data compiled by author

The value of the agricultural sector has not only fallen in terms of its percentage contribution to GDP in Saint Lucia, but also in terms of its absolute value. In 1995, this sector was worth approximately EC$120 mill (Figure 4), but by 2009, it was worth only approximately EC$50 mill despite having a slightly increasing growth rate from about 2005.

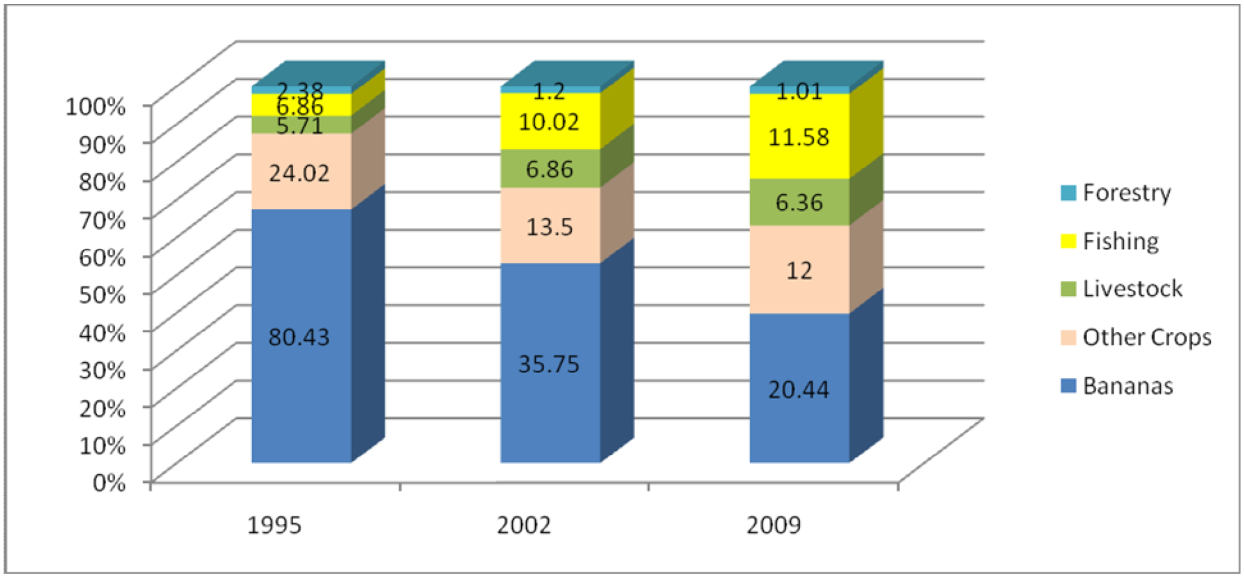
Figure 4: Value and Annual Growth Rate of Agricultural GDP



Source: Data compiled by author

From 1995 the banana sub-sector accounted for about 67% of agricultural GDP (actual GDP values shown), followed by Other Crops at approximately 20%, the Fishing, Livestock and Forestry, respectively (Figure 5). However, by 2009, banana's contribution fell to approximately 40% of agricultural GDP, replaced largely by fishing and Other Crops, which now accounted for approximately 23% each.

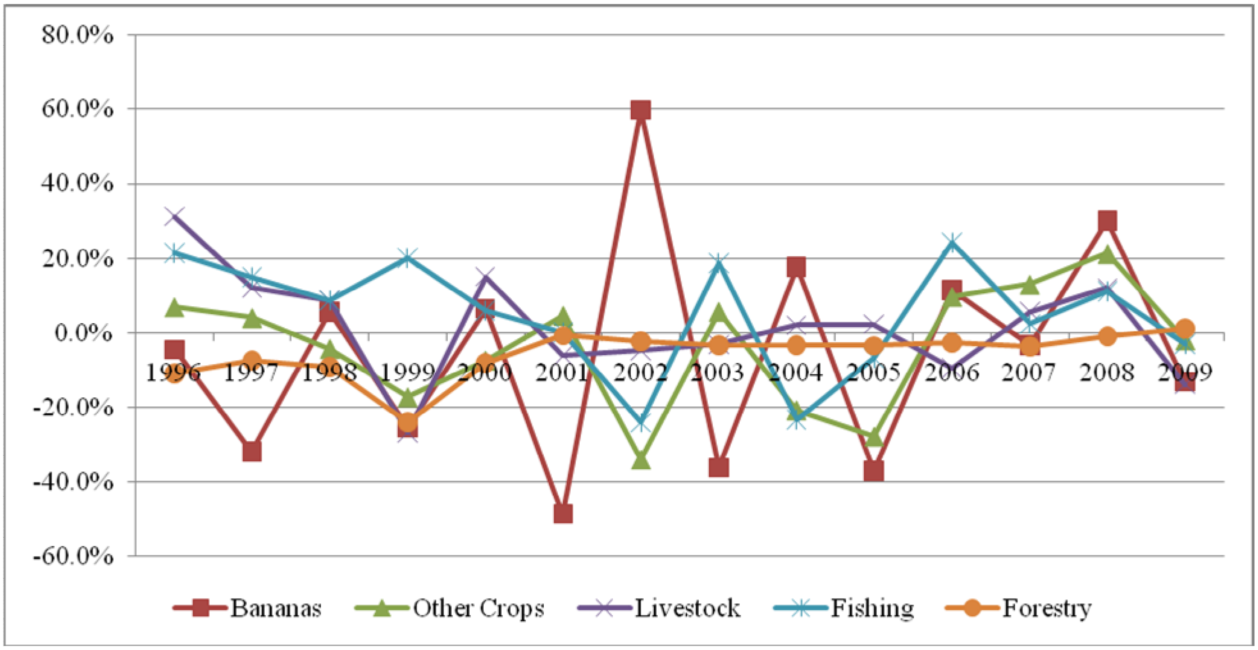
Figure 5: Percentage Contribution of Agriculture Subsectors in Saint Lucia



Source: Data compiled by author

Annual growth rates of each of the agricultural sub-sectors also showed a large degree of variability (Figure 6), especially for bananas, which had the largest changes historically. This may be a reflection of production "shocks' such as the occurrence of a tropical cyclone, or economic "shocks" which may affect investment in the sector.

Figure 6: Annual Growth Rates of Agriculture Sub-Sectors in Saint Lucia (%)



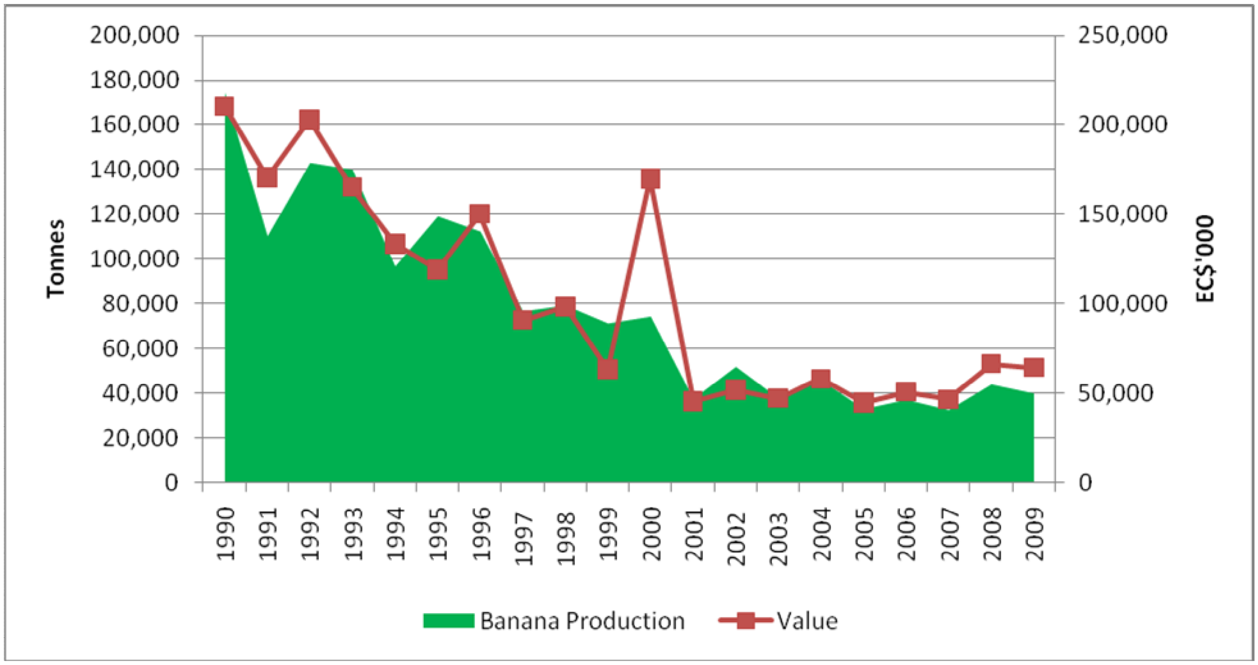
Source: Data compiled by author

St Lucia is the largest of the Windward Islands banana exporters, and has historically had this dominance. In 2009, banana exports from Saint Lucia were 33,925 tonnes, which accounted for 71.39% of total Windward Islands banana exports (Ministry of Finance, Economic Affairs & National Development 2010).

A. BANANAS

Under the Lomé Convention, banana exports from the Caribbean enjoyed preferential access to EU markets. This allowed them to be shielded from open market prices, as they received a price premium for their exports. Under this system, each country had an export quota, had a guaranteed price for bananas, this market was protected by exceedingly high out-of-quota costs to non ACP exporters. Ever since the early 1990s exports of bananas from Windward Islands producers have steadily declined, even though they had access to the EU market under preferential status. The shortfall in exports was filled by increasing exports from the Dominican Republic, and more so by African ACP countries, and producers in Latin America (FAO 2007). This decline in Windward Island bananas is reflected in the overall steady decline in banana production in Saint Lucia (Figure 7) and an associated decline in value.

Figure 7: Quantity and Value of Banana Production in Saint Lucia

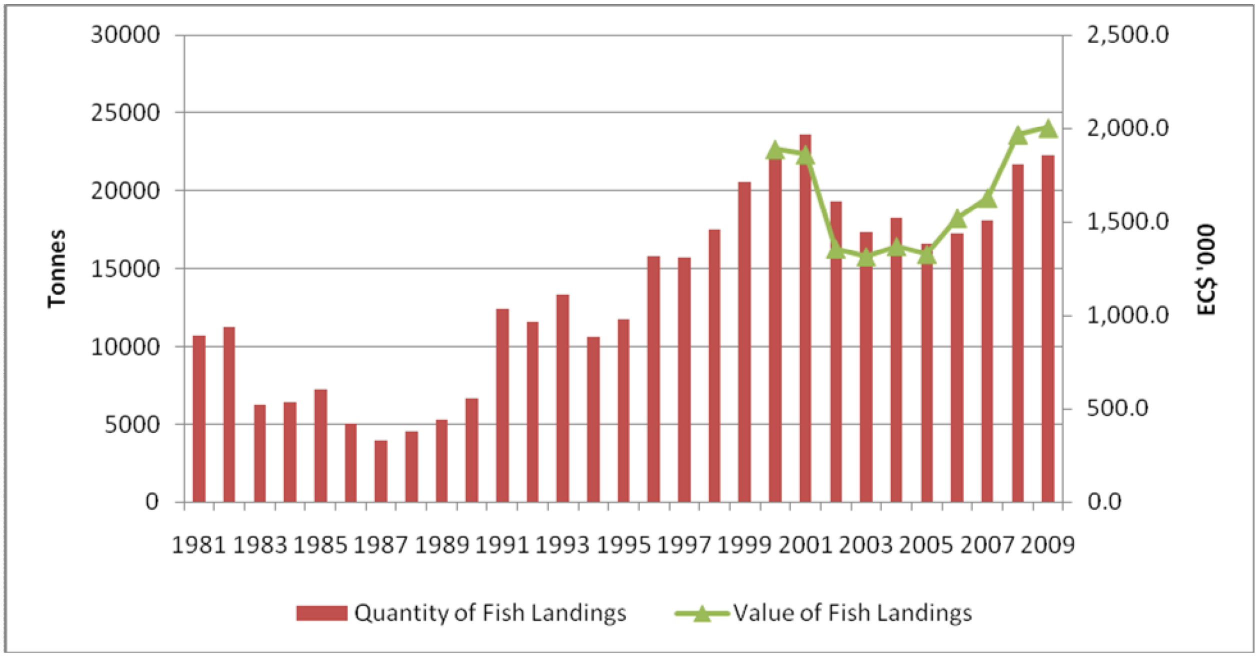


Source: Ministry of Agriculture, Lands, Forestry and Fisheries, Saint Lucia.

B. FISH LANDINGS

In the 1980s, fish landings in Saint Lucia showed an overall decline, but during the 1990s, the quantity of landings increased sharply (Figure 8), as the government began to see fisheries as an underexploited resource, and put policies and other measures in place to spur investment in this sub-sector and improve the livelihoods of fishing communities. In the 2000s, landings fluctuated, but remained high. Landings were subsequently further enhanced by the introduction of Fish Aggregating Devices (FADs), which provide an easy way of "finding" fish, reduces search time and the associated costs.

Figure 8: Quantity and Value of Aggregate Fish Landings in Saint Lucia, 1981 – 2009



Source: Department of Fisheries, Ministry of Agriculture, Lands, Forestry and Fisheries, Saint Lucia.

C. PHYSICAL AND SOCIO-ECONOMIC VULNERABILITIES OF THE CARIBBEAN

The Caribbean region is more vulnerable than many other Least Developed Countries (LDCs) when hurricanes and tropical storms strike, as the coast exposure is very high, relative to land mass (FAO 2007). In addition, hurricanes not only cause severe damage, but occur with a high frequency. In addition, vulnerability is increased, as a significant portion of the arable land in the Caribbean exists on steep slopes, which make them susceptible to soil erosion. Compared to LDCs, the per capita arable land availability is about half, which with the difficulty of achieving economies of scale due to the small populations, the productivity of agricultural production has declined over time.

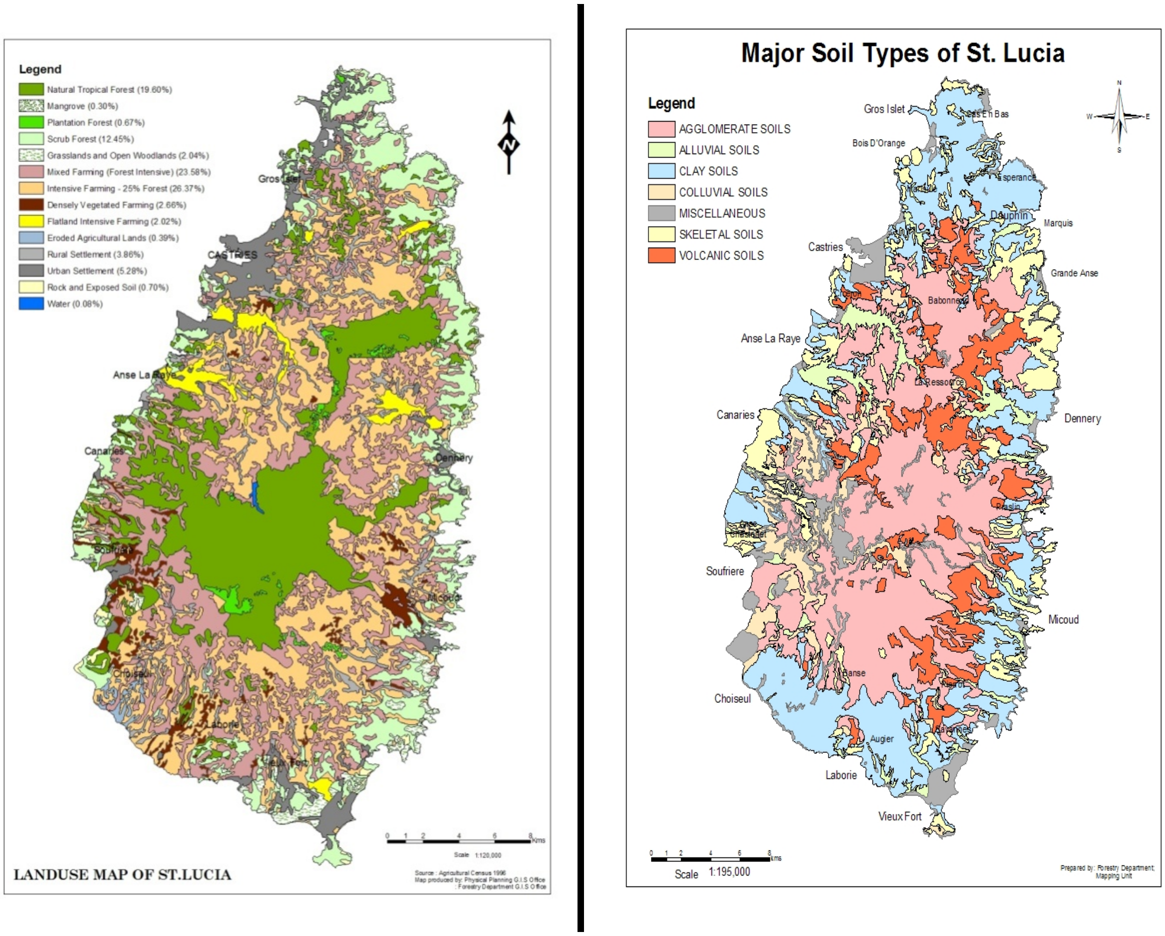
"As barriers to world trade are dismantled, the most competitive producers increase their market share. Caribbean economies have low levels of competitiveness due to higher unit costs of production (caused by scarce resources, high transport costs, low economies of scale, small size of firms, etc.) and thus their market share will decrease under the new conditions." FAO (2007)

Also, as a result of limited production diversity, most of the inputs needed for agricultural production, such as machinery, fertilizers and pesticides are imported, which further raises the vulnerability of the agricultural sector.

D. LAND RESOURCES

Most of the banana farming in Saint Lucia takes place in the pink and orange areas denoted as "Mixed Farming" and "Intensive Farming". Given that the centre of the island rises to a peak, much of this production takes place on gentle to steep slopes (Figure 9). Most of the soil under this use is also clay or agglomerate soils.

Figure 9: Land Use and Soil Types in Saint Lucia

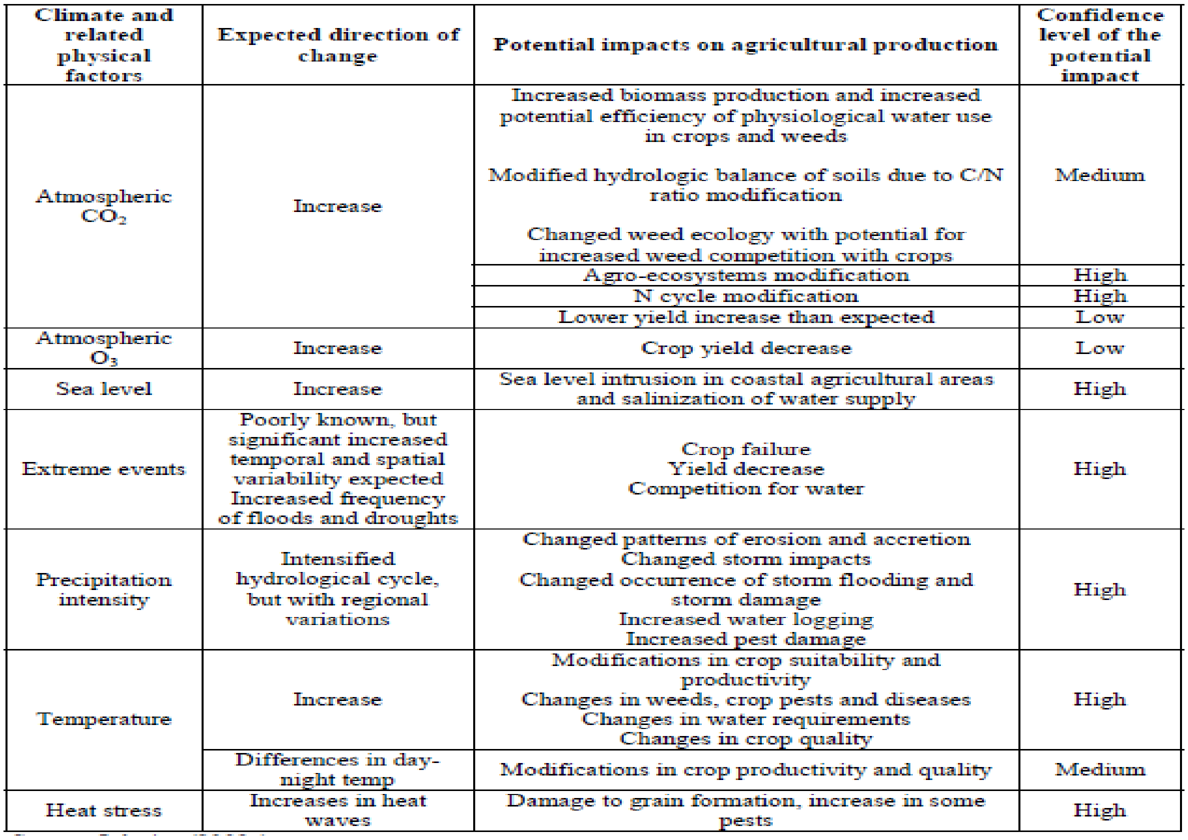


Source: Ministry of Agriculture, Lands, Forestry and Fisheries, St Lucia.

