Swedish University of Agricultural Sciences
Faculty of Natural Resources and Agricultural Sciences
Department of Economics

The Impact of Climate Change on Agriculture in The Republic of Mauritius

A Socio-Econometric Study on Mauritian Farming

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Abstract

"Food security is a situation that exists when all people, at all times, have physical and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life" (FAO Summit, 2003, pp. 28).

Food insecurity is of concern regarding the Republic of Mauritius (ROM) since it is defined as a net food importing country. (Farming news, 2008). The impacts of climate change followed by their complexity could potentially have an increased risk effect upon the social and environmental welfare as well as the economic drivers in the ROM (www, UNESCO1, 2009). The primary victims when it comes to the impacts of climate change are the Mauritian agricultural producers since agriculture is highly dependent on climate stability, therefore affecting the yields of the producers. (Pers. com. S. Seenattun, 2010). Without increased research and development of sustainable agricultural models in order to tackle the consequences of climate change, socio-economic development risks to stagnate and affect the income of private households in Mauritius (ibid.). The main aim of the thesis is to determine, from a micro perspective using an econometric and survey approach, the impact of climate change upon tomato yields and further Mauritian agriculture.

The study is based on two methodological approaches, determining how the impacts of climate change, more precisely how temperature, rainfall, sunshine hours and other socio-economic variables are affecting the yields of tomato and agricultural practice on Mauritius. The method applies two different tools, a Ricardian model based approach and a survey. The Ricardian based model calculates and analyzes the impacts of fluctuations in climatic variables upon tomato yields. The socio-economic study examines from a Mauritian farmer perspective, the impacts of climate change upon the yields of agricultural food crops and farmers production. It shall moreover examine how they perceive changes in climate. Further, the survey will analyze the socio-economic issues experienced by the farmers.

The econometric results illustrate that increased temperatures and a decrease in precipitation would negatively affect tomato yields over the whole island, where monthly tomato yields in the Eastern region would decrease by 8.2% in the short-run and 13.3% in the long-run with a 1°C temperature increase and 10% precipitation decrease for instance. The result per region permits to analyze which area is more sensitive to an increase or decrease in a specific climatic variable. The main findings from the survey demonstrated which socio-economic variables are important according to the farmers, such as input costs and lack of labour. The survey also showed that indeed, Mauritian farmers have perceived changes in climate and that accordingly changes in climate is negatively affecting their yields.

The thesis is concluded with a table summarizing the main point from both studies followed by the main topics that should be incorporated in a Sustainable Agricultural Model for the Republic of Mauritius.

Key terms: Econometrics, Food crops, Agriculture, Mauritius, Ricardian modeling, Socio-economic survey, Farmers, SWOT-analysis, Statistical significance, ANOVA-test.

Sammanfattning

Den växande livsmedelsosäkerheten är ett bekymmer för Mauritius eftersom denna ö är definierad som ett importland av livsmedel. (Farming News, 2008). Klimatförändringarnas påverkan till följd av dess komplexitet skulle kunna öka riskerna för den sociala-, ekonomiska- och miljövälfärden på Mauritius. (www, UNESCO1, 2009). De först drabbade vad det gäller klimatförändringarnas effekter är Republikens bönder eftersom jordbruket är en av de första sektorerna som berörs av vädrets beteende. (Pers. com. S. Seenattun, 2010). Vid instabila väder- omständigheter påverkas grödorna, avkastningen och därmed böndernas inkomst och leverne. Utan ökad forskning och utveckling av hållbara jordbruksmodeller för länder placerade i övärldar för att kunna hantera klimatförändringarnas påföljder, riskerar den socioekonomiska utvecklingen att stagnera och påverka de privata hushållens ekonomi. (ibid). Huvudsyftet med denna uppsats är att examinera, utifrån ett mikroperspektiv med användning av en ekonometrisk- och en enkätmodell, klimatförändringarnas influens på Mauritius tomatavkastning samt deras jordbruk.

Studien är baserad på två metoder kapabla att analysera hur det förändrade klimatet, mer precist hur temperatur, regnfall, timmar solsken och olika socioekonomiska variabler påverkar avkastningen av tomat samt jordbrukssektorn på Mauritius. Den första metoden är baserad på en Rikardiansk modell, vilken räknar ut och examinerar hur förändringar i klimatet påverkar tomatavkastning såväl för hela ön, som regionvis. Enkäten undersöker, från en bondes perspektiv, hur klimatförändringarna inverkar på deras produktion och avkastningen på deras grödor. Enkäten utreder även hur jordbrukarna upplever klimatförändringarna och vilka socioekonomiska problem de upplever.

De ekonometriska resultaten visar att ökade temperaturer och minskning i regnfall och solskenstimmar skulle negativt påverka tomatavkastning för ön då t.ex. en temperaturökning på 1°C samt 10 procent regnfallsminskning på den Östra delen, skulle innebära en 8.2 procents minskning på kort sikt och 13.3 procent på längre sikt i tomatavkastning per månad. Resultaten per område klargör vilka delar av ön som är mer eller mindre känsliga i förhållande till en ökning eller minskning av en särskild klimatvariabel. Det socioekonomiska perspektivet, exempelvis insatskostnader samt brist på arbete, visade sig vara statistiskt signifikanta gällande enkätresultaten. Undersökningen påvisade även att jordbrukarna på Mauritius har upplevt förändringar i klimatet och att denna omväxling berör negativt deras avkastning.

Uppsatsen avslutas med en tabell vilken sammanfattar de väsentliga slutsaterna från båda studierna. Dessa följs av förslag till de huvudämnen som borde integreras i en hållbarutvecklingsmodell specifik för Mauritius.

Nyckelord: Ekonometri, livsmedelsgrödor, jordbruk, Mauritius, Rikardiansk modellering, enkät, jordbrukare, SWOT-analys, statistisk signifikans, ANOVA-test.

Abbreviatons

AREU: Agricultural Research and Extension Unit
FAO: Food and Agricultural Organization of the United Nations
GDFCF: Gross Domestic Fixed Capital Formation
GDP: Gross Domestic Product
GNP: Gross National Product
GHG: Green House Gases
IPCC: Intergovernmental Panel on Climate Change
MPP: Marginal Physical Product
MSIRI: Maurituis Sugar Industry Research Institute
NRHA: Net Revenue per Hectare
PNUD: Programme des Nations Unies pour le Développement
ROM: Republic of Mauritius
SPWF: Small Planters Welfare Fund
SSE: Sum of squared errors
SSI: Seasonal Storage Index
TPP: Total Physical Product
UNDP: United Nations Development Program
UNESCO: United Nations Educational, Scientific and Cultural Organization

Table of Contents

1 Introduction

The following chapter provides the reader with the problem background going from the global impacts of climate change regarding agriculture to its effects upon Mauritian farming. The section is followed by the problem, aim and delimitations as well as the outline of the study.

1.1 Problem background

Facing the threats of climate change today followed by its impacts on the environment is certainly a challenge difficult to tackle. (Stern, 2006). Moreover, the present environmental situation has created a greater issue regarding human development, especially in developing countries, where the situation of poverty is already out of great complexity. Approximately 800 million individuals survive with an income inferior to US$1 per day. (Da Silva et al, 2009; Da Silva et al, 2002). 75 percent of these 800 million people live in rural areas, where agricultural practice is their main source of livelihood. (Rayner et al, 1998).

There is a large concern regarding the impacts of climate change and its variability upon agricultural practices worldwide (Fisher et al, 2005). The global distress of food insecurity is but one consequential factor where each country and state is alarmed by the outcomes of the impacts of climate change that might arise over the coming decades. A large number of studies have analyzed the potential impacts of climatic variability and instability upon agricultural production in developed as well as countries in transition. The studies in question reveal that an increased variable climate could have potential positive impacts regarding agriculture in developed countries (Mendelshon et al, 1994; Fisher et al, 2005). Nonetheless, concerning agricultural production in developing countries, the impacts of climate change does not always provide a unified picture. (Fisher et al, 2005). The effects of climate change in transitional countries could instead depress yields and increase the risk of food insecurity, widening the gap between wealthy and poor.

The impacts of climate change are related to the phenomena of food insecurity (Schmidhuber & Tubiello, 2007). The FAO defines food security as *"a situation that exists when all people, at all times, have physical and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life"* (FAO Summit, 2003, pp. 28). On the other hand food insecurity occurs when individuals do not have the adequate social, physical or economic access to food. (Farming news, 2008). According to Farming news (2008) the global state of food insecurity is caused by:

- Increasing fossil fuel price
- The urge for biofuel
- Changes of food habits in developing countries
- Impacts of climate change
- Erstwhile factors such as demographic growth, urbanization and decrease in soil fertility

Food insecurity is of great concern regarding the Republic of Mauritius (ROM) since it is defined as a net food importing country. (Farming news, 2008). The impacts of climate change followed by their complexity could potentially have an increased risk effect upon the social and environmental welfare, as well as the economic drivers in the ROM (www,

UNESCO1, 2009). Furthermore, affordability is becoming increasingly difficult especially for low-income earners such a small food crop planters (www, UNESCO2, 2009). Moreover, the implications that the impacts of climate change has upon importing countries, such as increased droughts in Australia, which is in turn affecting Mauritius, exposed to increased prices and risk of lack of food providence (Pers. com. S. Seenattun, 2010).

Table 1 demonstrates ROM's dependence on raw material import. Approximately 80 percent of the feed requirements at Mauritius are imported, which shows that the Republic needs to increase their level of self-sufficiency in order to be less dependent upon importing industries, especially regarding the future threats of potential food insecurity (Ministry of Agro Industries and Fisheries 2007; pers. com. S. Seenattun, 2010).

Table 1: Production mix at the Mauritian market

Product	*Average annual production (%)*
Vegetables	100
Potato	60
Onion	60
Milk	2
Meat	5
Poultry & eggs	100
Imported raw material	80

Source: Ministry of Agro Industries and Fisheries, 2007.

According to Dr. Seenattun (2010), the primary victims regarding the impacts of climate change are the Mauritian agricultural producers since agriculture makes up for their main supply of income. (Pers. com. S. Seenattun, 2010). Further research and development is required for the improvement of sustainable agricultural models in order to tackle the consequences of climate change, where socio-economic development risks to stagnate and affect the income of private households in Mauritius (ibid.).

1.2 Problem

Empirical studies that have shown that climate change has impacts upon agricultural land and that the sector in question is vulnerable to climate change both economically and physically. (Gbetibouo & Hassan, 2004). Theories suggest that tropical regions in the developing world, such as the ROM, have shown to be particularly vulnerable when it comes to climate fluctuations (W. Hertel & D. Rosch, 2010). In the agricultural sector, yields could be reduced considerably due to the impacts of climate change, having drastic consequences upon famers production, which is why individual farming from an environ-economical perspective needs to be deeper analyzed in order to explore the possibility to adapt to climate change in Mauritius. (Pers. com. S. Seenattun, 2010; Mendelsohn & Dinar, 1999).

1.3 Aim and delimitations

The main aim of this project is to determine, from a micro perspective using an econometric and survey approach, the impact of climate change upon tomato yields and further Mauritian agriculture.

The econometric method, based on a production function approach, is analysing the impacts of different climatic variables upon tomato yields. According to the IPCC (1996), the earth is likely to experience temperature increases between 1-3°C and a rainfall and sunshine hour

decrease of 5-20%. The thesis analyses how much the level of monthly yields varies with an increased temperature of 1-3°C, rainfall decrease from 5% to 20%. The impacts will be expressed in terms of changed crop output, in other terms yields (tonnes/ha).

The socio-economic survey, which is analyzing small-scale, full-time, Mauritian farmers, will provide additional evidence to the econometric approach since the result of the survey evokes the possibility to complete the lack of socio-economical data. In other terms, the socio-economic study is needed to complete the econometric study, where the latter lacks of proof concerning socio-economical issues and is instead provided by the socio-economic analysis.

Additionally, the thesis aims at providing this type of structure, combining an econometric and a socio-economic study, as a framework for future studies assessing similar topics.

The study aims to answer the following questions:

- What is the present climatic and agricultural status on Mauritius?
- What are the long-term effects upon yields with regard to climatic changes, such as a 1°C temperature increase and/or a 5% decrease in precipitation?
- What are the socio-economical issues regarding agricultural practice in Mauritius?
- How are these variables affecting agricultural production and therefore, linked to the socio-economic survey, the Mauritian crop producers and their yields?

The thesis focuses on the Republic of Mauritius in cooperation with the United Nations Development Program (UNDP), The Government of Mauritius and The Swedish University of Agricultural Sciences, Uppsala, Sweden. Furthermore, it will deeper consider the impacts of climate change on agricultural practice from a micro perspective and not from a macro perspective. The main limitation to this project was the lack of data for the econometric study. There was no existing data of input quantities and well as costs. The data for the whole island was available from 1984-2009 and region wise from 1999-2009.

1.4 Outline of the study

Chapter 1 gives the introduction. Chapter 2 describes the Mauritian background; the different microclimates and available water resources. The different theories are demonstrated in chapter 3. Chapter 4 clarifies the methods used. Theory and method is put into practice; the empirical study and results are given in chapter 5 and 6. Followed by this, is the analysis and discussion in chapter 7. Finally, chapter 8 provides the final remarks of the Master thesis. The following figure provides an image of the structure of the thesis.

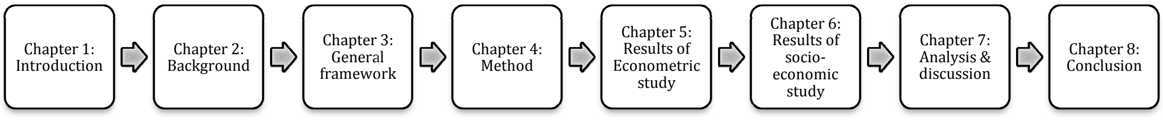

Figure 1: Outline of the study

2 Background

Chapter two describes the climate in Mauritius, followed by the agro-ecological and climatic conditions required to grow tomato. The purpose of this chapter is to give the reader some background on the country and why tomato was the analyzed food crop. The background will not be specifically brought up further in the work. A more detailed chapter on Mauritian history and present economical and social status can be found in Appendix 3.

2.1 Climate on Mauritius

The following section gives the reader an idea of the climatic situation on Mauritius as well as the available water resources on the island.

2.1.1 Meteorological profile

The island of Mauritius is of a volcanic origin composed by a flat plain in the North, a central plateau and on the remaining parts the landscape is of a mountainous type. The country disposes of two seasons; the moderately dry winter season from June to September and the wet and humid season, which is extending from November to April. (www, Mauritius Meteorological Services, 2010). May and October are classified as transition months. Moreover, the island disposes of a variety of different microclimates, which differ in amount of temperature, precipitation, solar radiation as well as soil types. (Cheeroo-Nayamuth & Nayamuth, 1999). The annual rainfall is approximately 2100 mm per year and the mean temperature of the island is 23°C. When it comes to precipitations, the central plateau receives a maximum of 4000mm, 1000mm in the Western coast and 1600mm in the east. 55% of the rainfall on Mauritius is brought by cyclones, which occur roughly ten times per year. Moreover, the maximum temperature varies between 19°C and 27°C in winter, 26°C and 32°C in summer. The minimum temperature ranges between 14°C and 20°C in winter and 19°C to 25°C in summer. The table beneath illustrates the different climatic zones on Mauritius. The areas are divided into five main sectors as well as specific districts (see table 2). (Cheeroo-Nayamuth & Nayamuth, 1999).

Table 2: Different microclimates on Mauritius and climatic characteristics.

Sectors	*District*	*Latitude*	*Soil types*[1]	*Climate*	*Average rainfall*	*Average temperature summer*	*Average temperature winter*
North	Pamplemousses	< 175m	L, H, P, M, D, T	Sub humid to humid	1000-1900 mm/year	26.5°C	20.5°C
East	FUEL[2]	Flat, sea level to 350m	L, H, P, F, B, G, T	Humid to super humid	1500-3200 mm/year	25.5°C	19.5°C
South	Plaisance	Rising gradually from sea level to 350m	L, H, F, P, B, T	Humid to super humid	1500-3200 mm/year	25.5°C	19°C
West	Médine	Rising gently from sea level to 275m	L, P, M, D	Sub humid	750-1500 mm/year	27°C	21°C
Central	Vacoas	Undulating plateau at 275-550m	L, H, F, P, B, G	Humid to super humid	1500-3800 mm/year	23.5°C	17.5°C

Source: Cheeroo-Nayamuth & Nayamuth, 1999.

[1] **P** - Latosolic Reddish Prairie, **B** - Latosoic Brown Forest, **L** - Low Humic Latosol, **H** - Humic Latosol, **F** - Humic Ferruginous Latosol, **M** - Dark Magnesium Clay, **D** - Grey Hydromorphic, **T** - Lithosol
[2] Flacq Union of Estates Limited (Cheeroo-Nayamuth & Nayamuth, 1999)

2.1.2 Water resources on Mauritius

Mauritius is of volcanic origin disposing of a maximum level at the central plateau of 600 meters. (Ramjeawon, 1994). The thickness and permeability of the late volcanic series on Mauritius offered good aquifers. The groundwater is extracted from the dolerite basalts of the later volcanic series that overlie the solid compacted impermeable rocks of the more ancient volcanics. Even though Mauritius has a decent level of rainfall per annum, irrigation is needed for the use of land.

The rainfall is generated by the south-eastern trade winds. The precipitations fall from an average of 1 300 mm/year on the windward eastern coast to 4 000 mm/year on the central plateau. The potential evapotranspiration drops from 2 000 mm/year on the coastal plains to 1 400 mm/year on the central plateau. The overall equilibrium is positive where the annual rainfall is of 2 100 mm/year. Nonetheless, the average evapotranspiration level reaches up to 1 700 mm/year, which is fairly large. The north and west are defined as the drier regions compared to the east, south and centre (ibid.).

The microclimates on the island are due to the orogenic effect. During the months of June, July and August has a seasonal rainfall variation of 10-20 percent whilst the months of January, February and March experience a seasonal variation with 40-50 percent. (Ramjeawon, 1994). The total annual estimated freshwater resources are estimated at 1 500 Mm^3 which connotes that the per capita freshwater availability is of 1 500 m^3 per annum, where only 38% of the water derived from precipitation can be exploited. Consequently, this places Mauritius in the category of water-poor countries since water development could potentially cause an obstacle to socio-economic development. Table 3 outlines the water balance for Mauritius.

Table 3: Mauritius water balance

Factor	***mm***	***%***
Precipitation	2100	100
Actual evapotranspiration	1330	63
Infiltration	211	10
Surface runoff	559	27

Source: Ramjeawon, 1994

There are moreover drainage areas on the island. (Ramjeawon, 1994). They range from 3.8 km^2 to 164 km^2. The current freshwater system includes 93 rivers in 47 river basins. The underground system includes four central aquifers exploited through 135 boreholes and small wells.

However, the main sectors using water resources on the island are agricultural, domestic, commercial and industrial. (Ramjeawon, 1994). The main consumers of piped water co-operatively account for 15 percent of all the sold water. Moreover, the growing tourism sector mainly concentrated in the coastal regions is, since 1994 of an issue to the Water Authorities because the water consumption per user varies from 200 litres day for ordinary hotels to 1000 litres day for five-star hotels. The point is that due to the uncertainties of yearly and seasonal rainfall distribution combined with the present level of production as well as the lack of proper water resource management; it is evident that sustainable water resource management is necessary within all socio-economic sectors.

2.2 Agro-ecological and climatic features of Mauritian tomato production

Agricultural activities on Mauritius stand at 4.5 percent of the GDP. The area harvested under food crops was 6,266 hectares in 2008 compared to 6,740 hectares in 2007, which implies a decrease of 7 percent. (Digest of Agricultural Statistics, 2008). Regarding the production of food crops, a decrease of 6.2 percent was noticed in 2008; a drop from 99,310 tonnes in 2007 to 93,021 in 2008. Tomato is one of the most prominent food crops on Mauritius, which is one of the reasons why tomato is analyzed in the study. (Ministry of Agro Industry and Fisheries, 2007). Additional explanations to this are since other food crops are not annually produced on Mauritius, such as potato and onion, where incomplete data was of an issue concerning other food crops. (Digest of Agricultural Statistics, 2008). Since tomato is one of the most important food crops produced on Mauritius, how changes in climate impacts upon the yields of tomato will also provide, to some extent, in what way the Mauritian agriculture will be affected. In order to study the climatic features linked to tomato production, the climatic data was collected every year for the period 1984 for the whole island and from 1999 per region[3]. Beneath are listed monthly yields of tomato, monthly precipitation, average temperature and monthly hours of sunshine per district.

Tomatoes are fairly sensitive to climatic changes, especially to water logging, diseases and insects. (D. Orzolek et al, 2006). The food crop grows the best in well-drained soils, with a soil pH between 5.8 to 6.6. It is important to provide a constant supply of moisture during the growing season. However, excessive water during any time of growth, especially after fruit set, can reduce both quality and yields. Moreover, tomatoes are sensitive to cold night temperatures below 13°C. The suitable temperatures for tomatoes lie between 16°C to 31°C. As follows are the agricultural features (table 4) and the plantation periods for Mauritian tomato production (table 5).

Table 4: Agricultural features of tomato production.

Climate	**Cycle**	**Irrigation**	**Soil characteristics**
Humid to Irrigated sub-humid	Cooking tomato: 5 months Salad tomato: 6 months Cherry tomato: 6 months	18 mm of water per week during the vegetative period over a four-week cycle. 34 mm of water during the flowering and fructification period, equally a four-week cycle. 23 mm of water per week over the last 12 weeks of growth.	Soils are light, well drained, and fertile with a pH-level slightly acid or neutral (5.5 to 7.0). All type of soils contaminated with bacteria wilt should be avoided. It is recommended not to cultivate consecutively tomato (pomme d'amour), eggplant, hot pepper, capsicum, potato, tobacco or other solanaceas in the soil.

Source: Le guide Agricole, 2004

Table 5: Plantation periods of tomato production on Mauritius

Months											
J	F	M	A	M	J	**J**	**A**	**S**	**O**	**N**	**D**
Low-level regions											
High-level regions										High-level regions	

Source: Le guide Agricole, 2004

[3] An agro-climatic analysis per regions of monthly tomato yields can be found in Appendix 4.

A few studies have pointed out the fact that tomato is positively or negatively correlated to rainfall, temperature and sunshine hours depending on different production phases. (Wada et al, 2006; Weerakkody et al, 1997). For instance, according to a study made in Sri Lanka by Weerakkody et al (1997) the variation in yields, fruit number, fruit size and fruit weight emphasized the need of rain almost up to the maturity stage, whilst late flowering and fruit ripening could be heavily damaged by heavy rainfall and increased temperatures.

On the other hand, rainfall during vegetative growth appeared to be a positive variable. Nonetheless, although there are positive effects of rainfall upon yields, a minority of the quality parameters were shown to be contradictory. Rainfall caused during the fruit growth stage, deceased pH fruit juice and increased fruit cracking, whilst the fruit ripening period experienced the opposite. In the end, heavy rainfall exceeding 300mm/month is negatively correlated to the different growth stages of tomato. Moreover, the study made by Wada et al (1997), analyzing the effects of shading upon tomato yields during summer season has a negative effect upon yields, which suggests that a decrease in sunshine hours combined with increased temperature could have a damaging impact upon tomato yields.

Although a decrease in area harvested and tomato production, the vegetable has experienced a yields increase of 3.6 percent in 2008 that is caused by the introduction of hybrids between 2000 and 2001, which have to capability to grow faster over a shorter period of time (see figure 2). (Digest of Agricultural Statistics, 2008).

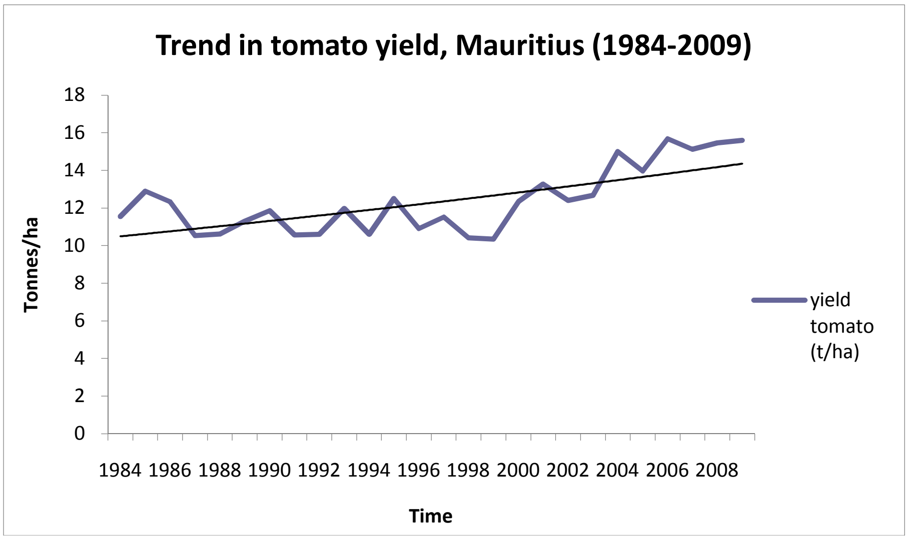

Figure 2: Trend in Tomato yields (1984-2009).

Climatic data and tomato yields

The figures beneath present the yields per month of tomato (t/hectare) in relation to monthly average temperature, monthly precipitation and monthly sunshine hours since 1984. (Digest of Agricultural Statistics,1984-2008; Meteorological Services, 1984-2009). Figure 3, shows the eventual connection between monthly tomato yields for the whole island with regards to monthly precipitation (*P*). It is hence important to notice scattered data, sudden heavy rainfall such as cyclones and the different effects precipitation might have upon yields. What can be observed from figure 3 is that monthly rainfall exceeding 300 mm/month results in a decrease in monthly tomato yields, such as the first couple of months in 1987, 1997 and 2006.

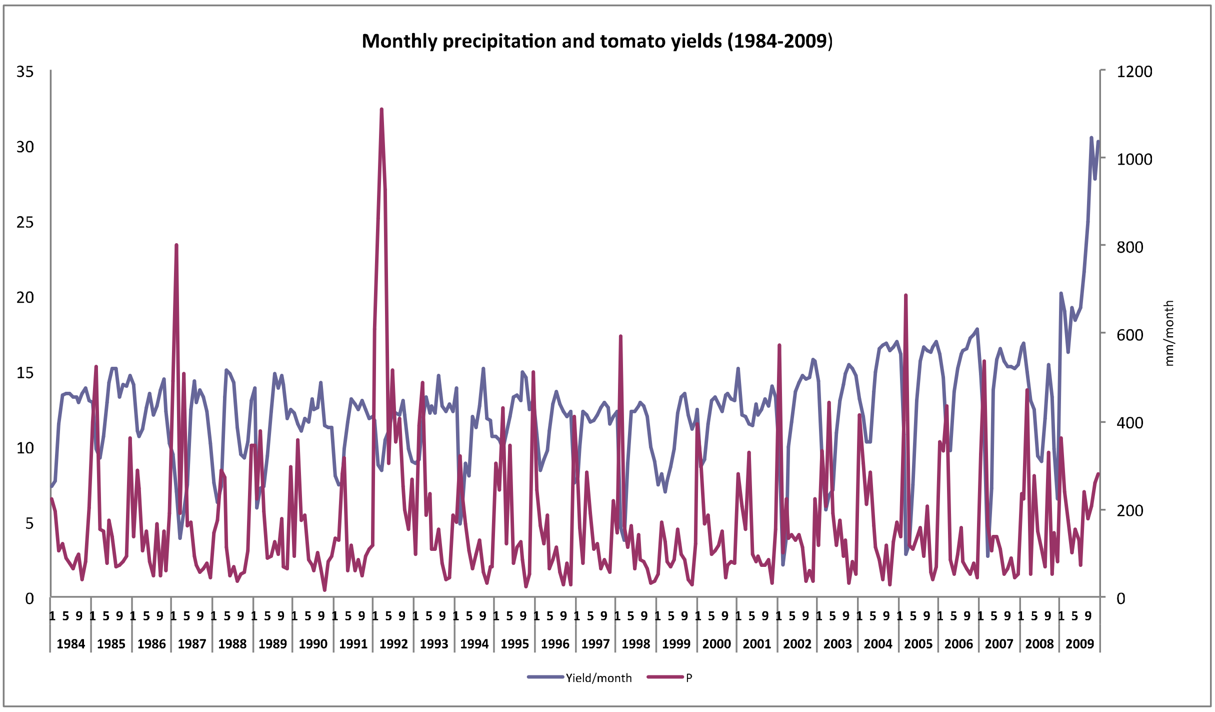

Figure 3: Monthly tomato yields and monthly precipitation since 1984.

A relationship between average temperature on the island of Mauritius and monthly tomato yields could be observed in figure 4; average temperatures above 25°C have an increased impact on monthly tomato yields. It can be noticed the first couple of months of the year, see for instance 1987, 1994 and 2002.

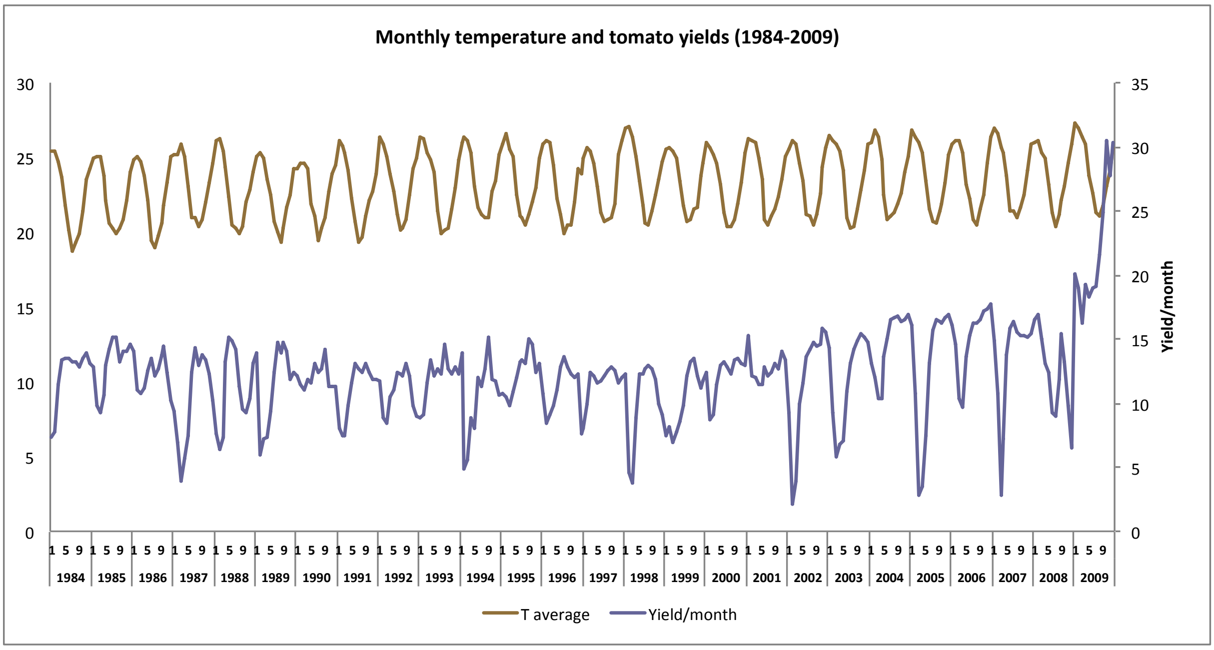

Figure 4: Monthly tomato yields and average temperature from 1984 to 2009.

The following figure 5 demonstrates the link between monthly tomato yields and sunshine hours. The sunshine hours are in this study replacing altitude and longitude variables since Mauritius is relatively small and not extremely high in altitude. Here, is it difficult to determine the impacts of monthly sunshine upon tomato yields. However, some observations can be made in for instance 1991, 1998 and 2007 where the monthly yields is lower as per

usual as well as the number of monthly sunshine hours, which are generally beneath 200 hours/month.

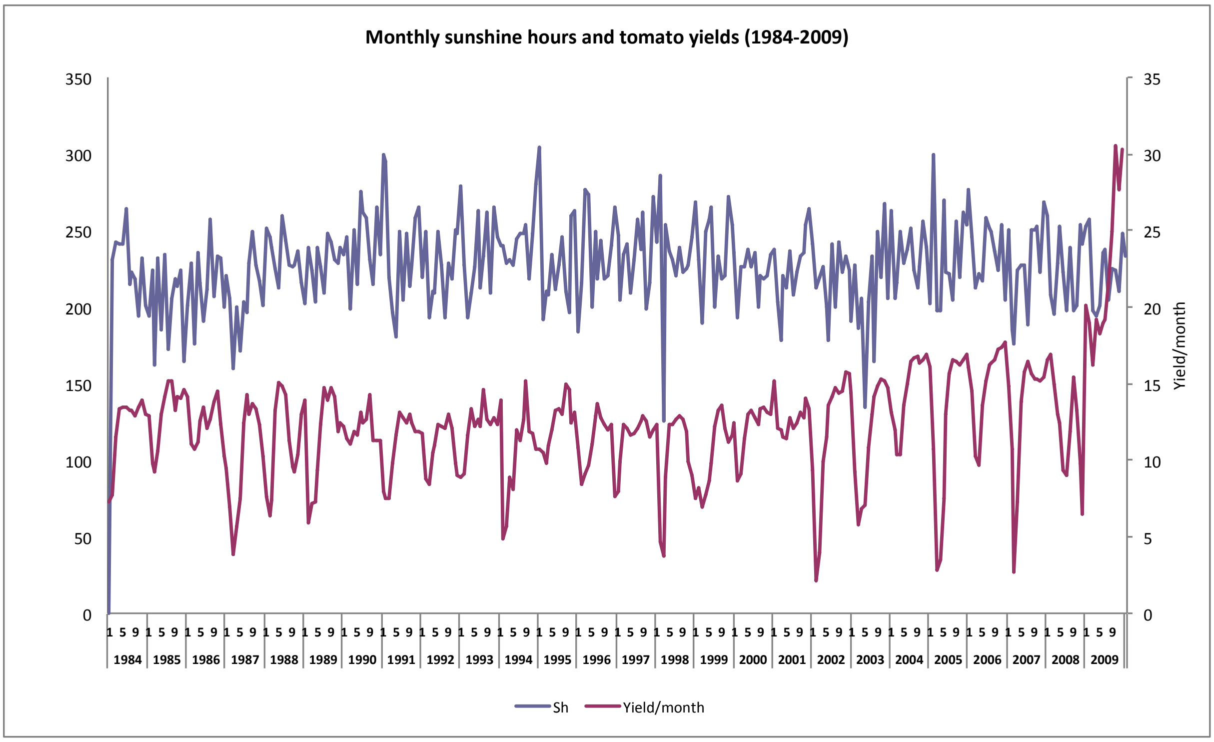

Figure 5: Monthly sunshine hours and tomato yields (1984-2009).

The following points gives the reader an agro-climatic summary of tomato with regards to its the climatic figures.

- **Temperature:** The yields is sensitive to increased temperatures where temperatures above 25°C seems to have a damaging effect upon tomato yields.
- **Rainfall:** Tomato yields decreases with increasing precipitation, especially above 500 mm per month.
- **Sunshine hours:** A decrease in sunshine hours decreases tomato yields, where less than 200 hours per month have a damaging effect upon yields.

3 General framework

The theoretical background is linked to the econometric and socio-economic study. The theories in the general framework are also used as a basis for the analysis. The first part is defining the Ricardian model as well as the empirical model based on regression analysis. Section 3.1 is followed by the theories behind a SWOT-analysis. Moreover, a chapter analyzing previous studies of farmer's perceptions and adaptations to climate change is included. Appendix 1 provides theories of the natural science of climate change and the economical and social impacts of climate change upon the agricultural sector, more precisely in developing countries.

3.1 Econometric approach

According to the Stern Review, with a predicted temperature increase of 1-5°C by 2100 (Stern, 2006), the impacts on African agricultural land with a tropical climate are likely to experience a decline in yields of 5-20% (Stern, 2006). Throughout literature studies and articles analyzing the impact of global warming on agriculture and the economic impact of climate change on agriculture, various methods and approaches have been revealed as effective. (N. Seo et al, 2009; Mendelsohn et al, 1994; Deschenes & Greenstone, 2004). The following sections will explain the underlying theories and models in order to determine the impacts of climate change upon agricultural practice in both developed and developing contexts.

3.1.1 The Ricardian model

The Ricardian model is part of cross-sectional models, based on a production function model, which observes responses of crops and farmers to varying climate where it uses observations of farm performance in various agro-climatic regions. (Gbetibouo & Hassan, 2004). The method (see chapter 4) specifically examines farm performance across different agro-climatic zones. It measures how long term farm profitability varies in relation to local climate conditions whilst controlling other factors, such as socio-economic parameters. The reason for the choice of the Ricardian model is due to the fact that it has been used in other contexts, by Mendelsohn et al (1994) for instance, determining the impacts of climatic changes upon a specific agricultural output variable.

The Ricardian approach has the flexibility to incorporate private adaptation that gives the farmer the opportunity to modify the operational environment in order to increase profit; change crop due to climatic conditions since crops are adjusted differently when it comes to various climatic scenarios. (Gbetibouo & Hassan, 1994). Furthermore, the model can be used and adopted on national as well as regional level impacts. Additionally, the model is independent of controlle for experiments. Finally, the model offers the possibility to measure the direct impact of climate on farm income or revenue and the indirect substitution effects of different inputs and the potential adaptation of dissimilar climates.

With regards to the study made by Gbetibouo and Hassan (2004), the authors decided to use a cross-sectional method, comparing choices and performance of already existing South African farms facing different climate and soil conditions. The approach accounts for the direct impacts of climate on yields of different crops as well as the indirect substitution of different inputs. However, what is important to mention is the fact that the model does not

include technological change. Additionally, the method treats price as a constant, which could then overestimate benefits and further underestimate damages. The basic assumption, of the impacts of different socio-economic and environmental variables upon land value over time, was based upon the following equation:

$$V = \int_0^\infty P_{Lt} e^{-rt}\, dt$$

$$V = \int_0^\infty \left(\sum_i [P_{it} Q_{it}(K_{it} E) - C_{it}(Q_{it}, w, E)] / L_{it}) \right) * e^{-rt} dt$$

where V designates the land value, Q_i is the quantity produced of good *i, K_i* represents the vector of all purchased inputs in the production of good *i. E* stands for the exogenous environmental variables, such as climatic variables, soil types and economical factors. (Gbetibouo & Hassan, 2004). P_L is the annual cost or the rent of land, further the land under production of good *i* is represented by L_i and C_i is the cost function for all purchased inputs other than land. Furthermore w characterizes the vector of factor input prices. Finally, the choice of integral is since integrals calculate the net-signed area of the region.

Every estimate relies on a production-function approach, with a Ricardian perspective, that examines the impact of climate and other variables on land values and farm revenues. (Mendelsohn et al, 1994). The difference when it comes to the Ricardian method with an underlying production-function approach is that that it estimates impacts by varying one or a few input variables, such as precipitation, temperature and carbon dioxide levels in order to determine the impacts of climate upon yields. The technique in question puts economic data on the value of land into use. The model in question analyzes how climate in different places impacts for instance the net rent of value of farmland (*NRHA*) or the land value. The approach in question should give the opportunity to measure the economic value of different activities and further to verify if the economic impacts implied by the production-function approach are reproduced in the field.

The main hypothesis made by Mendelsohn et al (1994) is that the climate shifts the production function for crops and that the farmers adjust their inputs and outputs accordingly (figure 6). In addition, perfect competition is assumed. Moreover, Mendelsohn et al (1994) assumes that the economy has fully adapted to the climate, which implies that land prices have attained the long-run equilibrium associated with each country's climate.

The authors are, as mentioned, using a Ricardian model in order to correct partiality in the production-function technique and are, in their case, using the climatic and economic data on the significance of land, put in other words, the authors examine how the net rent or the value of farmland is affected by the climate. (Mendelsohn et al, 1994). Related to this, Mendelsohn et al (1994) have made usage of a figure measuring the economic value of altered activities, in this case the value of output less the value of the inputs altogether, which is represented on the y-axis (figure 6). The temperature is delineated on the x-axis. According to the figure one expects that farmers increasingly adapt their production according to climatic and socio-economic changes and where in the end what is left of the production implies "retirement back home", which implies that the farmers finally decides to stop their agricultural production once they have made the most possible usage out of the land.

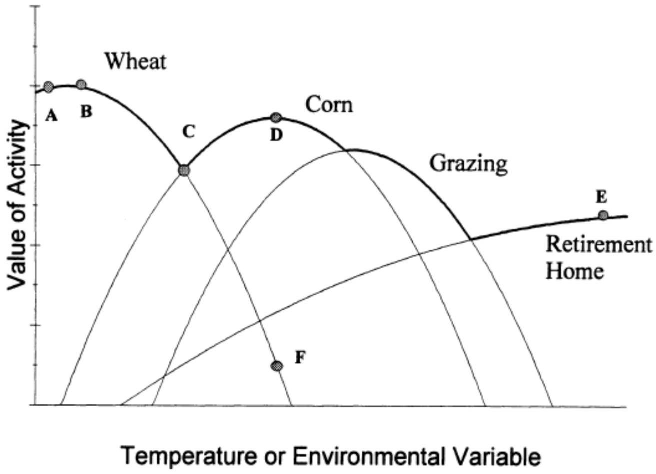

Figure 6: Net revenue per acre of land related to changes in temperature (Mendelsohn et al, 1994,).

The criticisms of the Ricardian model is hence important to mention, where there have been a few studies questioning the production function technique, such as the study made by Mendelsohn et al (1994). The study points out the fact that the production-function approach have a tendency to *"overestimate the damages from climate change because it does not, and indeed cannot, take into account the infinite variety of substitutions, adaptations, and old and new activities that may displace no-longer-advantageous activities as climate changes."* (Mendelsohn et al, 1994, pp. 755).

Furthermore, other's criticizing the model is authors such as Gbetibouo & Hassan (2004) and W. Hertel & D. Rosch (2010). The approach assumes that the way farmers respond to alternative climates over space is the same way that farmers will respond in the long run to those same climates over time. Nonetheless, this assumption may not be accurate since important variables are likely to be correlated when climate have been excluded. What is further limiting is that the model assumes that the only limiting factor to agriculture is the climate, not water availability and supply constraints for example. In this case, a sophisticated hydrological-economic model is necessary. An additional criticism is the fact that the model treats prices as a constant and is therefore underestimating damage and overestimating benefits. As a final point, the approach is criticized for presumptuous implicit zero adjustment costs and therefore give way to a lower-bound estimate concerning the costs of climate change.

3.1.2 Empirical model based on regression analysis

Regression analysis is a statistical tool specifically used for the exploration of relationships between variables[4]. (G. Keat & K. Young, 2000; O. Sykes). The investigator seeks to determine the cause of one variable upon another; the outcome of a price increase upon demand for example or in this case scenario analysis; the effect of temperature fluctuations upon different crop production. In order to investigate such matters, data requires collection and further utilizes regression to assess the quantitative effect of the underlying variables upon the dependent variable; the variable that is influenced. Furthermore, the statistical significance of the approximate relationships is then assessed. A simple regression is illustrated in the following formula:

[4] Appendix 2 provides definitions and explanations of different elements making up the regression analysis.

$$I = \alpha + \beta E + \varepsilon$$
$$\alpha = cons\tan t$$
$$\beta = effect / coefficient$$
$$I = dependent$$
$$E = exogenous$$

Within this formula there are observable as well as unobservable variables. (G. Keat & K. Young, 2000; O. Sykes). *I* and *E* are observable variables since they are available from collected data. On the contrary, α, β are unobservable parameters and ε a random term. The purpose of regression analysis is then to produce an estimate for these three parameters based on the data set. The example above is of a linear nature, which is common in regression analysis. There are indeed nonlinear relationships although investigators yet change them in a way that makes the nonlinearity linear. An example of this is $y = cx^{\alpha x}$ which can then be transformed into $\log y = \log c + \alpha \log x$.

Coming back to the first formula expressed above, in order to understand the relationship between *I* and *E* and how the parameters generated the noise, ε, can be ignored for a while. (G. Keat & K. Young, 2000; O. Sykes). Graphically, the relationship between *I* and *E* constitutes the equation for a line where β is the slope and α the intercept on the vertical axis. Integrating the noise ε suggests that there can be numerous lines depending on the value given to ε. Further, in order to then choose one line in particular for the regression analysis relates to the estimated noise term, the error for each observation. For each probable line, a set of errors will result and among the possible lines, the regression analysis will select the "*sum of the squares of the estimated errors at a minimum",* so called the *"minimum sum of squared errors (SSE)"* (O. Sykes, pg 7).

With regards to the purpose of this paper, a multiple regression is hereby defined.

"A multiple regression is a technique that allows additional factors to enter the analysis separately so that the effect of each can be estimated" (O. Sykes, pg 8).

Furthermore, a multiple regression is a technical tool permitting to quantify the impact of several synchronized influences upon a specific dependent variable. (G. Keat & K. Young, 2000; O. Sykes). The expression for a multiple regression formula results in $I = \alpha + \beta E + \gamma X + \varepsilon$ for example where γ is expected to be positive. The coefficients α, β and γ remain estimates. In addition, the SSE will depend upon the particular value of ε drawn, in this case crop, within the data set. Moreover, the regression properties involve the relationship between the true values of the parameters and the probability distribution of those parameter estimates. Each parameter estimate that is produced by an estimator[5] is defined as a random variable strained from a selected probability distribution. If the mean of the probability distribution in question is equivalent to the true value of the parameter that is attempted to estimate, the estimator is unbiased. In other terms, if the estimator is unbiased, on average, the true value of each parameter was recovered.

Besides, if an estimator requires additional data in order to generate more accurate estimates, the estimator is defined as consistent. (G. Keat & K. Young, 2000; O. Sykes). With an

[5] Alternative criteria for generating parameter estimates (O. Sykes, pg 10).

increasingly larger sample size, the probability distribution of the estimate for whichever parameter will logically obtain a lower variance[6].

3.1.3 Log-linear models

The model used by Gbetibouo & Hassan (2004) is based upon a log-linear model. Gujarati (2004) gives an example of how to calculate the change in Y with respect to changes in X, according to the log-linear model. The model in question is generally give changes in (1) absolute changes, (2) relative change or (3) percentage change or percentage growth rate. If one considers the following model, which is equally recognized as the *exponential regression model*:

(1) $Yi = \beta_1 x X_i^{\beta 2} e^{ui}$

and could be expressed as follows:

(2) $lnYi = ln\beta_1 + \beta_2 lnX_i + u_i$

The parameters β_1, β_2 is here linear and fits into the logarithms of the variable X and Y and the Ordinary Least Squares (OLS) regression. (Gujarati, 2004). Due to the linearity, these models are called *log-log, double-log, or loglinear* models. The model in question has been used worldwide where the main attractive feature of the model is the fact that the slope coefficient β_2 measures the *elasticity* of *Y* with respect to *X*: "*the percentage change in Y for a given (small) percentage change in X." (Gujarati, 2004, pp. 176.)* The following formulas illustrate the short and long run elasticity. The elasticities are calculated from the following formula (3):

(3) $lnY = \alpha + \beta lnY_t + \theta Z_t$

Here, it is assumed that *Y* is linked to Y_t which is a lagged-variable and the variable Z_t. The formula is expressed as such (4):

(4) $Y = f(Y_t, Z_t)$

The total differential of expression (4) is:

(5) $(\partial Y/Y) = (\partial f/\partial Y_t)\partial Y_t + (\partial f/\partial Z_t)\partial Z_t$

In order to the the relative percentage change in Y with regards to relative changes in Y_t and Z_t we obtain from (5):

(6) $(\partial Y/Y) = \left[\left(\frac{\partial f}{\partial Y_t}\right)\left(\frac{Y_t}{Y}\right)\right](\partial Y_t/Y_t) + \left[\left(\frac{\partial f}{\partial Z_t}\right)\left(\frac{Z_t}{Y}\right)\right](\partial Z_t/Z_t)$

Expression (6) can then be stated in elasticity terms:

(7) $(\partial Y/Y) = [E_{YYt}](\partial Y_t/Y_t) + [E_{YZt}](\partial Z_t/Z_t)$

[6]Variance is a measure of the dispersion of the probability distribution of a random variable (O. Sykes, pg. 11)

The elasticity of Y with respect to Y_t and Z_t is therefore:

$$E_{YYt} = \frac{\partial f}{\partial Y_t} * \frac{Y_t}{Y}$$

$$E_{YZt} = \frac{\partial f}{\partial Z_t} * \frac{Z_t}{Y}$$

Furthermore, the long-run elasticity relationship for Y with regards to the lagged-variable Y_t is beneath demonstrated.

$$\ln(Y_t) = \alpha + \beta \ln(Y_t) + \theta Z_t$$

(9) $E_{YYt}^{LR} = \frac{\partial f}{\partial Y_t} * \frac{Y_t}{Y} = \frac{\beta}{(1-\beta)} * Y_t$

Y is the dependent variable, Y is the lagged variable and Z_t is an independent variable, α, β and θ represents the coefficients of the function. The semi-elasticity on the other hand is defined as follows:

(10) $E_{YYt} = \frac{\delta Y}{\delta Y_t} * 1/\delta Y$ and the long-run semi-elasticity if therefore:

(11) $E_{YYt}^{LR} = \beta/(1-\beta)$

The following example is further used in the thesis developed in cooperation with Surry, Y. (2010). It shows how to calculate short- and long-run elasticities using a log function with regards to yields per hectare (Y_t) and a rainfall (R) variable on a production cycle of three months.

(12)
$$\ln(Y) = \alpha + \beta_1 \ln(Y) + \beta_2 M_2 + \beta_3 M_3 + (\beta_4 + \beta_5 + \beta_6) R + (\beta_7 + \beta_8 + \beta_9) R^2 + (\beta_{10} + \beta_{11} + \beta_{12}) Sun + \beta_{13} T + \beta_{14} T^2$$

From (12), the short-run elasticity for the change in Y_t with regards to R takes the shape of:

$$E_{YR} = \left(\frac{\partial f}{\partial R_t}\right)\left(\frac{R_t}{Y_t}\right)$$

$$E_{YR-1} = (\theta_1 + 2\theta_{11} R_{t-1}) * R$$
$$E_{YR-2} = (\theta_{21} + 2\theta_{22} R_{t-2}) * R$$
$$E_{YR-3} = (\theta_{31} + 2\theta_{33} R_{t-3}) * R$$

The long-run elasticity for the change in Y_t with regards to R takes the shape of:

$$E_{YR}^{LR} = \left(\frac{\partial f}{\partial R_t}\right)\left(\frac{R_t}{Y_t}\right) = \frac{(\beta_4 + \beta_5 + \beta_6) + 2(\beta_7 + \beta_8 + \beta_9) R}{(1-\beta_1)} R$$

3.2 SWOT-analysis

The SWOT-analysis is a strategic planning tool to evaluate Strengths, Weaknesses, Opportunities and Threats involved in a project, a business venture or any situation requiring a decision. (E.K. Valentin, 2001). The purpose of the SWOT analysis yields strategic insights and will further be brought up in the anaylsis. The model is illustrated in table 7.

Table 7: SWOT-analysis structure

	INTERNAL FACTORS	EXTERNAL FACTORS
FAVORABLE FACTORS	Strengths	Opportunities
UNFAVORABLE FACTORS	Weaknesses	Threats

Source: E.K. Valentin, 2001

It is a tool that provides guidance within, for instance, projects to identify what is going well, what requires deeper attention and which measures that are needed in order to meet the demands of, not only stakeholders and clients but also staff and employees. (Sabbaghi et al, 2004). Strengths would define any internal asset that will help to meet demands and fight of threats. Weaknesses are internal deficits, such as lack of motivation that hinders the organization to meet the demand. Opportunities define any external circumstances that operate in favor of the project, such as trends, political, economical and/or technological factors (ibid.). Linked to this, it is important that the internal structure of the company is correctly working in order to operate in the targeted environment. Threats would be the contrary to opportunities where an organization, project or individual operates in an unfavorable environment, such as political and/or climatic instability.

3.3 Farmers perceptions and adaptations to climate change

Previous studies have analyzed how farmers perceive changes in climate. (Gbetibouo, 2009; Maddison, 2007; Deressa, 2008). The section analyses farmer's perception of climate change followed by the transitory cost of adapting to changes in climate.

Related to the present survey analysis are previous studies, (Gbetibouo, 2009; Maddison, 2007; Deressa, 2008) which indicate that farmers have noticed changes in climate but do not adapt well enough due to lack of knowledge, techniques and capital assets. Indeed, they have perceived changes in both temperature and rainfall patterns where the temperature is increasing whilst precipitation is decreasing. Moreover, the study made by Deressa (2009) in the Nile Basin of Ethiopia, illustrates that socio-economic indicators also revealed to be of significant importance but also wealth, social capital and agro-ecological settings have shown noteworthy impact on the perception to climate change. Furthermore, factors demonstrating adaptation to climate change indicates that education, household size, gender, livestock ownership, extension of crop and livestock production, accessibility of credit and temperature have a positive and significant impact on adaptation to climate change.

According to the preceding studies (Gbetibouo, 2009; Maddison 2007) a farmer could perceive several warm summers although attribute them to casual variation in stationary climate. The cost of adaptation in this case would be distinguished once all desired modifications have been made and anticipations no longer lag behind reality since the transitional cost would occur from misperceptions. The difference between transitional and adaptation cost is further clarified. The transitional cost is the difference between the

maximum value of revenues per acre following perfect adaptation and where the net revenues are experienced by farmers given that their beliefs of how the climate will change lag behind what it essentially does. If farmers in this case could correctly predict the climate instantly, there would be no transitional cost. The cost of adaptation on the other hand is the difference between the maximum value of net revenues per acre evaluated in the present and perfectly perceived future climate. The main issue here would then be how agriculturalists update their expectations of the climate in response to atypical weather patterns.