IV. CLIMATE CHANGE IMPACTS ON AGRICULTURE

Potential impacts of climate change on agriculture are quite varied. A summary of key potential climate impacts are shown in Table 2 below.

Table 2: Climate Change and Related Factors Relevant to Agricultural Production at the Global Scale



Climate and related physical factors	Expected direction of change	Potential impacts on agricultural production	Confidence level of the potential impact
Atmospheric CO_2	Increase	Increased biomass production and increased potential efficiency of physiological water use in crops and weeds Modified hydrologic balance of soils due to C/N ratio modification Changed weed ecology with potential for increased weed competition with crops	Medium
		Agro-ecosystems modification	High
		N cycle modification	High
		Lower yield increase than expected	Low
Atmospheric O_3	Increase	Crop yield decrease	Low
Sea level	Increase	Sea level intrusion in coastal agricultural areas and salinization of water supply	High
Extreme events	Poorly known, but significant increased temporal and spatial variability expected Increased frequency of floods and droughts	Crop failure Yield decrease Competition for water	High
Precipitation intensity	Intensified hydrological cycle, but with regional variations	Changed patterns of erosion and accretion Changed storm impacts Changed occurrence of storm flooding and storm damage Increased water logging Increased pest damage	High
Temperature	Increase	Modifications in crop suitability and productivity Changes in weeds, crop pests and diseases Changes in water requirements Changes in crop quality	High
	Differences in day-night temp	Modifications in crop productivity and quality	Medium
Heat stress	Increases in heat waves	Damage to grain formation, increase in some pests	High

Source: Iglesias *et al* (2009)

While many early climate models predicted very severe impacts on the world's food supply, more recent models have indicated there will be very negative impacts in some areas, especially in the tropics and in areas vulnerable to changes such as sea level rise, and in areas heavily dependent on rain fed agriculture (rural areas) for the sustenance for their livelihoods (Antle 2008). In many of these cases, incomes are very low, and there is a high dependence on agriculture. However, it is also likely that there will be positive impacts, particularly in upland tropical and temperate regions. So as food supply increases in some areas, this could offset the negative impacts in other areas via price reductions and international trade. Globally overall, the impacts of climate change may well be positive (Antle 2008).
Cline (2007) however, indicated that aggregate world agricultural impacts of climate change will be negative, though moderate, by late this century, which contradicts the view that world agriculture would actually benefit in the aggregate from business as usual global warming over that horizon. What is consistent, and key for the Caribbean, is that his work, like previous research agree that damages will be disproportionately concentrated in developing countries.

Further analysis therefore needs to assess the projected increases in temperature (and changes in rainfall) to add further information on potential impacts on production. Crop specific climate impacts such as these, are also discussed in Box 1 below.

Box 1: Crop Responses to Changing Climate

Crop responses in a changing climate reflect the interplay among three factors: rising temperatures, changing water resources, and increasing carbon dioxide concentrations. Warming generally causes plants that are below their optimum temperature to grow faster, with obvious benefits. For some plants, such as cereal crops, however, faster growth means there is less time for the grain itself to grow and mature, reducing yields.193 For some annual crops, this can be compensated for by adjusting the planting date to avoid late season heat stress.164 The grain-filling period (the time when the seed grows and matures) of wheat and other small grains shortens dramatically with rising temperatures.

Analysis of crop responses suggests that even moderate increases in temperature will decrease yields of corn, wheat, sorghum, bean, rice, cotton, and peanut crops. Some crops are particularly sensitive to high nighttime temperatures, which have been rising even faster than daytime temperatures.

…. Further, as temperatures continue to rise and drought periods increase, crops will be more frequently exposed to temperature thresholds at which pollination and grain-set processes begin to fail and quality of vegetable crops decreases. …Higher temperatures will mean a longer growing season for crops that do well in the heat, such as melon, okra, and sweet potato, but a shorter growing season for crops more suited to cooler conditions, such as potato, lettuce, broccoli, and spinach. Higher temperatures also cause plants to use more water to keep cool. …But fruits, vegetables, and grains can suffer even under well-watered conditions if temperatures exceed the maximum level for pollen viability in a particular plant; if temperatures exceed the threshold for that plant, it won't produce seed and so it won't reproduce.

Source: U.S. Global Change Research Program (2009)

V. LITERATURE REVIEW

Several approaches have been used to assess the impact of climate change on the agricultural sector. In some cases, impacts were measured in relation to specific dominant commodities, and other cases, the impact was measured on country – level impacts. Most of the models can be classified as:

1. Ricardian Models
2. Panel/Fixed Effects Models
3. Agroeconomic Models
4. Agroecological Models
5. Crop Production Functions

A. RICARDIAN MODELS (CROSS-SECTIONAL REDUCED-FORM HEDONIC PRICING MODELS)

By far, most of the literature has focused on the use of Ricardian Models. These models look at the impact of climate change on farm land value or net farm income. Theoretically, it is assumed that changes in farm output in terms of the quantity of products or the value of products, together with the opportunity cost of the land is reflected in the farm's land value. Farmland net revenues reflect net productivity. In addition, "*the value of a parcel of land should reflect its potential profitability, implying that spatial variations in climate derive spatial variations in land uses and in turn land values*." Its clear advantage is that if land markets are operating properly, prices will reflect the present discounted value of land rents into the infinite future (Deschenes and Greenstone 2006). In this case, farm land value is usually seen as dependent on output prices, labour costs, the level of capital investment, climate variables such as rainfall and temperature, and soil characteristics.

In addition, the effects are often modeled in terms of differences in the projected response of agricultural systems that are either rain fed or irrigated. This model has been used primarily for agricultural systems in Africa (Kurukulasuriya and Mendelsohn 2008a; Kurukulasuriya and Mendelsohn (2008b), Sri Lanka (Seo, Mendelsohn and Munasinghe 2005; Deressa and Hassan 2009; Molua and Lambi 2007; Deressa, Hassan and Poonyth 2005; Maddison, Manley and Kurukulasuriya 2007; Seo and Mendelsohn 2006; Kurukulasuriya *et al* 2006), Latin America (Seo and Mendelsohn 2008; Seo and Mendelsohn 2007), and the US (Schlenker, Hanemann and Fisher 2006).

The main strength in this kind of model is that it incorporates the possibility of farmers adapting to climate change over time, using a number of mechanisms such as changing the type of crops or livestock farmed, changing crop varieties or livestock breeds, changing sowing times (in response to changing climatic conditions), or changing their production systems (by employing additional and/or different hard or soft technologies). Since farm-level data is used, the impacts of climate change in the Ricardian model is determined from the changes in farm output from farms which are located in wide variety of climatic zones (with distinct variations in soil and climate parameters).

Based on work in Zimbabwe by Mano and Nhemachena (2007), which utilized surveys of 700 smallholder farm households, temperature and precipitation were found to have significant impacts on net farm revenues. Net farms incomes were negatively affected by temperature increases and benefitted from increases in rainfall. Seo, Mendelsohn and Munasinghe (2005) also found similar temperature and precipitation effects in Sri Lanka. Further, based on sensitivity analysis, net farm incomes for farms which utilized rain fed systems were very sensitive to changes in these climatic variables, relative to irrigated farms. This suggested that irrigation is an important adaptation strategy in the face of climate change. It was also discovered that farmers in Zimbabwe were already adapting to climate change by planting drought-resistant crops, changing planting dates and using irrigation.

A criticism of this model is that it may fail to include other variables that are also expected to affect farm net incomes, such as market access and soil quality, but for which data may be scarce. In such cases, the model may be subject to misspecification errors. In a climate change scenario, it is likely that agricultural output levels will change, which will affect prices. Since the Ricardian model also assumes that prices remain constant, this is another limitation, so that damages may be understated (as potential price drops are ignored) and benefits could be overstated (as increased supply values are inflated) (Mano and Nhemachena 2007). The method also cannot measure the effect of variables that do not vary across space such as CO_2 (Seo, Mendelsohn and Munasinghe 2005).

Another flaw of the Ricardian model is that it is static and therefore assumes that technology, policy and land use (which all have significant impacts on farmers' production decisions) do not change. In a country like Zimbabwe, the model also does not always take into account the potential for water supply, whether within or outside the country borders, and instead relies in rainfall impacts only. This is seen as another shortcoming. Therefore in the study by Mano and Nhemachena (2007), runoff is taken as a proxy for surface water availability.

Once the relationship between the climatic and other independent variables on net farm income was established, projections for various global climate scenarios were then undertaken. Seo, Mendelsohn and Munasinghe (2005) confirms that based on their research findings for Sri Lanka, and the findings of others, climate change damages could be large in tropical developing countries, but highly dependent on the actual climate scenario. Analyses that do not include efficient adaptation (such as the early agronomic studies) overestimate the damages associated with any deviation from the optimum. Adaptation can explain the more optimistic results found with the Ricardian method compared to more pessimistic results found in purely agronomic studies (Kurukulasuriya and Mendelsohn 2008a).

B. PANEL/FIXED EFFECTS MODELS

The Ricardian model was also extended to a panel data model (Polsky 2004), which may also be conditional on county and state by-year fixed effects, for assessing the impact of climate in the US (Deschenes and Greenstone 2006). They found that the predicted increases in temperature and precipitation will have virtually no effect on yields among the key crops (corn for grain, soybeans, and wheat), even though there is a wide disparity in the results across states, with some states suffering significant losses, while others benefitting from climate change.

"This approach differs from the hedonic one in a few key ways. First, under an additive separability assumption, its estimated parameters are purged of the influence of all unobserved time invariant factors. Second, it is not feasible to use land values as the dependent variable once the county fixed effects are included. This is because land values reflect long run averages of weather, not annual deviations from these averages, and there is no time variation in such variables.

Third, although the dependent variable is not land values, our approach can be used to approximate the effect of climate change on agricultural land values. Specifically, we estimate how farm profits are affected by increases in temperature and precipitation. We then multiply these estimates by the predicted changes in climate to infer the impact on profits. Since the value of land is equal to the present discounted stream of rental rates, it is straightforward to calculate the change in land values when we assume the predicted change in profits is permanent and make an assumption about the discount rate." (Deschenes and Greenstone 2006).

This approach was also applied in Deschenes and Greenstone (2004, 2007).

C. AGRONOMIC-ECONOMIC CROP MODELS

This approach to modeling climate change impacts in agriculture uses well-calibrated crop models from carefully controlled experiments in which crops are grown in field or laboratory settings that simulate different levels of precipitation, temperature and carbon dioxide. Under these conditions, farming methods are not allowed to vary. In addition, farmers' adaptation to changing climate cannot be captured in these models. Scientists are able to estimate a yield response of specific crops to various conditions. The presumed changes in yields from the agronomic model are fed into an economic model, which determines crop choice, production, and market prices.

Rosenzweig and Parry (1994) predicted that doubling of atmospheric carbon would have only a small negative effect on global crop production, but the effects would be more pronounced in developing countries. Cline (2007) predicted overall significant falls in overall yields in Sub-Saharan Africa, using various global circulation models. Parry *et al* (2004) used this approach to estimate the potential impacts of climate change on global food production for the A1FI, A2, B1, and B2 IPCC climate change scenarios developed from the HadCM3 global climate model.

(Finger and Schmid 2007) also used an agronomic model to analyze corn and winter wheat production on the Swiss Plateau with respect to climate change scenarios. Yield functions were also modeled by Furuya, S. Kobayashi, and S. D. Meyer (2009), using subsidized producer price, and a time trend, in addition to temperature and precipitation variables.

D. AGRO-ECOLOGICAL ZONE MODELS (ALSO CALLED THE CROP SUITABILITY APPROACH)

In this case crops are categorized into various agro-ecological zones and yields are then predicted. These models combine crop simulation models with land-use decision analysis and model changes in inputs and climate variables to assess changes in agricultural production, assuming that lands can shift from one agro-ecological classification to another with changes in environmental conditions (Cline, 2007). The agro-ecological models examine changes in agro-ecological zones and crops as climate changes and predict the effect of alternative climate scenarios on crop yields. Economic models then use the projected changes in yields to predict the overall supply effects.

One of the biggest advantages associated with agroecological zonesis that the geographic distribution of the zones in [many] developing countries has been published (Mendelsohn and Dinar 1999). However, there are still many problems. The climate zones usually represent large temperature categories, so that subtle shifts within a zone have no effect but a small shift from one zone to another has a dramatic consequence. Further, the effects of soils and climate are computed independently, which ignores the interrelationship of these variables. Here, as with the agroeconomic models, researchers must explicitly account for adaptation. Large price changes along with small changes in aggregate supply have often been found, indicating that there may be problems with the calibration of the underlying economic model (Mendelsohn and Dinar 1999).

Some of the models have also been developed at the global scale, such as Golub, Hertel and Sohngen (2007), who estimated a linked supply and demand model for global land using a dynamic general equilibrium (GE) model that predicts economic growth in each region of the world, based on exogenous projections of population, skilled and unskilled labor and technical change, and that differentiate the demand for land by Agro-Ecological Zone (AEZ).

E. CROP PRODUCTION FUNCTIONS

Production function models generally link the outputs of crops or livestock as functions of inputs to the production process, such as land, labour, capital and entrepreneurial skill. These inputs can be incorporated individually, or as an index, such as the Laspeyres Quantity Index, which can combine any physical inputs together. As was shown for Spain by Quiroga Gómez and Iglesias (2005), these types of models utilized panel data to estimate the relationship between production (such as tonnes per hectare) as a function of socio-economic and climate variables in various agro-climatic zones. In this case, not only was the impact of mean temperature analyzed, but also the impact of maximum temperature, minimum temperature and years for which annual rainfall fell below the mean (considered to be “dry” years) for the period under consideration. In addition, the impacts of various technological variables were also included such as machinery value, fertilizer use, pesticide imports, and % irrigated land for production of wheat, grapes, olives and oranges.

While the production function approach is the least common approach used to model the impacts of climate change on agricultural outputs to date, it is empirically sound. According to Deschenes and Greenstone (2006), the production function approach provides estimates of weather effects on crop yields that do not include bias due to agricultural output factors that are beyond farmers’ control such as soil quality. On the other hand, these authors noted that a disadvantage is that production function estimates do not account for the full range of adaptation responses that farmers can make to changes in weather in order to maximize their profits. Since farmer adaptations are completely constrained in the production function approach, it is likely to produce estimates of climate change that are biased downwards.

JieMing, WenJie and DuZheng (2007) evaluated the impact of climate changes on grain yields in China, using the Cobb-Douglas production function. In this study, a monthly climate drought index was calculated (i.e. the monthly rainfall anomaly divided by the normal of this monthly rainfall), together with a climate input indicator to analyze and verify the relationship between yearly grain yield and yearly key month drought index.

One advantage of the production function approach is that historical farm-level and aggregated data takes into account farmers' historical reactions to changes in climatic and economic conditions. However, this historical data is not able to capture future plant-climate interactions in a sufficient manner, especially where the crop-weather relationship is restricted to a few variables such as temperature and rainfall. In addition, these models cannot sufficiently integrate expected CO_2 fertilization effects on plants due to low variation in historical CO_2 concentrations (Finger and Schmid 2007).

Gay *et al* (2006) determined the relation between coffee production in Veracruz, Mexico and economic and climatic variables. The model showed that temperature was the most relevant climatic factor for coffee production, and that coffee production might not be economically viable for producers, since the model predicts a fall in production by 34%. The model used mean seasonal temperature, mean seasonal precipitation, and the seasonal variance of climatic variables. In addition, economic variables such as state and international coffee prices, a producer price index for raw materials for coffee, and national and US coffee stocks were considered as well as the state real minimum wage, as a proxy for the price of labor employed for coffee production. These variables however, were not all modeled at the same time, due to the limited number of production data. Gay *et al* (2006) suggested that other explanatory variables could be used to assess climate change impacts on cop production. These include: seasonal averages of precipitation and temperature (linear and quadratic), their variations from a 20 year mean value, the percentage of full-time farm households, land slope and a time trend to account for technology changes.

Other models utilized economy-wide, global computable general equilibrium model such as the one used by Zhai, Lin, and Byambadorj (2009) who computed the impacts of climate change on the Republic of China's agricultural sector. Bosello and Zhang (2005) also used a global general equilibrium model.

F. SUMMARY

All of the above mentioned models were theoretically appropriate for use in modeling agricultural production in Saint Lucia, however, given that household level data on output, prices and input use were no available, the utilization of the Ricardian model, the fixed effects model and agroeconomic model had to be ruled out. Therefore, only the production function approach could be considered.

VI. DATA

Rainfall and temperature data were obtained from the Caribbean Institute of Meteorology and Hydrology (CIMH) for 1973 – 2008 via personal communication and its online database[3] for the Husbands site. The Consumer Price Index (CPI) for Saint Lucia was computed from data obtained from three sources: The Easter Caribbean Central Bank (2006-2008); the Saint Lucia Central Statistical Office (1987 -2005) and Nationmaster.com (1981 – 2004). Real prices were calculated using the CPI, with 2008 as the base year.

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[3] Rainfall data for 2006 and 2007 were used from the University of Delaware Monthly Gridded Air Temperature Database. Some monthly gas in data existed for rainfall and temperature in 1973, 1976, 1978 and 1979.

For the PRECIS model the mean annual rainfall and mean monthly temperature were 771 mm and 26.22 °C respectively. Since there was a large difference between the historical means for rainfall and the PRECIS estimates, and based on the advice of INSMET in Cuba via personal communication, the model anomalies were used. The ECHAM anomalies for the estimated A2 and B2 climate variables were added to the mean historical rainfall and temperature for 1973-1990, a similar period used as the base period in the ECHAM model (1961-1990), to determine the future climate levels under the A2 and B2 scenarios.

The nominal cost of the import value of NPK fertilizers was used as a proxy for production costs, as NPK fertilizers are used in banana production, and represent a significant input in the traditional banana production system (relative to the Fair Trade banana production system). Since data on banana production were only available from 1990 – 2009, banana export quantities were used as a proxy for production, to allow the use of a longer time series. This information was obtained from 1981 – 2008, in tonnes from various Saint Lucia Annual Agricultural Statistical Digests. Price ($/tonne) was obtained from the same source, based on the price paid to the Saint Lucia Banana Growers Association for these exports. A dummy variable was created for years in which Saint Lucia experienced a tropical storm or hurricane (a value of 1; 0 otherwise). These data were obtained from CDERA's online database for Saint Lucia. Data on input use for labour, machinery, fertilizers or pesticides were not available from either the Saint Lucia Central Statistical Office, or online trade data bases consistently for the model period. In cases where some data were available, such as at FAOSTAT, the variable values changed very infrequently over the estimation period and were largely FAO estimates. These data were therefore not utilized.

Other Crops was made up of 24 commodities: sweet potato, yams, tannia, tomatoes, cabbage, cucumber, carrot, sweet pepper, ockro, melon, pumpkin, ginger, lime, sweet orange, grapefruit, avocado, dasheen, plantain, lettuce, breadfruit, soursop, hot pepper, mango and pineapple. Production and value data for these crops were obtained from the Ministry of Agriculture, Lands, Forestry and Fisheries Statistical Unit, via personal communication. This information was only available for 1990 – 2008. Associated data on area under production, or input use in each year were not available. Similar data problems as reported for banana above were encountered.

The quantity of fish landed were obtained from the Fisheries Division, Ministry of Agriculture, Lands, Forestry and Fisheries, Saint Lucia from 1981 – 2009. From this source, the value of these landings were only available from 2000-2009, based on ex-vessel prices. Value of Landings from 1981-1999 were derived from per pound annual estimated values of fish, obtained from the Saint Lucia Central Statistical Office. Number of trips taken per year (obtained from the Department of Fisheries) was only available for 2001-2009.

VII. METHODOLOGY

Tests of the stationarity of all model variables (logged) were done. The tests conducted were: the Augmented Dickey-Fuller (ADF) test, the Phillips-Perron (PP) test and the Kwiatkowski, Phillips, Schmidt, and Shin (KPSS) Unit Root test Based on these, several of the model variables were found to be non-stationary. Tests for cointegration were then performed using the Engle-Granger procedure, as well as the Johansen system approach. In cases where cointegration was found, an Error Correction Model was estimated. Where the variables were not cointegrated, models using the differenced non-stationary variables were estimated.