Another option could be that farmers engage in a simple Bayesian framework constantly updating their past experiences. (Maddison, 2007). Nonetheless, it is argued that the process of updating is probable to be a long drawn-out process. Moreover, past studies suggest that some farmers actually give more importance to recent information proved to be efficient. An example brought up is a study by Maddison (2007) analyzing how Canadian farmers tend to adjust their varieties of hybrid corn selection based on the previous year's climatic conditions. Farmers are recommended to match hybrid climatic requirements to the next 30-years at their locations but regularly chose options above or below the means. Approximately 30 percent of the farmers mentioned that this was due to previous year's climatic conditions.

Furthermore, no indication was found that farmers plan on the basis of climatic norms. The model was based upon two different equations elucidating planting choice's and realized output of corn from US regions expressed as a function of climate and recognized weather. This model would then simulate the adjustment that would occur with a 3°C temperature increase during the month of July. The model showed that farmers appear to discover the changes in climate astonishingly slowly, where they tend to be more focused on the quantity of corn they presently produce under the current climate. Here they also fail to seize the opportunity to plant wheat instead, which consequently represents the transitional cost of climate change. However, farmers yet endure transitional losses even whilst using Bayesian updating of their attitudes when experiencing damage.

Obviously, there are a few limitations to the model in question. (Maddison, 2007). Firstly, with the eventuality in future weather uncertainties, farmers may implement practices that are increasingly vigorous in order to tackle changes in climate. Secondly, the concern of fixed assets is not taken into account, where all machinery and buildings might not be suitable for all climates. The third limitation, which is of greater importance in developing country contexts, is the assumption that farmers dispose of enough comprehension to move along the envelope of maximum net revenue per acre, taking full advantage of whatsoever weather brings, not being concerned of the long-term climate impacts. The hypothesis of free and prompt knowledge with respect to the best crop choice could eventually become difficult, since the possibility exists and have been dicussed that farmers progressively learn about which techniques to apply based on the fact that they progressively discover changes in climate.

As a matter a fact, learning about the most suitable production technique and crops could take a multiplicity of shapes, learning by copying or from instruction and learning by doing for example. (Maddison, 2007). The costs of alteration emphasizes on the efficiency of these mechanisms, although they imply delays. The different learning techniques requires time and possibly finances. An example of this are the experiences of agriculture in Africa, where new green technologies are constantly being adopted but in many cases without success; the rate at which these have been adopted has been extremely slow and unsure of the actual outcome.

4 Method

The thesis makes usage of two tools: a Ricardian model based approach and a survey. The Ricardian method, combined with a regression analysis is presented within the first section. The method's for the socio-economic study includes the construction of a survey and ANOVA-test.

4.1 Ricardian model based approach

The proposed econometric method is developed based upon a study made by Gbetibouo & Hassan (2004) measuring the economic impacts of climate change on major South African field crops with a Ricardian approach. The coefficients of the production function are set via regression analysis. The Ricardian model used in Gbetibouo & Hassan's (2004) article offers the possibility to measure the effect of how yields vary with changes in seasonal temperature (°C) and precipitation (% mm/season). In previous studies, such as Mendelsohn et al (2004), the dependent variable used was land value. Nonetheless, due to the difficulty of using land value as a dependent variable because of the imperfect land market and weak documentation in the South African regions, Gbetibouo & Hassan (2004) choose to use the Net Revenue per Hectare *(NRHA)* as responsive variable.

Table 8 presents the resulting variables from the regression analysis obtained in this study. The authors have firstly divided temperature and precipitation into two different categories; summer (T_s, P_s) and winter (T_w, P_w). The quadratic relationship between the *NRHA* and the climate factors in question are there to indicate the non-linearity between output and climate variables; temperature and precipitation. In addition, the other variables that can be found is this are soil types *(Soildum)* and socio-economic variables such as population density *(Popd)*, irrigated land *(Irrigation)*, labour *(Labour)*, altitude *(Altitude)* and latitude *(Latitude)*. The crops analysed where sugar cane and different cereals. Table 8 provides an example of such regression for field crops.

Table 8: Parameter estimates of the Ricardian field crops model in South Africa with the Response variable of Log(NRHA) in revenue/ha.

Variable	***Coefficient***
Intercept	10.60 (2.89)**
T_s	-1.28 (-3.71)**
T_s^2	0.03 (4.06)**
T_w	0.72 (3.58)**
T_w^2	-0.03 (-3.79)**
P_s	0.002 (1.43)
P_s^2	0.0001 (3.36)**
P_w	0.015 (1.25)
P_w^2	-0.0004 (-2.70)**
TxP_s	-0.001 (-2.33)**
TxP_w	0.003 (1.56)
Popd	5.77E-05 (2.47)*
$Soildum_1$	-0.22 (-1.91)*
$Soildum_3$	0.08 (1.84)*
Labour	0.0004 (2.18)*
Irrigation	0.338 (4.23)**

Latitude	0.12 (3.95)**
Altitude	-0.0004 (-2.21)*
R^2	0.66
F statistic	40.11
Adjusted R^2	0.63

Number of observations: 300
* Level of significance at 5% level
** Level of significance at 1% level
Source: Gbetibouo & Hassan, 2004

The winter climate variable indicates a hill-shaped function whilst the summer climate function denotes a u-shaped relationship, which implies that with the current levels of temperature, an increase in precipitation in summer is detrimental for the *NRHA* whereas in winter, a higher level of rainfall is beneficial in terms of output. (Gbetibouo & Hassan, 2004). With a change in variables, in other words, an increase in temperature although the level of precipitation remains the same, has a negative effect on the *NRHA* in both seasons.

The optimal levels of temperature where found to be 14.78°C in winter and 22°C summer in combination with the most advantageous levels of precipitation; 390 mm respectively 570 mm (table 9). However, the present temperatures and precipitations combined in the South African regions are 15°C and 130 mm in winter and 23°C and 462 mm in summer. It indicates that the South African plants are fairly sensitive to changes since there is a large difference between the optimal combination of temperature and rainfall with regards to the current state.

Table 9. Optimal versus present levels of temperature and precipitation combined in South Africa

	Temp. summer	***Precipitation summer***	***Temp. winter***	***Precipitation winter***
Optimal level	22°C	570mm	14.78°C	390mm
Presently	23°C	462mm	15°C	130mm

Source: Gbetibouo & Hassan, 2004

The figures found within table 9 originates from a production function, $y = ax + bx^2 + c$ for instance, where the coefficients can be found in table 8 above. In order to get the *NRHA* (13) and further the short-run elasticity (14) the authors would have composed the following models:

(13)

$$\ln(NRHA) = \alpha_0 + (\alpha_1 T_s + \alpha_2 T_s^2) + (\alpha_3 T_w + \alpha_4 T_w^2) + (\alpha_5 P_s + \alpha_6 P_s^2) + (\alpha_7 P_w + \alpha_8 P_w^2) + (\alpha_{10} T_s * P_s) + (\alpha_{11} T_w * P_w)$$
$$+ (\alpha_{12} Popd) + (\alpha_{13} Soildum_1) + (\alpha_{14} Soildum_3) + (\alpha_{15} Labour) + (\alpha_{16} Irrigation) + (\alpha_{17} Latitude) + (\alpha_{18} Altitude)$$

(14)

$$E_{NRHA,Ts} = (\partial NRHA / \partial T_S) * (T_S / NRHA) = \alpha_1 + 2\alpha_2 T_S + \alpha_{10} P_S$$

Once *NRHA* is calculated, the main approach in order to measure the different impacts is to calculate the different elasticities with regards to temperature and precipitation. Nevertheless, there are several steps beforehand in order to explain the path of thought. An enlightening example would be to demonstrate, with the number from table 2, how the elasticity for the average summer temperature was calculated. From equation (15), one can observe the formula for the elasticity of temperature in summer with respect to *NRHA*, (16).

(15)

$$\ln(NRHA) = 10.6 + (-1.28T_s + 0.03T_s^2) + (0.72T_w + -0.03T_w^2) + (0.002P_s + 0.0001P_s^2) + (0.015P_w + -0.0004P_w^2) + (-0.001T_s x P_s) + (0.003T_w x P_w)$$
$$+(5.77e^{-05} Popd) + (-0.22 Soildum_1) + (0.08 Soildum_3) + (0.0004 Labour) + (0.338 Irrigation) + (0.12 Latitude) + (-0.0004 Altitude)$$

(16)

$$E_{Ts} = -1.28 + 2 * 0.03T_S - 0.001P_S$$

From the final result, the most likely average temperature and precipitation that have been used is 14.5°C and 130.62mm in winter respectively 23°C and 462mm in summer. The elasticities are beneath in table 10 represented.

Table 10: The estimates of elasticities of climate factors.

	Temperature	***Precipitation***
Winter season	-0.08	0.89
Summer season	-0.115	-0.406

Source: Gbetibouo & Hassan, 2004

Further in the study, comparisons are demonstrated; the impact caused by temperature and precipitation as well as the impacts triggered by the two variables interrelated. It is here that the difference in elasticity of temperature and precipitation has been calculated.

$E_{T,P} = (Y_0 - Y_1)/Y_0$, then gives the percentage change in yields, where for example, in table 11, there is a temperature increase by 2% and a precipitation decrease by 5%. A plainer picture of y_1 would give the following (17):

(17)

$$Y_0 = f(T, P)$$
$$Y_1 = f(T + X, P * 0.95)$$

In this case it would then be $(y_0 + y_1)/y_0 = 0.09$, in this case a temperature increase by 2°C and a change in precipitation by 5% gives an increase in *NRHA* of 9%.

Table 11: Sensitivity of the impacts of climate change on *NRHA*.

Climate change scenarios	***Impacts on net revenue hectare (%)***
+2°C and 5% reduction in rainfall	9
+2°C and 20% reduction in rainfall	-4.4
+3°C and 5% reduction in rainfall	17.3
+2°C and 20% reduction in rainfall	-11.3

Source: Gbetibouo & Hassan, 2004

4.2 Ricardian model based approach applied to Mauritian tomato

In order to apply the method illustrated in chapter 2.1, data of tomato yields from the Central statistical office in Port Louis was collected monthly since 1984 for the whole island and per region since 1999. The data was assembled to set up the variables for a regression analysis (Digest of Agricultural Statistics 1984-2009). With the variables then provided from the regression analysis, the eventual differences in yields with regards to temperature, rainfall and sunshine hour fluctuations could be determined via the Ricardian model.

Concerning Mauritius present data availability; most parameters within the formula were changed (18). Moreover, since one of the main aims in this study is to determine the impacts of temperature and precipitation upon yields, the *NRHA* is substituted by monthly yields (Y) given in tonnes/ha.

$$(18)\quad \begin{aligned} \ln(Y_t) = \alpha + \beta_1 \ln Y_{(t-1)} + \beta_2 M_2 + \beta_3 M_3 + \beta_4 Rain_{t-1} + \beta_5 Rain_{t-2} + \beta_6 Rain_{t-3} \\ + \beta_7 Rain_{t-1}^2 + \beta_8 Rain_{t-2}^2 + \beta_9 Rain_{t-3}^2 + \beta_{10} Sun_{t-1} + \beta_{11} Sun_{t-2} + \beta_{12} Sun_{t-3} + \beta_{13} T_{t-2} + \beta_{14} T_{t-2}^2 \end{aligned}$$

The variables of latitude and longitude were replaced by monthly sunshine hours (*Sun*) (Pers. com. Ramnauth, 2010) since it incorporates these two variables. Further, the climatic variables of rainfall *(Rain)* and temperature *(T)* where tested against yields/ha (Y_t) both quadratically and non-quadratically. Table 12 explains the different variables used within the method.

Table 12: Defintion of explanatory variables.

Variable	*Explanation*
Y_t	The dependent variable, yields (tonnes/hectare)
α	The constant variable that does not change once the experiment has started
$Y_{(t-1)}$	Lagged-variable in order to calculate short and long run responses
M_2	Monthly dummy, every second month of the production cycle
M_3	Monthly dummy, every third month of the production cycle
Rain	Monthly climatic variable of rainfall (mm/month)
$Rain^2$	Quadratic monthly variable of rainfall (mm^2/month)
Sun	Monthly climatic variable of sunshine hours
T	Monthly climatic variable of temperature (°C)
T^2	Monthly quadratic variable of temperature (°C^2)
-1, -2, -3	Number representing each month of the production cycle on a yearly basis.

Further, a sensitivity analysis should be completed via partial derivation. The following formulas are an example of partial derivation with regards to the temperature, rainfall and sunshine hours.

As a starting point, let us assume that tomato yields are linked to temperatures (T), rainfall (*Rain*) and sunshine (*Sun*) by the following general relationship:

$$(19)\quad Y_t = f\left(T_t, Rain_t, Sun_t\right)$$

The total differential of expression (19) then give:

$$(20) \; dY_t = \frac{\partial f}{\partial T_t} dT_t + \frac{\partial f}{\partial Rain_t} dRain_t + \frac{\partial f}{\partial Sun_t} dSun_t$$

Furthermore, expression (20) could also be expressed in terms of relative percentage changes:

$$(21) \; \frac{dY_t}{Y_t} = \left(\frac{\partial f}{\partial T_t}\right)\left(\frac{T_t}{Y_t}\right)\frac{dT_t}{T_t} + \left(\frac{\partial f}{\partial Rain_t}\right)\left(\frac{Rain_t}{Y_t}\right)\frac{dRain_t}{P_t}{}_t + \left(\frac{\partial f}{\partial Sun_t}\right)\left(\frac{Sun_t}{Y_t}\right)\frac{dSun_t}{Sun_t}$$

Expression (21) can equally be expressed using elasticity terms, which yields:

$(22) \; \frac{dY_t}{Y_t} = E_{YT}\frac{dT_t}{T_t} + E_{YRain}\frac{dRain_t}{Rain_t} + E_{YSun}\frac{dSun_t}{Sun_t}$, where E_{YT}, E_{YRain} and E_{YSun} are the elasticities of tomato yields with respect to temperature, rainfall and sunshine. These three are formally defined as follows:

$$E_{YT} = \left(\frac{\partial f}{\partial T_t}\right)\left(\frac{T_t}{Y_t}\right), \; E_{YRain} = \left(\frac{\partial f}{\partial Rain_t}\right)\left(\frac{Rain_t}{Y_t}\right) \text{ and } E_{YSun} = \left(\frac{\partial f}{\partial Sun_t}\right)\left(\frac{Sun_t}{Y_t}\right)$$

These three elasticities can also be viewed as long term elasticities, then it is possible to undertake scenario analysis by varying percentage wise the climatic or weather variables. The key element in this sensitivity analysis is to make sure that the long term elasticities have been derived the right way. In order to derive these long run elasticities, a long run relationship linking tomato yields to temperature, rainfall and sunshine is assumed. Such long term relationship can be written as follows:

$$(23) \; \begin{aligned} &\ln(Y) = \alpha + \beta_1 \ln(Y) + \beta_2 M_2 + \beta_3 M_3 + (\beta_4 + \beta_5 + \beta_6) Rain + (\beta_7 + \beta_8 + \beta_9) Rain^2 \\ &+ (\beta_{10} + \beta_{11} + \beta_{12}) Sun + \beta_{13} T + \beta_{14} T^2 \end{aligned}$$

From expression (23), it is possible to derive the long run elasticities of tomato yields with respect to temperature, precipitations and sunshine.

$$(24) \; E_{YT}^{LR} = \left(\frac{\partial f}{\partial T_t}\right)\left(\frac{T_t}{Y_t}\right) = \frac{\beta_{13} + 2\beta_{14} T}{(1-\beta_1)} T$$

$$(25) \; E_{YRain}^{LR} = \left(\frac{\partial f}{\partial Rain_t}\right)\left(\frac{Rain_t}{Y_t}\right) = \frac{(\beta_4 + \beta_5 + \beta_6) + 2(\beta_7 + \beta_8 + \beta_9) Rain}{(1-\beta_1)} Rain$$

and $(26) \; E_{YSun}^{LR} = \left(\frac{\partial f}{\partial Sun_t}\right)\left(\frac{Sun_t}{Y_t}\right) = \frac{(\beta_{10} + \beta_{11} + \beta_{12})}{(1-\beta_1)} Sun$

Once the elasticity is calculated for all three climatic variables, different climatic scenarios can be set up in order to calculate the climatic effects on yields.

Furthermore, in order to calculate the sensitivity in tomato yields with an increase in temperature and decrease in precipitation the following reasoning is used, based upon the study by Gbetibouo & Hassan, 2004.

(27) $Y_0(T; Rain)$

(28) $Y_1(T + \Delta T; Rain\Delta Rain)$

(29) $Y_1 = (Y_0 + E_t Y_0 \Delta T) + (E_{Rain} Y_0 \Delta Rain)$, where (29) becomes,

(30) $Y_1 = Y_0(1 + E_t \Delta T + E_{Rain} \Delta Rain)$

The relationship between the dependent variable Y_t with regards to the independent climatic variables are interesting to examine from different perspectives concerning the sensitivity analysis. In order to analyse the percentage changes in yields as a result of one 1°C temperature increase, is expressed in the form of a semi-elasticity, which is defined in chapter 3. On the other hand, rainfall is expressed in percentage changes, showing the percentage changes in yields as a result from a percentage change in precipitation. In addition, sunshine hours were not considered as an elasticity estimate due to the fact that it does not have a quadratic relationship to the dependent variable *Yt.* The results are presented in chapter 5.

4.3 Additional explanations

There was a lack of data concerning the socio-economic variables. With regards to the fertilizer and pesticide application levels, the Agricultural and Extension Unit (AREU) on Mauritius have recommendations in order to control the pesticides regarding the quantity used upon the production. Nonetheless, it was not possible to incorporate these parameters within the model used because the pesticides and fertilizers are sold every two to three years to the farmers and therefore the data of the monthly usage of the chemicals in question are non-existent. Moreover, parameters such as labour and irrigation are also lacking. This is caused by the deficiency in Mauritian data.

As mentioned, the variables impacting upon yields might not only be caused by climatic factors. (Pers. com. Ramnauth, 2010). The reasons for this could also be explained by changes in demand, consumption patterns as well as farmer behavior. An example of this the history of tomato cropping where approximately 30 years ago, a popular variety of tomato that was planted along the island was that of *quatre carré* or *pomme d'amour*. Approximately ten years later, Mauritius experienced a shift in generation and variety; the *quatre carré* was replaced by *MST32*. This was then a variety that was imported from Taiwan. The flavor of *MST32* was less sweet then the *quatre carré* variety and therefore met the demand of the consumers. Furthermore, fifteen years ago, hybrid varieties were introduced on the market, which from a farmer's perspective was more profitable, since the hybrids gave higher yields over shorter production periods.

4.3 Survey method

A method can either be classified as quantitative or qualitative. (Eriksson et al, 2008). A quantitative approach is a generic term in socio-economic science. The researcher systematically collects empirical and quantifiable data. Once this is done, the data is statistically analyzed. One procedure is via a survey. (ibid.). The choice of method is restricted to a defined area with a relatively large population. Studies of a qualititative origin are a study where population sizes is relatively small, giving the possibility to carry out personal interviews.

To plan the statistical review is of outmost importance since it guides the implementation of the work. (Eriksson et al, 2008). The following questions should be asked: Who is investigated? What is investigated? How shall the investigation be carried out?

Once the objective of the investigation is specified, the population is defined and limited. (Eriksson et al, 2008). A population is defined is a grouped unit, where their characteristics and attitudes are being studied. A population does not need to be individuals; it can also be objects or different happenings. The units should be related to a specific juncture or time interval in a well-defined geographical area. A specific framework, such as a register or a record is required in order to select a population size. The units that are part of a framework are defined as the sampling unit. The framework creates the base structure of a survey. Survey comes from the French word *"enquête"*, which directly translated means testimony or examination of the witness. (ibid.).

Before the survey is applied upon the targeted unit group, a test run is done by verifying what questions still remains unclear (Eriksson et al, 2008). The questions are then used within the survey must be linked to the question formulations in the investigation. It is important that the respondents are filling in the questionnaire voluntairly in order to get a transparent picture of the answers. It is also essential to remain ethically correct where for instance anonymity implies that the respondent remains unknown to the investigator. (ibid.).

In order to obtain a well-defined questionnaire, the methodological steps are (Astner & Johansson, 2005):

(1) To do a background survey
(2) Extract variables
(3) Produce the questionnaire

Firstly, the background survey consists of assembling information from previously made studies (Astner & Johansson, 2005). There have been numerous surveys carried out in different African countries based on farmer's perceptions and adaptations to climate change (Maddison, 2007; Deressa 2009). It will be further investigated in chapter 3.3. Furthermore, with the information collected, a procedure is developed, which will then clarify the subject to be studied. (Astner & Johansson, 2005). Moreover, variables influencing the study need to be extracted to further generate the questionnaire. The procedure is firstly to determine which areas are influencing the group subject to the study.

In order to determine the variables, the investigator has to go back to the purpose of the work: in other words, what the author wants to find out, which is mentioned in the paragraph above.

(Astner & Johansson, 2005). It is important to select the variables with regards to the subject being influenced by these variables and how to then measure them. Figure 7 made by Astner et al. (2005) illustrates a procedure of which variables to analyze and from these, what type of questions to ask.

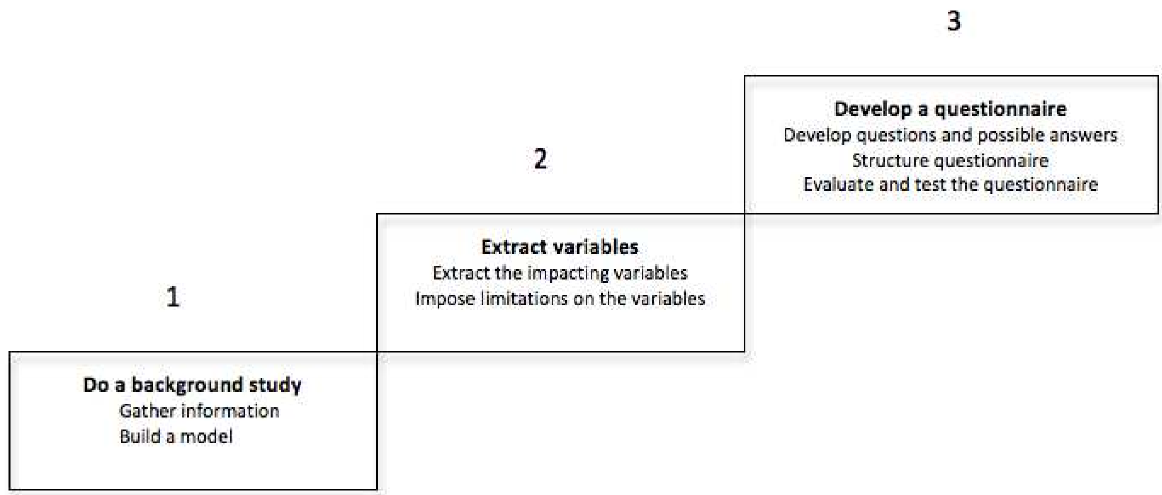

Figure 7: A way of measuring and extracting the correct variables for the construction of a questionnaire (Astner & Johansson, 2005).

4.3.1. Structure of the survey

The structure of the survey implies that the organisation of all questions shall be planned in advance. (Eriksson et al, 2008). A well-structured questionnaire is essential since the results of the answers shall reply to the main aim questions. The respondents should also be able to feel that they can give honest answers and preferably achieve a general positive picture of statistical surveys.

It is further important, whilst constructing a questionnaire to clearly state the purpose of the investigation, the aimed questions and define quantifiable variables. (Eriksson et al, 2008). Followed by this is the formulation of the aimed questions. Together with the purpose, they should be able to answer the issue that is analyzed. Once the questions are defined, it is important to analyze the existence of each question. An imperative requirement is that the questions should be as neutral as possible, which implies that they should not enhance positive or negative answer-options, which is essential when attitudes or values of a group of people are to be measured. Prestigious questions are to be avoided, which is when the respondent “should” or is “expected” to answer in a certain type of way. Moreover, the questionnaire should not mix questions: one question should be asked at a time. A larger question should be divided up into a main question followed by sub-questions. It is also central to formulate the questions in a short and concise way using simple language. Word shortenings are to be avoided. (ibid.).

Arrived at the layout of the different answer alternatives, the investigator should firstly decide whether to use closed or open questions. (Eriksson et al, 2008). A closed question signifies that the answer alternatives are predefined whilst open alternatives give the respondent an opportunity to personally write down his/her answers. Both closed and open answers can be used in a questionnaire. Simultaneously, a coding system should be set up for the different answer alternatives. The advantage with closed answer alternatives is that they are simpler to

answer, code and compile. When it comes to sensitive questions, such as salary related topics, it is preferable to use open answer alternatives. The problem with open answer alternatives is however that they are increasingly difficult to code and compile. In order to solve this problem, closed answer questions with an "other" or "unknown" option for instance could be a solution.

Another factor that matters regarding the quality of the answers is how the questions are ranked and set up. (Eriksson et al, 2008). A general rule is to start off with the most neutral and uncontroversial questions followed by the sensitive questions. The thought behind this assumption is for the respondent to sense a positive and trustworthy experience regarding the survey. The most common way to begin a questionnaire would be to ask questions related to gender, age and marital status. Sensitive questions such as income should be asked at the very last of the questionnaire. It is important to point out that the information remains secret, where ethical laws and rules regarding protection of inappropriate personal intrusion should be included somewhere in the survey. It is furthermore important that the layout is lucid and spaced but at the same time not sparse.

4.3.2 Procedure

It is of large importance to incorporate this field study into the thesis in order to get credible results of how the impacts of climate change are affecting agriculture on Mauritius. The survey shall provide additional evidence to the econometric method used within the thesis since the result of this survey should indeed evoke the possibility to explain the results obtained from the econometric study[7]. Given that it is not possible to include all the different variables[8] that could affect yields within the regression analysis, the results from the survey could then explain what other variables that are not included in the econometric study, mainly due to lack of data, have an impact on yields. In other words, the statistical results, such as R^2, could be further explained with the results from the survey[9].

There are approximately 10 000 Mauritian farmers today of which 2 000 are working as full-time farmers. (Pers. com. Ramnauth, 2010). In order for the study to be reliable, 250 interviewees (12.5%) were randomly selected, within the five main agricultural districts of South, East, West, Centre and the North. In addition, the interviewees in question should preferably have more than five years of experience within the agricultural production domain and be full-time farmers. Further, in order to make the survey possible, additional aid was needed when it comes to the interviews. The AREU and Small Planters Welfare Fund (SPWF) provided additional aid for the surveys, identifying the farmers matching the profile requested. Moreover, AREU interviewed 100 farmers and SPWF 100 respectively. Besides, AREU and SPWF provided additional help, making it possible to personally interview 50 additional farmers.

The questionnaire is a short questionnaire of 16 questions, mainly ranking system questions, starting the general questions concerning age, sex, education, the farmers general agricultural status, if and how they have perceived changes in climate. The survey ends up with two

[7] For the survey see Appendix 5.
[8] The socio-economic variables are parameters such as input costs, lack of labour, pesticides and fertilizers. The climatic variables included in the study are linked to the parameters analyzed in the econometric study. Extreme climatic events are also included; heat waves, flash flooding and droughts for instance. This is according to previous literature studies by for instance W. Hertel & D. Rosch, 2010.
[9] For the underlying theories and motives behind the survey questions see Appendix 6.

sensitive questions concerning farmer's income. The survey was tested upon ten randomly selected farmers. The answers of the survey were coded in order to keep the answers anonymous.

Once the questionnaires completed, the answers were coded and put into an excel sheet. The answers were analyzed via an ANOVA-test on a 99%-level and 95%-level, in order to verify if any significant differences existed in farmer's opinion per region. For further explanation regarding the ANOVA-test, see following section (2.2.4).

4.3.4 ANOVA testing: Analysis of Variance between groups

The t-test shows if the variation between two groups is significant. (G. Keat & K. Young, 2000). The ANOVA-test on the other hand, puts all the data into one number (F) and gives one p-value for the null hypothesis. Also, since the variables used in the test are categorical, which are more complicated to measure, compared to e.g. ordinal variables, the ANOVA-test is a suitable approach. Furthermore, the ANOVA-test is used to compare the means of more than two samples, in order to verify whether two samples, drawn from two populations with altered averages, differ significantally. If both samples are large, unequal variances should be assumed. Regarding the t-test, by assuming unequal variances, the samples n_1 and n_2 from two populations are independent. Likewise, it is the same procedure for the ANOVA-test although the ANOVA-test considers all or multiple parameters and variables in the same table. (ibid.).

Moreover, the ANOVA-test is a test of statistical significance and in order to determine statistical significance at one, five or ten percent level and the independent variables should be greater than two. (G. Keat & K. Young, 2000). The H_0 hypothesis means in general that there is no relationship between the dependent variable Y and the independent variables X. (G. Keat & K. Young, 2000). In other words, changing X's would have no impacts of Y. The H_0 hypothesis is set up against and H_1 hypothesis, which implicates that a relationship exists between the variable X and Y. In other words, when H_0 is rejected, the H_1 hypothesis is true, there is a relationship between X and Y. See the following example, which is based on a two-tailed test, with a binomial distribution at the 10 percent level. (G. Keat & K. Young, 2000).

Assume a coin is tossed 10 times and we get 7 heads. (G. Keat & K. Young, 2000). We want to test whether or not the coin is fair. If the coin is fair then p = 0.5. Therefore, the null hypothesis:

H_0: p=0.5
H_1: p≠0.5

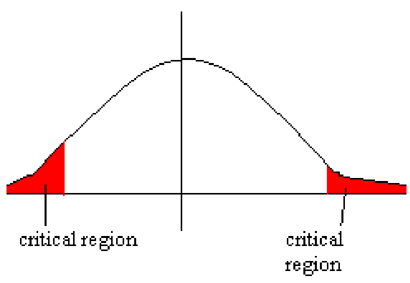

Figure 8: Two-tailed test (G. Keat & K. Young, 2000).

Figure 8 illustrates a two-tailed test. (G. Keat & K. Young, 2000). Since the test is two-tailed, the critical region has two parts. Half of the critical area is at the right side and half is at the left side. The critical region consequently includes the top five percent of the distribution and the bottom five percent of the distribution since we are testing at the 10 percent level.

If H_0 is true, $X \sim Bin(10, 0.5)$

If the null hypothesis is true, what is the probability that X is seven or above?

$P(X \geq 7) = 1 - P(X < 7) = 1 - P(X \leq 6) = 1 – 0.8281 = 0.1719$

It is not in the critical region since the probability that X is at least seven is not less than five percent. (G. Keat & K. Young, 2000). However for H_0 to be rejected, the probability that X is at least seven should be less than five percent. There is then no significant evidence at the 10 percent level to reject the null hypothesis.

5 Results of the econometric study

The following section demonstrates the parameter estimators, the regressor explanatory tests and their role used within the model from the methodological setion in chapter 2. Furthermore, the results for monthly tomato yields for the whole island as well as per region are beneath presented.

5.1 Parameter estimates

The regressors of the model (table 13) used within this work are monthly average temperature, precipitation and sunshine hours as well as a monthly dummy from month one to three. Regarding tomato production, which is an all year food crop on Mauritius, a detailed analysis per region since 1999 was found to be possible as well as an analysis for the whole island since 1984. The explanatory variable that was chosen for the purpose of this study was monthly yields (Y_t), based upon previous studies (Mendelsohn et al, 1994; Gbetibouo & Hassan, 2004). The regressors are presented in table 13.

Table 13: Regressors of the model

Variable	***Definitions***
Y_t	The dependent variable, yields (tonnes/hectare)
α	The constant variable that does not change once the experiment has started
Y_{t-1}	Lagged dependent variable in order to calculate short and long run responses
M_2	Monthly dummy, every second month of the production cycle
M_3	Monthly dummy, every third month of the production cycle
Rain	Monthly climatic variable of rainfall (mm/month)
$Rain^2$	Quadratic monthly variable of rainfall (mm^2/month)
Sun	Monthly climatic variable of sunshine hours
Temp	Monthly climatic variable of temperature (°C)
$Temp^2$	Monthly quadratic variable of temperature (°C^2)
-1, -2, -3	Number representing each month of the production cycle on a yearly basis.

The following table 14 are the tests that indicates which equations that should be chosen the from the output result of the regression analysis.

Table 14: Regression explanatory tests and role.

Regression explanation tests	***Role***
Standard deviation of a dependent variance	Gives an indication of how close or spread the individual X values are distributed around their mean value.
Lagrange Multiplier (LM) test	This method tests whether hypotheses can handle regression models or not, where the number should be close to 1.
Durbin-Watson *d* test	The *d* variable in the test should be close to 2, since if this is the case, one may assume that there is no first order autocorrelation between the variables, either positive or negative.
Durbin *h* test	The test is used to detect if there exists autocorrelation between the variables. The test depends on the level of significance, for instance, if *h* value is higher than 1.96 at the 5%-level, autocorrelation is present in the 1^{st} order error term.
F slope	Goes together with the RESET-test, demonstrating the misspecification amongst variables.

5.2 Econometric results

The following part is firstly analyzing the monthly regression results for the whole island since 1984 to 2009 followed by the monthly results per region since 1999 to 2009.

5.2.1 Tomato for the whole island

The results of tomato yields for the whole island are hereby presented. The statistical data analysis was based on a production cycle for three months. Dummy *M2* and *M3* represent each second and third month on a three months basis during a year. Table 15 shows which variables are statistically significant (* or **)[10] when it comes to precipitation, temperature and sunshine hours per month.

Table 15: Parameter estimates of the Ricardian food crops model for the whole of Mauritius with the Response variable of Log(LYIELDS) in t/ha per month.

WHOLE ISLAND		
Method of estimation: Ordinary Least Squares (OLS)		
Variable	***Coefficient***	***T-statistic***
C	-10.9867	-1.88564
LYIELDS(-1)	0.525866	(6.31194)**
M2	-0.28347	-1.63184
M3	-0.501007	(-2.80518)**
RAIN(-1)	3.71E-03	(2.62342)**
RAIN(-2)	-1.53E-04	-0.116817
RAIN(-3)	1.12E-03	0.871176
$RAIN^2(-1)$	-1.03E-05	(-3.65866)**
$RAIN^2(-2)$	1.91E-06	0.725053
$RAIN^2(-3)$	-4.98E-07	-0.19662
SUN(-1)	3.98E-03	(2.55916)**
SUN(-2)	6.81E-04	0.41139
SUN(-3)	-1.29E-03	-0.745421
TEMP(-2)	1.00385	(2.00202)**
$TEMP^2(-2)$	-0.022503	(-2.08022)**
R^2	*0.73*	
Adjusted R^2	*0.693*	
Durbin-Watson	*1.725*	
Durbin's h alt.	*0.09*	
F-stat	*19.53*	

Interestingly, the squared variables of rainfall and temperature are statistically significant in different months of the production cycle. There seems to be a significant relationship between the second months of cyclic production regarding temperature whilst for precipitation it is in the first month of the production cycle. The sign in front of the squared variables demonstrate a u-shaped or hill-shaped function depending on the month. The u-shaped function, with the continuous levels of precipitation, a decrease in temperature could be detrimental for the monthly yields. Moreover, *Durbin's h test* in table 15 demonstrates if there is

[10] Statistical significance on the 1%-level** and on the 5%-level*

autocorrelation[11] or not, where a number >1.96 is most likely auto-correlated (Gujarati, 2004). Table 16 beneath is showing the present approximate levels of monthly temperature, rainfall, sunshine hours and yields per ha (Y_t), where the monthly yields was obtained via the set up of a production function using the coefficients from table 15 above.

Table 16: Present levels of the monthly climatic parameters as well as the monthly yields per ha.

	Temperature (°C/month)	*Rainfall (mm/month)*	*Sunshine (h/month)*	*Monthly yield(t/ha)*
Whole Island	23.2	177	227,7	9.15

Moreover, the climatic elasticities for the island where calculated in order to quantify the climatic effects upon yields. The elasticities where obtained via partial derivation[12].

Table 17: Estimates for the whole island of short- and long-run elasticities for the different climate factors.

	Region
Short-run	*Whole Island*
Elasticitites	
Rt-1	-0.006
Rt-2	0.052
Rt-3	-0.064
Rainfall total	*-0.018*
Semi elasticities	
Temperature	*-0.04*
Long-run	
Elasticities	
Rainfall	*-0.07*
Semi-elasticities	
Temperature	*-0.08*

According to the formulas demonstrated in chapter 2 and 3, the short-and long-term climate prospectus for tomato yields over the whole island is shown in table 17, which demonstrates the short-term sensitivity in yields with regards to different changes in climate. The elasticities stress that with the current levels of rainfall for example; the monthly Y_t would decrease with an increase in temperature.

Table 17 equally illustrates the long-term[13] prospectus of the impacts of climate fluctuations upon yields. Here one can observe that the effects are almost doubled. The reason for this is since the variables are affected by the impacts of the coefficient in front of the lagged-variable Y_{t-1}, which has the value 0.52 (table 15). Once the coefficient of temperature is divided with (1-0.52) for example, the value obtained is of -0.08. It implies that tomato yields decreases by 8% as a result of 1°C temperature increase, since it is in the long run, which is what the semi-elasticity of temperature shows. Furthermore, a negative percentage change by 7% percent in tomato yields is the result of a percentage change in precipitation, which is an elasticity estimate. The sensitivity impacts are illustrated in table 18. An increase of 1°C, as predicted by the elasticities, would cause a 4% decrease in monthly Y_t. Consequently, it seems that the

[11] Auto-correlation of a mathematical technique used to detect repetive patterns, e.g a missing signal buried or hidden under a noise term (Gujarati, 2004).
[12] See Chapter 2.1, A Ricardian Based model Approach
[13] The long-term impacts are, as predicted by the IPCC, over 90 years from now (2100).

impacts of the climatic effects are moderately small for rainfall. One could also observe that temperature and rainfall work in the opposite way around; a combined increase in temperature and a continuous decrease in rainfall reduce the overall effect of climatic changes upon yields. It further implies that with an increased rainfall, the yield would most likely decline increasingly. A temperature level of 3°C was added in the short-run in order to demonstrate that tomato yields keep declining quite drastically with increasing temperatures. In the long-run, the effects are almost doubled.

Table 18: Sensitivity analysis of the impacts of climate change on monthly tomato yields per hectare for the whole island.

	Climate change scenairos		*Impacts on monthly yield*
Time period	***ΔT***	***ΔRain***	***Whole Island***
Short-run	*+0.5°C*	-	-2%
	+1°C	-	-4%
	+2°C	-	-8%
	+3°C	-	-12%
	-	*-5%*	0.1%
	-	*-10%*	0.2%
	-	*-20%*	0.4%
	+0.5°C	*-5%*	-1.9%
	+0.5°C	*-10%*	-1.8%
	+0.5°C	*-20%*	-1.6%
	+1°C	*-5%*	-3.9%
	+1°C	*-10%*	-3.8%
	+1°C	*-20%*	-3.6%
	+2°C	*-5%*	-7.9%
	+2°C	*-10%*	-7.8%
	+2°C	*-20%*	-7.6%
Long-run	*+0.5°C*	-	-4%
	+1°C	-	-8%
	+2°C	-	-16%
	-	*-5%*	0.4%
	-	*-10%*	0.7%
	-	*-20%*	1.4%
	+0.5°C	*-5%*	-3.7%
	+0.5°C	*-10%*	-3.3%
	+0.5°C	*-20%*	-2.6%
	+1°C	*-5%*	-7.7%
	+1°C	*-10%*	-7.3%
	+1°C	*-20%*	-6.6%
	+2°C	*-5%*	-15.7%
	+2°C	*-10%*	-15.3%
	+2°C	*-20%*	-14.6%

5.2.2 Tomato per region

The results of tomato yields per region related to the climatic variables are beneath illustrated. The different tables demonstrate the resulting variables for the regression results per region[14] (table 19, 20, 21 and 22). The variables are explained in section 5.1. One can, from the tables, observe which months are statistically significant (* or **) regarding monthly tomato yields per region with regards to temperature, rainfall and sunshine hours. The Southern region did not show any statistical significance regarding temperature, which means that the region in question is not directly affected by temperature. The Central part of the island is not represented due to the fact that the analysis did not show any statistically significant results regarding the climatic variables. It could be due to erratic data for instance. Nonetheless, the reasons for this result remain unclear.

Table 19: Parameter estimates of the Ricardian food crops model for the northern region of Mauritius with the Response variable of Log(YIELDS) in t/ha per month.

NORTH		
Method of estimation: Ordinary Least Squares (OLS)		
Variable	**Coefficient**	**T-statistic**
C	-10.62	-1.84
LYIELDS(-1)	0.5353	(6.63)**
M2	-0.3127	(-1.93)*
M3	-0.5088	(-2.87)**
RAIN(-1)	-0.00371	(2.36)**
RAIN(-2)	-0.000253	(-0.197)
RAIN(-3)	0.00109	0.85
$RAIN^2$ (-1)	-0.0000102	(-3.66)**
$RAIN^2$ (-2)	0.000002137	0.82
$RAIN^2$ (-3)	-0.000000483	(-0.191)
SUN(-1)	0.00389	(2.53)**
SUN(-2)	0.0006562	0.398
SUN(-3)	-0.00137	(-0.807)
TEMP(-2)	0.973	(1.96)*
T^2(-2)	-0.0218	(-2.04)**
R^2	0.732	
Adjusted R^2	*0.695*	
Durbin-Watson	*1.73*	
Durbin's h alt.	*2.31*	
F-stat	*19.95*	

[14] The statistical program that was used in order to retrieve the following results was TSP Through the Looking Glass.

Table 20: Parameter estimates of the Ricardian food crops model for the eastern region of Mauritius with the Response variable of Log(YIELDS) in t/ha per month.

EAST		
Method of estimation: Ordinary Least Squares (OLS)		
Variable	**Coefficient**	**T-statistic**
C	-8.55	(-2.43)**
LYIELDS(-1)	0.396	(4.81)**
M2	-0.301	(-3.34)**
M3	-0.365	(-3.88)**
RAIN(-1)	0.00139	(2.30)**
RAIN(-2)	-0.000104	(-0.17)
RAIN(-3)	0.00125	(2.19)**
$RAIN^2$ (-1)	-0.00000252	(-3.04)**
$RAIN^2$ (-2)	6.84E-07	0.85
$RAIN^2$ (-3)	-0.00000101	(-1.33)
SUN(-1)	0.00195	(2.37)**
SUN(-2)	0.000684	0.795
SUN(-3)	-0.000874	(-0.982)
TEMP(-2)	0.885	(2.833)**
T^2(-2)	-0.02	(-2.927)**
R^2	0.743	
Adjusted R^2	*0.7*	
Durbin-Watson	*2*	
Durbin's h alt.	*0.06*	
F-stat	*21.06*	

Table 21: Parameter estimates of the Ricardian food crops model for the western region of Mauritius with the Response variable of Log(YIELDS) in t/ha per month.

WEST		
Method of estimation: Ordinary Least Squares (OLS)		
Variable	**Coefficient**	**T-statistic**
C	2.784	(3.51)**
LYIELDS(-1)	0.437	(4.79)**
M2	0.094	0.811
M3	-0.348	(-0.679)
RAIN(-1)	0.00483	(2.25)**
RAIN(-2)	0.00146	0.433
RAIN(-3)	-0.00252	(-1.03)
$RAIN^2$ (-1)	-0.0000107	(-2.792)**
$RAIN^2$ (-2)	-0.00000303	(-0.55)
$RAIN^2$ (-3)	0.00000292	0.698
SUN(-2)	-0.00292	(-1.32)
SUN(-3)	-0.00303	(-1.25)
TEMP(-2)	0.0074	(2.62)**
T^2(-2)	-0.00003823	(-1.48)
R^2	*0.71*	
Adjusted R^2	*0.675*	
Durbin-Watson	*1.76*	
Durbin's h alt.	*2.42*	
F-stat	*19.53*	

Table 22: Parameter estimates of the Ricardian food crops model for the southern region of Mauritius with the Response variable of Log(YIELDS) in t/ha per month.

SOUTH		
Method of estimation: Ordinary Least Squares (OLS)		
Variable	**Coefficient**	**T-statistic**
C	0.971	(3.81)**
LYIELDS(-1)	0.614	(8.83)**
M2	-0.044	(-0.639)
M3	-0.275	(-3.95)**
RAIN(-1)	0.000831	1.49
RAIN(-2)	-0.000164	(-0.29)
RAIN(-3)	0.000787	1.37
$RAIN^2$ (-1)	-0.00000314	(-2.77)**
$RAIN^2$ (-2)	0.000000705	0.59
$RAIN^2$ (-3)	-0.000000667	(-0.57)
SUN(-2)	0.000809	1.7
SUN(-3)	-0.00106	(-1.97)*
R^2	*0.67*	
Adjusted R^2	*0.635*	
Durbin-Watson	*1.82*	
Durbin's h alt.	*1.41*	
F-stat	*19.4*	

The quadratic relationship between yields and rainfall as well as temperature is based on, as mentioned earlier, past studies (Gbetibouo & Hassan, 2004; Mendelsohn et al, 1994). For all regions a part for the Centre, the quadratic variables of rainfall and/or temperature where found to be statistically significant. The signs in front the quadratic variables denote a u-shaped or as hill-shaped function depending on the month. The u-shaped function indicates that with a change in for instance temperature in the North or the East although precipitation remains the same, has a negative effect on the monthly yields.

As follows is table 23 of the present approximate levels of monthly temperature, rainfall and sunshine hours per region. With these climatic conditions, the monthly yields per region are exemplified. The monthly yields per area were obtained via a set up of dissimilar production functions, using the coefficients from the tables above.

Table 23: Present levels of the monthly climatic parameters as well as the monthly yields per ha per region.

	Temperature (°C/month)	***Rainfall (mm/month)***	***Sunshine (h/month)***	***Monthly yields (t/ha)***
North	23.8	112	230.6	6.7
East	24.3	132	211	7.7
West	25	71	226.6	14.6
South	23.2	183	199.5	9.2
Centre	21.9	165	221.7	8.7

Furthermore, the climatic short-term elasticities per region where calculated in order to measure their impacts upon yields (table 24). As mentioned above, the temperature variable is not included in the Southern region. It does however not eliminate the impact of temperature in the Southern region. One could argue that the effect of sunshine also implicates to a certain extent that the effect of temperature since the temperature variable could be considered as an

unobservable variable according to Almon's law[15] (Gujarati, 2004). Further, as mentioned in chapter 2.1.1, the Southern climate has a similar seasonal climate as the East where one could argue that the Southern yields actually could be affected by temperature as well and that the southern results provided by the regression could be due to erroneous data.

Table 24: Short- and long-run estimates of elasticities of the different climate factors.

	Regions			
Short-run	*North*	*East*	*West*	*South*
Elastiticites				
R_{t-1}	-0.06	0.007	0.03	-0.003
R_{t-2}	0.002	0.001	0.01	0.001
R_{t-3}	0.01	0.01	-0.021	0.006
Rainfall (total)	*-0.048*	*0.018*	*0.022*	*0.004*
Semi elasticities				
Temperature	*-0.06*	*-0.08*	*0.0055*	-
Long-run				
Elasticities				
Rainfall	-0.01	0.03	0.04	0.01
Semi elasticities				
Temperature	*-0.13*	*-0.13*	*0.01*	-

The short-run elasticities in table 24 illustrate that with the current levels of rainfall in the East for example the Y_t would decrease with a change in temperature. However, the short-run elasticities gives the change in Y with one unit change in X and the inputs are in general fixed. Interestingly, one can observe the impacts of rainfall per monthly period. With the current levels of temperature, rainfall during the first cyclical period, affects the yield negatively by 0.6% as a result of one percent in rainfall in the northern region. With regards to the semi-elasticity for temperature, 1°C increase affects tomato yields negatively by 6% percent in the short run and 13% in the long run. The southern tomato yields react negatively with small changes in rainfall during the first month whilst the west is increasingly sensitive to a decreased rainfall in the third production cycle. The estimates offer the possibility to precisely observe how sensitive tomato yields is to small changes in the different climatic variables.

The long-run elasticities on the other hand, have varied inputs over time, which is defined by the lagged-variable Y_{t-1}. The long-run elasticites can also be observed in table 24 and one can notice that the numbers are twice as large. The elasticites imply that with 1°C increase in temperature whilst the other variables remain constant, Y_t will decreases by 13% in the East for instance. The West does not seem as highly affected by 1°C temperature increase since it increases by 1% in the long-run.

As noticed, a few of the elasticties are quite small. It would be due to the impact it has per month, which can also be noticed in table 25, where some of the impacts of different climate change scenarios does not have a large monthly effect. See for instance a 2°C temperature increase in the West. Furthermore, the northern and the eastern tomato yields appear to be the most impacted by changes in climate. As for the whole island results, an additional

[15] Almon's approach explains that, from the original variables X, of which Y is constructed upon, the variable Z could be derived as an unobserved parameter, in this case, temperature (Gujarati, 2004, ch. 17).

temperature level of 3°C was analyzed in the short-run in order to demonstrate that tomato yields keep declining quite drastically with increasing temperatures. The large differences between the North and East compared to the West for instance may also be due to errors in the historical data. Likewise, the long-run effects are twice as large compared to the short-run climatic effects.

Table 25: Sensitivity analysis of the impacts of climate change on monthly tomato yields per hectare per region.

	Climate change scenairos		*Impacts on monthly yield*			
Time period	***ΔT***	***ΔRain***	***North***	***East***	***West***	***South***
Short-run	*+0.5°C*	-	-3%	-4%	-0.4%	-
	+1°C	-	-6%	-8%	-0.8%	-
	+2°C	-	-12%	-16%	-1.6%	-
	+3°C	-	-18%	-24%	-2.4%	-
	-	*-5%*	0.2%	-0.1%	-0.1%	-0.02%
	-	*-10%*	0.5%	-0.2%	-0.2%	-0.04%
	-	*-20%*	1%	-0.4%	-0.4%	-0.08%
	+0.5°C	*-5%*	-2.8%	-4.1%	-0.5%	-0.02%
	+0.5°C	*-10%*	-2.5%	-4.2%	-0.6%	-0.04%
	+0.5°C	*-20%*	-2%	-4.4%	-0.8%	-0.08%
	+1°C	*-5%*	-5.8%	-8.1%	-0.9%	-0.02%
	+1°C	*-10%*	-5.5%	-8.2%	-1%	-0.04%
	+1°C	*-20%*	-5%	-8.4%	-1.2%	-0.08%
	+2°C	*-5%*	-11.8%	-16.1%	-1.7%	-0.02%
	+2°C	*-10%*	-11.5%	-16.2%	-1.8%	-0.04%
	+2°C	*-20%*	-11%	-16.4%	-2%	-0.08%
Long-run	*+0.5°C*	-	-6.5%	-6.5%	0.5%	-
	+1°C	-	-13%	-13%	1%	-
	+2°C	-	-26%	-26%	2%	-
	-	*-5%*	0.05%	-0.1%	-0.2%	-0.05%
	-	*-10%*	0.1%	-0.3%	-0.4%	-0.10%
	-	*-20%*	0.2%	-0.6%	-0.8%	-0.20%
	+0.5°C	*-5%*	-6.5%	-6.6%	0.3%	-0.05%
	+0.5°C	*-10%*	-6.4%	-6.8%	0.1%	-0.10%
	+0.5°C	*-20%*	-6.3%	-7.1%	-0.3%	-0.20%
	+1°C	*-5%*	-13%	-13.2%	0.8%	-0.05%
	+1°C	*-10%*	-12.9%	-13.3%	0.6%	-0.10%
	+1°C	*-20%*	-12.8%	-13.6%	0.2%	-0.20%
	+2°C	*-5%*	-26%	-26.2%	1.8%	-0.05%
	+2°C	*-10%*	-25.9%	-26.3%	1.6%	-0.10%
	+2°C	*-20%*	-25.8%	-26.6%	1.2%	-0.20%

Moreover, table 25 illustrates that a monthly effect of increased temperature combined with a decrease in precipitation is negatively affecting tomato yields per region, apart for the Southern region. Also, with regards to table 18, the island as a whole has shown that the total climatic effect is negatively affecting monthly tomato yields. As mentioned, the Central part of the island is not included due to the fact that it did not show any statistically significant results for the climatic variables.

6 Results of the survey

The following section illustrates the statistical results from the survey as well as the evaluation of the answers from the survey put into relation with the statistics.

6.1 Statistical results

Regarding the statistical data of the survey results, a two-way ANOVA-test was applied to verify the relative strengths between the different variances per region as well as on a regional basis. The ANOVA-test was tested on a 1%-level and 5%-level[16]. The two-way ANOVA-test was applied instead of the one-way ANOVA-test due to the fact that there are, for each question, two parameters. Question 5a for instance: *How much land do you produce on?* dipose of (1) *Quantity of land* and (2) *Region.* Tables 26 demonstrate the statistical results of the survey and shows the statistical significance per regions as well as on a regional basis, e.g. whether or not the Northern region has replied more yes or no with regards to question *7b: Have you shifted the variety?* Moreover, the questionnaire can be found in Appendix 5.

[16] 1%-level: ** and 5%-level:*

Table 26: Statistical significance on the 1%-level** or 5%-level* per question comparing regions to one another.

Questions	Significant at the 1 % level** or 5 % level*	
	Between regions	*Regional basis*
5a How much land to you produce on?	**	**
5b How has your land size changed?		
5c If it has increased/decreased, what are these changes due to?	**	**
6a What vegetables have you grown?		**
6b Have you changed food crops since you started farming?	*	
6b1 If yes, what are the changes due to?	*	**
7b Have you shifted the variety?	*	**
7b1 If yes, what are the reasons?		**
8a What type of water system do you use?		
8b Are you applying organic or inorganic fertilizers?		**
8b Are you applying organic or inorganic pesticides?		**
9a Have you changed the way you water your production?		
9a1 If yes, when did you change?		**
9b What are the reasons for adapting?		**
10a Based on what recommendations do you fertilize/pesticide your production?		
10a1 If based on personal knowledge, what is it due to?		
11 Which are the factors affecting the yield of your crops?	**	
12a Do the yields differ regarding different seasons?		**
12a1 If yes, in what way?	*	**
12b Have you noticed changes in seasonal yield during the last 10 years?		**
12b1 If yes, what are these due to?		**
13 What are the constraints of agricultural practice on Mauritius?	**	
14a Have you noticed any changes in weather patterns?		**
14a1 If yes, has this affected your food crops?		**
15 What is your household income per year (in Rupees)?		*
16 What is your monthly income per food crop?	*	**

6.2 Evaluation of results

Starting from question 5a, the farmers were asked how much land they produce on. Table 26 illustrates that there is a statistical difference per region but also between producers' opinions within each region, which could be put into relationship to table 27. Indeed, most farmers in the Northern region produce on less than 2 ha whilst the South and the Centre seem to have a few larger productions.