A. BANANAS

Based on a Production function framework, banana exports (QB) in the current period were estimated as a function of the current real export price (PBR), the presence of a tropical cyclone (H), rainfall (RAIN) and temperature (TEMP) and the real cost of fertilizer (COSTFR). It was also assumed that the presence of a tropical cyclone in the previous year would negatively affect banana exports in the current period, as banana plants damaged in these events are no longer usually productive. The plants are removed, and new plants established. This process of clearing of damaged plants and re-growth usually takes from 9-12 months. The squared climate variables were included as it was assumed that the effect of increasing levels of these variables exhibited diminishing returns. Where the squared term was found to be insignificant at conventional levels, the variables was dropped from the model. All variables in the paper were estimated in logged form, except the cyclone dummy. A Vector Error Correction Model was estimated for banana exports, with banana exports and export price as the dependent variables:

$$D(QB) = A_{1,1}[ECT] + C_{1,1}D(QB(-1)) + C_{1,2}D(PBR4(-1)) + C_{1,3} + C_{1,4}H + C_{1,5}H(-1) + C_{1,6}RAIN + C_{1,7}(RAIN)\hat{}2 + C_{1,8}TEMP + C_{1,9}COSTFR + \mu \qquad Eq1$$

$$D(PBR4) = A_{2,1}[ECT] + C_{2,1}D(QB(-1)) + C_{2,2}D(PBR4(-1)) + C_{2,3} + C_{2,4}H + C_{2,5}H(-1) + C_{2,6}RAIN + C_{2,7}(RAIN)\hat{}2 + C_{2,8}TEMP + C_{2,9}COSTFR + \mu \qquad Eq2$$

where ECT (Error Correction Term) $= B_{1,1}QB(-1) + B_{1,2}(PBR4(-1)) + B_{1,3}TREND + B_{1,4}$ Eq3

QB = quantity of bananas exported (tonnes)
PBR = Real banana export price ($/tonne)
H = Incidence of a tropical cyclone
Temp = mean monthly temperature (°C)
Rain = mean monthly rainfall (mm)

A huge spike in fertilizer prices in 2008, changed the fertilizer variable to an I(1) variable when the 2008 data point was included, but was stationary when 2008 was excluded. Visual inspection of the real fertilizer price variable suggested that it had a stationary mean and variance, so the model was estimated for 1981 – 2007 and forecasted to 2050 using actual variable values for 2008.

1. Other crops

Initial models of the relationship between other crops (as a single group) and the variables used in the banana model, resulted in unexpected signs for the climate variables, as well as the temperature variable being insignificant. Therefore the group of 24 crops was divided into types of crops with similar characteristics: root crops, tree crops and vegetable crops, and the estimation done on these three sub-groups.

For 1990 – 2008, all the crop yields and prices, together with the temperature variable were found to be I(1). For root crops, these non-stationary variables were not cointegrtaed, therefore a model of differenced variables was estimated:

$$D(QRC) = A_1 + C_1D(RPRC) + C_2H + C_3RAIN + C_4TEMP + C_5D(COSTFR(-1)) + \mu \qquad Eq4$$

where QRC = Root crop yield (tonnes)
RPRC = Real weighted root crop price ($/kg)

For tree crops and vegetable crops, these non-stationary variables were cointegrtaed, therefore Vector Error Correction Models were estimated for each, with the differenced non-stationary variables as the dependent variables in the system. The equations with yield as the dependent variable are shown:

$$D(TC) = A_{1,1}[ECT] + C_{1,1}D(QTC(-1)) + C_{1,2}D(RPTC(-1)) + C_{1,3}D(TEMP(-1)) + C_{1,4}H + C_{1,5}RAIN + \mu \qquad Eq5$$

where **ECT** (Error Correction Term) = $B_{1,1}QTC(-1) + B_{1,2}(RPTC(-1)) + B_{1,3}TEMP(-1) + B_{1,4}$ *Eq6*
QRC = Root crop yield (tonnes)
RPRC = Real weighted root crop price ($/kg)

and

$$D(QVC) = A_{1,1}[ECT] + C_{1,1}D(QVC(-1)) + C_{1,2}D(RPVC(-1)) + C_{1,3}D(TEMP(-1)) + C_{1,4}H + C_{1,5}RAIN + \mu \quad Eq7$$

Where **ECT** (Error Correction Term) = $B_{1,1}QVC(-1) + B_{1,2}(RPVC(-1)) + B_{1,3}TEMP(-1) + B_{1,4}$ *Eq8*
QVC = Vegetable crop yield (tonnes)
RPRC = Real weighted vegetable crop price ($/kg)

For the fisheries sub-sector, secondary research was used to estimate losses to 2050. All models were estimated using *Eviews* Version 7.

VIII. RESULTS AND FORECASTS

A. BASE PERIOD

For the base period of 1981-2008, an average of 75,674 tonnes of bananas per year were exported at a price of $1,791.98/tonne (Table 3). Average monthly rainfall was 128.87 mm and average temperature was 27.04°C.

Table 3: Descriptive Statistics of Banana Model Variables

	Banana Exports (tonnes)	**Real Export Price ($/tonne)**	**RAIN**	**TEMP**	**Real Cost of Fertilizer ($/tonne)**
Mean	75673.82	1791.976	128.8696	27.04732	1370.023
Median	70493.50	1680.664	121.1000	27.16458	1150.661
Maximum	136102.0	2451.840	204.1250	27.80833	5811.321
Minimum	30007.00	1388.345	86.25833	25.50000	758.5485
Std. Dev.	35974.46	339.7728	27.39374	0.573640	905.1439
Jarque-Bera	2.407111	2.626548	7.321650	8.941658	525.2768
Probability	0.300125	0.268938	0.025711	0.011438	0.000000
Observations	28	28	28	28	28

Source: Data compiled by author

For the period of 1990-2008, the yields and prices of other crops are shown in Table 4. Vegetable crops had the highest unit price ($4.31/kg), but the tree crops accounted for the largest quantities, with average yield of 7,350 tonnes per year.

Table 4: Descriptive Statistics of Yield and Prices of Other Crops

	Yield of Tree Crops ('000 kg)	Yield of Root Crops ('000 kg)	Yield of Vegetable Crops ('000 kg)	Real Price of Tree Crops ($/kg)	Real Price of Root Crops ($/kg)	Real Price of Vegetable Crops ($/kg)
Mean	7350.474	1290.766	1850.210	1.562864	3.698323	4.308814
Median	7475.700	1212.030	1758.100	1.616129	3.642649	4.394420
Maximum	11769.10	2943.700	2757.700	2.264006	5.190313	5.452781
Minimum	3687.500	705.6142	1245.516	0.994980	1.626521	2.224696
Jarque-Bera	1.481393	19.12657	1.680757	1.431404	1.738889	9.716268
Probability	0.476782	0.000070	0.431547	0.488849	0.419184	0.007765
Observations	19	19	19	19	19	19

Source: Data compiled by author

Model variables are shown in Figures 10 and 11 below.

Figure 10: Annual Values of Model Variables (in levels), 1981-2008

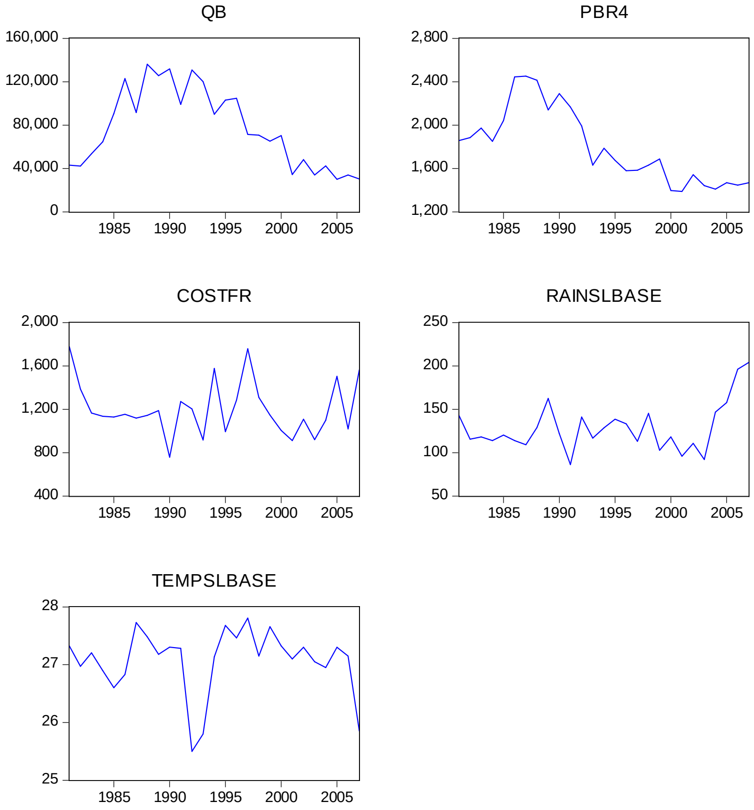
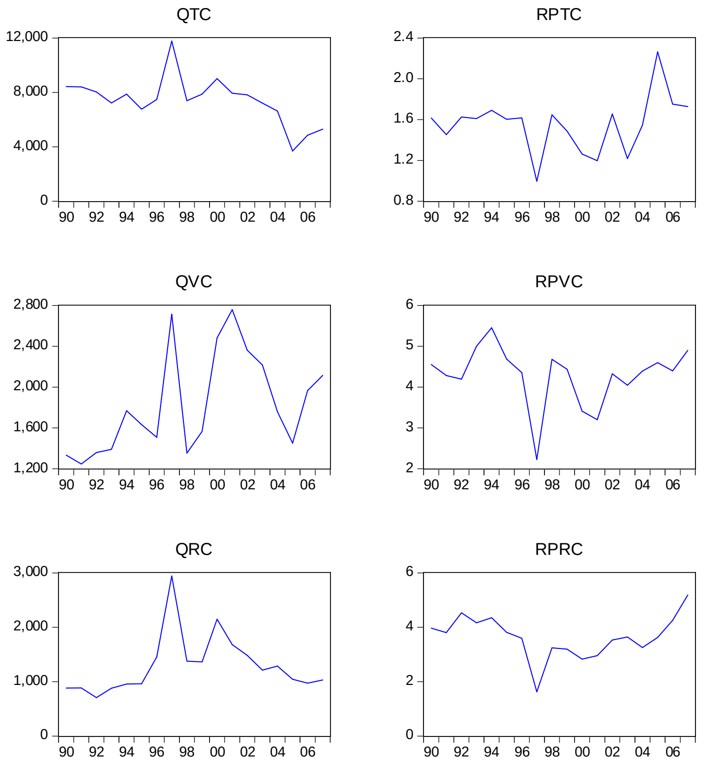
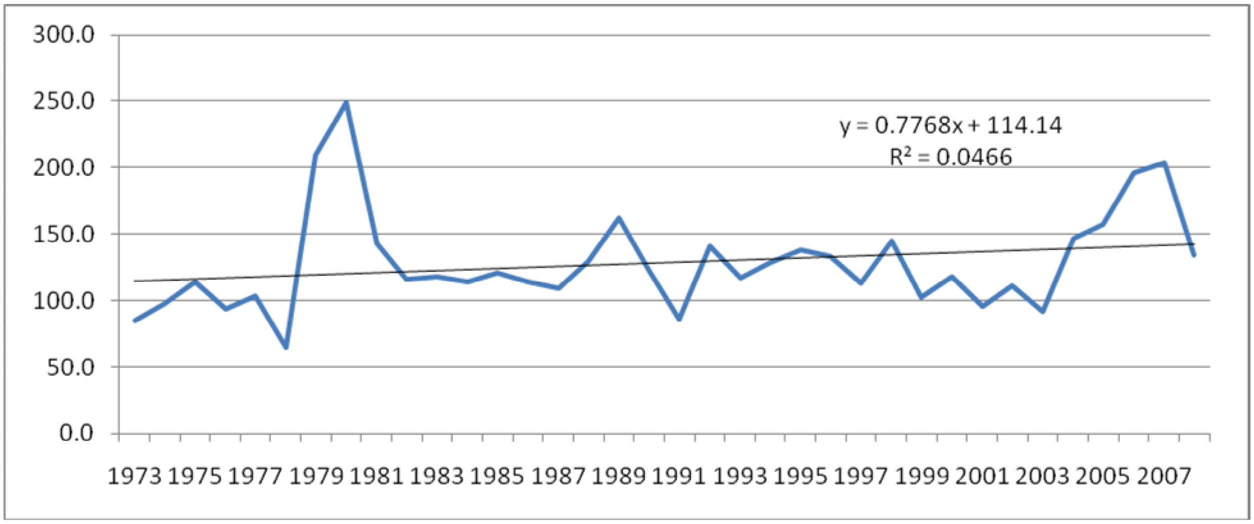


Figure 11: Annual Values of Other Crop Variables (in levels), from 1990-2008



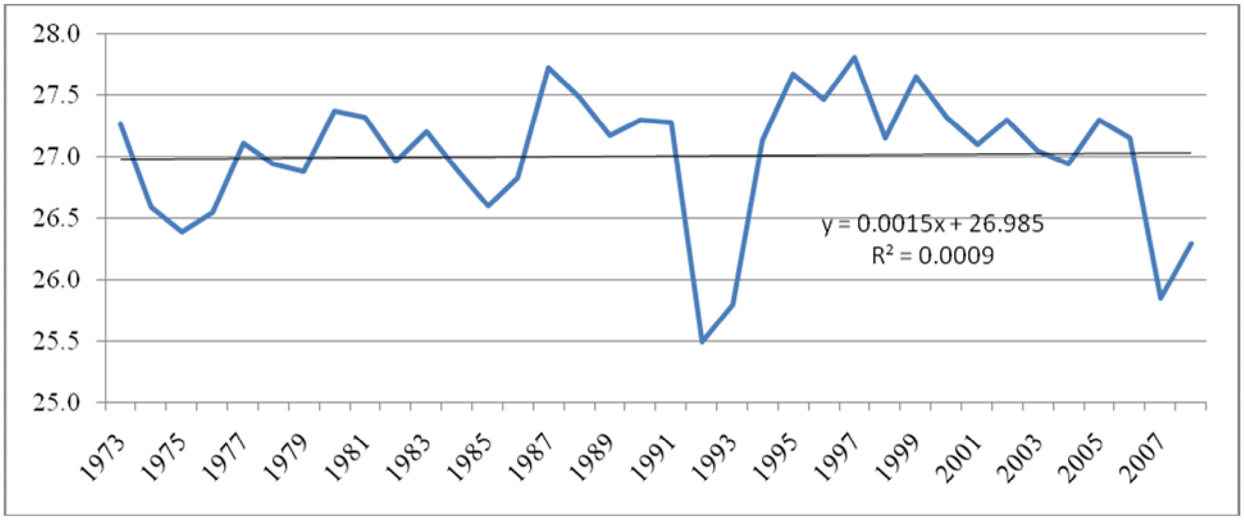
From 1973 to 2008, average monthly rainfall and temperature showed a slightly upward trend, but with high variability in each case (Figures 12 and 13).

Figure 12: Historical Mean Monthly Rainfall – Saint Lucia (1973-2008) (mm)



Source: Data compiled by author

Figure 13: Historical Mean Monthly Temperature – Saint Lucia (1973-2008) (°C)



Source: Data compiled by author

B. BASELINE CASE

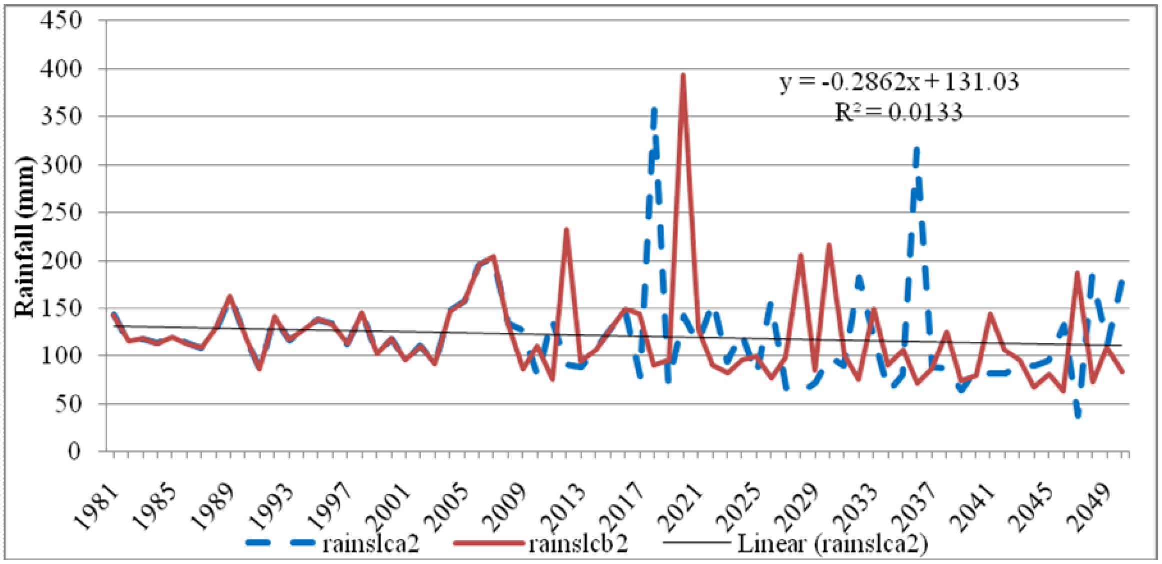
The impact of climate change was compared to a "no climate change" baseline, which, similar to (ECLAC 2010), adopted the period 1980 – 2000. Therefore, the mean monthly temperature and rainfall for this period was used for the projected climatology under this baseline case. It was also assumed that the real price of bananas remained unchanged at the 2008 price of $1,535.68/tonne, as for approximately from 2000 to 2008, the real price has been fairly stable, despite having reached much higher levels in the 1980s. Hurricanes are assumed to follow the historical average of 1 in every 4 years, taking into consideration the incidence of Hurricane Tomas in 2010.

In 2008, there was a major spike in global fertilizer prices, with urea prices rising by 59%, for example. Prices subsequently fell drastically by the end of 2008, and in some cases have returned to 2007 levels. From 1981 to 2007 the real cost of fertilizer was estimated to fall by $2.84/tonne annually (which was reversed if the 2008 spike was included). Given the current and anticipated continued increase in energy prices, it is assumed that the real price of fertilizer will remain unchanged at the 2007 price ($1,563.80) to 2050. The real price of each crop sub-group was also assumed to remain constant at the 2008 level, through to 2050.

C. A2 AND B2 SCENARIOS

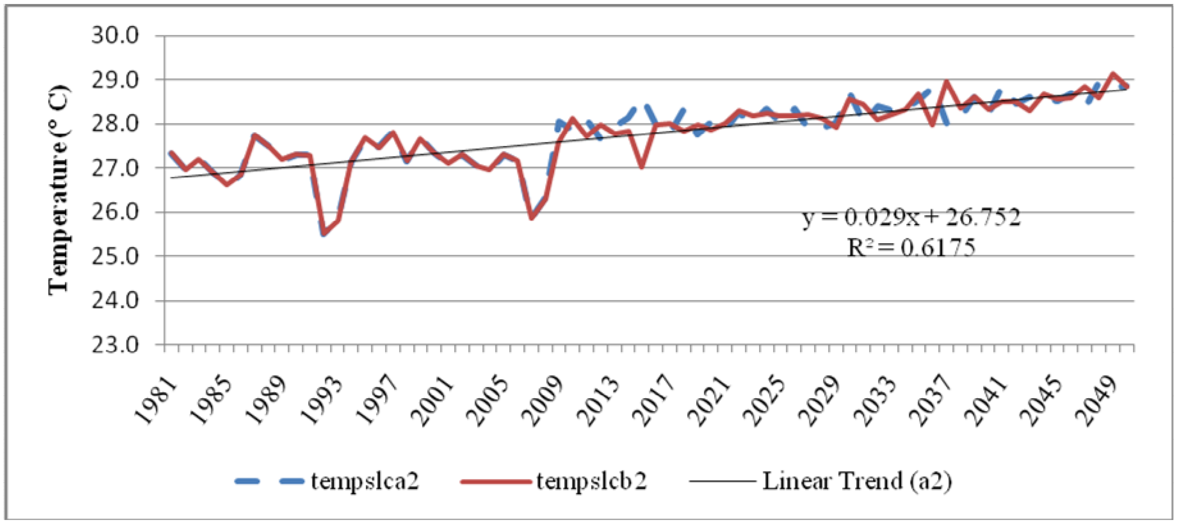
In each of these scenarios, the same assumptions for the behavior of the non-climate variables in the baseline case into the forecast period were made, except for temperature and precipitation where the forecasted A2 and B2 values (based on the PRECIS ECHAM model) were utilized. Graphical forecasts of rainfall and temperature to 2050 are shown in Figures 14 and 15 below.

Figure 14: Historical and Projected Mean Monthly Rainfall – Saint Lucia for the A2 and B2 Scenarios



Source: Data compiled by author

Figure 15: Historical and Projected Mean Monthly Temperature – Saint Lucia for the A2 and B2 Scenarios



Source: Data compiled by author

For the A2 scenarios, rainfall is expected to change greatly through to 2020 (see Table 5), increasing slightly by approximately 5% in the current decade, then fall rapidly by approximately 21% in the 2020s, and remaining below the baseline mean, ending with a 17% reduction by the 2040s. The B2 scenario exhibited similar swings, and by the 2040s, rainfall is expected to fall by approximately 22% under this scenario. Over the same period, temperature is expected to increase by 1.53°C and 1.52°C under A2 and b2 respectively.

Table 5: Historical and Projected Mean Monthly Temperature – Saint Lucia for the A2 and B2 Scenarios

	2011-2020		2020s		2030s		2040s	
	A2	B2	A2	B2	A2	B2	A2	B2
Mean Temperature (1980-2000) = 27.13°C								
Temp (°C)	28.03	27.80	28.13	28.19	28.33	28.40	28.66	28.65
Temp (°C Δ)	0.90	0.67	1.00	1.06	1.20	1.27	1.53	1.52
Mean Rainfall (1980-2000) = 129.53 mm								
Rain (mm)	135.41	151.23	102.89	117.91	118.0	96.2	108.3	101.3
Rain (% Δ)	4.54	16.75	-20.57	-8.97	-8.90	-25.70	-16.43	-21.79

Source: Data compiled by author

D. BANANAS

Tests of the stationarity of all model variables (logged) were done (see Table 6 below). The tests conducted were: the Augmented Dickey-Fuller (ADF) test, the Phillips-Perron (PP) test and the Kwiatkowski, Phillips, Schmidt, and Shin (KPSS) Unit Root test Based on these, banana export quantities, the real banana price, and the real cost of fertilizer were found to be non-stationary, I(1) variables.