Table 27: Answers per region, 5a.

	North	*South*	*East*	*West*	*Centre*
< 2ha	70%	55%	68%	66%	56%
2-5ha	30%	33%	29%	31%	32%
6-10ha	0%	7%	3%	3%	8%
> 10ha	0%	4%	0%	0%	3%

In question 5b, the farmers were asked if their land had increased, decreased or remained the same. Further, Table 26 gives the statistical significance level, where the Southern and Central region differs from the North, East and West. Moreover, observing the statistical significances and the results from table 28, demonstrate that the differences between region have a greater influence compared to the non-significant ones – i.e. where the p-level is greater than 0.01. Coming back to question 5b, the South is the region where most of the farmers land have decreased whilst the Western and Central region are partially divided between an increase or a decrease in land. The North and East seem to have an increase in land.

It is noteworthy to mention that most of the farmers are small planters since they in general cultivate on an area inferior to two hectares, which implies that quite a few, especially in the North, South and Centre are decreasing the amount of land cultivated. There are a few large planters situated in the Southern and Central parts of the island producing on areas superior to ten hectares. Table 28 gives in percentage which farmers per region who have augmented or decreased their area of land cultivated. Surprisingly, quite a few producers have decided to decrease land under cultivation in the Southern and Central parts of the region.

Table 28: Answers per region, question 5b.

	North	*South*	*East*	*West*	*Centre*
Increased land	33%	35%	32%	10%	33%
Decreased land	17%	38%	10%	10%	31%
Remained the same	50%	27%	58%	80%	36%

Table 29 below summarizes answers to question 5c in the questionnaire. The farmers were asked to answer why they have increased or decreased the area of land cultivated. Only a small percentage of the farmers surveyed find the Mauritian climate suitable for producing food crops during the last ten years. Factors provided for the reduction in area cultivated were: (1) availability of less cultivable land, and (2) climate was unfavorable for the food crops. There is a large majority of farmers in the South and Centre who finds that the climate is in general unfavorable for their food crops, whereas the increase in the North for instance seems to be due to the availability of more cultivable land. One of the reasons for this increase has been the release of land formerly under sugar cane plantation to food crop farmers.

Table 29: Answers per region, question 5c.

	North	*South*	*East*	*West*	*Centre*
Less cultivable land	17%	4%	8%	33%	5%
More cultivable land	50%	36%	38%	33%	35%
Climate is favorable for the food crops	4%	2%	8%	0%	5%
Climate is unfavorable for the food crops	21%	34%	15%	17%	30%
Other factors such as increase of family members	8%	24%	31%	17%	25%

Linking these reported changes to the statistical significance test, there is also a clear difference between regions. From table 28 and 29 it is possible to associate the questions together; the decrease in land in the South might be affected by an unfavorable climate compared to the North. In the North, table 28 and 29 shows that the increase of 33% of land area under cultivation would be due to the fact that farmers experience more cultivable land.

Question 6a shows statistical significance on a regional basis. In this case, it is most probable that the farmers from the five different regions alternate between different food crops during the year and per season. Question 6b and 6b1 showed statistical significance on the 5% level per region (table 26). In question 6b, the farmers where asked if they have changed food crops since they started farming. In total 54.4% answered affirmatively to this question. Therefore farmers reported that they have indeed changed food crops since they started farming, although some farmers more than others. The North has for instance changed food crops more often compared to the other regions. Moreover, question 6b1, which is a follow-up question to 6b, there producers were asked; *"If you have changed food crops since you started farming, what are the changes due to?"* (Annex 3). Figure 9 clearly shows that the major motivation for a food crop shift is mainly due to two factors, notably changes in weather patterns and price uncertainty.

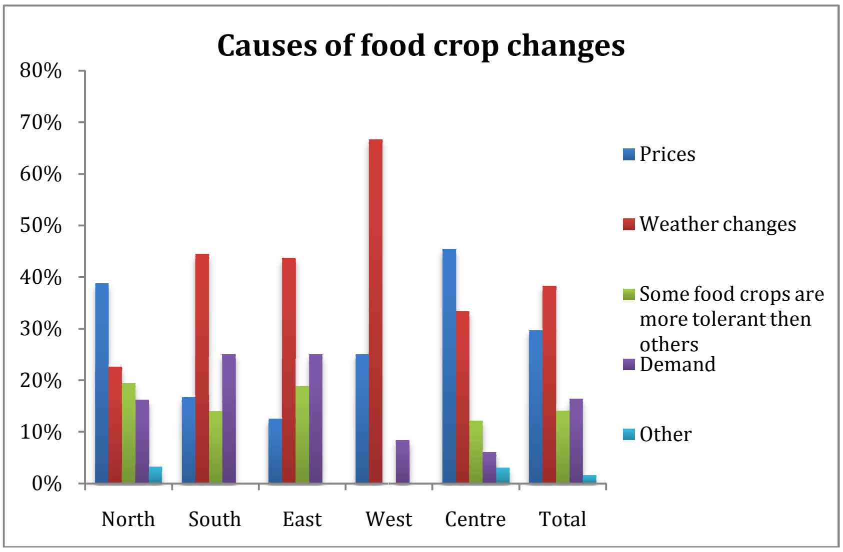

Figure 9. Bar chart showing the strengths of different factors that cause farmers to change food crops for different regions.

In question 7b, it is possible to observe that most of the Mauritius food crop producers have shifted variety. However, the Northern and Eastern region seem to have made the largest shifts (table 30).

Table 30: Answers per region, 7b.

	North	*South*	*East*	*West*	*Centre*
Yes	77%	62%	81%	59%	61%
No	23%	38%	19%	41%	39%

The statistical significance level from table 26 equally demonstrates this. Further, the statistical significance in 7b1 mainly differentiaties on a regional basis, where the farmers seems to have diversed opinions per region (table 31).

Table 31: Answers per region, 7b1.

	North	*South*	*East*	*West*	*Centre*	*Total*
Price	3%	7%	0%	6%	14%	7%
Climate	14%	19%	32%	35%	35%	26%
Yield and revenue	72%	65%	64%	59%	47%	61%
Consumer preferences	11%	9%	4%	0%	5%	7%

Nonetheless, most of the farmers in total tend to reply that the shift in food crop varieties was due to yields and revenue. In the Centre, the reason provided related primarily to adaptation of climate variability. The answers to question 7b1 will be analyzed in conjunction with answers to question 13 further below.

Question 8a verified the statistical difference between the water usage systems per region and on a regional basis. There are no differences per region. Nonetheless, the North and South points to a rain fed system with traditional irrigation, South and Centre almost completely rain fed and whilst the West is mainly irrigated with an overhead water system. Figure 10 gives a brief description of which regions are using what type of water system. The Centre is the wettest region of the island, which is why the production is mainly rain fed. The West is the driest per definition and the production is mainly under overhead irrigation due to the sugar cane plantations. Interestingly, it is mainly in the East that the farmers have changed food crops due to weather changes (see figure 9) and also where the drought factor is the most influencing feature (figure 12).

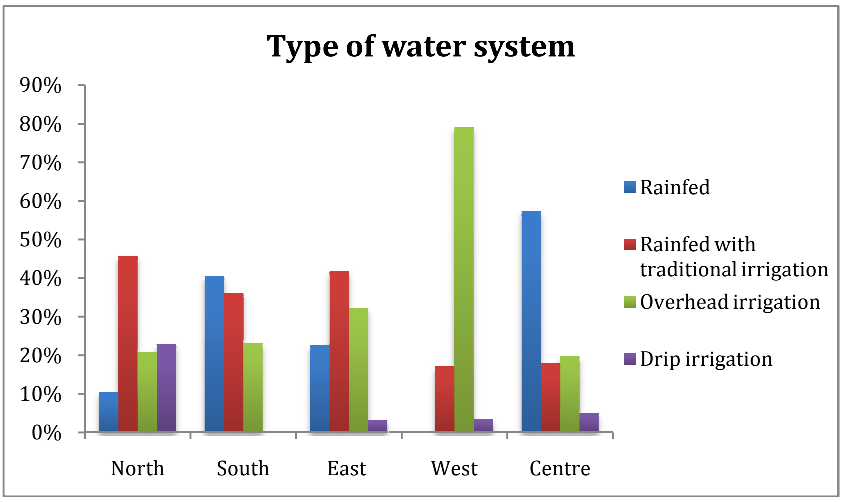

Figure 10: prominent type of water system per region.

Question 9 continued to cover the part of the farming water system. Here it is worthy of note to verify which regions are in need of irrigation, which ones can rely upon rainfall and further, linked this to question eleven from the questionnaire, where the issue of drought and lack of fresh water is in average, for all regions, a negative yields factor. Coming back to question nine; *"have you changed the way you water your production?"* 40.5% of the planters replied yes. The question was shown to be statistically significant between per option for each region but not statistically different per region (table 26). It is however the North that seems to have changed the water system, due to climatic conditions. From question 7, the North is, not only, going from rain fed to rain fed with traditional irrigation but also to drip and overhead irrigation. The subsequent figure shows when the producers decided to change their water system, from completely rain fed to a certain type of irrigation[17] system. In the Centre, West and South, the majority answered two to five years ago, whereas in the East, the mainstream responded more than five years ago. The North is a mix between two to five years ago and more than five years. The reasons for the answers given in figure 11 could be clarified via figure 10, explaining the major water systems depending on region.

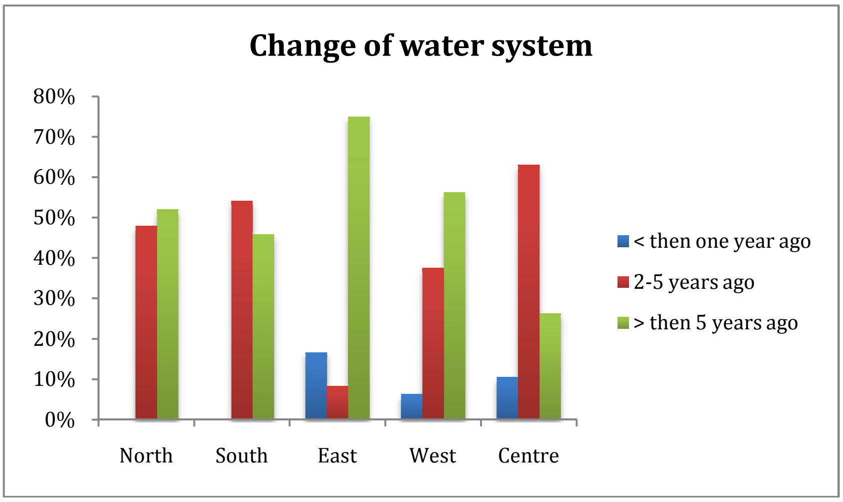

Figure 11 demonstrates how many years ago the planters changed water system per region.

According to figure 11, the South and the Centre seems to be changing their water systems, from completely rain fed to rain fed with traditional irrigation and/or overhead irrigation. The South, for instance, according to question 11, has an average of 2.5 for the drought factor. It tells us that droughts are of an increasing issue for the planters. Table 32 provides an image of the possible incentives to a water change, where the climatic conditions, is the leading factor in all regions apart from in the South. The South, depending on the change of water system, has replied either increased amount of land or climatic conditions, as shown in table 32.

Table 32: Reasons for adapting to a certain type of irrigation system.

	North	*South*	*East*	*West*	*Centre*
Increased amount of land	4%	25%	0%	6%	5%
Decreased amount of land	0%	0%	0%	6%	0%
Climatic conditions	76%	75%	100%	81%	95%
Higher demand on the market	20%	0%	0%	6%	0%

Figure 12 and table 33 are demonstrating the factors affecting the yields and the major constraints in agricultural production for Mauritian farmers. The questions where set up via a

[17] Here it is hence important to take into account that some of the food crops are planted in between sugar cane land and are therefore under irrigation since sugar cane plantation are under over head irrigated.

ranking system from 1 to 7, where number 1 represents the most influencing factor. Further, table 26 gives the statistical difference per variable comparing the five different regions. The question is statistically significant on the 1%-level per region. The fact that there is significant difference between regions certifies and elucidates that dissimilar climatic factors are affecting yields differently depending on region. It also confirms that the impacts of a certain variable, such as drought and lack of fresh water, are increaslingly significant in the West compared to the Centre (figure 12).

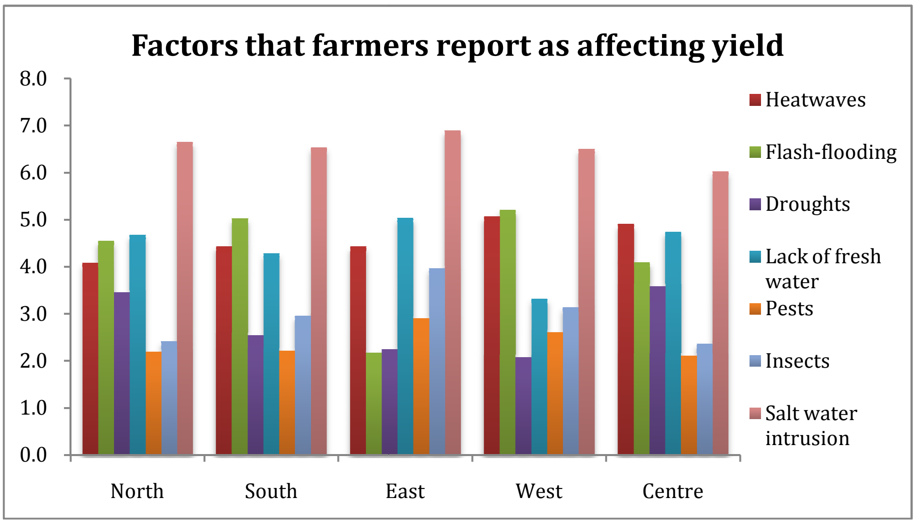

Figure 12: Factors affecting the yields of small planters food crops per region.

According to table 33, where the average weight for each influencing factor is given, in all regions, pests, insects and droughts are negatively influencing factors for the farmers. For instance, drought is an important variable in the West, South and even East, which is recognized as the wettest region of the island. Remarkably, the East still believes that the most relevant factor affecting the regional yields is flash-flooding occurring during the summer season. It demonstrates that the Eastern region is experiencing issues with droughts in winter and flash-flooding in summer.

Table 33: Scale for each variable per region and in total for the whole island[18].

	Variables						
Region	Heat waves	Flash-flooding	Droughts	Lack of fresh water	Pests	Insects	Salt water intrusion
North	4.1	4.6	3.4	4.6	2.2	2.4	6.7
South	4.4	5.0	2.6	4.3	2.2	3.0	6.5
East	4.4	2.2	2.2	5.0	2.9	4.0	6.9
West	5.1	5.2	2.1	3.3	2.6	3.1	6.5
Centre	4.9	4.3	3.6	4.7	2.0	2.4	5.9
Grand Total	4.6	4.4	2.9	4.4	2.3	2.9	6.4

As shown in figure 12, table 33 and also whilst interviewing the planters, they tend to complain mainly about pests followed by insects. Related to this, is the relationship the planters seem to have when it comes to pesticides and fertilizers. The table below gives an idea of what type of fertilizers and pesticides that are mainly used on the island. The statistical significance given above in table 26 shows that there is no difference however between regions but that there are differences on a regional basis, which is probably the most coherent

[18] Number 1 is the most influencing yields factor and number 7 represents the least influencing yields factor.

with the Central part of the island. Nonetheless, table 34 illustrates that the Central part are the most prominent users of organic fertilizers and pesticides.

Table 34: Type of fertilizers is applied amongst planter per geographical area.

	North	*South*	*East*	*West*	*Centre*
Fertilized chemically	100%	80%	90%	93%	65%
Fertilized organically	0%	1%	0%	3%	7%
Both	0%	19%	10%	3%	28%
Pesticide chemically	100%	100%	100%	97%	76%
Pesticide organically	0%	0%	0%	0%	6%
Both	0%	0%	0%	3%	18%

Linked to this, is the fact that 52.5% of the farmers are applying according to personal knowledge and experience rather than following the recommendations set up by AREU and MSIRI. The question, (10a), has not shown a statistical difference between regions. It seems however that the South and East are following the chemicals guide to a higher extent compared to the West or the Centre. The main reasons for this are shown in figure 13 beneath.

Further, arriving at question 10a1, the planters in total reckon that the main reason for applying chemicals[19] via own experience is due the blue staple: recommendations made by AREU and/or MSIRI and are not possible for follow up. It is nonetheless important to notice that the difference between the green and the blue staple in minimal, 36% and 35% respectively. It demonstrates that farmers are experiencing difficulties in the climate, which is why they apply the quantity needed to adjust. On the other hand, regarding geographical areas, figure 13 points out the fact that the East and South finds that the climatic situation differs compared to the other regions. Accordingly, the other regions apply chemicals with personal knowledge because of the input costs or that the recommendations are not possible to follow up. Moreover, there seem to be a lack of adaptation tools in order to aid the farmers towards agro-ecological progress. Figure 13 shows this, where in total the "*Recommendations by AREU and/or MSIRI are not possible to follow up*".

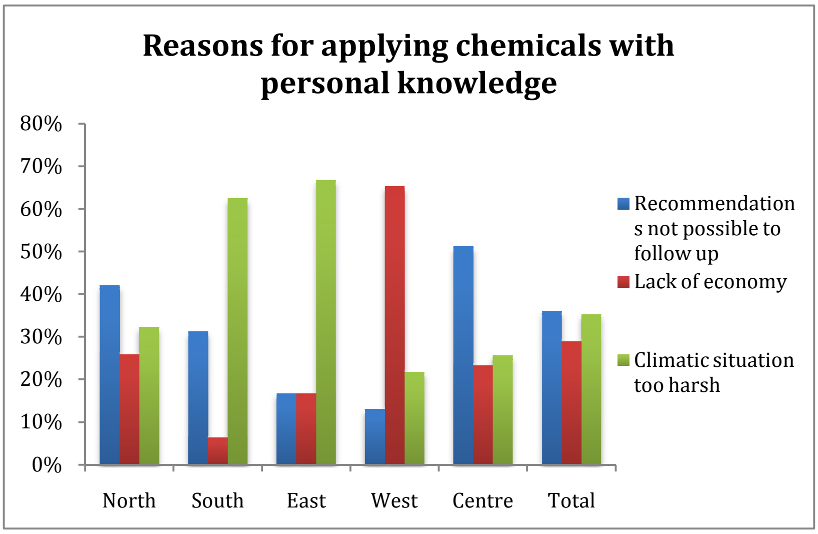

Figure 13 demonstrates the farmer's explanations for applying chemicals with personal knowledge.

Question 12a and 12a1 mainly demonstrates that there exists a difference per region on the 5%-level whether or not the seasonal yield differs. There are equally differences on a regional basis, which may be observed in table 35. In the North for instance, 25% of the farmers

[19] Including pesticides and fertilizers.

reckons that the yields is higher in winter and therefore more profitable in winter, whilst others, 16%, thinks that it is more profitable in summer.

Table 35: Answers per region, 12a1.

	North	***South***	***East***	***West***	***Centre***
Higher in summer	11%	26%	8%	0%	23%
Lower in summer	7%	5%	0%	4%	9%
Higher in winter	25%	8%	13%	37%	18%
Lower in winter	14%	2%	0%	0%	3%
More profitable in summer	16%	21%	54%	52%	24%
More profitable in winter	27%	39%	25%	7%	23%

Moreover, mentioning that a certain number of planters are capable of linking pest and insect issues to changes in climate could also be linked to the answers in figure 14 (question 12b) where the farmers where asked if they have noticed or observed changes in seasonal yields during the last ten years and 92% of the interviewees answered yes. Nonetheless, there is no statistical significance between regions. However, almost all farmers share the same opinion: they have experienced weather changes during the last ten years.

Nonetheless, this query was accompanied by a follow-up question: *"If yes, what are these changes due to?"* pursued by six different options, which can be observed in figure 14. Increased weather uncertainty is in total the most outstanding factor. Even so, region wise, differences are noticeable. The West and South consider increased drought as the largest seasonal change since 2000. The Western region also reckons that humidity changes are of an important feature. Further, the West and South would rather highlight that there exists an increased drought effect since the last ten years and that it is affecting their yields. It is similar for the other regions, apart for the climatic factor, which accordingly is the increased weather uncertainty factor, such as rainfall and temperature fluctuations. Additionally, table 26 highlights the opition differences for each region. The producers per region have different opinions when it comes to the cause of seasonal changes e.g. the Southern farmers have observed increased weather uncertainty but also increased drought (figure 14).

Besides, the answers in figure 14 could be linked to figure 13 where a certain number of farmers per region have noticed changes in weather patterns, which is mainly in the East and South. Furthermore, the different answers between figures 13 and 14 demonstrates that there are equally other factors but climatic variables, such as for instance lack of economy. The matter is important to stress since there is not enough proof to exemplify that there is an existent consciousness concerning changes in climate amongst Mauritian farmers.

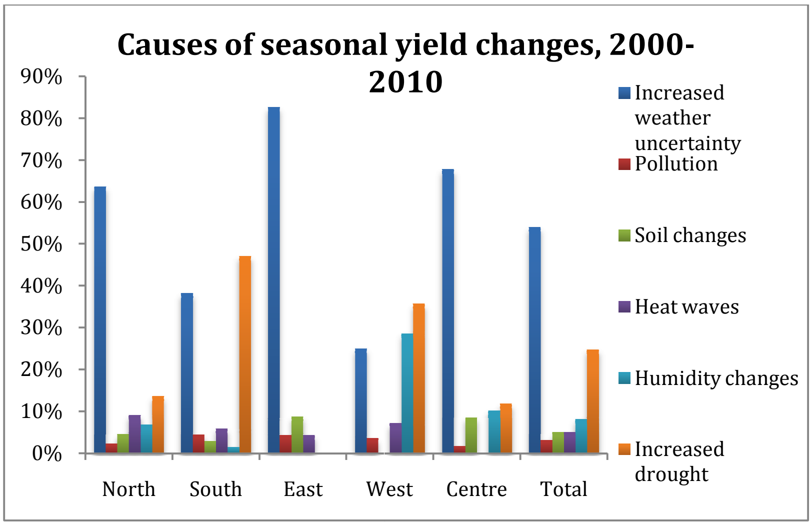

Figure 14: Causes of seasonal yields changes from 2000-2010.

Another issue mentioned by a certain number of planters was the demand uncertainty for organic products, where the retail prices of the market would likely increase with organic farming (1) due to the uncertainty in yields and (2) an increase in input costs. Further, the price factor has shown to be one of the major concerns for Mauritian farmers, referring to figure 15, where they are constantly trying to adjust the type of food crops according to prices since the prices of the market are dependent upon the yields, which in turn is dependent upon input costs. The paragraph above can is linked to question 7b1; there exist various differences between the regions since the Centre and West are also giving importance not only to yields and revenue but also to the climatic factor (table 31).

Coming back to the paragraph above, linked to the dependence upon input costs, a pattern appears in the answers of the survey, for instance in question 13, figure 16; input costs are the largest constraints affirmed by the planters. Also, linked to yields importance is question 7b from the questionnaire were the producers where requested to confirm a shift in variety and if yes, why so. 68.4% replied that they have changed varieties during their time as planters, where the main reason for this is due to yields and revenue (see graph 15).

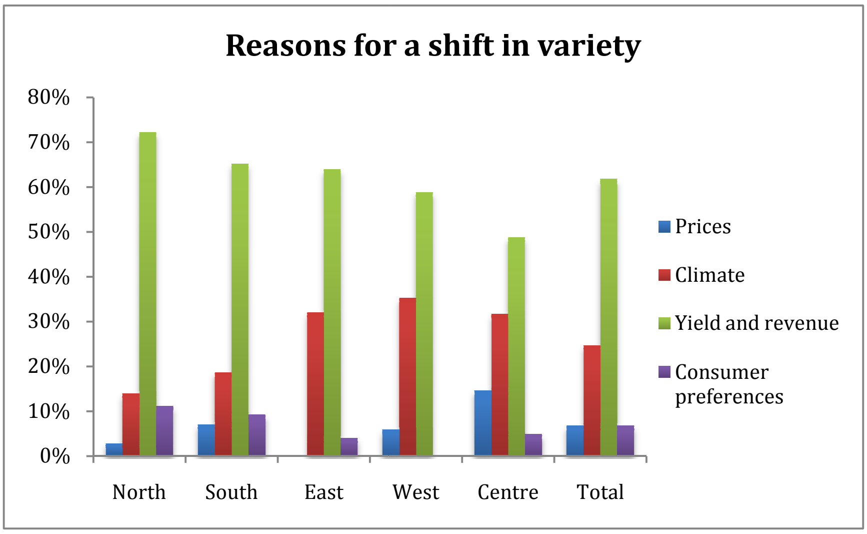

Figure 15: reasons for a shift in variety, question 7b1.

Furthermore, farmers were asked to rank the most influencing constraint (1) of agriculture on Mauritius to the least influencing one (7). For all regions, input costs and lack of labor represent the largest constraints for Mauritian farmers. According to figure 16, precipitation followed by temperature is in general for the whole island perceived as the subsequent constraints after input costs and labor. However, according to table 26, one can observe that there are arithmetical discrepancies between regions. For instance, see figure 16, rainfall is a larger constraint for the Eastern and Southern regions compared to the Centre, which could for instance be caused by diverse rainfall fluctuation patterns in the island. Moreover, the labor factor is of greater importance for the Western region compared to the East. In sum, the West is experiencing both issues with increased droughts, deficiencies in fresh water, need of modernized water systems and lack of labour.

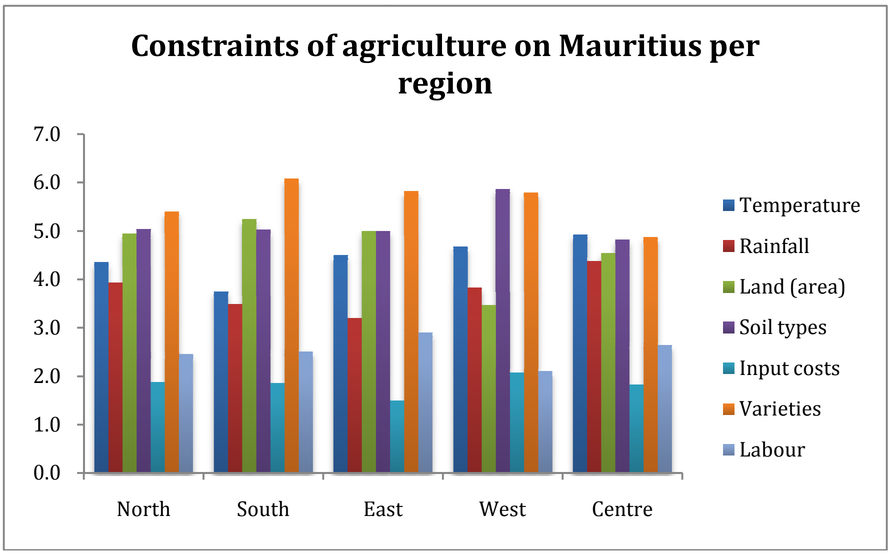

Figure 16: constraints of agriculture on Mauritius per region.