Table 6: Results of Unit Root tests for logged model variables

Variable	**Unit Root Tests**			**Unit Root**[1]
	ADF (Probability Values)	**PP (Probability Values)**	**KPSS (LM-Stat)**[2]	
Qb	0.1625	0.6325	0.336	Yes
Pbr4	0.7080	0.7314	0.502	Yes
Costfr	0.3811	0.3464	0.210	Yes
Rain	0.0153	0.0154	0.201	No
Temp	0.0104	0.0104	0.290	No

Source: Data compiled by author

[1] Assumed an intercept in the test equation. [2] Critical values = [1%, 0.7390; 5%, 0.4630; 10%, 0.3470]

Using the Engle-Granger procedure, the residuals of the cointegrating equation *(LOG(QB) = C(1) + C(2)*LOG(PBR4) +* ϕ*)* were non stationary. Probability values of the unit root tests were: ADF - 0.8462; PP - 0.5384 and the KPSS statistic was 0.4411.

However, the residuals of the equation D(Resid)$_t$ = Resid$_{t-1}$ + μ had a significant coefficient (0.0257), which indicates that the residuals of the cointegrating equation is stationary (Enders 1995), which is contrary to the previous test results. The Engle-Granger Single Equation Cointegration test failed to reject the null hypothesis that the series for banana exports and price were not cointegrated (tau-statistics probabilities of 0.5812 and 0.2109 respectively). However, Trace and Max-Eigenvalue statistics in the Johansen System Cointegration test indicated the presence of one cointegrating relationship as shown in Table 7 below.

Table 7: Results of Johansen System Cointegration Test

Sample: 1990 2007
Included observations: 18
Trend assumption: Linear deterministic trend (restricted)
Series: LQB LPBR4
Exogenous series: H H(-1) LOG(RAINSLBASE) LOG(RAINSLBASE)^2 LOG(TEMPSLBASE)
Warning: Critical values assume no exogenous series
Lags interval (in first differences): 1 to 1

Unrestricted Cointegration Rank Test (Trace)

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**
None *	0.683506	28.58952	25.87211	0.0224
At most 1	0.354581	7.881390	12.51798	0.2615

Trace test indicates 1 cointegrating eqn(s) at the 0.05 level
* denotes rejection of the hypothesis at the 0.05 level
**MacKinnon-Haug-Michelis (1999) p-values

Unrestricted Cointegration Rank Test (Maximum Eigenvalue)

Hypothesized No. of CE(s)	Eigenvalue	Max-Eigen Statistic	0.05 Critical Value	Prob.**
None *	0.683506	20.70813	19.38704	0.0320
At most 1	0.354581	7.881390	12.51798	0.2615

Max-eigenvalue test indicates 1 cointegrating eqn(s) at the 0.05 level
* denotes rejection of the hypothesis at the 0.05 level
**MacKinnon-Haug-Michelis (1999) p-values

Given the close movement of banana exports and its price from visual inspection, it is assumed that these variables are cointegrated. Based on this, a Vector Error Correction (VEC) Model was estimated. Results are shown in Table 8 below.

Table 8: Model Estimates for Banana Exports

Vector Error Correction Estimates
Sample (adjusted): 1983 2007
Included observations: 25 after adjustments
t-statistics in [ ]

Cointegrating Eq:	CointEq1	t-stat		t-stat
LOG(QB(-1))	1.000000			
LOG(PBR4(-1))	0.632831	[0.37798]		
@TREND(81)	0.131468*	[2.74971]		
C	-17.76382			
Error Correction:	D(LOG(QB))		D(LOG(PBR4))	
CointEq1	-0.160381*	[-3.80662]	-0.057419***	[-1.88785]
D(LOG(QB(-1)))	-0.346185*	[-3.25910]	-0.077824	[-1.01491]
D(LOG(PBR4(-1)))	1.155286*	[3.34095]	-0.269079	[-1.07793]
C	-5.087484	[-0.36828]	0.323102	[0.03240]
H	-0.160757*	[-2.55807]	0.010113	[0.22291]
H(-1)	0.193320*	[2.58771]	-0.035129	[-0.65139]
LOG(RAINSLBASE)	9.516325***	[1.75464]	-2.331625	[-0.59553]
LOG(RAINSLBASE)^2	-0.950868***	[-1.71516]	0.240301	[0.60044]
LOG(TEMPSLBASE)	-5.092127*	[-3.45021]	1.338667	[1.25646]
LOG(COSTFR)	-0.264908***	[-1.79475]	0.127718	[1.19865]
R-squared	0.872163		0.318809	
Adj. R-squared	0.795461		-0.089905	
Sum sq. resids	0.244997		0.127673	
F-statistic	11.37078		0.780030	
Log likelihood	22.34387		30.49098	
Schwarz SC	-0.499959		-1.151728	
Log likelihood			53.43839	
Schwarz criterion			-1.313706	

where *statistically significant at the 1% level, **statistically significant at the 5% level and *** statistically significant at the 10% level.

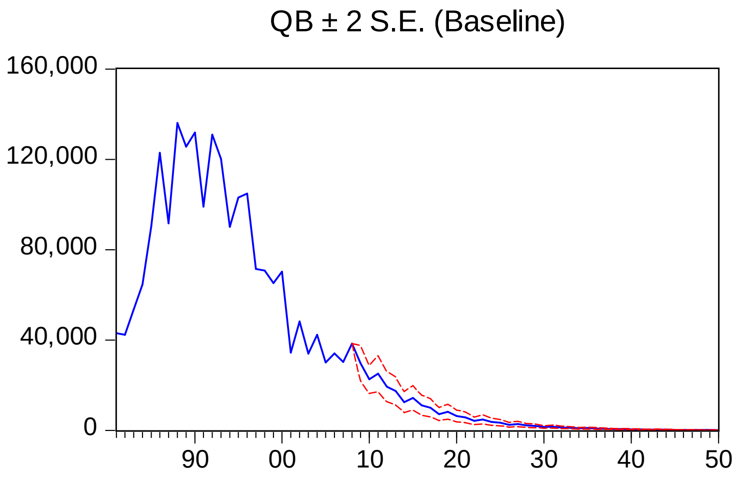
These results indicated that the cointegrating relationship had the expected negative sign, and was significant at conventional levels, therefore this further indicated that banana exports and prices were indeed cointegrated.

All the key explanatory variables were significant at conventional levels. Given the mean monthly rainfall of 128.87 mm from 1981 to 2008, the mean annual rainfall is 1546.44 mm. This value is well below the optimal rainfall range for bananas (see ANNEX 1). Therefore it is expected that any further increase in rainfall should have a positive effect on banana production. In addition, the upper temperature limit for bananas was 30 °C. Given that the mean temperature from 1981 to 2008 was 27.05

°C, further expected increases in temperature will result in the ambient temperature likely exceeding the optimal end of the range. Therefore the sign for temperature was negative, as expected.

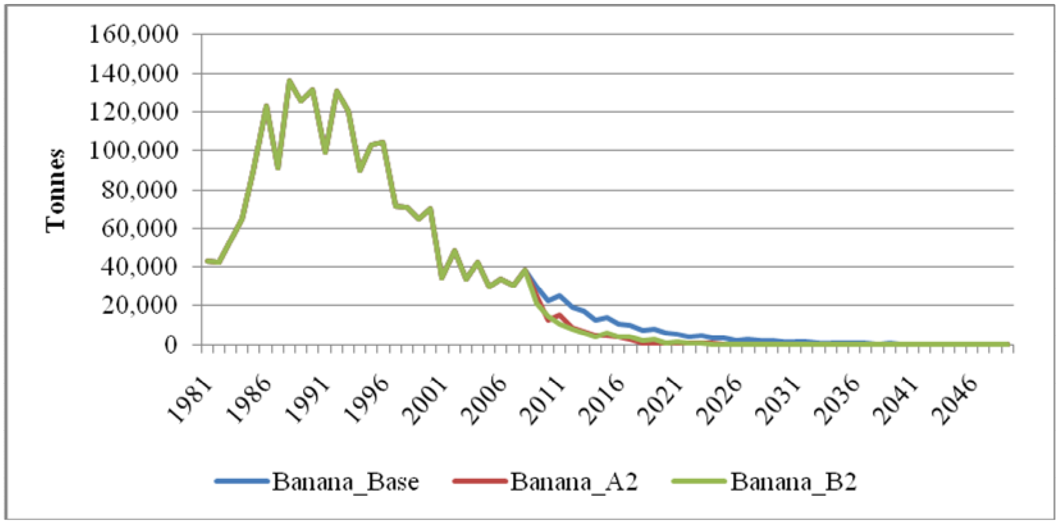
The signs on all the other variables were as expected, except for the lagged export variable. The model results indicated that a 1% growth in the previous year's banana export prices would lead to a 1.15% growth in exports. A 1% increase in rainfall is expected to cause an approximate 0.27% increase in the growth of banana exports. A 1% increase in temperature is expected to cause an approximate 5.1% decrease in the growth of banana exports. Therefore, banana is double affected by the expected rise in temperature and fall in rainfall. Forecasts of banana exports were then forecasted, using the VEC system, but holding the value of banana export price constant from 2009 to 2050 and are shown in Figure 16 below. There is a rapid fall-off in expected banana exports, so that by 2050, banana exports are minimal. Further, the 95% confidence bands on these forecasts remain narrow throughout the forecast period, indicating that the model forecasts are very robust further in the future.

Figure 16: Forecasted Banana Exports Under the Baseline Case, (tonnes)



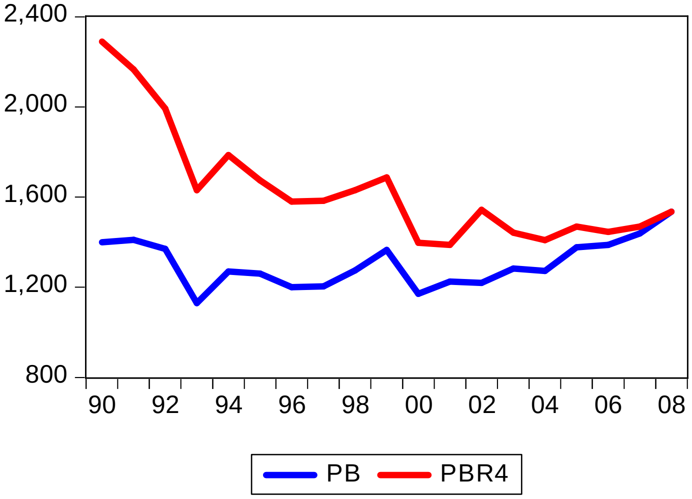
Forecasts of banana exports under the Baseline, A2 and B2 scenarios are shown in Figure 17 below. All scenarios showed the same general downward trend in expected harvests over time.

Figure 17: Projections for Banana Exports under the Baseline, A2 and B2 Scenarios (Tonnes)



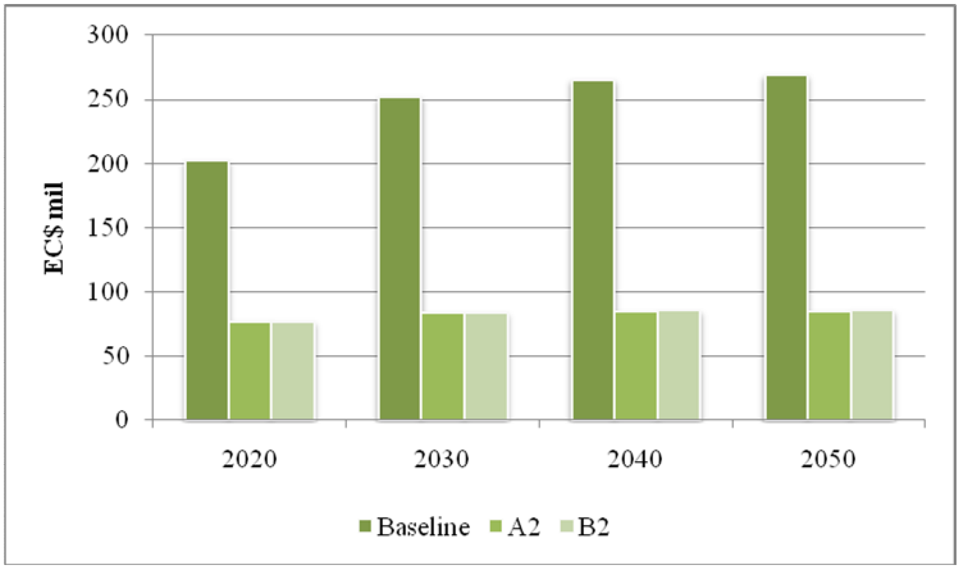
The real banana price is shown below (Figure 18). Overall the banana real price has fallen gradually over time up to the early 2000s. Since then, it remained relatively flat, despite the growing nominal price in the same period.

Figure 18: Nominal and Real (2008$) Banana Export Price (EC$/tonne)



The cumulative values of banana exports are shown for successive decades beginning from 2011-2020, 2021-2030 etc in Figure 19 below. For all decades the production values are highest under the baseline “no climate change” case. The results for A2 and B2 are extremely similar, and up to 2030, B2 has the lowest production values, but are second highest thereafter.

Figure 19: Cumulative Values of Banana Exports



Source: Data compiled by author

The cumulative present value of yield (in 2008 dollars), relative to the baseline was determined under assumptions of a 1%, 2% and 4% rate of discount (Table 9). These low discount rates were used as it was assumed they reflect the social rate of discounting used to reflect the high value that society places in conserving natural resources, including food and agricultural resources for future generations. More than one rate was used to determine how the losses would change under different discount rate assumptions.

Table 9: Present Value of Banana Export Cumulative Losses Relative to the Baseline* (EC $mil)

	2020		**2030**		**2040**		**2050**	
	A2	**B2**	**A2**	**B2**	**A2**	**B2**	**A2**	**B2**
1%	117.05	117.68	153.32	153.87	163.01	163.25	165.36	165.54
2%	109.44	110.48	140.29	141.28	147.77	148.52	149.41	150.12
4%	96.06	97.79	118.54	120.24	123.04	124.59	123.85	125.38

Source: Data compiled by author
*This shows the cumulative loss from 2011 up to each specified year.

By 2050, the value of cumulative yield losses (2008$) for banana, is expected to be $165.36 mil under the A2 scenario and $165.54 mil under the B2 scenario. In addition to the potential climate impacts, it should be noted that there are several non-climate factors that have contributed, perhaps overwhelmingly, to the decline in the banana sector. The key contributor is the loss of preferential prices in the EU market by Caribbean exporters, who previously enjoyed above-market rates under the Lomé Convention. With challenges from "dollar bananas" from Central America, this protection was broken, and Caribbean producers were forced to accept lower prices, as the previous regime was judged to be trade distorting under World Trade Organization rules. Even though several banana growers have switched to a potentially more lucrative Fair Trade Banana production, increasing competition by the Central American producers, together with a historic inability to fill import quotas, resulted in lost market share and declining competitiveness and exports from Saint Lucia. These impacts, though important, could not be appropriately included in the banana model, but it is clear that even without climate change, the banana sector may have continued declines without increases in competitiveness in the sector.

E. OTHER CROPS SUB-SECTOR

Tests of the stationarity of all Other Crops model variables (logged) were done (see Table 10 below). The tests conducted were: the Augmented Dickey-Fuller (ADF) test, the Phillips-Perron (PP) test and the Kwiatkowski, Phillips, Schmidt, and Shin (KPSS) Unit Root test Based on these, none of the model variables were found to be non-stationary.

Table 10: Results of Unit Root tests for logged model variables

Variable	**Unit Root Tests**			**Unit Root**[1]
	ADF (Probability Values)	**PP (Probability Values)**	**KPSS (LM-Stat)**[2]	
Qtc	0.2421	0.2421	0.4219	Yes
Ptc	0.2558	0.3061	0.5353	Yes
Qrc	0.2126	0.2284	0.2153	Yes
Prc	0.3303	0.3730	0.3859	Yes
Qvc	0.0907	0.1099	0.4378	Yes
Pvc	0.1225	0.1302	0.4554	Yes
Rain	0.0348	0.0843	0.2472	No
Temp	0.1575	0.1345	0.1345	Yes

[1] Assumed an intercept in the test equation. [2] Critical values = [1%, 0.7390; 5%, 0.4630; 10%, 0.3470]

1. Root crops

Using the Engle-Granger procedure, the residuals of the cointegrating equation *(LQRC = C(1)*LRPRC + C(2)*LTEMPSLC + C(3) +* ϕ*)* were non-stationary. Probability values of the unit root tests were: ADF, 0.3084; PP, 0.3740 and the KPSS statistic was 0.4541.

Further, the residuals of the equation $D(Resid)_t = Resid_{t-1} + \mu$ had a significant coefficient (P = 0.0554), which indicated that the residuals of the cointegrating equation are stationary (Enders 1995), which was contrary with the previous test results. The Engle-Granger Single Equation Cointegration test suggested a rejection of the null hypothesis that the three series were not cointegrated in two cases , when lqb and lrprc were the dependent variable). The tau-statistics had probabilities of 0.0147 (ltemp), while the z-statistics had a probability of 0.0000 for this variable, which indicated the presence of one cointegrating relationship The Trace and Max-Eigenvalue statistics in the Johansen System Cointegration test indicated the presence of two cointegrating relationships (not shown).

Based on this, a Vector Error Correction Model was estimated. Results are shown in Annex 2. These results indicated that the cointegrating relationship on the yield equation had the expected negative sign, and was significant at conventional levels, therefore this further indicated that root crop yield and prices were indeed cointegrated.

Short-run temperature effects were insignificant, but long-run effects were, which indicated that root crops were able to adapt to short run variations in temperature with little negative impact on yield within a year. All the other key explanatory variables, such as lagged production, lagged price and the presence of a tropical cyclone were insignificant at conventional levels. This model also resulted in yield forecasts under the baseline case with exceedingly high rises, which are not justified given the model assumptions of contact prices, rainfall and temperature. Therefore, since OLS is justified in the presence of cointegrated variables, even though they are integrated of the same order (here all I(1)), an OLS model is estimated. The results are shown in Table 11.

Table 11: Model Estimates for Root Crops

Dependent Variable: LOG(QRC)
Method: Least Squares
Sample: 1990 2008
Included observations: 19
Failure to improve SSR after 7 iterations
MA Backcast: 1989

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-1566.965	703.4881	-2.227422	0.0458
LOG(RPRC)	-1.190407	0.243266	-4.893446	0.0004
H	-0.036413	0.059609	-0.610870	0.5527
LOG(RAINSLBASE)	0.229138	0.218146	1.050389	0.3142
LOG(TEMPSLBASE)	960.7701	429.5671	2.236601	0.0451
LOG(TEMPSLBASE) ^2	-146.5551	65.55925	-2.235461	0.0452
MA(1)	0.999950	0.156358	6.395243	0.0000

R-squared	0.891601	Mean dependent var	7.101043
Adjusted R-squared	0.837401	S.D. dependent var	0.344261
S.E. of regression	0.138818	Akaike info criterion	-0.833991
Sum squared resid	0.231246	Schwarz criterion	-0.486040
Log likelihood	14.92292	Hannan-Quinn criter.	-0.775104
F-statistic	16.45029	Durbin-Watson stat	1.752009
Prob(F-statistic)	0.000037		

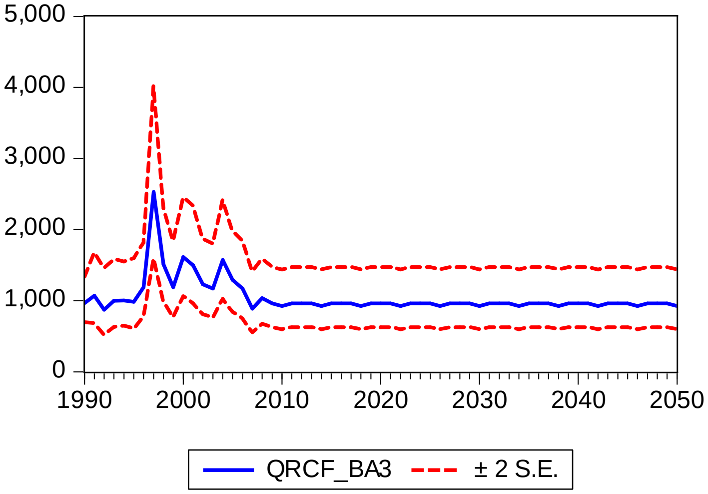
Inverted MA Roots -1.00

*statistically significant at the 1% level **statistically significant at the 5% level and ***statistically significant at the 10% level. $\eta_{Q,rain}$=0.2291; $\eta_{Q,temp}$= -5.2733

Given the mean monthly rainfall of 130.71 mm from 1990 to 2008, the mean annual rainfall is 1568.52 mm. This value is well below the optimal rainfall range for the main root crops of yam and sweet potato (see Annex 1). Therefore it is expected that any further decrease in rainfall should have a negative effect on root crop production. In addition, the upper temperature limit for yam and sweet potato was 30 °C. Given that the mean temperature from 1990 to 2008 was 27.00 °C, further expected increases in temperature will result in the ambient temperature likely exceeding the optimal end of the range. Therefore the sign for temperature was negative, as expected. The signs on all the other variables were as expected, except for price, which was counter-intuitive. A 1% increase in rainfall is expected to cause an approximate 0.23% increase in the root crop production. A 1% increase in temperature is expected to cause a 5.3% decrease in root crop production. Therefore, root crops are likely to be worse off overall from the expected fall-off in rainfall and the rising temperature.

The forecast of root crop production is shown in Figure 20 below. Production remains relatively stable through to 2050. Further, the 95% confidence bands on these forecasts remain fairly narrow throughout the forecast period, indicating that the model forecasts are fairly robust.

Figure 20: Forecasted Root Crop Production Under the Baseline Case (tonnes)



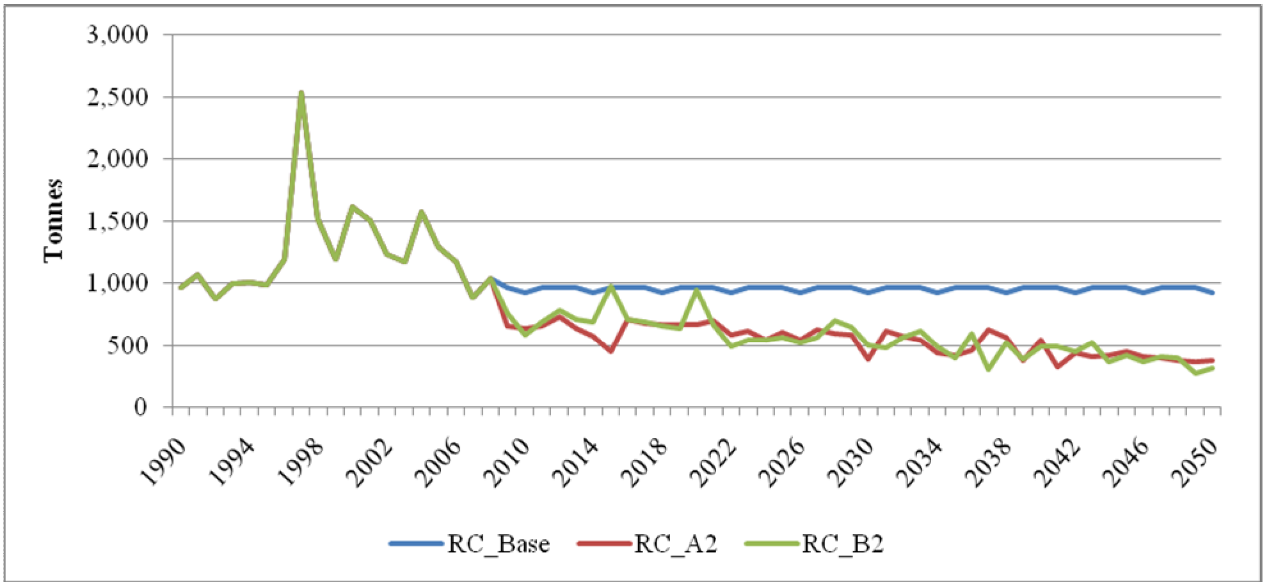
Forecast: QRCF_BA3
Actual: QRC
Forecast sample: 1981 2050
Adjusted sample: 1990 2050
Included observations: 19

Root Mean Squared Error	231.0579
Mean Absolute Error	196.0032
Mean Abs. Percent Error	14.96031
Theil Inequality Coefficient	0.085705
Bias Proportion	0.027613
Variance Proportion	0.362242
Covariance Proportion	0.610145

Source: Data compiled by author

Forecasts of root crop production under the Baseline, A2 and B2 scenarios are shown in Figure 21 below. The A2 and B2 scenarios showed the same general downward trend in expected harvests over time.

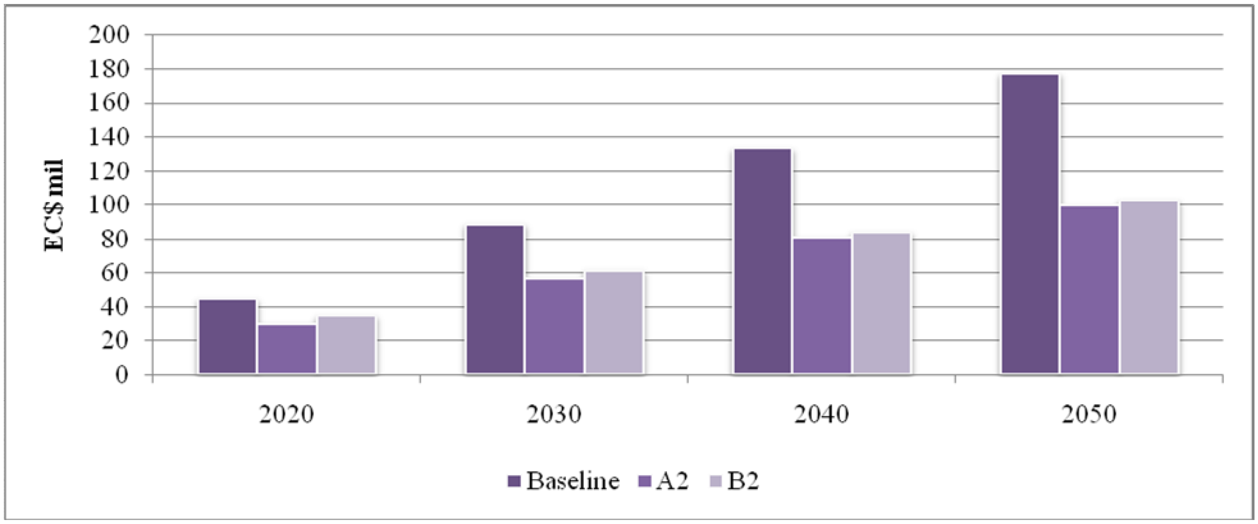
Figure 21: Projections for Root Crop Production under the Baseline, A2 and B2 Scenarios (Tonnes)



Source: Data compiled by author

The cumulative values of root crops are shown for successive decades beginning from 2011-2020, 2021-2030 etc in Figure 22 below. For all decades the production values are highest under the baseline "no climate change" case, with A2 having the lowest values in all decades.

Figure 22: Cumulative Values of Root Crop Production



Source: Data compiled by author

The cumulative present value of yield (in 2008 dollars), relative to the baseline was determined under assumptions of a 1%, 2% and 4% rate of discount (Table 12).

Table 12: Present Value of Root Crop Cumulative Losses Relative to the Baseline* (EC $mil)

	2020		**2030**		**2040**		**2050**	
	A2	**B2**	**A2**	**B2**	**A2**	**B2**	**A2**	**B2**
1%	13.47	9.03	28.06	23.81	43.61	40.46	61.37	58.04
2%	12.53	8.41	24.79	20.87	36.64	33.56	48.93	45.69
4%	10.90	7.33	19.60	16.26	26.57	23.70	32.52	29.55

Source: Data compiled by author

*This shows the cumulative loss from 2011 up to each specified year. Gains are expressed as negative values.

By 2050, the root crops are expected to lose $61.37 mil under the A2 scenario and $58.04 mil under the B2 scenario (2008$).

2. Tree crops

Using the Engle-Granger procedure, the residuals of the cointegrating equation ($LQTC = C(1)*LRPTC + C(2)*LTEMP + C(3) + \phi$) were non-stationary. Probability values of the unit root tests were: ADF, 0.6435; PP, 0.0460 and the KPSS statistic was 0.5219.

Further, the residuals of the equation $D(Resid)_t = Resid_{t-1} + \mu$ had a significant coefficient (P = 0.0062), which indicated that the residuals of the cointegrating equation are stationary (Enders 1995), which was contrary with the previous test results. The Engle-Granger Single Equation Cointegration test in general suggested the absence of cointegration, but had mixed results. It suggested a rejection of the null hypothesis for the three dependent variables with the tau-statistics, while the z-statistics failed to reject the null for the temperature variable (P = 0.0000). The Trace and Max-Eigenvalue statistics in the Johansen System Cointegration test indicated the presence of up to two cointegrating relationships. Based on this, a Vector Error Correction Model was estimated. Results are shown in Annex 2.

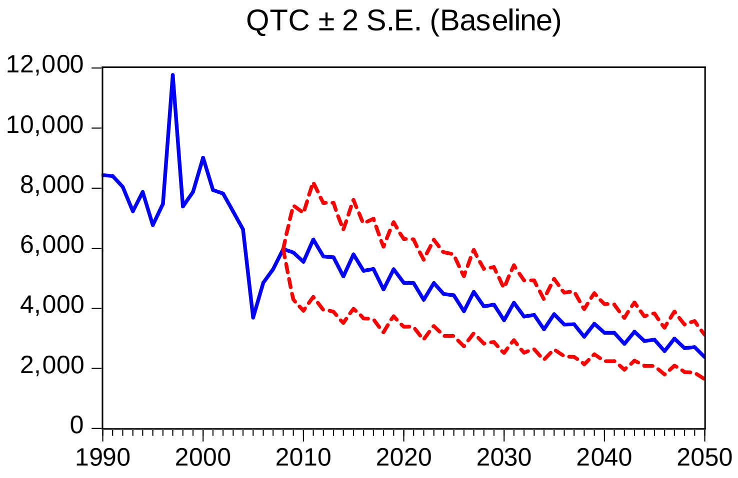
These results indicated that the cointegrating relationship on the yield equation had the expected negative sign, and was significant at conventional levels, therefore this further indicated that tree crop yield and prices were indeed cointegrated.

Both short and long run temperature effects were insignificant. Other key explanatory variables, such as lagged production, lagged price and the presence of a tropical cyclone were also insignificant at conventional levels. Given the mean monthly rainfall of 130.71 mm from 1990 to 2008, the mean annual rainfall is 1568.52 mm. This value is at the lower end of the optimal range for breadfruit, far below the optimum for avocado, but is well within the optimal ranges for soursop and mango (see Annex 1). Therefore it is expected that any further decrease in rainfall should have a deleterious effect on breadfruit and avocado yield, and possibly the tree crop group since breadfruit and mango are the most valuable commodities in this group. The sign for temperature was also negative as expected. This is so, as given the mean temperature from 1990 to 2008 was 27.00 °C, this already exceeds the optimal temperature range for soursop, but further expected increases in temperature will result in the ambient temperature being very close to the optimal end of the range avocado and mango, but well within the range for breadfruit. This may therefore account for the insignificance of temperature in the model.

The sign of the price variable is also unexpected. A 1% decrease in rainfall is expected to cause an approximate 1.24% increase in the growth of tree crop harvests. A 1% increase in temperature is expected to cause an approximate 0.56% decrease in the growth of tree crop harvests (in the short run).

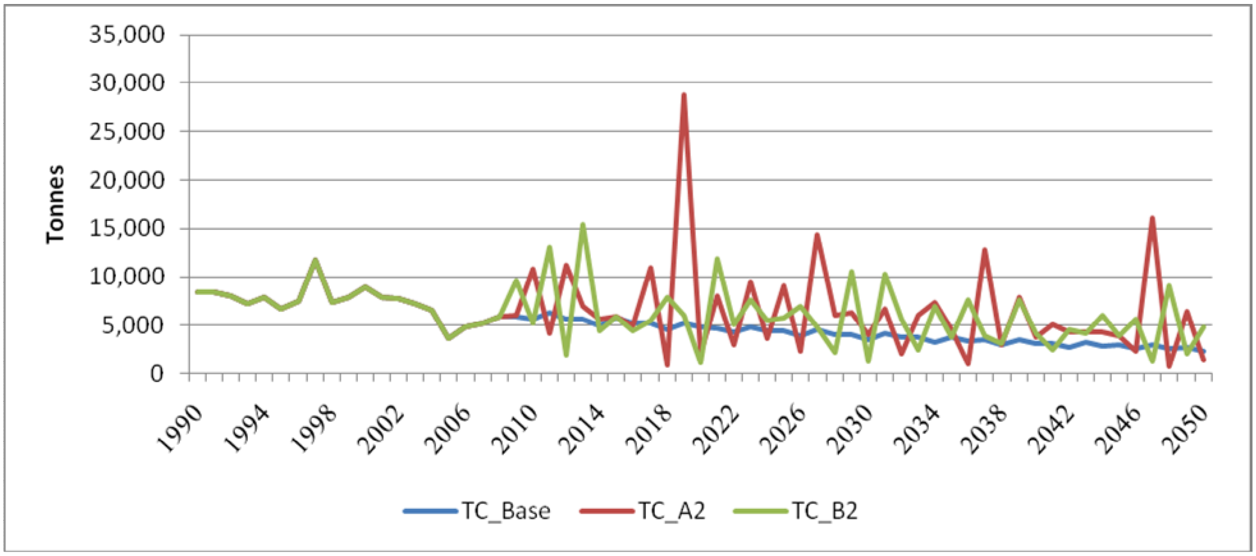
Forecasts of tree crop production were then calculated, using the VEC system, but holding the value of price constant from 2009 to 2050 and are shown in Figure 23 below. There is a gradual fall in tree crop production, through to 2050. However, the 95% confidence bands on these forecasts remain fairly narrow throughout the forecast period, indicating that the model forecasts are fairly robust.

Figure 23: Forecasted Tree Crop Production under the Baseline Case, (tonnes)



Forecasts of tree crop production under the Baseline, A2 and B2 scenarios are shown in Figure 24. In all cases, there was a general decline in tree crop harvests over time, though yields were highest under the A2 scenario, followed by the B2 scenario.

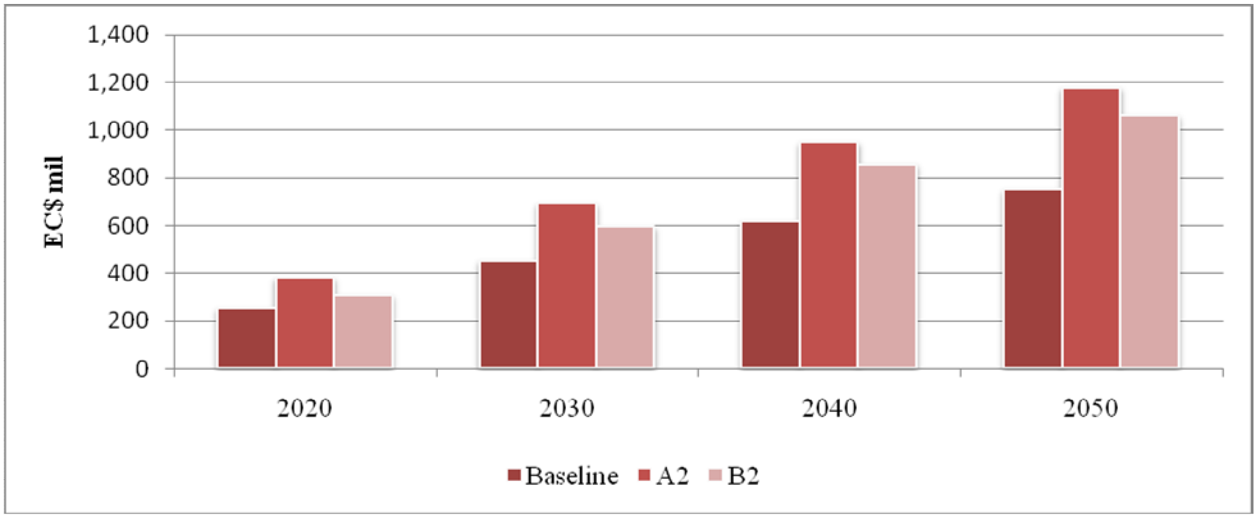
Figure 24: Projections for Tree Crop Production under the Baseline, A2 and B2 Scenarios (Tonnes)



Source: Data compiled by author

The cumulative values of tree crops are shown for successive decades beginning from 2011-2020, 2021-2030 etc in Figure 25 below. For all decades the production values are lowest under the baseline "no climate change" case, with A2 having the highest values in all decades.

Figure 25: Cumulative Values of Tree Crop Production



Source: Data compiled by author

The cumulative present value of yield (in 2008 dollars), relative to the baseline was determined under assumptions of a 1%, 2% and 4% rate of discount (Table 13).

Table 13: Present Value of Tree Crop Cumulative Losses Relative to the Baseline* (EC $mil)

	2020		**2030**		**2040**		**2050**	
	A2	**B2**	**A2**	**B2**	**A2**	**B2**	**A2**	**B2**
1%	-118.24	-53.59	-209.47	-128.83	-279.87	-201.48	-345.35	-251.63
2%	-107.79	-51.69	-184.46	-116.22	-237.86	-172.09	-283.06	-206.48
4%	-89.98	-48.07	-144.50	-95.85	-175.53	-129.24	-197.34	-145.62

Source; Data compiled by author

*This shows the cumulative loss from 2011 up to each specified year. Gains are expressed as negative values.

By 2050, the tree crops are expected to gain $345.35 mil under the A2 scenario and $251.63 mil under the B2 scenario (2008$).

3. Vegetable crops

Using the Engle-Granger procedure, the residuals of the cointegrating equation (LQVC = C(1)*LRPVC + C(2)*LTEMP + C(3) + ϕ) were non-stationary. Probability values of the unit root tests were: ADF, 0.0896; PP, 0.5013 and the KPSS statistic was 0.4911.

Further, the residuals of the equation $D(Resid)_t = Resid_{t-1} + \mu$ had a significant coefficient (P = 0.0976), which indicated that the residuals of the cointegrating equation are stationary (Enders 1995), which was contrary with the previous test results. The Engle-Granger Single Equation Cointegration test failed to reject the null hypothesis that the series are not cointegrated for all statistics. The Trace and Max-Eigenvalue statistics in the Johansen System Cointegration test indicated the presence of up to three cointegrating relationships. Based on this, a Vector Error Correction Model was estimated. Results are shown in Annex 2.

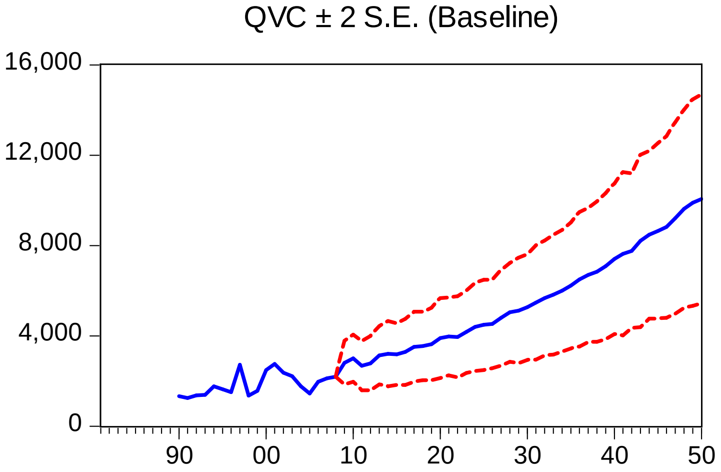
These results indicated that the cointegrating relationship on the yield equation had the expected negative sign, and was significant at conventional levels, therefore this further indicated that vegetable crop yield and prices were indeed cointegrated.

Both short and long run temperature effects were insignificant. Other key explanatory variables, such as lagged production, lagged price and the presence of a tropical cyclone were also insignificant at conventional levels. For the tropical cyclone coefficient, this is not unexpected as production can resume relatively quickly after a cyclone, so annual production may not have a significant fall-off.

Given the mean monthly rainfall of 130.71 mm from 1990 to 2008, the mean annual rainfall is 1568.52 mm. This value is much lower than the ideal rainfall for tomato, the main vegetable crop, though it is within the range for sweet peppers (see Annex 1). Therefore it is expected that any further decrease in rainfall should have a deleterious effect on vegetable crop yield. The sign for temperature was also negative as expected. This is so, as given the mean temperature from 1990 to 2008 was 27.00 °C, this already exceeds the optimal temperature range for tomato, but is well within the ideal range for several other vegetable crops. Given the relative weight of tomatoes, it was expected that increases in temperature will result in the ambient temperature exceeding the optimal end of the tomato range, and hence an overall negative impact on the production of vegetable crops. A 1% decrease in rainfall is expected to cause an approximate 1.08% increase in the growth of vegetable crop harvests, which is contrary to expectations. It is possible that the small sample size, and the omission of key farm input variables, such as labour, may be leading to biased and therefore unexpected coefficient results.

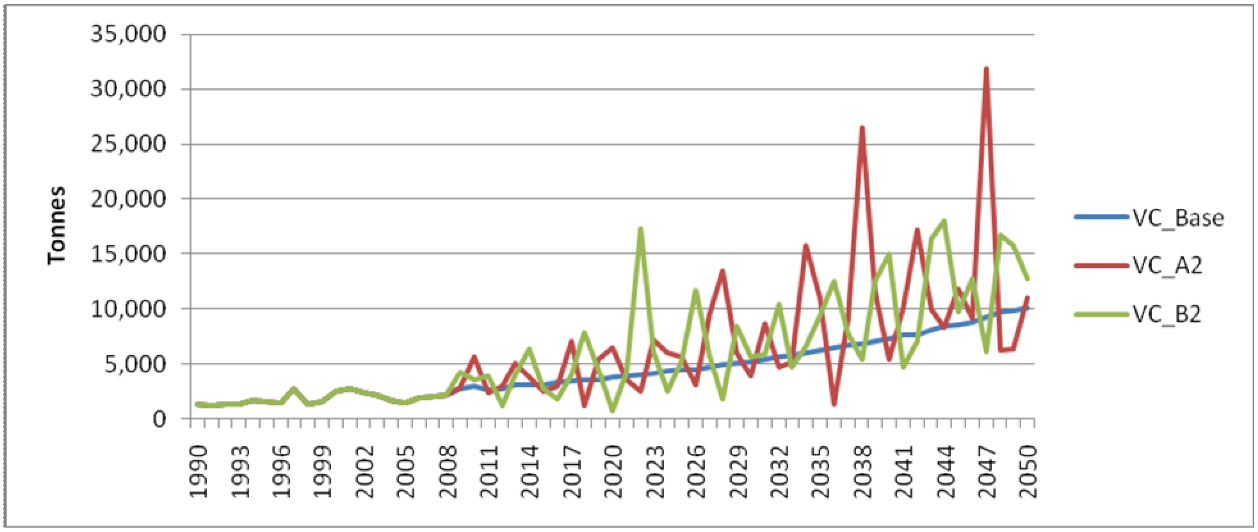
Forecasts of vegetable crop production were then forecasted, using the VEC system, but holding the value of price and temperature constant from 2009 to 2050 (in the baseline case) and are shown in Figure 26. There is a gradual rise in vegetable crop production, through to 2050. However, the 95% confidence bands on these forecasts widen throughout the forecast period, indicating that the model forecasts become less robust over time.