Table 36, completes table 26, showing the average weight given to each constraint factor per region. The table points out which factors are the most prominent ones per region and in total for the whole island. Interestingly, there are a few differences that can be noticed. In the East for instance, rainfall is classed as a higher constraint tp the producers compared to the other regions. The South is more sensitive to temperature changes and the West to land size.

Table 36: Scale for each variable per region and in total for the whole island[20].

	Variables						
Regions	Temperature	Rainfall	Land (area)	Soil types	Input costs	Varieties	Labor
North	4.4	3.9	4.9	5.0	1.9	5.4	2.5
South	3.8	3.5	5.2	5.0	1.9	6.1	2.5
East	4.5	3.2	5.0	5.0	1.5	5.8	2.9
West	4.7	3.8	3.5	5.9	2.1	5.8	2.1
Centre	4.9	4.4	4.5	4.8	1.8	4.9	2.6
Grand Total	4.4	3.8	4.8	5.1	1.8	5.6	2.5

Figure 17 illuminates the fact that farmers have identified changes in climate where the majority, 97.5 % of the interviewed producers, has indeed noticed a change in weather patterns on Mauritius. Out these 97.5 %, 87.8 % reckon that the changes in question have negatively affected the yields of their food crops, in other words a diminished return in yields (see figure 17). Nevertheless, according to figure 16 and table 36, the socio-economic

[20] Number 1 is the most influencing constraint and number 7 represents the least influencing constraint.

variables seem to have a larger negative impact compared to the climatic variables stated by the planters.

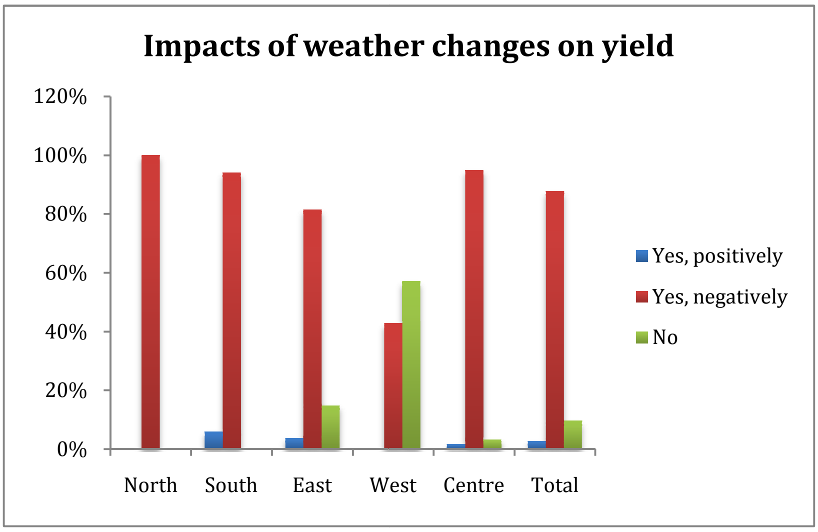

Figure 17 demonstrates how the farmers are presently experiencing the effects of weather changes upon their yields.

The two last questions of the survey were optional for the farmers to answer. They were asked their yearly household income (question 15) and approximate monthly income per food crop (question 16). Question 15 illustrates that there is a significant difference (table 26) amongst the farmers' total income in each region. Some farmers in the East, for instance, earn more money compared to the other producers. Question 16 showed statistical significance on the 5%-level, which signifies that the farmers have different revenue per food crop depending on region. Table 37 points out that the farmers in the Central part seem to have a larger revenue compared to, for instance, the South and the North. It might be possible that the Central part is experiencing a better climate and therefore has better yields compared to the other regions.

Table 37: Answers per region, 16.

	North	*South*	*East*	*West*	*Centre*
0-15 000	73%	73%	46%	64%	42%
16 000-25 000	24%	27%	38%	28%	21%
26 000-35 000	0%	0%	13%	0%	23%
>35 000	3%	0%	4%	8%	13%

As follows a few summarized points. It is hence important to mention that the information provided is according to the interviewed farmers, whose opinions might be somewhat subjective.

- In general all farmers have observed changes in seasonal yields due to weather uncertainty.
- The South, East and West are since the last two to five years changing water system, which is mainly due to, according to the farmers, climatic factors.
- All regions experience issues with droughts and lack of fresh water apart from the Centre.
- Precipitation and temperature are recognized as climatic constraints when it comes to agricultural production according the producers. Nonetheless, rainfall differentiates the East and South to the Centre, where the Centre does not experience fluctuations in rainfall as an issue.

- Even though the West seems to have issues with drought and lack of fresh water, the Western region is the area of which the land has remained the same.
- The East is encountering issues with flash flooding in summer and droughts in winter.
- The Western farmers have observed that there is a change in humidity affecting in turn the yields.
- The North, compared to the other regions, is more focused on yields, revenue, costs and economy rather than climatic changes.
- The Central part seems to have an superior monthly revenue per food crop compared to the other regions.

7 Analysis and discussion

This chapter aims to address the research questions stated in chapter one, based on the theoretical section and the empirical data. The research questions are presented in the following parts:

- What is the present climatic and agricultural status on Mauritius?
- What are the long-term effects upon yields with regards to climatic changes, such as a 1°C temperature increase and/or a 5% increase on precipitation?
- What are the socio-economical issues regarding agricultural practice in Mauritius?
- How are these variables affecting agricultural production and therefore, linked to the socio-economic survey, the Mauritian crop producers and their yields?

7.1 Econometric approach

As mentioned in chapter 3, regression analysis is a statistical tool specifically used for the exploration of relationships between variables[21]. (G. Keat & K. Young, 2000; O. Sykes). The present study enquired to determine the cause of several variables upon one dependent variable, which is defined as a multiple regression analysis. The analysis made it possible to quantify the impact of several synchronized influences upon a specific dependent variable; temperature and rainfall upon yields (Y_t).

Furthermore, the Ricardian model examines the impact of climate and other variables on land values and farm revenues. (Mendelsohn et al, 1994). The difference when it comes to the Ricardian method with an underlying production-function approach is that it estimates impacts by varying one or a few input variables, such as precipitation, temperature and carbon dioxide levels in order to determine the impacts of climate upon yields. From the theory, Mendelsohn et al (1994) are, as mentioned, using a Ricardian model in order to correct partiality in the production-function technique and are, in their case, using the climatic and economic data on the significance of land, put in other words, the authors examine how the net rent or the value of farmland is affected by the climate. (ibid). Concerning Gbetibouo & Hassan's (2004) article, upon which the method of the current study is based, a similar analysis was made, based on the Ricardian approach. The regression and Ricardian method combined made it is possible to assess and calculate how the yields vary with changes in seasonal temperature (°C) and precipitation (% mm/season).

7.1.1 Tomato Whole Island

The empirical part illustrates the present climatic and agricultural status on Mauritius, for the whole island is provided in table 16, see chapter 5. This is provided via the statistical data from 1984 to 2009.

Further, the regression analysis combined with the basis of the Ricardian model demonstrated how monthly tomato yields for the whole island would be affected by; increased temperatures and a decrease in precipitation. Based on the Ricardian model, the following formula permitted to calculate the climatic effects upon yields.

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[21] Appendix 2 provides definitions and explanations of different variables in the regression analysis.

$$(31)\ \ln(Yt) = \alpha + \beta_1 Y_{t-1} + \beta_2 M_2 + \beta_3 M_3 + \beta_4 Rain_{t-1} + \beta_5 Rain_{t-2} + \beta_6 Rain_{t-3} + \beta_7 Rain^2{}_{t-1} + \beta_8 Rain^2{}_{t-2} + \beta_9 Rain^2{}_{t-3} + \beta_{10} Sun_{t-1} + \beta_{11} Sun_{t-2} + \beta_{12} Sun_{t-3} + \beta_{13} T_{t-2} + \beta_{14} T_{t-2}{}^2$$

As observed, the monthly climatic effects upon tomato yields for the whole island would imply a decrease in yields and therefore also affect the farmer's production. As demonstrated in 5.2.1, increase of 1°C would cause a 4% decrease in the short-run and 8% in the long-run in monthly Y_t. Furthermore, an increase of 2°C and a decrease of 5% in monthly precipitation would reduce the monthly yields for the whole island by 7.9% in the short-run and 15.7% in the long-run. Besides what can be observed from the sensitivity analysis in chapter 5.2.1 is that temperature is the variable that would have the largest negative impact upon yields. A precipitation decrease of 5-20% does not have a significant negative effect upon yields per hectare. However, equal or over a precipitation decrease of 20%, the yields are slightly negatively affected.

Further, according to the agro-climatic summary, based on previous agronomic studies that can be found in section 4.3, mentions that temperatures above 25°C seems to have a damaging effect upon tomato yields. Moreover, contradictory to the predicted impacts of climate change, which implies a decrease in rainfall, tomato yields decreases with increased precipitation, especially with levels above 500mm per month. As mentioned above, this would be the case for Mauritian tomato yields; the yields do not decrease significantly with a decrease in rainfall. Nonetheless, combining the climatic effects does reduce the tomato yields. However, as observed in 5.2.2, depending on what region of the island, the yields react differently to the climatic variables.

7.1.2 Tomato per region

The Ricardian model from the theoretical chapter made it possible to calculate the future impacts on regional monthly tomato yields in Mauritius. The climatic estimates demonstrates that small units of change on the different climatic variables, affects negatively or positively, depending on the month, unit changes in tomato yields. The short-run rainfall estimates especially points out how changes in each production month affect tomato yields in all regions. Furthermore, the estimates offers the opportunity to analyse how changes in each variable affects tomato yields, and if the unit changes affects tomato yields negatively, what the eventual adaptational tool or options might be.

Further, the Ricardian model permits to analyze the long-term effects of the impacts of different climate change scenarios upon tomato yields. It is based on the formula expressed above (31). Regarding the tomato results per region, the three climatic variables affected the yields differently. Table 38 gives the reader an image of how the regions of North, East and West would be affected by different climate change settings. As monthly impacts per region, the effects could be detrimental for the Mauritian farmers.

Table 38: Sensitivity analysis of the impacts of climate change on monthly tomato yields per hectare in the North, East, West and South.

	Climate change scenairos		*Impacts on monthly yield*			
Time period	***ΔT***	***ΔRain***	***North***	***East***	***West***	***South***
Short-run	*+1°C*	-	-6%	-8%	-0.8%	-
	+3°C	-	-18%	-24%	-2.4%	-
	+2°C	*-5%*	-11.8%	-16.1%	-1.7%	-0.02%
	+2°C	*-10%*	-11.5%	-16.2%	-1.8%	-0.04%
	+2°C	*-20%*	-11%	-16.4%	-2%	-0.08%
	-2°C?	***+10%?***	**11.5%**	**16.2%**	**1.8%**	**0.04%**
Long-run	*+1°C*	-	-13%	-13%	1%	-
	+3°C	-	-39%	-39%	3%	-
	+2°C	*-5%*	-26%	-26.2%	1.8%	-0.05%
	+2°C	*-10%*	-25.9%	-26.3%	1.6%	-0.1%
	+2°C	*-20%*	-25.8%	-26.6%	1.2%	-0.2%
	-2°C?	***+10%?***	**25.9%**	**26.3%**	**-1.6%**	**0.1%**

As observed, another case scenario has been investigated, analysing a decrease in temperature and an increase in precipitation. Tomato yields in the northern and eastern region seem to benefit from this type of scenario whilst the western region, in the impacts in the long-run, have decreased yields effect. Nonetheless, as predicted by the IPCC (IPCC, 1996; Stern 2006), the most likely climatic scenario for tropical areas is an experienced increase in temperature and decrease in precipitation. Furthermore, if this type of scenario occurs, tomato yields in Mauritius is most likely to decline in several areas of the island, which is indeed alarming since e.g the North is a region highly dependent upon tomato production both supporting the economy of private Mauritian households as well as the local market sector.

Coming back to the main questions of the thesis, where the second question is "*what are the long-term effects upon yields with regards to climatic changes, such as a 1°C temperature increase and/or a 5% increase on precipitation?"* the Northern region, according to the results from chapter 6.1, is hereby brought up as an example. As observed in table 38, the Northern area of Mauritius has a monthly rainfall of approximately 112mm with an average temperature of 23.8°C and a monthly yields of roughly seven tonnes per hectare. In addition, the North has a mean of 235 monthly sunshine hours. According to table 20, there is a significant quadratic and non-quadratic relationship between the dependent variable Y_t, precipitation and temperature. The quadratic variable is the most interesting one, where the variable of $T^2_{(t-2)}$ indicates a negative relationship during the second month of the production cycle, denoting a hill-shaped function, which can be scrutinized in figure 18. When the temperature increases, forming a hill-shaped function, yields decrease.

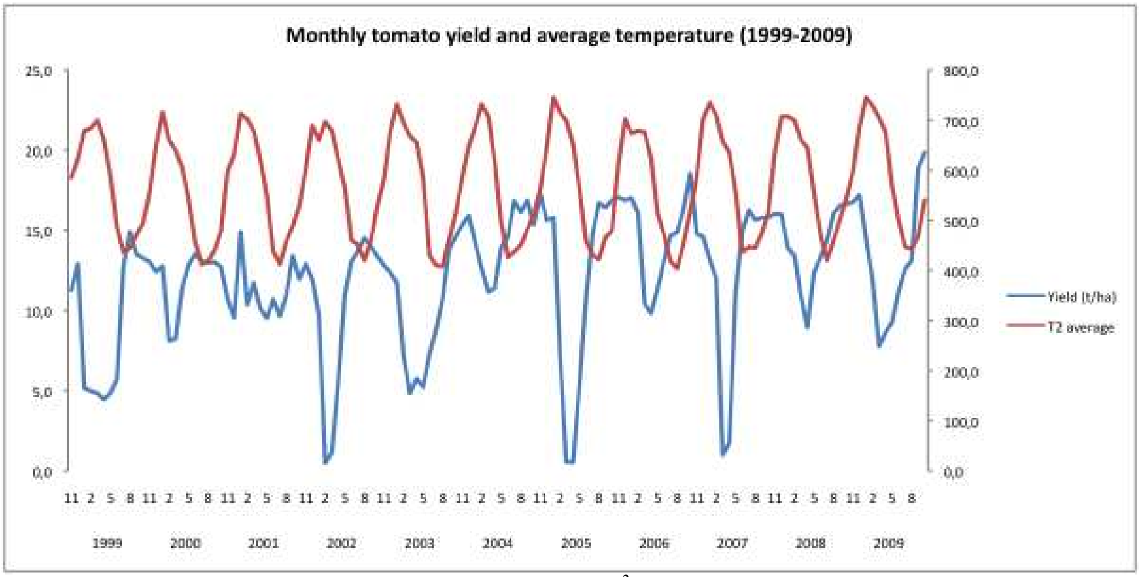

Figure 18: The relationship between monthly yields and T^2 for the Northern region (Appendix 4).

Furthermore, the temperature estimate is the variable affecting most importantly the monthly yields. This can be observed in table 38, which shows the impacts of climate change in monthly yields. A temperature increase of 1°C for instance, would decrease the monthly yields by 6% in the short-run and 13% in the long-run. On a seasonal or yearly basis, this could be detrimental for the Northern based farmers.

As follows, is figure 19; the quadratic relationship between monthly yields and precipitation for the North. Table 19 from chapter 5.2.2 shows the statistical link between *Y*, precipitation and precipitation^2. The non-quadratic as well as the quadratic variable demonstrates that rainfall during the first and third month of the production cycle is impacting upon yields. The quadratic variable represents, as for temperature, a hill-shaped function. It is here likely that yields decreases with heavy rainfall.

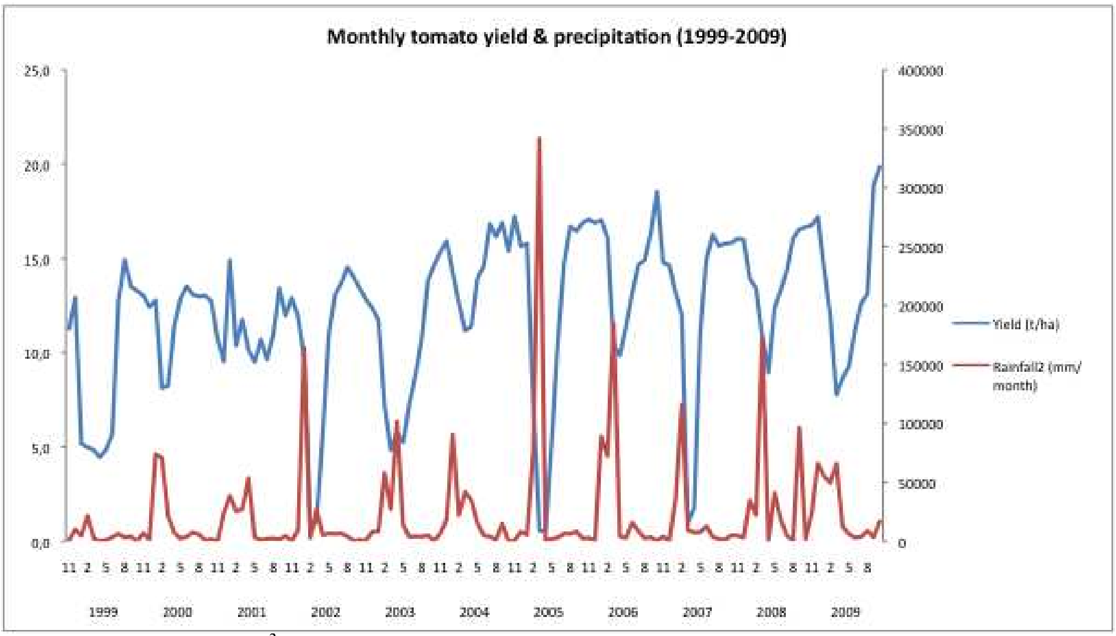

Figure 19: Monthly $Rain^2$ and tomato yields, Northern region (Appendix 4).

As for the predicted impacts of climate change, where the prognosis suggests a decrease in rainfall does not seem to have negative effect upon yields for the North. Nonetheless, this is not the case for all regions; the East and the West does indicate a decline in yields with a decrease in precipitation (see table 38). Coming back to the North, the yields are not to likely increase by a large number. For a precipitation decrease by 10%, yields would increase by 2% monthly. However, what is interesting to analyze is how the yields reacts with a temperature increase and precipitation decrease. In table 38 it is foreseen that with a 2°C temperature increase and 10% rainfall decrease the yields would decrease by 11.5% monthly. It is however the temperature parameter that does have the largest negative effect upon yields, both for the North as well as the East.

Furthermore, monthly sunshine hours indicated a significant liaison for the first month of every production cycle. The parameter of sunshine hours does not have a quadratic relationship to the dependent variable *Y*, which is why the elasticity of sunshine hours was not calculated. The parameter of sunshine hours was taken into account in order to compensate for latitude and longitude variables, estimating the Mauritius is fairly small and not extremely high in altitude. Sunshine hours can be examined in figure 20 below, where the yields seem to decrease with a decline in sunshine hours. According to the background studies upon tomato yields, the food crop in question seem sensible to shadoweffects and therefore a lack of sunshine. The decrease in the North could be due to different shadoweffects, not providing enough sunshine to the tomato yields.

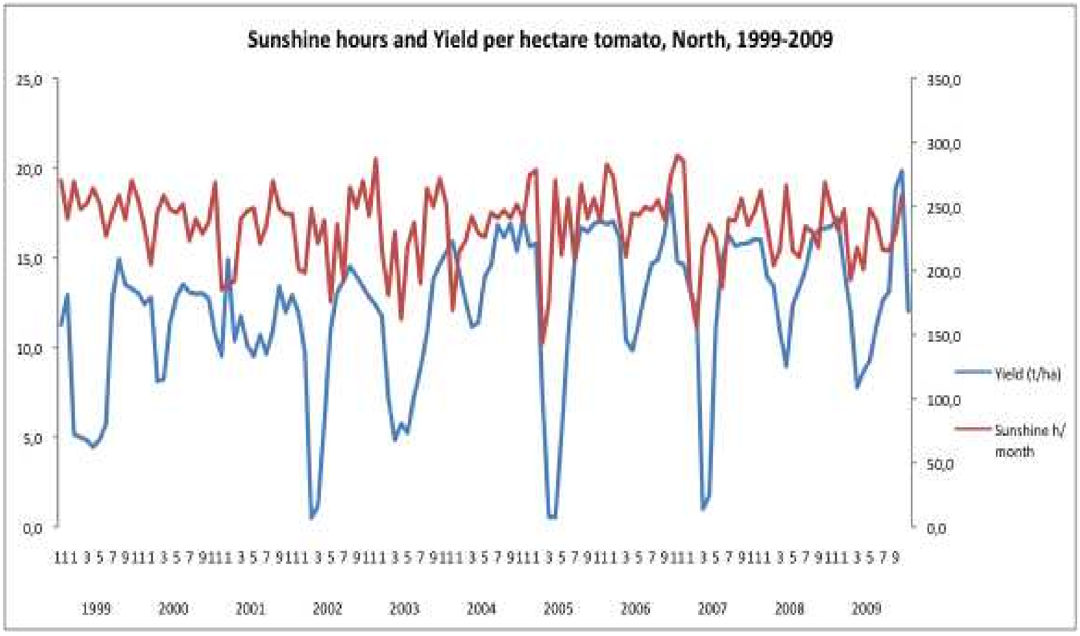

Figure 20: Monthly sunshine hours and yields per ha for tomato production in the North of Mauritius (Appendix 4).

7.2 SWOT-analysis

Table 39 analysis strengths, weaknesses, opportunities and threats of the Mauritian farmer, which originates from the scrutinized results of the survey and evaluates the present climatic and agricultural status on Mauritius according to the Mauritian producers.

Table 39: SWOT-analysis of the Mauritian farmer.

Strengths Personal experience Agricultural knowledge Knowledge of the local demand	**Weaknesses** Difficulties to expand due to lack of land Low and unstable income No knowledge of modern technology Input costs Loss from production (waste) Insecurity in yields Isolation
Opportunities Sustainable agricultural practice Organic fertilizers and pesticides Expansion of fruit and vegetable market on the island Sector specialization Hotel demand sector The microclimates of the island (if properly exploited)	**Threats** The microclimates of the island (if not properly exploited) Increased variability in precipitation Natural risks such as cyclones for example Flash flooding Heat weaves Salt water intrusion International competition Increased insects/diseases Changes in demand Size of the island: Economies of scale Theft of food crops

7.3 Farmers perceptions and adaptations to climate change

The subsequent part shall clarify one of the main aim questions of the thesis: *What are the socio-economical issues regarding agricultural practice in Mauritius?* The results from the survey provide the opportunity to analyse, according to the interviewed farmers, the present agricultural and climatic status on Mauritius. Further, chapter 3.2 provides an image of how farmers in African countries perceive changes in climate. (Gbetibouo, 2009; Maddison, 2007; Deressa, 2008). African farmers have noticed changes in climate but due to lack of knowledge, techniques and capital assets, does not adapt well enough. (Gbetibouo, 2009; Maddison, 2007; Deressa, 2008). Nonetheless, African producers have perceived changes in both temperature and rainfall patterns where the temperature is increasing whilst precipitation is decreasing. What can equally be observed in the survey results is that 92% of the interviewed Mauritian farmers have noticed changes in weather patterns, where 87.8% of these farmers have noticed that changes in climate over the last ten years have affected their yields negatively.

Moreover, the study made by Deressa (2009) in the Nile Basin of Ethiopia, illustrates that socio-economic indicators also revealed to be of large importance. Wealth, social capital and agro-ecological settings have shown significant impact on the perception to climate change. According to the survey results, the socio-economic factors of labour, input costs and the importance of agricultural chemicals revealed to be of large magnitude. Linked to the answers of the survey, many of the farmers apply an important amount of pesticides and fertilizers upon their food crops caused accordingly by the tropical climate, humidity and weather changes. Additionally, there is a relationship between climate, pests and insects where changes in precipitation patterns for instance, initiates farmers to apply an increased amount of chemicals since the rainfall washes off the sprayed chemicals. Therefore the producers apply gradually, with an increased amount of input costs, which is further recognized as the most relevant constraint of agriculture on Mauritius (see figure 24, chapter 6.1).

Further, during personal interviews with the planters, there are a couple of farmers that seems to have an interest in organic agriculture where 13.4% of the fertilizers and 6% of the pesticides are mixed organic and chemical. These mixes can be found mainly in the Central part of the island. However, the interviewees mentioned that even though their interest for organic agriculture, the economies of scale on Mauritius poses a problem; if one farmer decides to shift from conventional to organic farming, the distance to the planter's neighbour is approximately 20 cm away. The organic farmer would therefore only convert if his colleague would be willing to since the chemicals are directly affecting the soil and surface circumstances.

In the end, the results of the survey mainly analysed how farmers perceive changes in climate and its effect upon yields. It also provides the importance of the socio-economic variables, which are lacking in the econometric analysis. In all regions, farmers have perceived changes and fluctuations in the climate over the last ten years, annually and seasonally. The socio-economic parameters that proved to be significant as a whole were labour and input costs.

Maddison (2007) suggests that with eventual future weather uncertainties, farmers may adopt practices that could be increasingly robust in order to tackle changes in climate such as fixed assets; machinery and buildings. (Maddison, 2007). Adaptation has is equally been brought up in chapter 3, figure 6 (pp. 12), which is based on the Ricardian approach by Mendelsohn et

al (1994). Here, the authors argue that farmers would change and constantly adopt their actitivites and therefore productivity with regards to changes a certain climatic variable.

Nonetheless, this might not always be the case especially in developing countries, which then becomes a limitation facing the impacts of climate change. Followed by this limitation in developing contexts is the fact that industrial countries assumes that farmers dispose of enough comprehension to move along *the envelope of maximum net revenue per acre (Maddison, 2007, pp.9)*, taking full advantage of whatsoever weather brings, not being concerned of the long-term climate impacts, which is not always the case.

The hypothesis of spontaneous and prompt knowledge with respect to the best crop choice could eventually become problematic since it appears to be erroneous, where it is arguable that farmers progressively learn about which techniques to apply for the same purpose that they gradually discover that the climate has changed. An example of this could be linked to the applications of chemicals, where the farmers seem to apply an increased amount of fertilizers and pesticides with an increased variability in rainfall.

With regards to the paragraph above, where farmers are "*taking full advantage of whatsoever weather brings, not being concerned of the long-term climate impacts*" *(Maddison, 2007, pp.9)*, seemed to be biased regarding the Mauritian farmers. On one hand, they are concerned about the long-term effect of their production regarding their family. Many of the producers are highly dependent upon their production since it's their main household income, where a few of the farmers expressed their concerns for the future generation taking over the production. On the other hand, they do not see, to have the knowledge, capital or technology to adapt towards a somewhat more sustainable future.

8 Conclusions

The main aim of the thesis was to determine, from a micro perspective using an econometric and survey approach, the impact of climate change upon Mauritian agriculture. Table 40 gives the reader a summarized understanding of how the analyzed climatic variables are affecting tomato yields and whether the Mauritian farmers are aware of the climatic effects[22]. The table also indicates what the consequences for the Mauritian farmers would be without adaptation.

Table 40: Conclusion from econometric and survey results per region.

Regions	***Econometric analysis***	***Socio-economic analysis***	***Econometric analysis***	***Socio-economic analysis***
	Temperature		***Rainfall***	
North	Monthly tomato yields decrease with a temperature increase.	Farmers are not fully aware of the impacts of temperature changes.	Small increase in tomato yields with precipitation decrease.	Farmers are not fully aware of the impacts of precipitation fluctuations.
East	Monthly tomato yields decrease with a temperature increase.	Producers recognize recent temperature rise and fluctuations as an issue, affecting negatively their yields.	Small decrease in tomato yields with precipitation decrease.	The precipitation fluctuations are acknowledged as lager constraint according to the farmers, where the awareness seems fairly distinct.
West	Slight tomato yields decrease with a temperature increase.	Farmers do not seem to be fully aware of the impacts of temperature changes upon their production.	Monthly tomato yields decrease with a precipitation decrease.	The producers are experiencing increased droughts and deficiencies in fresh water. The changes in climate have increased farmer's awareness in the West.
South	Did not show statistical significance in the econometric study. Could nonetheless act as an unobservable variable in sunshine hours.	The farmers recognize recent temperatures as an issue and therefore seem increasingly aware of the potential climatic impacts affecting their yields.	Small monthly tomato yields decrease when rainfall decreases.	The farmers have noticed changes in precipitation patterns but they believe that increased rainfall would affect their yields negatively. Nonetheless, the awareness exists in the South.

Coming back to the objective of the thesis, the combination of the two methods were able to complete each other; the survey results gave proof of the importance regarding socio-economic variables further completing the econometric study. Nonetheless, due to the lack of socio-economic data, a pure agro-climatic model would be recommended since, as indicated, it was difficult to retrieve any sort of historic socio-economic data on Mauritius. My recommendation is firstly to carry out deeper research in the econometric agricultural domain on Mauritius. A suggestion would be to implement a project over the duration of approximately five years in order to quantify monthly labour, input costs, chemical appliance, soil quality and water resources related to yields and revenue per hectare and further to

[22] The Central part is not represented due to the non-significant results from the econometric analysis.

calculate, according to the Ricardian model, the socio-economic impacts of climate change on yields.

Finally, table 40 illustrates what the consequences will be for the Mauritian farmers if they don't adapt; they will most likely experience a decrease in monthly yields unless they adjust their production to the future climate. Figure 21, brought up in the epilogue (see next chapter), suggests a way towards acclimatization for Mauritian farming, which does not have a defined future in this case. Nonetheless, agriculture plays a vital role for Mauritius economy and development. Agriculture stands for 14% of the labour force by occupation (Appendix 3) and the share of agriculture amongst industrial activities is of 4.5%. The annual growth has gone from 0.6% in 2008 to 5.7% in 2009 and according to table 43 in appendix 3, agriculture and fishing has increased according to the GDP whilst sugar cane production for instance is decreasing. These numbers show that Mauritius demand for agriculture within the food security and self-sufficiency sector is increasingly important.

With an adaptation strategy, Mauritius can exploit its natural resources and take advantage of the different microclimates of the island, altering specific crops in particular regions for instance and further increase the level of self-sufficiency. However, if the Government of Mauritius does not react to these threats, it is likely that yields decreases also increasing the risk of food insecurity. Without adaptation towards the impacts of climate change, the Republic of Mauritius is likely to increase their dependence upon the import of raw material, decreasing the levels of national socio-economic standards as well as putting at risk the livelihoods of a large percent of the local population.

Epilogue

A suggested Sustainable Agricultural Model specific for Mauritius ought to be developed. Figure 21 is an example of the main pillars for the structure of the model in question. The topics are presented with an objective, the means to achieve the objective followed by the risks. Figure 21 is placed in the epilogue since it is not directly linked to the main or questions formulated in the aim. It is however an important recommendation to take into account especially for the Government of Mauritius.

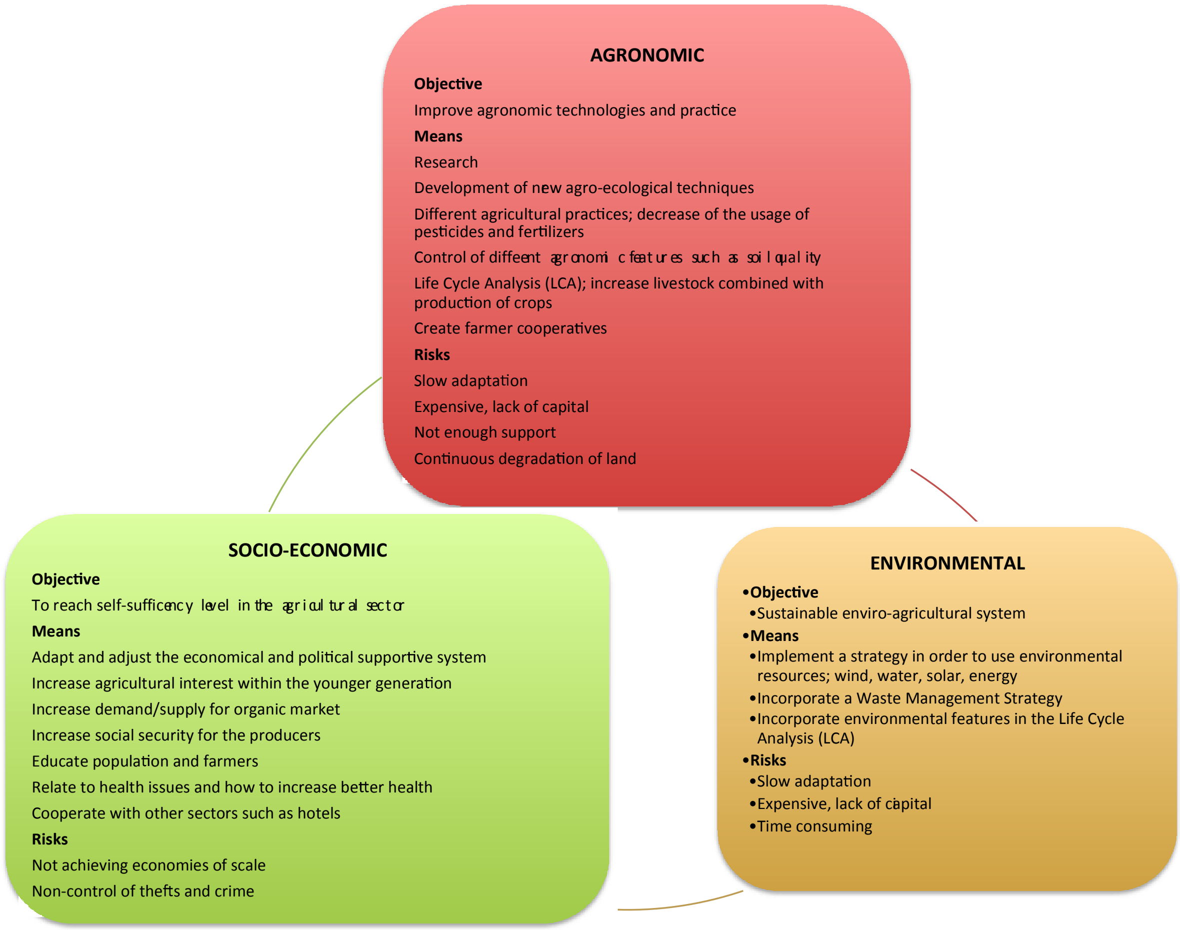

Figure 21: Main topics and sub-topics to incorporate for a Sustainable Agricultural Model for Mauritius.

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Appendix 1: Theories on climate change

1.1 The climate; causes and effects

Over the past century, the global mean surface temperature has increased by 0.3-0.6 degrees K (Kelvin). (Rayner et al, 1998). The warming is evident in both sea-surfaced-based and land-based measurements. It is important to notice the fact that in recent years, global temperatures have been among the warmest in historical records. On the other hand some areas, mainly the Northern continents, have shown a cooling rather than a heating effect. In addition, recent studies differ somewhat from each other where a couple suggests that the climatic disturbances could be due to natural variability whilst others point out the fact that global warming is mainly caused by human activities. These human activities would include emissions of CO_2 as well as other radiatively important gases and particles (aerosols).

"Climate is generally defined as a description of the average (or typical) behaviour of the atmosphere, and thus the aggregation of the weather." (Rayner et al, 199, pp.3)

The fundamental climate variable is the *planetary annual average surface temperature.* (Rayner et al, 1998). The greenhouse effect is a natural process and represents a physical property of the Earth's atmosphere. In combination with the atmosphere and the greenhouse effect, the earth's temperature has an average temperature of 15°C rather than –18°C. In the normal Earth state, the Earth and atmosphere balances the absorption of solar radiation by emission of infrared radiation into space. As follows, the atmosphere does in this case absorb more infrared energy compared to what it radiates to space. This particular phenomenon causes a net warming of the surface temperature and therefore the warming of Earth. This occurrence is called the greenhouse effect, which is further illustrated in figure 22.

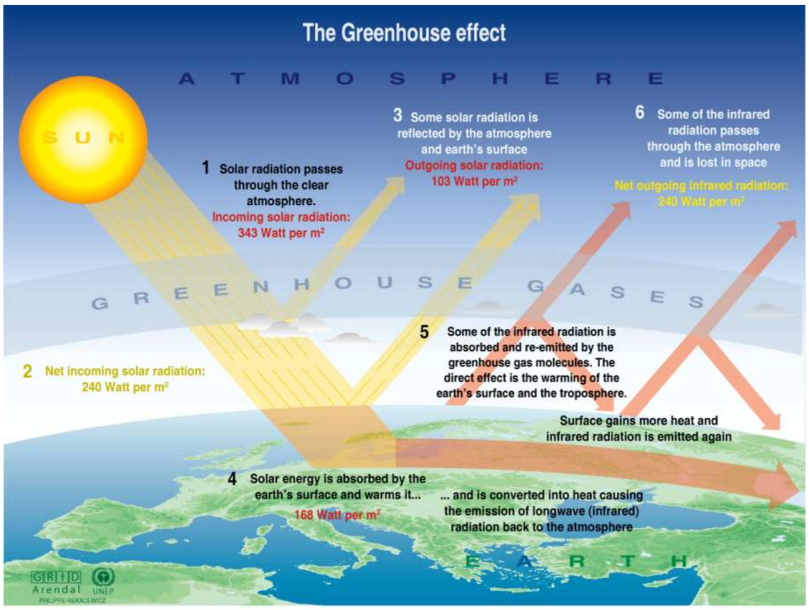

Figure 22: The Greenhouse effect (IPCC, 1996).

Solar radiation is emitted from the sun and travels towards the earth. In passage, via the atmosphere, solar radiation diminishes in intensity through reflection, scattering and absorption caused by water vapor, other gases, aerosols and suspended particles. (Rayner et

al, 1998). The solar energy, which is absorbed by the surface, is partly used to evaporate moisture (latent hest flux) and to directly heat the atmosphere (sensible heat flux). The atmospheric emission of infrared radiation downward to the surface is approximately equal to the solar radiation, which is reaching the highest point of the atmosphere. The solar radiation is twice as large as the amount of solar radiation absorbed at the surface. Due to this, the surface can warm to a greater extent compared to if the surface would be solemnly heated by the solar radiation alone.

Further, Earth's surface emits infra-red radiation which is trapped by atmospheric gases and reemit downward, warming the surface of the earth and the lower atmosphere: the GHG effect. (Rayner et al, 1998). Moreover, the GHG gases allow the infra-red radiation to be retained where the main gases are composed of water vapor, Carbon dioxide, (CO_2), methane (CH_4), Nitrous oxide (N_2O), cholorflouorocarbons and ozone (O_3). Without GHG effect, the earth would be 34°C colder compared to today. Solar radiation absorbed by the surface provides the energy that evaporates water, heats the soil and air, and drives photosynthesis. (Rayner et al, 1998). It is yet important to point out that with changes in *albedos*, followed by surface roughness as well as changes in land use (such as replacement of forests with pastures), results in altered temperature and humidity regimes. In other words, there are an amount of triggers that could cause potential warming of the Earth's lower surface, which are (1) the increase in concentration of each greenhouse gas, (2) the radiative properties of the gases in question, (3) the concentration of other greenhouse gases already present in the atmosphere, (4) the interactions with other radiatively important atmospheric constituents, (5) the effects of climate feedbacks and (5) local effects since GHG varies with altitude. (ibid).

IPCC projected that global average surface temperature will increase by 1.4°C to 5.8°C over the period 1990-2100 causing amongst others melting of the glaciers and the thermal expansion of the oceans. Additionally, it is likely that higher world temperatures will increase the hydrological cycle activity leading to a general increase in precipitation and evapotranspiration as well as a decrease in sunshine hours; the so called the dimming effect. (Trenbert & Jones, 2007; www, Hadley centre, 2010). The dimming effect is a widespread reduction of solar radiation received at the Earth's surface up until about 1000km. However, it has been dicussed that global dimminig is rather confined to large urban areas. Moreover, what is slightly confusing concerning the dimming phenomena are the trends in pan evaporation and actual evaporation. Evapotranspiration, or surface evaporation in dependent upon the main components of available energy at the surface and the accessibility of surface moisture, mainly related to soil moisture quantities over land areas. Evaporation pans supply the estimates of the impendent evaporation that would take place if the surface were wet. (ibid.).

A partial part of the elucidation to the paradox of conflicting trends in evaporation and pan evaporation lies in changes in the atmospheric circulation and the hydrological cycle. (Trenbert & Jones, 2007). An increase in clouds and precipitation has been observed, which is currently reducing the solar radiation available for actual and potential evapotranspiration. Moreover, increased soil moisture links the actual evapotranspiration closer to the potential evapotranspiration. An increase in both clouds and precipitation has occurred over many parts of the global land surface, even though not in the tropics and subtropics. Nonetheless, this reduces solar radiation available for evapotranspiration, as ascertained since the late 1950s or early 1960s over the USA, parts of Europe and Siberia, India China and over land more generally. (ibid.).

Increased precipitation also amplifies soil moisture and thus, increases evapotranspiration. (Trenbert & Jones, 2007). Additionally, amplified clouds inflict a greenhouse effect and reduce outgoing LW radiation, where changes in net radiation can be relatively small or even of reversed sign. Recent re-assessments suggest increasing trends of evapotranspiration over southern Russia during the last 40 years. As mentioned, dimming remains predominant in large urban areas where pollution could be the main cause effect. Increases in aerosols are apt to redistribute cloud liquid water over more and slighter droplets, brightening clouds, diminishing the potential for rainfall and possibly altering the lifetime of clouds. Increases in aerosols also decrease direct radiation at the surface under clear skies, which appears to be a key part of the explanation in China for instance. (ibid.).

What occurs more concretely, from a surface energy balance standpoint, is that if surface radiation decreases, it should be compensated by a decrease in evaporation especially since an increase in the surface air temperature has been observed. (Trenbert & Jones, 2007). Moreover, it is important to notice that radiation from greenhouse gases and clouds operate in the opposite direction. The primary change would then occur in the partitioning of sensible versus latent heat at the surface. Further, increased soil moisture implies that supplementary heating goes into evapotranspiration at the expense of sensible heating causing local temperature increases. Temperatures are on the other hand affected above the surface where latent heating from rainfall is recognized. The following issue is subsequently where the full dynamics of the atmospheric motions, such as horizontal advection, adiabatic cooling in rising air and warming in compensating subsiding air, come into play. The net outcome is therefore a non-local energy balance. (ibid.).

1.2 Economical and social impacts of climate change on agriculture

According to the Stern Review, all regions in the world will surely sense the effects of climate change. (Stern, 2006). However, climate change impacts will have disproportionate effects on the globe. The changes in climate will most likely intensify the exsiting challenges posed by tropical geography, where an already rapid population growth, poverty, and a limtied capacity have to cope with an uncertain climate. Furthermore, the individual circumstances per country will define the magnitude of social, economic and environmental effects of climate change. (ibid.).

Agriculture still remains one of the most vulnerable sectors since the impacts of climate change directly affect the sector through temperature, rainfall, CO_2 and indirectly via water and forestry. (Gbetibouo & Hassan, MSc, 2004). The impacts of climate change are presently affecting (1) crops and forage productivity and production costs, (2) soil suitability for agricultural production, (3) livestock productivity and production costs are affected both directly and indirectly, (4) irrigation water supply and (5) pests and diseases. On the other hand, agriculture is mentioned as both an emitter and sink of green house gas emissions (GHG) in the Kyoto Protocol, which indicates that there are yet measures of adaptation within the agricultural sector that require development of new technologies and strategies, policies and structures. (ibid.).

Additionally, agriculture accounts for approximately 4.5% of the warming potential due to farmers' activities that contributes to the amount of GHG let into the atmosphere. (Gbetibouo & Hassan, MSc, 2004). Global agriculture emits 50% of total methane, 70% of N_2O and 20% of CO_2. These gases arise from fossil fuel usage, soil tillage, deforestation, biomass-burning

and land degradation. Nonetheless, with good adaptation measures, agriculture has the potential to reduce GHG, where viable adaptation options should be defined within the micro level sector, market response sector, institutional changes and technological development. However, there is a difference between the agricultural emitters in developing and developed countries since developing countries are unfortunately categorised as the most vulnerable sector when it comes to the impacts of climate change (Stern, 2006).

The vulnerability to climate change can be ranked firstly as (1) *exposure* to climatic changes, followed by (2) *sensitivity* that implicates the degree to which a system is affected by or receptive to climate stimuli and further, the ability to get prepared and to tackle the effects of climate change, in other means; (3) *adaptive capacity.* (Stern, 2006). Regarding *exposure*, geographical exposure is the main treated topic since the geographical zones of a country plays a determining role regarding the growth and developing prospects of a country. It is argued in the agricultural sector for instance, that the presence of pests and insects, poor soils, increased crop respiration rates due to warmer temperatures, difficulty in water availability as well as control management are yet but a few reasons of tropical disadvantage in agriculture. Furthermore, the threats and impacts of climate change are likely to increase these already challenging conditions. A delicate variation in climate, such as a slight temperature increase followed by its effect on crop production, can cause the enhancement of costs in developing countries. In other words, climate change will consequently cause a disproportional damaging economic and social effect especially upon developing countries. (ibid.).

The sensitivity factor in developing countries is directly linked to the agricultural sector in developing countries due to the vulnerability effects mentioned above. (Stern, 2006). The rural sector contributes 21% of the GDP in India, 39% in Malawi, 61% and 64% of the population in South Asia and sub-Saharan Africa respectively. Figure 23 demonstrates the dependence in agriculture in GDP and as well as incomer per capita in 2004. In addition, something not to forget, in parallell with agriculture, is equally the dependence upon vulnerable ecosystems, where poorer populations are highly sensitive to degradation and destruction of natural assets such as destruction of the Amazon forest for example. Another important issue followed by agricultural vulneraibility and sensitivity is food insecurity, malnutrition and health. (ibid.).

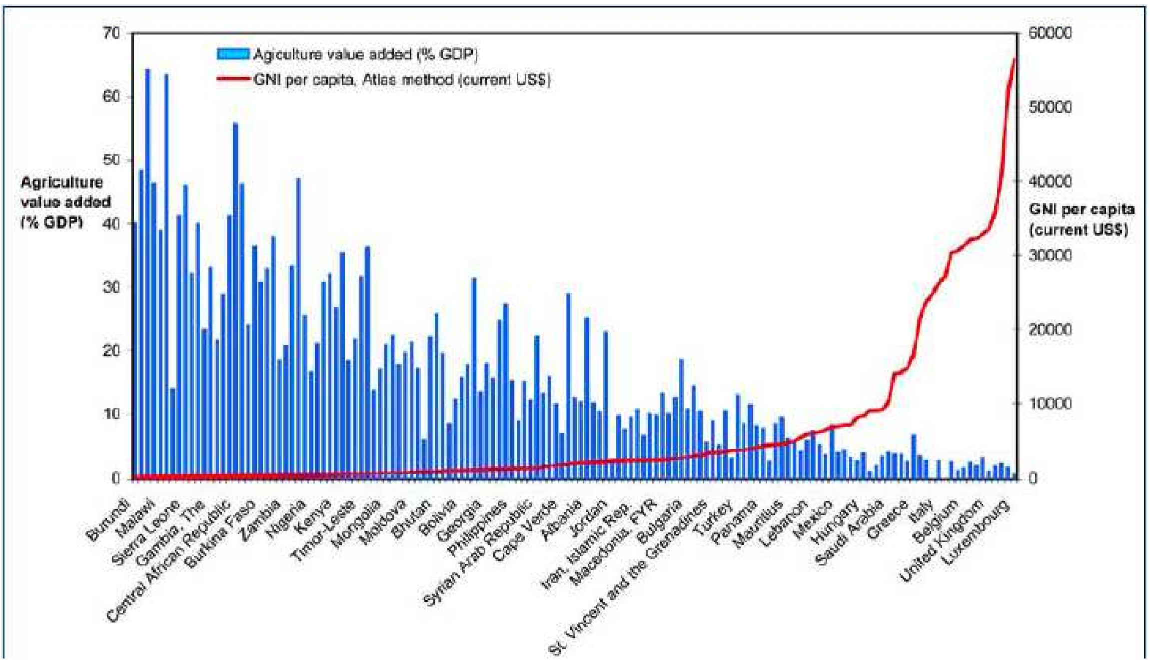

Figure 23: The share of agriculture in GDP and per capita income in 2004. GNI stands for Gross National Income. (Stern, 2006).

Adaptive capacity connotes that people will adapt to the impacts of climate change to the extent that their knowledge in combination with their resources shall allow them to. (Stern, 2006). However, the main issue remains with developing countries due to the lack of infrastructure, financial resources and access to public services. It can be illustrated in table 41, which shows the investment in water storage in developing contries in 2006 where the seasonal storage index (SSI) indicted the volume of storage needed to assure the annual water demand based on the mean seasonal rainfall cycle.

Table 41: Investment in water storage in developing countries.

	Seasonal Storage Index (km3)	SSI as % of Annual Volume	% Hard Water (of total)	Current Storage (% of SSI)	GDP ($, 2003)
India	356.6	21%	17%	76%	555
Bangladesh	62.28	41%	40%	33%	385
Ethiopia	40.99	10%	100%	8%	91
Nepal	29.86	47%	100%	0%	233
Vietnam	27.64	10%	100%	3%	471
North Korea	23.32	45%	100%	0%	494
Senegal	22.3	40%	100%	7%	641
Malawi	18.98	34%	100%	0%	158
Algeria	6.6	6%	100%	91%	2,049
Tanzania	5.5	1%	33%	76%	271
El Salvador	5.45	37%	100%	59%	2,302
Haiti	3.73	25%	79%	0%	300
Guinea	3.71	2%	100%	51%	424
Eritrea	2.75	11%	15%	3%	305
Burundi	2.64	19%	27%	0%	86
Albania	2.64	23%	100%	21%	1,915
Guinea-Bissau	2.48	11%	100%	0%	208
Sierra Leone	2.21	3%	100%	0%	197
The Gambia	2.14	56%	100%	0%	224
Rwanda	1.38	9%	3%	0%	185
Mauritania	1.34	2%	100%	66%	381
Swaziland	0.98	15%	100%	59%	1,653
Bhutan	0.4	1%	13%	0%	303

Source: Stern, 2006

The hard water column illustrates the water storage requirements. (Stern, 2006). Groundwater development or surface water reservoir development could here provide additional storage. A few countries in development will also necessitate soft water, which is water that can be captured from internal renewable water resources. Nonetheless, the mean GDP countries with soft water requirements requires $8,477 compared to the average GDP of $601 of countries with hard water requirements. The whole Southern Asia region faces problems of inter-annual and seasonal deficits, requiring both seasonal and inter-annual storage as well as soft water.

Regarding the implications for future vulnerability of different growth pathways, declining agricultural output and weakening conditions in rural zones caused by climat change will directly amplify poverty of households in poor countries. (Stern, 2006). The three following examples of extreme weather events highlight how devastating floods and droughts can be for low household income.

- El Niño in 1997-1998 in Eucador contributed to a loss of harvest and raise in unemployment that together augmented poverty by 10% in the concerned Eucadorian municipalities (Stern, 2006).
- The droughts of 1998-2000 in North-Eastern Ethiopia estmiated losses in crop and livestock were up to $266 per household, where $266 is superior to the annual income for more than 75% of households in the particular studied region (Stern, 2006).
- The drought in Zimbabwe in 1991-1992 caused an increase in food prices by 72% followed by a loss in environmental assests and ecosystems that would or else cover as safety net for the population concerned (Stern, 2006).

A way of further demonstrating the market impacts of climate change on economic growth can be illustrated via the usage of a theoretical framework, starting off with a production function where the utput of an economy in a given year depends on the stock of capital, labour and environmental quality available in that year. (Stern, 2006). The expression would have to following shape:

$Y(t) = F(K,L,E)$

Where $Y(t)$ is the output of the economy in year t. Y is a function of K, capital, L, labour and E, environmental quality. In other words, environmental quality is a natural capital asset that provides a flow of services on which output then depends. (Stern, 2006). If the net impacts of climate change are negative, E decrases and is therefore reduced. It will then reduce the obtainable output with a given supply of K and L since the output is jointly dependent on all three factors of production. Concretely, either productivity of capital and labour is directly reduced, or a segment of the output produced in a given year is damaged that same year by an extreme weather event, for instance drought. However, the reverse situation could also occur, since the impacts of climate change causes net benefits, increasing the quality of the environmental. Adaptation to climate change is an abstract but also concrete term that can reduce losses in E combined with a cost relative option meaning that the opportunity cost of adaptation represents investment or lost spending diverted away from adding to K. This is a simplified way of demonstrating the dependent relationship between economics, climate change and the environment; output versus input. (ibid.).

Appendix 2: Regression Analysis: Definitions and Explanations

There are independent variables (X) that ideally are believed to have an impact on the dependent variable (Y). (G. Keat & K. Young, 2000). There exist two types of data used within regression analysis; cross-sectional and time series. Cross-sectional data provides information on variables for a given period of time whilst time series give information about the variables over a number of periods of time. When it comes to variables, it is important to denote the unit of each variable. Furthermore, the unit of measurement for a specific location or time scale variable for instance is relatively different from the other variables, where the analysis would take the value of 1 against 0, campus and urban area respectively. Measuring a location as such makes the location variable become a binary or dummy variable. The following definition of regression analysis parameters is provided by G. Keat & K. Young (2000) and Gujarati (2004).