Figure 26: Forecasted Vegetable Crop Production under the Baseline Case, (tonnes)



Forecasts of vegetable crop production under the Baseline, A2 and B2 scenarios are shown in Figure 27 below. In all cases, there was a general increase in vegetable crop harvests over time, though yields were highest under the A2 scenario, followed by the B2 scenario.

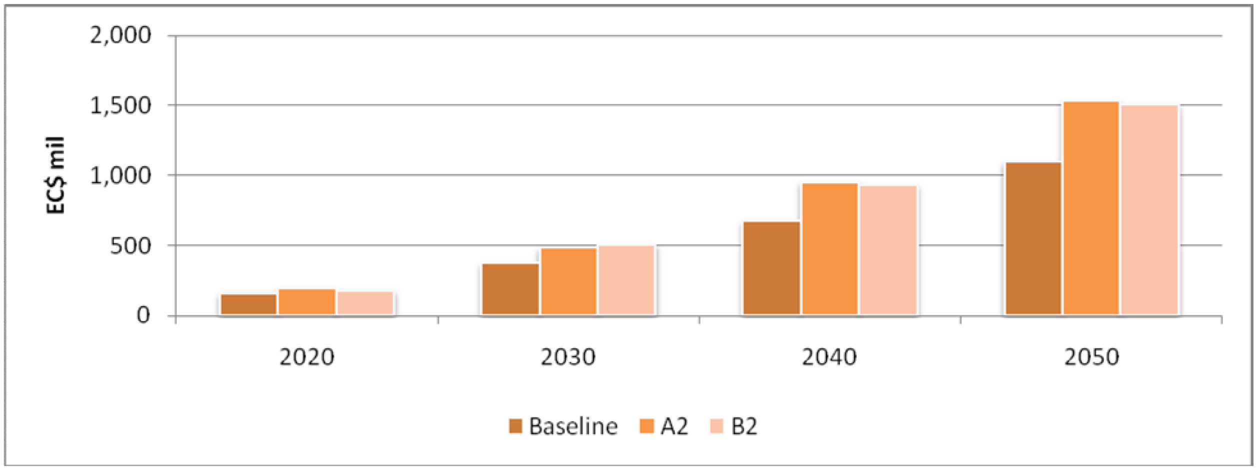
Figure 27: Projections for Tree Crop Production under the Baseline, A2 and B2 Scenarios (Tonnes)



Source: Data compiled by author

The cumulative values of vegetable crops are shown for successive decades beginning from 2011-2020, 2021-2030 etc in Figure 28 below. For all decades the production values are lowest under the baseline “no climate change” case, with A2 having the highest values in all decades.

Figure 28: Cumulative Values of Vegetable Crop Production



Source: Data compiled by author

The cumulative present value of yield (in 2008 dollars), relative to the baseline was determined under assumptions of a 1%, 2% and 4% rate of discount (Table 14).

Table 14: Present Value of Vegetable Crop Cumulative Losses Relative to the Baseline* (EC $mil)

	2020		**2030**		**2040**		**2050**	
	A2	**B2**	**A2**	**B2**	**A2**	**B2**	**A2**	**B2**
1%	-31.15	-19.96	-92.20	-114.20	-221.52	-209.56	-333.31	-313.82
2%	-28.46	-18.83	-79.18	-99.58	-177.05	-171.43	-255.10	-242.93
4%	-23.89	-16.76	-59.07	-76.42	-115.69	-117.65	-154.18	-151.69

Source: Data compiled by author

*This shows the cumulative loss from 2011 up to each specified year. Gains are expressed as negative values.

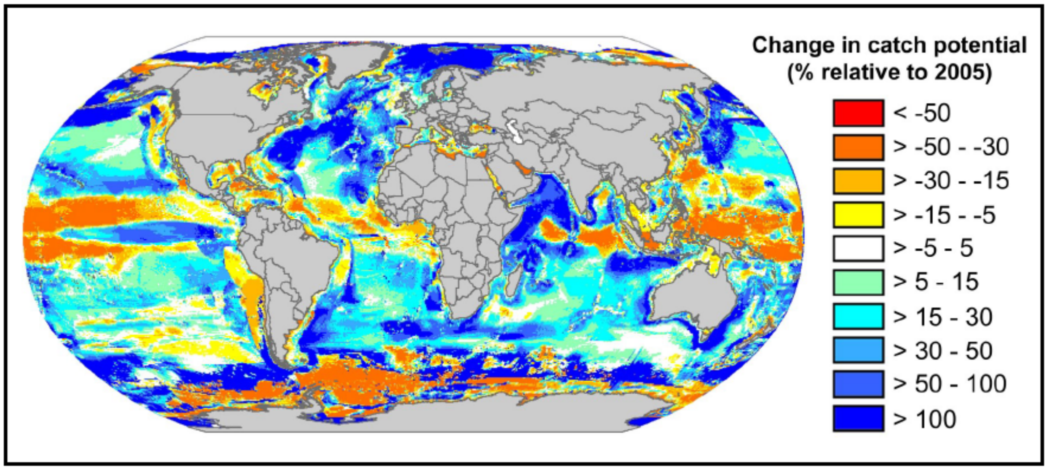
By 2050, the vegetable crops are expected to gain $333.31 mil under the A2 scenario and $313.82 mil under the B2 scenario (2008$).

F. FISHERIES SUB-SECTOR

Historical and projected data on sea surface temperature were not available. Therefore an econometric model was not estimated as these data were deemed to have an important role in determining fish landings in such a model, and its omission would lead to misspecification. However, work by Pauly (2010) in the *Sea Around Us* project, indicated that fish productivity would shift largely away from tropical regions and towards higher latitudes (towards the poles), which would in general have a severe impact in the Caribbean. Utilizing data on the landings of all commercial species worldwide, a temperature preference profile was created for each species, which showed the regions that each species prefers to inhabit based on historical temperatures. Then, on a small scale (each 0.5 degree latitude and longitude), a population dynamics model was formulated to indicate the distribution range of each species, incorporating biological relationships, including the incidence of egg and larvae production, which are also affected by sea temperature.

The model used projections of sea temperature from the Ocean-Atmosphere Coupled General Circulation model (GCM) CM 2.1 of NOAA's Geophysical Fluid Dynamics Laboratory, and also accounted for changes in currents for three greenhouse gas emission scenarios: 720 ppm, 550 ppm and 370 ppm CO_2 concentration by 2100. The potential catch was then determined based on productivity in the new distribution area for each of the 1066 species in the model. By generating global maps in changes in catch potential (see Figure 29 below), Pauly (2010) estimated that for the Caribbean Large Marine Ecosystem, there will be a decrease in catch potential of 10 - 20% by 2050 relative to 2005 catch potentials, other things remaining constant. Individual country estimates were not presented.

Figure 29: Predicted Changes in Global Catch Potentials



Source: Pauly (2010), Figure 3

Given the range in possible reductions by Pauly (2010), and since the A2 scenario is the expected higher impact (higher greenhouse gas emission scenario) scenario, it was estimated that under the A2 and B2 scenarios, fisheries revenue loss would be 20% and 10% of the 2005 fish landings revenue, respectively. The 2005 total commercial landings of 1,386.2 tonnes for Saint Lucia were used as the baseline case for the analysis. The 2005 total value of landings (ex-vessel) were EC$15,927,115.86. The 2005 landings were assumed constant to 2050 in the Baseline case, and real prices were fixed during this period at the mean 2008 real price. The real price was also assumed to be fixed under the A2 and B2 scenarios.

The cumulative present value of losses, relative to the baseline was determined under assumptions of a 1%, 2% and 4% rate of discount (see Table 15), based on 2008$. By 2050 under the A2 and B2 scenarios, losses in real terms were estimated to be $62.59 mil and $31.29 mil respectively, at a 1% discount rate.

Table 15: Present Value of Fisheries Cumulative Losses Relative to the Baseline (EC$ mil)

	2020		**2030**		**2040**		**2050**	
	A2	**B2**	**A2**	**B2**	**A2**	**B2**	**A2**	**B2**
1%	7.78	3.89	21.58	10.79	40.20	20.10	62.59	31.29
2%	7.18	3.59	18.76	9.38	32.94	16.47	48.40	24.20
4%	6.14	3.07	14.36	7.18	22.67	11.33	30.14	15.07

Source: Data compiled by author

G. AGGREGATE VALUE OF YIELD LOSS FOR BANANAS, OTHER CROPS AND FISHERIES

Relative to the Baseline case, the key subsectors in agriculture are expected to have mixed impacts under the A2 and B2 scenarios. Banana, fisheries and root crop outputs are expected to fall with climate change, but tree crop and vegetable production is expected to rise. In aggregate, in every decade up to 2050, these sub-sectors combined are expected to experience a gain under climate change, all scenarios, with the highest gains under A2. By 2050, the cumulative gain under A2 is calculated as approximately $389.35 mil and approximately $310.58 mil under B2 (Table 16). These values as a percentage of the 2008 nominal GDP are shown in Table 17.

Table 16: Present Value of Cumulative Losses for Agricultural Yield Relative to the Baseline (EC $mil)

	2020		**2030**		**2040**		**2050**	
	A2	**B2**	**A2**	**B2**	**A2**	**B2**	**A2**	**B2**
1%	-11.08	57.04	-98.71	-54.56	-254.58	-187.23	-389.35	-310.58
2%	-7.11	51.97	-79.80	-44.27	-197.56	-144.97	-291.42	-229.40
4%	-0.77	43.36	-51.07	-28.60	-118.94	-87.27	-165.01	-127.31

Source: Data compiled by author

Table 17: Estimate of the Cumulative Cost of the Impact of Climate Change (in 2008 GDP* % of the Net Present Value)

	2020		**2030**		**2040**		**2050**	
	A2	**B2**	**A2**	**B2**	**A2**	**B2**	**A2**	**B2**
1%	-0.51%	2.63%	-4.55%	-2.51%	-11.72%	-8.62%	-17.93%	-14.30%
2%	-0.33%	2.39%	-3.67%	-2.04%	-9.10%	-6.68%	-13.42%	-10.56%
4%	-0.04%	2.00%	-2.35%	-1.32%	-5.48%	-4.02%	-7.60%	-5.86%

*Economic and Social Review (2009)

IX. POTENTIAL LAND LOSS DUE TO SEA LEVEL RISE

Based on IPCC projections (Meehl *et al* 2007), sea level was projected to rise between the 1980-1999 level and the end of the century (2090-2099) under the SRES A2 by 0.23 - 0.52m (3.0 – 8.5 mm/yr), and under B2 by 0.20 - 0.43 m (2.1-5.6 mm/yr). Based on these projections, it was estimated that using the upper limits, sea level rise (SLR) in 2050 would be half of the end of century projected rise at 0.255 m under A2 and 0.215m under B2. Toba (2007) also estimated that sea-level would rise by 0.35m for CARICOM countries, based on an assumption of a 2°C temperature rise between 1980 and 2099. As a result, he determined that this would lead to an 8% loss of land in CARICOM over that period. Further, Simpson *et al* (2009) estimated that as a result of a 1m SLR, there would be no agricultural land loss in Saint Lucia.

Preliminary GIS maps obtained from Charles-Soomer, of the Ministry of Finance, Economic Affairs and National Development (personal communication 2011) indicated that naturally occurring sea level rise would have minimal (less than 0.5%) impact on agricultural land in Saint Lucia. The main potential areas for land loss were in the south-east of the island near the areas of Micoud. Therefore, for this study, it is assumed that sea level rise losses for Saint Lucia are $0.

X. POTENTIAL IMPACTS OF TROPICAL CYCLONES

Between 1955 and 2009, Saint Lucia has been hit by eleven tropical cyclones, which caused significant damage in terms of death, injuries to persons, property damage and loss of crops, livestock and infrastructure (Table 18). In some cases, as in the case of Tropical Storm Debby (Table 19), most of the losses in the agricultural sector are usually due to damage of banana and tree crops.

Table 18: Recent Occurrence and Damage of Tropical Cyclones to Saint Lucia

Year	Event	Killed	Injured	Homeless	Total Losses US$
2004	Tropical Cyclone Hurricane Ivan	0	1	0	$10,464,720.00
1998	Tropical Cyclone Tropical Wave	1	0	12	$230,185.00
1996	Tropical Cyclone Tropical Wave	0	0	0	$4,444,444.00
1994	Tropical Cyclone Tropical Storm Debby	3	0	0	$85,185,185.00
1980	Tropical Cyclone Hurricane Allen	9	0	6,000	$92,592,593.00
1979	Tropical Cyclone Hurricane David	0	0	0	$0.00
1967	Tropical Cyclone Tropical Storm Beulah	1	0	0	$740,741.00
1966	Tropical Cyclone Tropical Depression	0	0	0	$277,778.00
1963	Tropical Cyclone Hurricane Edith	0	0	0	$277,778.00
1960	Tropical Cyclone Hurricane Abby	6	0	0	$1,421,481.00
1955	Tropical Cyclone Hurricane Janet	0	0	0	$0.00

Source: CDERA (2010).

Table 19: Estimated Loss Due to a Tropical Cyclone Debby in Saint Lucia

	Units	Number	Unit Value (EC$)	Total Value (EC$ mil)
Crops				
Bananas	Hectares	3,197	23,774	76.00
Tree Crops	Hectares	1,417	14,986	21.24
Fruit Crops	Hectares	8,858	12,700	11.25
Root Crops	Hectares	1,299	10,160	13.20
Vegetables	Hectares	75	15,240	1.14
Total Crops	Hectares			**122.83**
Livestock				
Cattle	Head	300	2,000	0.60
Pigs	Head	600	400	0.24
Other	Head	3,318	95	0.32
Total Livestock				**1.16**
Forestry				
Natural	Hectares	315	25,400	8.00
Plantation	Hectares	61	18,542	1.13
Total Forestry				**9.13**
Infrastructure/Facilities				
Farm Roads	Kilometers	50	80,000	4.00
Tracks/Paths	Kilometers	14	8,000	0.12
Forest Roads	Kilometers	0.6	120,000	0.08
Drains	Kilometers	3,938	3,200	12.60
Farm Storage	Units	52	2,500	0.21
Field Sheds	Units	270	1,500	0.65
Animal Pens	Units	35	13,600	0.76
Greenhouses	Units	10	18,000	0.18
Total Infrastructure/Facilities				**18.60**
Grand Total				**151.72**

Source: Ministry of Planning, Development, Environment & Housing, Climate Change Vulnerability and Adaptation Assessment: Agriculture Sector (2010), pg 91

There is ongoing debate as to whether changes in the pattern of tropical cyclones are due to climate change or not. Nevertheless, there is general consensus that the pattern of these events is changing over time, and while it is uncertain if there will be an increase in frequency over time, it is widely expected that there will be an increase in the intensity of these events (which has direct impacts associated with wind speed, rainfall intensity, rainfall duration, and the likelihood of flooding and the creation of waterlogged conditions). Based on the actual damage caused by Tropical Storm Debby, Hurricane Ivan and Hurricane Tomas, the mean damage to bananas, other crops, fisheries and infrastructure was calculated in Table 20. These damage estimates represent the value of commodities lost as a result of the event, and do not include “losses” which accrue over the long term as a result of forgone income-earning opportunities. The damage estimates therefore represent a lower bound of the total costs of these events. Indirect losses were only available for Hurricane Tomas, and were therefore excluded from the analysis.

Table 20: Average Estimates of Tropical Storm Damage Only (EC$)

	Tropical Storm Debby - 1994	Hurricane Ivan[1] (Cat 3) - 2004	Tomas[2] (Cat 3) - 2010	Mean Damage (Cat 3)	Mean Damage (TS and Cat 3)
Bananas	76,000,000	10,125,000	37,642,005	23,883,503	23,883,503
Other Crops	46,830,000		7,589,320	7,589,320	27,209,660
Infrastructure	17,760,000		7,985,200	7,985,200	12,872,600
Fisheries			1,384,000	1,384,000	1,384,000
Total					**65,349,763**

Source: [1]NEMO (2005); [2]ECLAC (2011)

Given that Landsea *et al* (2006) determined an expected increase in Tropical Storm intensity by approximately 5 % by 2100, it was assumed that by 2050, there will be a 2.5% increase in intensity under the A2 scenario, and 90% of this increase attributed to the B2 scenario. Based on the historical rates of tropical cyclones since 1981, there is a cyclone every four years, on average. Based on these assumptions, the expected additional damage due to the increased intensity of tropical cyclones (not the total damage caused by the cyclone) was calculated and presented in Table 21.

Table 21: Present Value of Tropical Cyclone Cumulative Losses (EC$ mil)

	2020		**2030**		**2040**		**2050**	
	A2	**B2**	**A2**	**B2**	**A2**	**B2**	**A2**	**B2**
1%	0.904	0.814	2.143	1.929	4.757	4.282	6.904	6.213
2%	0.836	0.752	1.882	1.694	3.881	3.493	5.371	4.834
4%	0.718	0.646	1.468	1.321	2.650	2.385	3.377	3.039

By 2050, additional losses due to an increased intensity of tropical cyclones is expected to be $6.9 mil under the A2 scenario and $6.2 mil under the B2 scenario, with a 1% discount rate.

XI. ADAPTATION OPTIONS AND BENEFIT COST ANALYSES

Saint Lucia's 2nd National Communication to the UNFCCC has identified a number of areas for focusing adaptation strategies. Some of these are highlighted in Annex 3. Further, recommendations were made in the Draft Vulnerability and Adaptation Plan, which will support Saint Lucia's 2nd National Communication to the UNFCCC.

However, this study expanded on the proposed recommendations and ranks each adaptation option from high (score of 5) to low (score of 1) based on internationally proposed criteria for adaptation strategies. The final rank of each proposal was based on resource availability and the policy environment currently in Saint Lucia, and recognized existing adaptation activities or proposals that are currently being planned by the Ministry of Food Production. These were analyzed in terms of feasibility and cost, to further prioritize these for the banana, other crops and fisheries sector, which made up approximately 85% of the agricultural GDP in 2009.The rankings are shown in Annex 3. Each of the criteria used had the same weight. Based on the eleven (11) evaluation criteria, the top ten (10) potential adaptation options were identified:

1. Mainstream climate change issues into agricultural management.
2. Adopt improved technologies for soil conservation.
3. Establish systems of food storage.
4. Alter crop calendar for short-term crops.
5. Use water saving irrigation systems and water management systems e.g. drip irrigation.
6. Repair/maintain existing dams.
7. Promote water conservation – install on-farm water harvesting off roof tops.
8. Design and implement holistic water management plans for all competing uses.
9. Establish early warning systems and disaster management plans for farmers.
10. Build on- farm water storage (ponds, tanks etc)
    In addition, the following option was evaluated based on promotion of protected agriculture locally:
11. Installation of Greenhouses.

All of these adaptation options are important, but the options which focus on conserving and using water more efficiently are particularly important given that rainfall levels are expected to decline for Saint Lucia through to 2050. The increased temperature is expected to exacerbate heat stress in plants, especially when coupled with a decline in precipitation, so water conservation techniques such as mulching (which conserves both soil and water) are particularly relevant in adapting to this climate change. The installation of protected agriculture, such as green houses has received increased attention locally, but is not suitable for root crop production, and may be more useful for vegetable production as temperatures continue to increase past the anticipated levels for 2050.

Establishing the benefits and costs associated with altering the crop calendar was not feasible given the wide variety of crops included in the study. Therefore, a Benefit Cost Analysis (BCA) was not conducted for this option. As a result, 10 options were used in the Benefit/Cost analysis.

Given all the costs and benefits for all adaptation options which are provided in the subsequent section, from 2012 to 2050, the present value of each option was calculated using a 4% discount rate and shown in Table 25 below. It indicates that the most attractive adaptation options, based on the Benefit-Cost Ratio are: (1) Design and implement holistic water management plans (2) Establish systems of food storage and (3) On-farm water harvesting systems. However, the options with the highest net benefits are, (in order of priority): (1) Use of Drip Irrigation, (2) Mainstreaming climate change issues into agricultural management and (3) Establish systems of food storage. It should be noted that under the two criteria, different options are proposed. The final choice by governments should include these assessments, as well as the omitted intangible benefits, as well as the provision of other social goals such as employment.

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Table 22: Summary of the Present Value Costs and Benefits of the Highest-Ranked Proposed Adaptation Actions for Saint Lucia

EC$	Details	Cumulative Present Value of Benefits	Cumulative Present Value of Costs	Benefit- Cost Ratio	Net Benefits	Payback Period (years)
Option 1	Mainstream climate change issues into agricultural management	$188,225,078.59	$27,119,881.94	6.9	$161,105,196.65	0.13
Option 2	Adopt improved technologies for soil conservation	$236,137,936.71	$94,286,451.75	2.5	$141,851,484.96	0.42
Option 3	Establish systems of food storage	$167,495,757.88	$7,186,091.26	23.3	$160,309,666.61	0.04
Option 4	Use water saving irrigation systems and water management systems e.g. drip irrigation	$360,969,473.96	$53,688,895.44	6.7	$307,280,578.52	1.42
Option 5	Repair/maintain existing dams	$117,527,553.19	$24,309,805.95	4.8	$93,217,747.25	0.21
Option 6	Promote water conservation – install on-farm water harvesting off roof tops	$144,387,789.58	$7,492,283.58	19.3	$136,895,506.01	0.03
Option 7	Design and implement holistic water management plans for all competing uses	$28,099,919.05	$1,003,296.96	28.0	$27,096,622.09	0.14
Option 8	Establish early warning systems and disaster management plans for farmers.	$97,531,499.08	$7,233,793.68	13.5	$90,297,705.40	0.60
Option 9	Build on- farm water storage (ponds, tanks etc)	$31,832,118.98	$60,996,697.63	0.5	($29,164,578.65)	1.91
Option 10	Installation of Greenhouses	$37,336,193.46	$7,350,423.87	5.1	$29,985,769.59	0.13

Assumptions Made in Calculating the Costs and Benefits of Adaptation Options

The analysis was done for the period 2012 – 2050.

Option 1: Mainstream Climate Change Issues into Agricultural Management.

It is assumed that:

- Mainstreaming requires the review of all national policies and projects to ensure that climate change issues are included.
- Training of 100 workers per year (in-house training, conferences, travel of experts, study abroad) is required.
- An annual policy review utilizes 12 persons.
- There is a 1% annual rise in salaries.
- The 2007 GDP (in constant $) = EC$1,417.70 mil.
- The salary of an Economist III (Grade 16) = EC$4,594.00.

Option 2: Adopt Improved Technologies for Soil Conservation e.g. Mulching

It was assumed that:

- Total acreage under green vegetables plus root crops in 2008 = 15,800.66 ac.
- One (1) roll of polyethylene mulching sheet = EC$919.23 + VAT (an area of 4000ft by 4ft).
- The plastic mulch is applied to 2% of the acreage of Other Crops per year (65.46 ac).
- The mulch application increased yield by 2% on 316 acres.
- There is a 90% reduction in the labour cost of weeding as a result of applying the mulch (CARDI 2009)
- There is a 30% adjustment for cost of living and shipping and handling.
- There is an avoided cost for weedicide (except pre-emergent weedicide), labour, material and equipment cost for insecticide in tomato production (Adams *et al* 2007).

Option 3: Establish Systems of Food Storage.

It was assumed that:

- Storage would provide food for 315,392 meals at 1 lb per meal, in the event of a national emergency.
- Food storage consists of dry/canned goods and grains such as rice and wheat flour.
- The products stored are bought as a fiscal incentive and are owned by private firms, except in national emergencies, when ownership reverts to the State.
- No replacement is needed for silos in the project period.
- Four (4) silos to be installed. The details of the cost are shown in Table 23.

Table 23: Breakdown of Food Storage Costs

Item	**Cost(EC$)**	**Reference**
Ten (10) ton wheat silo @Aus$5830	15,974.2	Moylan Grain Silos (2011)
Shipping & handling	15,974.2	
Sub-total	31,948.4	
Installation - labour	60,000	15 persons @$400/day*10 days
Total	91,948.4	
Four (4) warehouses (each of 25 by 40 ft) with holding capacity for143360 kg		
6.4 kg food per sq ft		
8 ft high stack		
70% warehouse capacity		
Wheat price EC$/metric tonne	816.48	IndexMundi
Rice price EC$/metric tonne	1,445.067	IndexMundi
Emergency meals:	315,392	1 lb food per meal

Source: Data compiled by author

Option 4: Use Water Saving Irrigation Systems and Water Management Systems e.g. Drip Irrigation.

An irrigation trial in Saint Vincent in 1995 using imported tissue culture plants on 3.18 acres drip irrigation was set up at a cost of EC$5,000 per acre. This system used a 10 Hp electric pump with a capacity to deliver 90 gallons of water per minute. Drip lines had emitters spaced at 80 cm. During peak periods, a total of 7,000 gals per acre were applied using water from a nearby river. The system was metered to deliver nine gallons of water per mat per day. The gross yield per acre was 20.93 metric tonnes, while net sales were 19.08 metric tonnes per hectare (Cain, Anderson and Greene 1997). Based on the FAO Saint Lucia Country profile, irrigation requirements are provided for Saint Lucia (Box 2).

- Currently, a fairly large and well managed irrigation system exists in Fond State, and is used to support the production of a wide range of crops, including bananas, pineapples and vegetables. In addition, there is a centrally organized scheme in the Mabouya Valley and there are a few individual small farm systems. In total, about 297 ha are irrigated. Of that figure, 65% apply to five large holdings of more than 15 ha each. Methods of application include drip and sprinklers as well as flooding of field drains. Irrigated crops include bananas, vegetables, limited amounts of tree crops and some 65 ha of pasture. Details on actual amounts abstracted and other data on irrigated agriculture are not currently recorded and no further analysis is therefore possible.

A recent FAO "Prefeasibility Study on Small-Scale Irrigation" estimated that the investment cost for irrigation schemes ranges from 6 400 to 16 000 US$/ha (the higher cost refers to a gravity-fed system). Annual operating costs were estimated at 475 US$/ha for a typical sprinkler pumping scheme, with maintenance costs estimated at 125 US$/ha for the same scheme and 90 US$/ha for a gravity-fed scheme.

Box 2: Irrigation Systems in Saint Lucia

Based on this, it was assumed that:

- There was transformation of 2% or 120.9 ac. of 2007 banana acreage to irrigated with gravity fed system (FAO Aquastat, 2007 Agriculture Survey-St Lucia), each year, for 20 yrs.
- There was a transformation of 2% or 65.46 ac. of 2007 temporary crops to irrigated with sprinkler systems.
- For the drip irrigation system, the investment cost per acre = EC$50,709.
- Year 1= 2012.
- Replacement of equipment occurs every 8 yrs.
- For non-tissue cultured banana plants, yield would increase from 5 tonnes per acre to 12 tonne/ac (60% of yield of tissue-cultured plants).
- There were 3,274 acres under temporary crops in 2007, and other crop yield was 8,883 tonnes, at a value of $25,794,340, which is equal to 2.71 tonnes/ac @ $2903.79/tonne.
- Irrigation of other crops increases yield by 30%.
- Rate of inflation = 4%.

Option 5: Repair/Maintain Existing Dams.

Under the Special Framework of Assistance (SFA99), an amount of EC $10,159,425.00 was made available for the Banana Commercialization Component. The objectives of this programme were to develop: a commercial and competitive banana industry; increase foreign exchange earnings and savings and increase rural sector employment and farm household income.

By the end of 2002, there was expected to be approximately 967 acres of land with off-farm infrastructure in Saint Lucia, mainly in the Cul-de-Sac (420 acres), Roseau (180 acres in Phase I and 150 acres in Phase 2), Mabouya (94 acres), Troumasse (57 acres), Canelles and Gauge (66 acres) (Saint Lucia Ministry of Agriculture, Forestry, Fishery and the Environment).

The works on the various projects started in April 2002 and all the works were completed by November 2003. The irrigation systems were to provide services to 70 farms in Cul-de-Sac, 28 farms in Roseau and 13 farms in Canelles. An allocation of 1.6 million was made under the programme to facilitate the operations and management of the irrigation system by the Irrigation Management Unit (IMU) of the Ministry of Agriculture and ran for 2 years until September 2006. It was expected that by that time, farmers in the three irrigated areas would be in a position to take over the operations and management of the systems. However this has not materialized and the IMU continues to provide the service and fund the operations.

The Government of Saint Lucia was also expected to manage the operations of the irrigation system when the EU support ceased, but this has not been done to date. The Cul de Sac reservoir has not been used by the farmers in that area (The Banana Industry Trust).

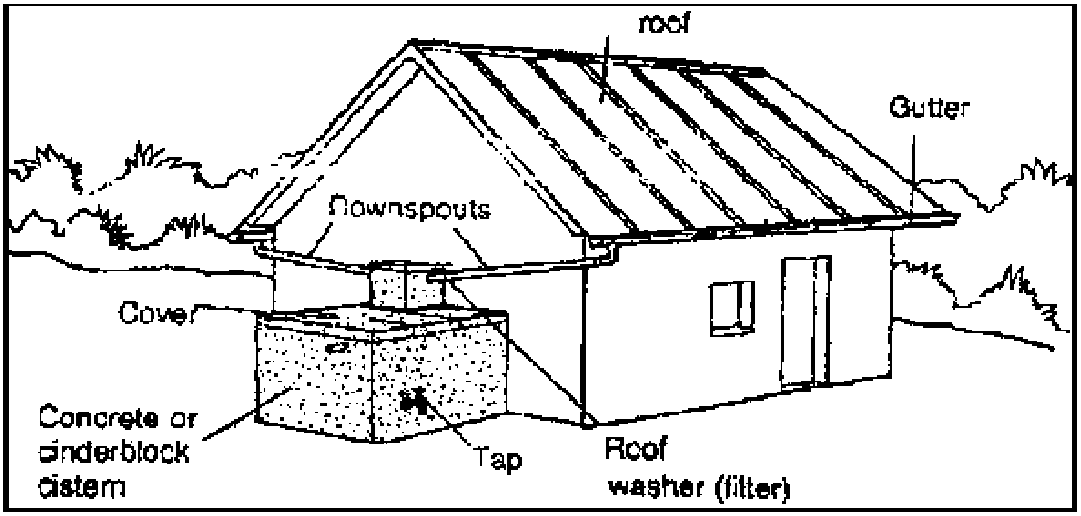
Based on this, it was assumed that:

- Cost of irrigation in the Cul-de-Sac region for 440 ac of bananas = $3,375,000.
- The cost of the Cul-de-Sac Reservoir = $3,850,000.
- Annual Maintenance cost of irrigation is EC$0.8 mil.
- Annual Maintenance cost of the reservoir is 3% of set-up costs
- Yield increases from 5 tonnes/ac to 12 tonnes per ac.
- The 2007 banana revenue was $1437.03/tonne.

Option 6: Promote Water Conservation – Installation of on-Farm Water Harvesting off Roof Tops (Rainwater Harvesting).

In Saint Lucia, storage tanks are constructed of a variety of materials, including steel drums (200 l), large polyethylene plastic tanks (1,300 to 2,300 l), and underground concrete cisterns (100,000 to 150,000 l). Systems to collect rainwater off roof-tops are similar to that shown in Figure 30 below.

Figure 30: Schematic of a Typical Rainwater Catchment System.



Source: UNEP (1997), Figure 1.

It was assumed that:

- Water can be collected off the roofs of on-farm sheds or buildings.

- The length of each on-farm shed/storage unit is 20ft.
- Two 1000 gallon tanks @ EC$894.36 each, plus gutters, spouts and brackets = EC$2,028.42.
- Equipment cost, 25% above the Trinidad and Tobago cost
- Benefit of water harvesting is 40% of the benefit of drip irrigation per acre.
- Labour costs = EC$166.16/man day, for 1 day.
- For 2 tanks, 10 ft down spouting and 10 brackets on the downspouts are required.
- There were 3927 holdings of temporary crops and 1552 holdings of banana (2007 Census)
- There is the establishment of 2% of holdings (110) per year with water harvesting technology.

Option 7: Design and Implement Holistic Water Management Plans for all Competing Uses.

It was assumed that:

- The design and implementation of an appropriate plan would result in an improvement in yield of 2% of the 2008 green vegetables and root crop values.
- Implementation requires 4 persons over 9 months.
- Follow up requires 2 persons for 6 months.
- There is a need for four (4) stakeholder consultations at a cost of EC$6000 each.
- Administration costs include: marketing, office supplies, travel costs, office equipment and services.
- The policy review and monitoring occurs every 5 yrs.
- Follow up administration costs = 20% of Yr1 costs.
- Persons at a rank of Economist 1 would be employed to undertake the policy writing, at a salary of EC$4,154/mth (based on the Trinidad and Tobago equivalent (Brathwaite 2011)).

Option 8: Early Warning Systems

It was assumed that:

- It was assumed that the avoided loss of crops and livestock = 5% of total crop revenue in 2007.
- Implementation costs = EC$2 mil.
- Operational costs are 10% of setup costs.

Option 9: Build on- Farm Water Storage (Ponds, Tanks).

It was assumed that:

- Impoundments are dug into the ground on-farm to collect surface runoff.
- Other reference for the construction cost: In Ecuador, the average cost to construct an on-farm pond was estimated at US$0.93/m^3 of water, but the range was from US $0.10 to US $2.00/m^3 (Unit of Sustainable Development and Environment General Secretariat 2011). The operation and maintenance costs ranged between US $0.01 and US $0.03/m^3 of storage capacity. Even using the upper level of cost, these costs are too low for the Caribbean.
- Established on 40 holdings per year for 10 years.
- Avoided crop losses = 40% of revenue on 40 farms (2007 data).
- 3927 parcels under temporary crops.
- Revenue of Other Crops/parcel = EC$6,568.56 in 2007.

Option 10: Greenhouses

Assumptions of costs and benefits are provided in Table 24.

Table 24: Greenhouse Installation Costs

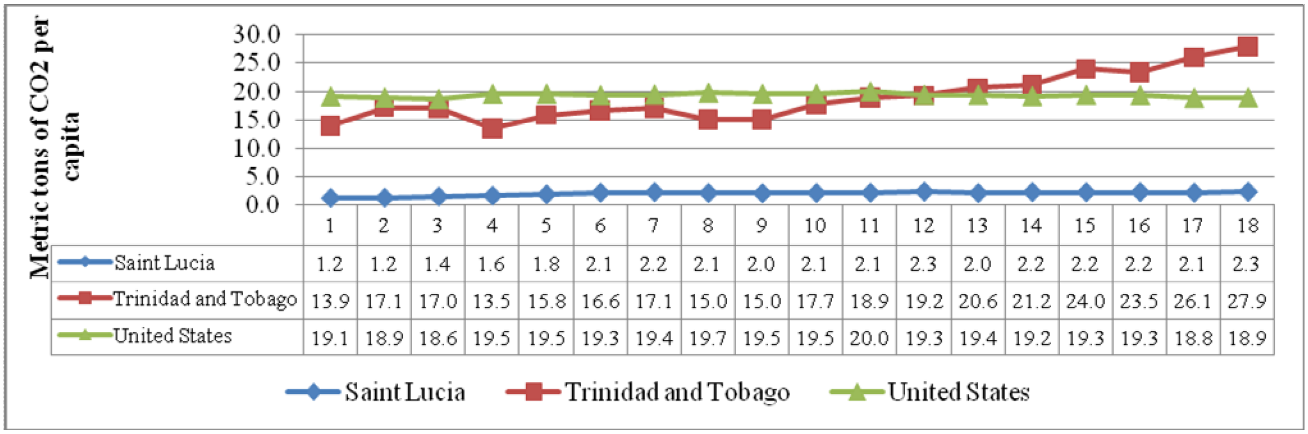
Item	**Cost (EC$)**	**Reference**
Greenhouse - 1 Southern Start Package (EC$)	47,820	Greenhouse Megastore
S&H (20%)	9,564	30' by 48' (20 lb rating, 6 ft sidewall)
Taxes (15%)	7,173	
Land Prep - labour &machinery	2,000	
Labour - Installation	2,000	
Benches, Drip irrigation	4,781.97	
Total	73,339	
Construct 5 per year for 10 years		
Traditional yield (tomatoes)	2,363.32	Vital Earth Resources (1999)
Additional% yield	0.6	
Crops/yr	5	
Additional yield	7089.96	
Price/kg (2007)	6.72	

XII. CONSIDERATIONS FOR MITIGATION OPTIONS IN SAINT LUCIA

A. EMISSIONS

St Lucia is not considered to be a high per-capita emitter of CO_2 (Figure 17), but has experienced rapid growth (over 130%) in carbon dioxide emission from 1990 to 2006 (Table 13).

Figure 31: Per-Capita CO_2 Emissions for Selected Caribbean Countries, 2006



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Saint Lucia	1.2	1.2	1.4	1.6	1.8	2.1	2.2	2.1	2.0	2.1	2.1	2.3	2.0	2.2	2.2	2.2	2.1	2.3
Trinidad and Tobago	13.9	17.1	17.0	13.5	15.8	16.6	17.1	15.0	15.0	17.7	18.9	19.2	20.6	21.2	24.0	23.5	26.1	27.9
United States	19.1	18.9	18.6	19.5	19.5	19.3	19.4	19.7	19.5	19.5	20.0	19.3	19.4	19.2	19.3	19.3	18.8	18.9

Source: UN Statistical Division

Table 25: CO2 Emissions in 2006

	CO_2 Emissions	% Change Since 1990	CO_2 Emissions Per Capita	CO_2 Emissions Per km^2
	mio.	%	tonnes	tonnes
Saint Lucia	0.38	130.9	2.34	706.86
St. Vincent and the Grenadines	0.20	145.5	1.65	509.00
Trinidad and Tobago	33.60	98.1	25.29	6 549.90
United Kingdom	557.86	-5.5	9.20	2 296.64
United States	5975.10	18.1	19.70	620.53

Source: UN Statistics Division.

In 1994, Saint Lucia's First National Communication on Climate Change indicated that agriculture, forestry and fishing accounted for 0.1 Gg of CO_2 of the total 265 Gg of CO_2 emitted in Saint Lucia (Ministry of Planning, Development, Environment & Housing 2001). The other identified greenhouse gases were methane (CH_4) and Nitrous Oxide (N_2O). In 1994, the agricultural sector emitted 0.5Gg CO_2 of methane and 0.055 Gg CO_2 of N_2O. Growth of forests and other woody biomass resulted in the storage of 516.06 Gg CO_2, while 68.06 Gg CO_2 was emitted by Forest and Grassland conversion, and 95.89 Gg CO_2 was emitted by forest soils. Non CO_2 emissions (CH_4, CO,N_2O and NO_x) accounted for only 2.6 Gg CO_2. Therefore, based on 61,500 hectares of total forest that is anthropogenically impacted, Saint Lucia's Land Use, Land Use Change and Foresty Sector acted as a net sink for 352.11 Gg CO_2 in 1994.

In the agricultural sector, most of the CO_2 emissions were attributed to the use of machinery for cultivation practices such as tillage, harvest and irrigation (Ministry of Planning, Development, Environment & Housing 2001). Therefore, the recommended mitigation options are:

1. Increased use of on-farm renewable energy.
2. Increase energy efficiency on farms (lighting, heating etc)
3. Generation of fuels on-farm e.g. biogas digesters from livestock production
4. Increase carbon storage in soils.

These measures are not appraised economically in this report, however, Saint Lucia should also consider one of the main off-farm sources of mitigation, which has a direct impact on the agricultural sector – the maintenance of their forest cover.

XIII. CLIMATE CHANGE AND THE IMPLICATIONS FOR FOOD SECURITY

Food security has four main elements. Firstly, food must be available from either local or imported sources, in a form that it is needed. Climate change threatens the availability of food from global sources as the increased incidence of drought in key production areas of Australia and Russia in 2009 and 2010 caused severe shortages. When traditionally exporting countries have reduced local production, this often causes a focus on meeting local demands, with exports given a lower priority, which may lead to a fall in exports and therefore lowered world supply with associated higher global prices. Furthermore, climate change in Saint Lucia is expected to result in lower rainfall through to 2050 and higher temperatures. Based on the analysis conducted, agricultural output for bananas, root crops and fisheries are expected to be adversely affected. This lower output will have a direct negative effect on employment in the agricultural sector as persons may be laid off as farmers' profits decline. This will have a negative multiplier on indirect employment in the sector, as well as supporting services such as marketing and distribution of produce. Overall, the livelihoods of farmers and their families will be affected, especially in the rural areas.

Secondly, for food security to exist, food must be accessible. This means that consumers must have the incomes needed to purchase food, and producers (who are mainly in rural areas) must also gain incomes to sustain their families and communities. Climate change effects that reduce farmers incomes immediately affect their access, and any real price increases will adversely affect consumers as well, with a greater effect on urban consumers, who generally have to access to food except via what can be purchased using their incomes. This is unlike rural consumers, who may often rely on back-yard gardens and the informal support of family members and friends who may be farmers or have backyard gardens. Of particular concern is the potential fall-off of banana export revenue, as this accounts for almost all the agricultural GDP. A decline here would also translate to a fall in foreign exchange earnings by Saint Lucia, and a reduction in foreign exchange to buy imported food, further undermining the country's accessibility to food.

A third key element is that food must be safe (free of pests and disease) and provide adequate nutrition. The final component of food security is that the availability, accessibility, safety and nutritious nature of our food must be stable at all times. Changes in climate which affect food quantities also threaten the stability of food flows to consumers. Overall, with lowered supply of food locally and strained ability to afford to spend more money on imported foods, any increased food prices will unfavorably affect the food security of the Saint Lucia population, with bigger impacts on poorer persons who typically spend a higher percentage of their incomes on foodstuffs.

Historically, the agricultural sector has been allowed to decline as the country suffered from "Dutch Disease", a case where rapid increases in incomes from the tourism sector stifled investments in non-tourism sectors, including agriculture. As a result, much of the infrastructure was not maintained or replaced over time, leading to declined support services and infrastructure. Many persons were also attracted to higher paying non-agriculture jobs, such as in the construction sector, as the real wages in these alternate sectors grew relative to agricultural wages. The agricultural sector also suffered from a poor perception in society that the tasks involved were menial, not profitable and too risky (due to praedial larceny and weather risks). A lack of insurance for farmers also added to the risks they endured. The threat of climate change therefore adds a new level of burdens to the country's agricultural sector, but one to which adaptation options must be fast-tracked, if the sector is to survive to continue to sustain the livelihoods of so many in the society.

XIV. DATA NEEDS FOR FUTURE WORK

Based on the data availability challenges encountered, it is suggested that the following data be collected, in a consistent and timely manner and be publicly available to support future work in this area:

- Monthly data on harvest and prices at various levels (farm-gate, wholesale and retail) – all crops.
- Monthly data on area under production – all crops.
- Monthly data for meats – quantity reared and slaughtered, price.
- Type of irrigation used and type and acreage under each kind of irrigation.
- Monthly data on input use at the farm level
- Fertilizer
- Pesticides
- Farm machinery
- Herbicides
- Labour – quantity and wages
- Technology

XV. CONCLUSIONS

For the A2 scenarios, rainfall is expected to change greatly through to 2020, increasing slightly by approximately 5% in the current decade, then fall rapidly by approximately 21% in the 2020s, and remaining below the baseline mean, ending with a 17% reduction by the 2040s. The B2 scenario exhibited similar swings, and by the 2040s, rainfall is expected to fall by approximately 22% under this scenario. Over the same period, temperature is expected to increase by 1.53°C and 1.52°C under A2 and b2 respectively.

The mean annual rainfall of 1546.44 mm is well below the optimal rainfall range for bananas. Therefore it is expected that any further increase in rainfall should have a positive effect on banana production. In addition, the upper temperature limit for bananas was 30 °C. Given that the mean temperature from 1981 to 2008 was 27.05 °C, further expected increases in temperature will result in the ambient temperature likely exceeding the optimal end of the range. Therefore the sign for temperature was negative, as expected. A 1% increase in rainfall is expected to cause an approximate 0.27% increase in the growth of banana exports. A 1% increase in temperature is expected to cause an approximate 5.1% decrease in the growth of banana exports. Therefore, banana is double affected by the expected rise in temperature and fall in rainfall. There is a rapid fall-off in expected banana exports, so that by 2050, banana exports are minimal.

By 2050, the value of cumulative yield losses (2008$) for banana, is expected to be $165.36 mil under the A2 scenario and $165.54 mil under the B2 scenario. In addition to the potential climate impacts, it should be noted that there are several non-climate factors that have contributed, perhaps overwhelmingly, to the decline in the banana sector. The key contributor is the loss of preferential prices in the EU market by Caribbean exporters, who previously enjoyed above-market rates under the Lomé Convention.

Given that the mean annual rainfall is well below the optimal rainfall range for the main root crops of yam and sweet potato, it is expected that any further decrease in rainfall should have a negative effect on root crop production. In addition, the upper temperature limit for yam and sweet potato was 30 °C. A 1% increase in rainfall is expected to cause an approximate 0.23% increase in the root crop production. A 1% increase in temperature is expected to cause a 5.3% decrease in root crop production. Therefore, root crops are likely to be worse off overall from the expected fall-off in rainfall and the rising temperature. By 2050, the root crops are expected to lose $61.37 mil under the A2 scenario and $58.04 mil under the B2 scenario (2008$).

It was expected that any further decrease in rainfall should have a deleterious effect on breadfruit and avocado yield, and possibly the tree crop group since breadfruit and mango are the most valuable commodities in this group. The sign for temperature was also negative as expected, but is insignificant. However, a 1% decrease in rainfall is expected to cause an approximate 1.24% increase in the growth of tree crop harvests. A 1% increase in temperature is expected to cause an approximate 0.56% decrease in the growth of tree crop harvests (in the short run). For all decades the production values are lowest under the baseline “no climate change” case, with A2 having the highest values in all decades. By 2050, the tree crops are expected to gain $345.35 mil under the A2 scenario and $251.63 mil under the B2 scenario (2008$).

Given the relative weight of tomatoes, it was expected that increases in temperature will result in the ambient temperature exceeding the optimal end of the tomato range, and hence an overall negative impact on the production of vegetable crops. However, a 1% decrease in rainfall is expected to cause an approximate 1.08% increase in the growth of vegetable crop harvests, which is contrary to expectations. It is possible that the small sample size, and the omission of key farm input variables, such as labour, may be leading to biased and therefore unexpected coefficient results. For all decades the production values are lowest under the baseline “no climate change” case, with A2 having the highest values in all decades. By 2050, the vegetable crops are expected to gain $333.31 mil under the A2 scenario and $313.82 mil under the B2 scenario (2008$).

Relative to the 2005 catch for fish, there will be a decrease in catch potential of 10 - 20% by 2050 relative to 2005 catch potentials, other things remaining constant. By 2050 under the A2 and B2 scenarios, losses in real terms were estimated to be $62.59 mil and $31.29 mil respectively, at a 1% discount rate.

Relative to the Baseline case, the key subsectors in agriculture are expected to have mixed impacts under the A2 and B2 scenarios. Banana, fisheries and root crop outputs are expected to fall with climate change, but tree crop and vegetable production is expected to rise. In aggregate, in every decade up to 2050, these sub-sectors combined are expected to experience a gain under climate change, all scenarios, with the highest gains under A2. By 2050, the cumulative gain under A2 is calculated as approximately $389.35 mil and approximately $310.58 mil under B2, which represents 17.93% and 14.30% of the 2008 GDP.

Sea-level rise is not expected to have any significant effect on agricultural land loss in Saint Lucia. Further, it was assumed that by 2050, there will be a 2.5% increase in intensity under the A2 scenario, and 90% of this increase attributed to the B2 scenario. Therefore, by 2050, additional losses due to an increased intensity of tropical cyclones is expected to be $6.9 mil under the A2 scenario and $6.2 mil under the B2 scenario, with a 1% discount rate.

The most attractive adaptation options, based on the Benefit-Cost Ratio are: (1) Design and implement holistic water management plans (2) Establish systems of food storage and (3) On-farm water harvesting systems. However, the options with the highest net benefits are, (in order of priority): (1) Use of Drip Irrigation, (2) Mainstreaming climate change issues into agricultural management and (3) Establish systems of food storage. Therefore, government policy should focus on the development of these adaption options where they are not currently being pursued, and strengthen those that have already been initiated, such as the mainstreaming of climate change issues in agricultural policy.

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ANNEX I: OPTIMAL GROWING CONDITIONS FOR SELECTED CROPS

	Crop	Optimal Temperature Range °C	Optimal Rainfall Range (mm/Yr)
	Fruit Vegetables		
1	Tomato [1]	21-27	3000
2	Cucumber[13]	23-28	
3	Sweet Pepper [1]	21-35	625-1250
4	Hot Pepper [1&3]	21-35	625-1250
5	Ochro [1]	21-35	300-2500
6	Melon [1]	24-29	
7	Pumpkin [1]	21-33	
8	Carrot [1]	7-30	
	Leafy Vegetables		
9	Cabbage [1&4]	22-26	
10	Lettuce [1&4]	25-30	
	Citrus		
11	Lime [6,11&12]	28-32	1250-1850
12	Sweet Orange[6,11&12]	20-37	1000-1500
13	Grapefruit [6,11&12]	20-27	1500-1800
	Tree Crops		
14	Breadfruit [6]	25-33	1500-3000
15	Avocado [9&10]	25-28	2000
16	Soursop [7]	18-25	1000-2500
17	Mango [6]	27-29	250-2500
	Rootcrops		
18	Dasheen [2]	24	1400-2000
19	Yam [2]	30	1150
20	Tannia [2]	13-29	1400-2000
21	Ginger [5&3]	25-35	2500-3000
22	Sweet Potato [2]	15-30	750-1000
	Other		
24	Banana [5& 8]	26-30; 21-32°C[14]	2400-2640; 1000-2000[14]
24	Plantain [5& 8]	26-30	2400-2640
25	Pineapple [5]	24-35	1000-1500

[1]GrowingAnything.com, [2]Horton (1988), [3]Douglas, Heyes and Smallfield (2005),[4]Colorado State University (2011),[5] Purseglove (1975),[6] Purseglove (1974),[7] CAB International (2005),[8]Bradtke,[9] Department of Agriculture, Forestry and Fisheries, Republic of South Africa ,[10] Ghosh (2000), [11]Hardy and Khurshid (2007), [12]FAO (nd), [13] Netafim, [14]St Lucia V&A Report, pg 87.

ANNEX II: MODEL TEST RESULTS

Table A-1: Model Estimates for Root Crop Yield

Vector Error Correction Estimates
Sample (adjusted): 1992 2008
Included observations: 17 after adjustments
t-statistics in [
]

Cointegrating Eq:	CointEq1	t-stat	CointEq2	t-stat		
LOG(QRC(-1))	1.000000		0.000000			
LOG(RPRC(-1))	0.000000		1.000000			
LOG(TEMPSLBASE(-1))	-52.68913*	[-4.24985]	-23.49021*	[-1.99376]		
C	173.8956*	[4.09498]	84.84077*	[2.10233]		
Error Correction:	D(LOG(QRC))		D(LOG(RPRC))		D(LOG(TEMPSLBASE))	
CointEq1	-0.442565*	[-2.51453]	0.299243*	[2.21880]	0.034397*	[2.68370]
CointEq2	0.743250*	[2.87536]	-0.525751*	[-2.65432]	-0.012502	[-0.66417]
D(LOG(QRC(-1)))	0.510242	[1.16044]	-0.860427	[-2.55373]	0.022789	[0.71171]
D(LOG(RPRC(-1)))	0.341110	[0.55953]	-0.839593***	[-1.79728]	0.060151	[1.35492]
D(LOG(TEMPSLBASE(-1)))	-1.495294	[-0.38704]	0.258263	[0.08724]	0.899155*	[3.19596]
H	-0.235301	[-1.40922]	0.224340***	[1.75339]	-0.022345***	[-1.83768]
LOG(RAINSLBASE)	-0.638425*	[-2.50556]	0.476261*	[2.43924]	-0.027892	[-1.50318]
R-squared	0.611949		0.694415		0.696891	
Adj. R-squared	0.379118		0.511064		0.515026	
Sum sq. resids	0.684662		0.402018		0.003631	
F-statistic	2.628297		3.787355		3.831912	
Log likelihood	3.180418		7.706055		47.71591	
Schwarz SC	0.792450		0.260023		-4.447019	
Log likelihood			71.42112			
Schwarz criterion			-3.569356			

where *statistically significant at the 1% level, **statistically significant at the 5% level and *** statistically significant at the 10% level.

Table A-2: Model Estimates for Tree Crop Yield

Vector Error Correction Estimates
Sample (adjusted): 1992 2008
Included observations: 17 after adjustments
Standard errors in ( ) & t-statistics in [ ]

Cointegrating Eq:	CointEq1		CointEq2	
LOG(QTC(-1))	1.000000		0.000000	
LOG(RPTC(-1))	0.000000		1.000000	
LOG(TEMPSLBASE(-1))	-1.223534	[-1.07634]	3.103163*	[3.87261]
@TREND(81)	0.020683*	[5.13669]	-0.001625	[-0.57238]
C	-5.234939		-10.62131	

Error Correction:	D(LOG(QTC))		D(LOG(RPTC))		D(LOG(TEMPSLBASE))	
CointEq1	-1.702858*	[-2.42882]	0.110693	[0.18437]	-0.277808*	[-2.11552]
CointEq2	0.242087	[0.32763]	-1.767858*	[-2.79391]	-0.347773*	[-2.51284]
D(LOG(QTC(-1)))	0.123978	[0.30723]	0.018579	[0.05376]	0.107750	[1.42556]
D(LOG(RPTC(-1)))	-0.657700	[-1.63585]	0.558338	[1.62168]	0.174537	[2.31771]
D(LOG(TEMPSLBASE(-1)))	-0.558446	[-0.29750]	2.238701	[1.39268]	0.645534	[1.83602]
C	6.054230	[4.44178]	-4.179336	[-3.58061]	0.396338	[1.55245]
H	-0.103670	[-1.27738]	-0.049002	[-0.70507]	-0.004333	[-0.28505]
LOG(RAINSLBASE)	-1.238157*	[-4.48915]	0.864434	[3.65992]	-0.080573	[-1.55967]
R-squared	0.844068		0.891553		0.560400	
Adj. R-squared	0.722787		0.807206		0.218488	
F-statistic	6.959630		10.56999		1.639020	
Log likelihood	16.08037		18.71679		44.55583	
Schwarz SC	-0.558532		-0.868698		-3.908585	

Log likelihood	89.74980
Schwarz criterion	-5.225693

where *statistically significant at the 1% level, **statistically significant at the 5% level and *** statistically significant at the 10% level.

Table A-3: Model Estimates for Vegetable Crop Yield

Vector Error Correction Estimates
Sample (adjusted): 1992 2008
Included observations: 17 after adjustments
Standard errors in ( ) & t-statistics in [ ]

Cointegrating Eq:	CointEq1		CointEq2	
LOG(QVC(-1))	1.000000		0.000000	
LOG(RPVC(-1))	0.000000		1.000000	
LOG(TEMPSLBASE(-1))	-0.128787	[-0.07458]	6.940058*	[5.34516]
@TREND(81)	-0.032905*	[-5.15995]	-7.42E-05	[-0.01547]
C	-6.446848		-24.31085	

Error Correction:	D(LOG(QVC))		D(LOG(RPVC))		D(LOG(TEMPSLBASE))	
CointEq1	-1.705324*	[-4.02195]	0.701816	[1.80024]	-0.047880	[-0.68048]
CointEq2	0.233020	[0.59282]	-1.139991*	[-3.15435]	-0.094754	[-1.45264]
D(LOG(QVC(-1)))	0.615996	[1.48577]	-0.215264	[-0.56470]	0.010124	[0.14715]
D(LOG(RPVC(-1)))	-0.096774	[-0.24163]	0.304922	[0.82807]	0.056571	[0.85118]
D(LOG(TEMPSLBASE(-1)))	1.199325	[0.40889]	2.953276	[1.09510]	0.556165	[1.14264]
C	5.278893	[3.47899]	-3.701724	[-2.65333]	0.226549	[0.89971]
H	-0.008152	[-0.06061]	-0.028214	[-0.22818]	-0.002291	[-0.10264]
LOG(RAINSLBASE)	-1.078462*	[-3.48153]	0.765805	[2.68881]	-0.046507	[-0.90471]
R-squared	0.798199		0.817209		0.371534	
Adj. R-squared	0.641242		0.675038		-0.117272	
F-statistic	5.085479		5.748068		0.760085	
Log likelihood	10.98430		12.41216		41.51780	
Schwarz SC	0.041006		-0.126978		-3.551170	
Log likelihood			74.54248			
Schwarz criterion			-3.436596			

where *statistically significant at the 1% level, **statistically significant at the 5% level and *** statistically significant at the 10% level.

ANNEX III: POTENTIAL RISKS AND ADAPTATION OPTIONS*

(High/Yes=5; Medium=3;Low/No=1)

Risk	**Source**	**Adaptation Option**	**Evaluation Criteria**											
			Low Cost	Effectiveness	Acceptance to Stakeholders	Endorsement by Experts	Short Time Frame	Institutional Capacity	Size of Beneficiary Group	Ease of Implementation	Adequacy for Current Climate	Potential Positive Social/Environmental Impact	Potential to Sustain Over Time	Score
↓ Water Availability	↓ Rainfall	Use water saving irrigation systems and water management systems e.g. drip irrigation	M	M	H	H	H	H	H	H	H	H	M	49
		Build on-farm water storage (ponds, tanks etc)	H	H	M	M	M	H	M	M	H	H	M	43
		Promote water conservation – install on-farm water harvesting off roof tops	L	M	M	H	H	H	H	H	H	H	H	47
		Install protected agriculture facilities	L	H	M	M	M	L	L	L	H	H	M	31
		Change agronomic practices e.g. mulching	M	H	L	H	H	M	H	M	H	H	M	43
		Change water pricing to reflect increasing	H	M	L	H	H	M	H	L	H	H	M	41

Risk	Source	Adaptation Option	Evaluation Criteria											
			Low Cost	Effectiveness	Acceptance to Stakeholders	Endorsement by Experts	Short Time Frame	Institutional Capacity	Size of Beneficiary Group	Ease of Implementation	Adequacy for Current Climate	Potential Positive Social/Environmental Impact	Potential to Sustain Over Time	Score
		scarcity												
		Build new dams	L	H	M	H	L	M	H	L	H	M	M	35
		Design and implement holistic water management plans for all competing uses	M	H	H	H	M	H	H	L	H	H	H	47
		Repair/maintain existing dams	M	H	H	H	H	M	H	H	H	H	M	49
		Provide fiscal incentives for water conservation	L	H	M	M	M	L	H	M	H	H	M	37
		Relocate farms to lands with good agricultural capability	L	M	M	H	M	M	M	L	M	H	H	35
		Establish germplasm bank of native drought tolerant varieties/ provide quick availability of planting material	L	M	M	H	L	L	M	M	M	H	M	31
		Mainstream climate change issues into	H	M	H	H	H	H	H	H	H	H	H	53

Risk	Source	Adaptation Option	Evaluation Criteria											
			Low Cost	Effectiveness	Acceptance to Stakeholders	Endorsement by Experts	Short Time Frame	Institutional Capacity	Size of Beneficiary Group	Ease of Implementation	Adequacy for Current Climate	Potential Positive Social/Environmental Impact	Potential to Sustain Over Time	Score
		agricultural management												
		Alter crop calendar for short-term crops	H	H	H	H	H	H	H	H	L	H	H	51
		Promote agricultural diversification	L	H	M	H	M	M	H	M	H	H	M	41
		Reduce non-native competition by controlling invasive species	L	H	L	H	M	M	H	M	M	H	M	37
	↑ incidence of drought	Introduce more drought resistant/ tolerate species	L	H	H	H	L	L	H	L	H	H	M	37
		Adopt improved technologies for soil conservation	H	H	M	H	H	H	H	M	H	H	H	51
		Implement land policy to retain high quality land	L	H	H	H	L	M	H	L	H	H	L	37
		Build new desalination plants to meet water demand deficit	L	H	M	M	L	L	H	L	H	H	M	33
		Utilize more	L	M	L	L	M	M	M	M	H	M	H	31

Risk	Source	Adaptation Option	Evaluation Criteria											
			Low Cost	Effectiveness	Acceptance to Stakeholders	Endorsement by Experts	Short Time Frame	Institutional Capacity	Size of Beneficiary Group	Ease of Implementation	Adequacy for Current Climate	Potential Positive Social/Environmental Impact	Potential to Sustain Over Time	Score
		ground water sources												
		Establish wild fire eradication scheme at national/farm level	M	H	M	H	M	M	H	M	L	M	M	37
Agricultural Land Loss	Seal level rise	Build defensive sea walls	L	H	M	M	L	M	L	M	L	M	H	29
		Relocate agricultural production	M	H	M	H	M	M	L	M	L	M	H	35
Soil salinization and reduced land quality	Sea level rise	Develop/introduce salt tolerant/ resistant crop varieties	L	M	H	M	L	L	L	L	L	H	H	27
		Adopt more intensive livestock farming	L	M	L	M	M	M	M	L	H	M	M	29
↑ Flooding	↑ Intensity of tropical storms	Establish systems of food storage	M	H	H	H	H	H	H	M	H	H	H	51
		Improve agricultural drainage systems	L	M	H	H	M	M	H	M	H	H	M	41
		Establish early warning	L	H	H	H	M	M	H	M	H	H	H	45

Risk	**Source**	**Adaptation Option**	**Evaluation Criteria**											
			Low Cost	Effectiveness	Acceptance to Stakeholders	Endorsement by Experts	Short Time Frame	Institutional Capacity	Size of Beneficiary Group	Ease of Implementation	Adequacy for Current Climate	Potential Positive Social/Environmental Impact	Potential to Sustain Over Time	Score
		systems and disaster management plans for farmers												
		Promote integrated watershed management	L	H	H	H	L	M	H	L	H	H	M	39
		Establish a crop and livestock insurance scheme	L	H	M	H	L	L	H	L	H	H	M	35
↑ Wind speed	↑ Intensity of tropical storms	Introduce wind breaks on farms	H	L	L	M	M	L	H	L	H	H	L	31
↑ Pest and disease outbreaks	Change in temperature and rainfall patterns	Establish R&D for adoption of cultural/ biological control measures	L	H	H	H	L	L	H	L	H	H	M	37
↑ Sea surface temperature		Establish aquaculture facilities	L	H	M	H	H	M	M	M	H	M	M	39

*Many of the adaptation options reviewed are “Prioritized Recommendations and Strategies for Short, Medium and Long-Term Adaptation in Saint Lucia” (St Lucia V&A Report 2010, pg 84)