- R^2 is defined as the coefficient of determination, which is a measure illustrating the percentage of the variation in a dependent variable accounted for by the variation in all of the independent variables within the regression equation. The measure is defined between 0 and 1, indicating that the variation in the dependent variable are not/are accounted for respectively, at all by the variation in the explanatory variables. In other words, the closer R^2 is to 1.0, the greater the power of the regression equation.
- Adjusted R^2 is a measure that adjusts for the number of independent variables used within the regression analysis so that equations with different number of explanatory variables can be more fairly compared.
- Standard error of the coefficient is the standard deviation of the sample regression coefficient.
- Degree of freedom (d.f.) is defined as *n-k-1*, where they represent the sample size, the number of independent variables and the intercept term respectively. For example, for a d.f. of 60, the probability that t will have a value of 1.671 or more is about 5 percent.
- Critical t-value is what level of significance the t-test in set on.
- F (F-test) measures the statistical significance of the entire regression equation rather than each individual coefficient. The F-statistic is a test of the statistical significance of R^2. If the null hypothesis is true, virtually no relationship between the dependent variable and the independent variables and whatever the value of R^2, which is the proportion of the variation in Y explained by X, it is most probably a chance occurrence in the sampling process. If it is over the value represented in the F-test tables, the entire regression model accounts for a statistically significant proportion of the variation.
- Residuals are the differences between the actual values of Y and those estimated from the regression equation.
- An unbiased estimator of the variance of the distribution of error terms (σ^2_u) is equal to the sum of the squared residuals of each of the sample points from the estimated regression line, divided by the sample size minus 2.
- The t-value shows how many t-units away from the expected value is the estimated coefficient b. In order to interpret the t-value, the number of degrees of freedom needs to be known.
- T-test: test of statistical significance and in order to determine statistical significance at 0.05 level, the independent variables should be greater than 2.

- H_0 means in general that there is a hypothesis that there is no relationship between the dependent variable Y and the independent variables X. In other words, changing X's would have no impacts of Y.
- A user who cannot obtain direct information about tastes and preferences may have to use a proxy variable to represent this factor in the regression equation, where these variables must be quantified. It can be done by creating a dummy of binary variable, which takes into account 1 if the unit of observation falls into a particular category and 0 if it does not. A dummy variable is a shift factor.
- Noise term represent the factors other than the independent variables, which can affect the value of the dependent variable. *Probabilistic* is the term generally used to define an equation that contains the error term (ε).
- The constant of the intercept of the line with the Y-axis is referred to as a parameter/coefficient of the regression equation.
- Standard deviation of dependent variance gives an indication of how close or spread the individual X values are distributed around their mean value.
- Lagrange Multiplier het. test; method that test whether hypotheses can handle regression models, linear or not. The number should be close to 1.
- Durbin-Watson test where the *d* should be close to 2.
- Dubin's h test; used to detect autocorrelation between variables. Depending on the level of the level of significance, if the h value is higher then for instance 1,96 at the 5%-level, there exists autocorrelation in the error term for the 1st order.
- Jarque-Bera test of normality mainly used for large sample sizes > to 2000.
- Ramsey's RESET2; general test for specification error, if the number is high as well as the F-test, there is misspecification.
- F (zero slopes) goes together with the RESET-test.
- Schwartz B.I.C. is a criterion for model selection along a class of parametric models with different numbers of parameters. The B.I.C. test shows unexplained variation in the dependent variable and the number of explanatory variables increases the value of B.I.C. As lower number of B.I.C. is preferred.

Appendix 3: Mauritian background

The republic of Mauritius has a total population of 1.25 million and is situated at the South-eastern coast of Africa, approximately 900km east of Madagascar. It has a size estimated to 1,860km^2. (www, Mauritnet, 2010). Since its independence in 1968, the annual growth rate has been approximately of 6%. Furthermore, the Mauritian economy relies on fours sectors: textile, sugar, tourism and service, where sugar represents 90% of the cultivated land area and accounts for 15% of the export earnings (Table 42). (ibid.).

Table 42: Mauritius economy in 2008.

GDP 2008	$8.128 billion
Real growth rate 2008	5.20%
Income per capita 2008	$12.100
Agriculture	4.5% of GDP
Manufacturing, export included	19.4% of GDP
Tourism sector	8.7% of GDP
Financial services	10.9% of GDP
Exports	$2.36 billion
Imports	$4.503 billion

Source: www, Mauritnet, 2010

The main exports of the island consists of textiles and clothing, sugar, canned tuna, molasses, jewellery, optical goods, travel goods and handbags, toys and games, and flowers. (www, Mauritnet, 2010). The major export partners are the UK with 35.1%, France with 14.4%, US with 7.7%, Madagascar with 6.3% and Italy with 5.8%.

On the other hand, the exports are principally manufactured goods, capital equipment, foodstuffs, petroleum products, chemicals, meat, dairy products, fish, wheat, rice, vegetable oil, iron and steel, cement, fertilizers and textile industry raw materials. (www, Mauritnet, 2010). The primary suppliers are firstly India 21.2% followed by China 11.4%, France 10.7% and South Africa 7.4%. Moreover, table 43 gives an indication of the main agricultural indicators of the island (Annual Report, 2007-2008).

Table 43: Main Agricultural Indicators, 2005-2008.

	2005	2006	2007[23]	2008[24]
	(Rs million)			
Gross Domestic Product at Basic Prices	162,171	182,099	206,981	232,264
Value Added at Basic Prices				
Agriculture and Fishing	9,790	10,130	9,834	9,748
- Sugar Cane	5,212	5,137	4,260	4,109
- Other Agricultural Products	4,578	4,993	5,214	5,639
- Sugar (Milling)	1,609	1,586	1,426	1,269
	(% Over Previous Year)			
Annual Real Growth Rate				
Gross Domestic Product at basic prices	2.3	5.1	5.4	5.6
Agriculture and Fishing	-5.4	0.6	-7.4	4.2
Sugar Cane	-9.2	-2.9	-13.6	5.5
Other Agricultural Products	-1.1	4.5	-1.1	3.0
Sugar (Milling)	-9.2	-2.9	-13.6	5.5
	(%)			
Percentage distribution in Gross Domestic Product				
Agriculture and Fishing	6	5.5	4.8	4.2
- Sugar Cane	3.2	2.8	2.3	1.8
- Other Agricultural Products	2.8	2.7	2.5	2.4
- Sugar (Milling)	1	0.9	0.7	0.5
	(Rs million)			
Investment in Agriculture in total GDFCF at Current Prices	2,225	2,764	2,508	2,587
	(% Over Previous Year)			
Annual Real Growth Rate				
Gross Domestic Fixed Capital Formation (GDFCF)	-1.9	19.2	8.6	6.5
Agriculture and Fishing	56.9	16.8	-17	-2.5
	(Rs million)			
Sugar Exports	10,536	11,198	9,264	n/a
As s percentage of domestic exports	25	23,5	18,3	n/a
As a percentage of domestic agricultural exports	67,8	62,2	53,9	n/a
As a percentage of total exports	17,8	16,2	14,4	n/a
	('000)			
Total employment - Including Foreign Workers	507,2	515,3	523,7	n/a
	(%)			
Share in Total Employment				
Agriculture and Fishing	9.6	9.3	9	n/a
- Sugar Cane	3.6	3.5	3.4	n/a
- Other Agricultural Products	5.9	5.8	5.6	n/a

Source: Annual Report, 2007-2008

[23] Revised estimates
[24] Forecast

Furthermore, in table 44 follows the labour force by occupation in order to give an overview of the most important occupations on the island related to the poverty level. (www, Mauritnet, 2010). The table equally shows the estimated poverty level in 2008, which is fairly high. The gap between social groups remains elevated in Mauritius and the population living in rural areas are most often the poorest.

Table 44: Labour force by occupation.

Agriculture and fishing	14%
Construction and industry	36%
Transportation and communication	7%
Trade, restaurants and hotels	16%
Finance	3%
Other services	24%
Poverty level (2008)	37,6%
Estimated reduced poverty level (2010)	30%

Source: Digest of Agricultural Statistics, 2008

In addition, agricultural activities, as noticed in table 43, stands for 4.5% of the GDP, where the resulted products mainly consist of sugar products, sugar derivatives, tea, tobacco, vegetables, fruits, flowers, cattle and fishing. Furthermore, historically, Mauritius have been securing their food supply by an indirect use of its agricultural systems mainly focusing on one crop, that of sugarcane. The crop in question has given the Republic of Mauritius social, economic and bioclimatic adaptability since the production of sugarcane has ensured enough foreign currency to cover the import of food requirements. On the other hand, the share of agriculture in the Mauritian economy has decreased from 5.5% in 2008 to 4.4% in 2009 (Figure 24). (Digest of Agricultural Statistics, 2009). However, the annual growth in agriculture has gone from +0.6% to +5.7 respectively, which indicates that agriculture yet is an important player regarding the socio-economic development of Mauritius.

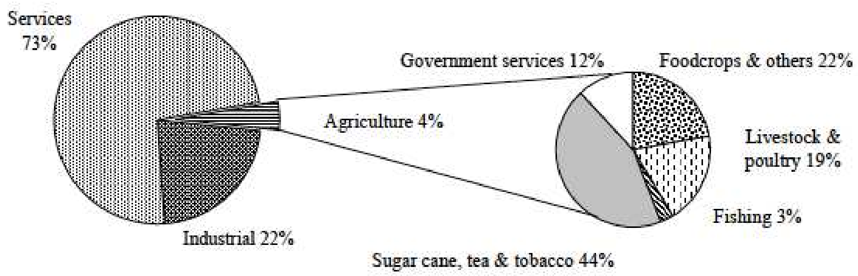

Figure 24: Share of agriculture in the Republic of Mauritius in 2009 (Digest of Agricultural Statistics 2009).

The total land area under agricultural production is of 186 475ha. (Cheeroo-Nayamuth & Nayamuth, 1999). 50% of this land is devoted to agriculture and 41% of the land in question is under the production of sugar cane, which means that 9% is devoted to other agricultural practices. Table 45 illustrates the division of land utilization on Mauritius (Digest of Agricultural Statistics 2009).

Table 45: Division on land utilization.

Type of activity	*Area in hectares*
Sugar cane	62 024
Tea plantation	701
Tobacco	206
Food crops	6 266

Source: Digest of Agricultural Statistics 2009

The share of agriculture with regards to the GDP declined from 4.9% in 2007 to 4.4% in 2008. (Digest of Agricultural Statistics, 2008). When it comes to the sugar industry, the share in GDP was 1.9% in 2008. Agricultural yields declined from 47,300 tonnes in other words by 1.1%, in 2007 to 46,800 tonnes in 2008. Furthermore, the employment in large establishments decreased by 12.3%, where the production decreased from 21,100 tonnes in 2007 to 18,500 tonnes in 2008. On the contrary, employment other than large organizations has increased by 8%.

Appendix 4: Agro climatic analysis per region for tomato yields

Region A: West

The South West region of Mauritius disposes of a sub-humid climate with an approximate annual rainfall of 750-1500 mm/year, where the average temperatures of 24.7°C. It is a relatively productive region, with 19 tonnes/ha per month. In the contrary, it is the driest and warmest area of the island. Due to the dry climate, irrigation is required. Furthermore, tomato production has a cycle of 5-6 months depending on the type of tomato. When it comes to temperature, tomato yields starts to decline once the temperature is above 30-31°C.

According to table 21 (chapter 5.2.2), there is a significant quadratic and non-quadratic relationship between the dependent variable *Y*, precipitation and temperature. The quadratic variable is the most interesting one, where the variable of $T^2_{(t-2)}$ indicates a negative relationship during the second month of the production cycle, denoting a hill-shaped function, which can be scrutinized in figure 25. When the temperature increases, forming a hill-shaped function, yields decrease.

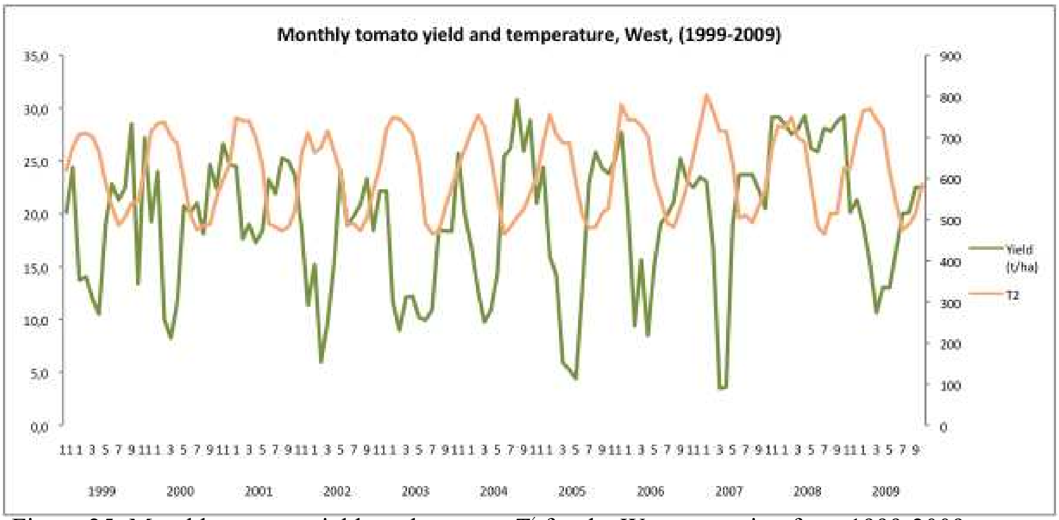

Figure 25: Monthly tomato yields and average T^2 for the Western region from 1999-2009.

As follows, is figure 26; the quadratic relationship between monthly yields and precipitation for the North. Table 21 (chapter 5.2.2) shows the statistical link between *Y*, precipitation and precipitation^2. The non-quadratic as well as the quadratic variable demonstrates that rainfall during the first month of the production cycle is impacting upon yields. The quadratic variable represents, as for temperature, a hill-shaped function. It is here likely that yields decreases with heavy rainfall.

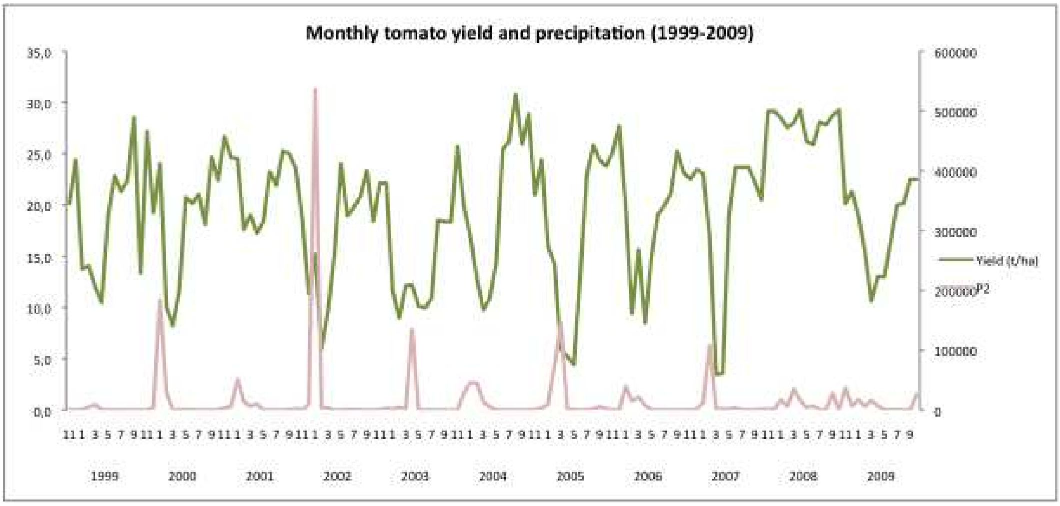

Figure 26: Monthly tomato yields and $Rain^2$ for the Western region from 1999 to 2009.

Nonetheless, table 25 indicates that a precipitation decrease would decrease monthly tomato yields in the West but only by a small percent. It could for instance be due to the present climatic circumstances in the West since it is classified as the driest and warmest region of Mauritius.

Furthermore, monthly sunshine hours did not indicate a significant for the West. The parameter of sunshine hours does not have a quadratic relationship to the dependent variable *Y*. Nevertheless, figure 27 illustrates that tomato yields seems to decrease with a decline in sunshine hours. It is however important to point out the fact that this would most likely be due to a combined effect of the three climatic variables.

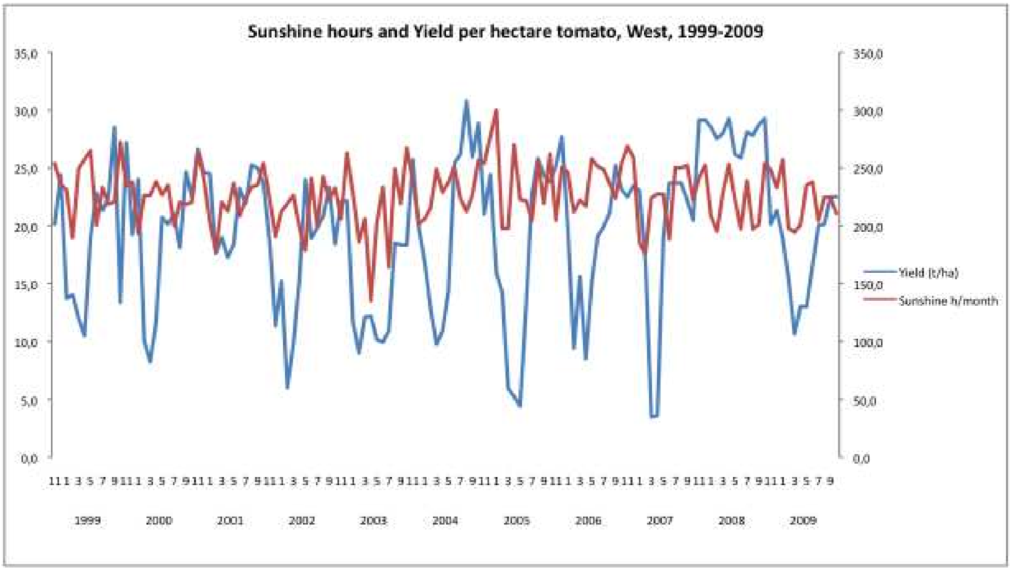

Figure 27: Monthly tomato yields and sunshine hours for the Western region from 1999 to 2009.

Region B: North

The Northern region, according to the results from chapter 6.1, is hereby brought up as an example. As observed in table 23, the Northern area of Mauritius has a monthly rainfall of approximately 112 mm with an average temperature of 23,8°C and a monthly yields of roughly 7 tonnes per hectare (table 25). In addition, the North has a mean of 235 monthly sunshine hours. According to table 19, there is a significant quadratic and non-quadratic relationship between the dependent variable *Y*, precipitation and temperature. The quadratic variable is the most interesting one, where the variable of $T^2_{(t-2)}$ indicates a negative relationship during the second month of the production cycle, denoting a hill-shaped function, which can be scrutinized in figure 28. When the temperature increases, forming a hill-shaped function, yields decrease.

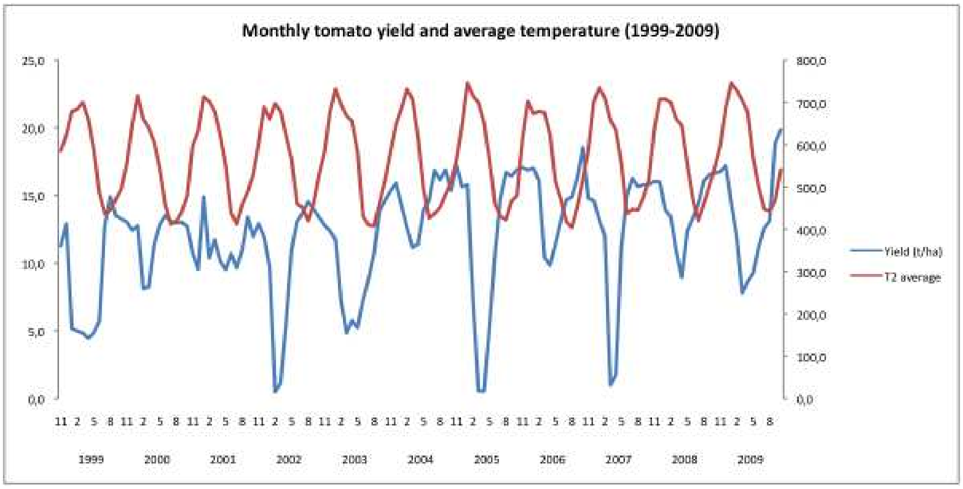

Figure 28: Quadratic relationship between monthly tomato yields and T^2 for the Northern region from 1999-2009.

Furthermore, the temperature estimate is the variable affecting most importantly the monthly yields. It can be observed in table 38, which shows the impacts of climate change in monthly yields. A temperature increase of 1°C for instance, would decrease the monthly yields by 6% in the short-run and 13% in the long-run. On a seasonal or yearly basis, this could be detrimental for the Northern based farmers.

As follows, is figure 19; the quadratic relationship between monthly yields and precipitation for the North. Table 19 from chapter 5.2.2 shows the statistical link between *Y*, precipitation and precipitation^2. The non-quadratic as well as the quadratic variable demonstrates that rainfall during the first and third month of the production cycle is impacting upon yields. The quadratic variable represents, as for temperature, a hill-shaped function. It is here likely that yields decreases with heavy rainfall.

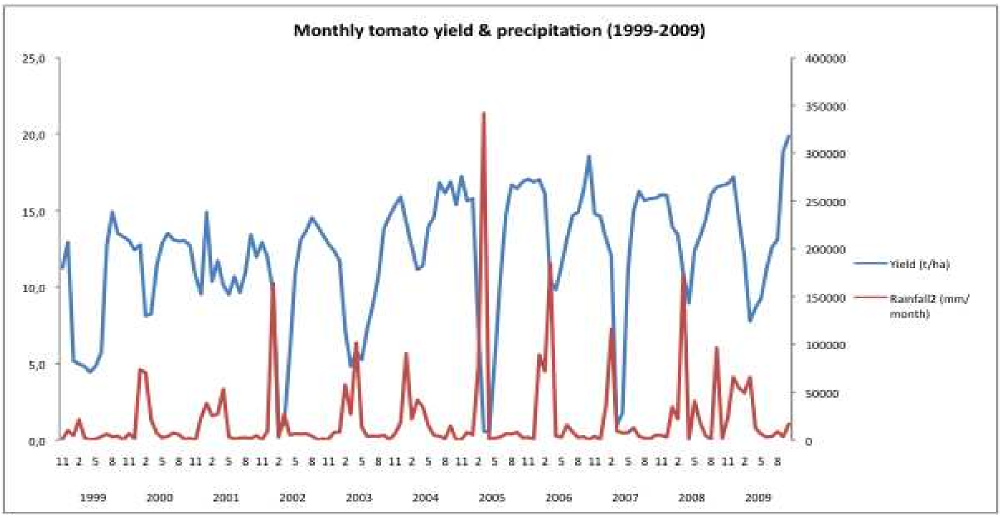

Figure 29: Monthly $Rain^2$ and tomato yields, Northern region from 1999 to 2009.

As for the predicted impacts of climate change, where the prognosis suggests a decrease in rainfall does not seem to have negative effect upon yields for the North. Nonetheless, this is not the case for all regions; the East and the West does indicate a decline in yields with a decrease in precipitation (see table 38). Coming back to the North, the yields are not to likely increase by a large number. For a precipitation decrease by 10%, yields would increase by 2% monthly. However, what is interesting to analyze is how the yields reacts with a temperature increase and precipitation decrease. In table 38 it is foreseen that with a 2°C temperature increase and 10% rainfall decrease the yields would decrease by 11.5% monthly. It is however the temperature parameter that does have the largest negative effect upon yields, both for the North as well as the East.

Furthermore, monthly sunshine hours indicated a significant liaison for the first month of every production cycle. The parameter of sunshine hours does not have a quadratic relationship to the dependent variable Y, which is why the elasticity of sunshine hours was not calculated. The parameter of sunshine hours was taken into account in order to compensate for latitude and longitude variables, estimating the Mauritius is fairly small and not extremely high in altitude. Sunshine hours can be examined in figure 20 below, where the yields seem to decrease with a decline in sunshine hours. According to the background studies upon tomato yields, the food crop in question seem sensible to shadoweffects and therefore a lack of sunshine. The decrease in the North could be due to different shadoweffects, not providing enough sunshine to the tomato yields.

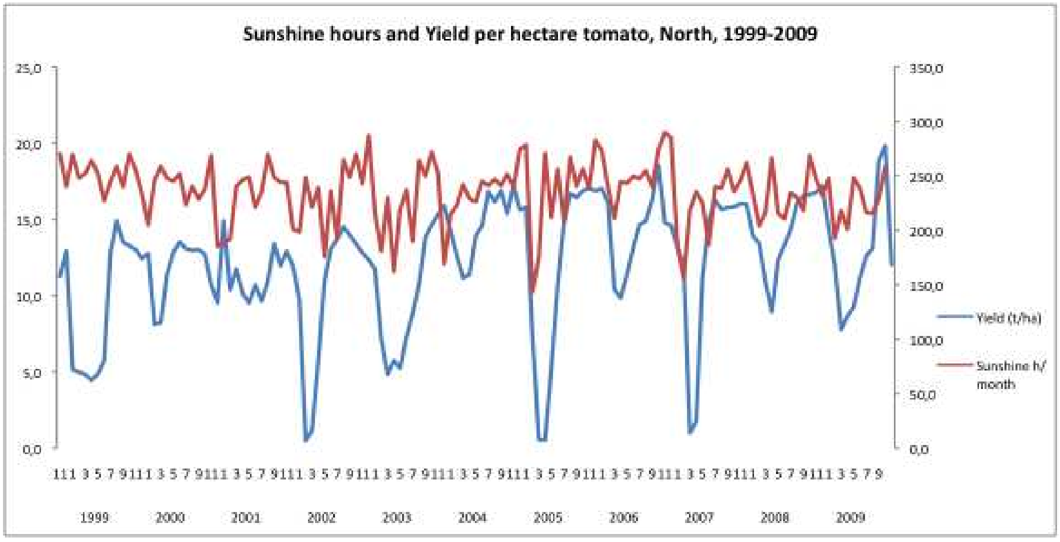

Figure 30: Monthly sunshine hours and yields per ha for tomato production in the North of Mauritius.

Region C: Centre

The centre of the island is characterized by a cooler climate, with an average yearly temperature of 21.9°C and an annual rainfall between 1500-3800 mm/year. The average yields per hectare in the Centre are approximately 15.4 tonnes/ha per month. The central part of the island was the only region that did not show quadratic or non-quadratic statistical significance for the climatic variables[25]. Therefore, the following figures 31, 32 and 33, gives the reader an idea of how tomato yields varies according to monthly average temperature, rainfall and sunshine hours. Nonetheless, according to figure 31, the yields seem to be at its minimum when the temperature is at the maximum.

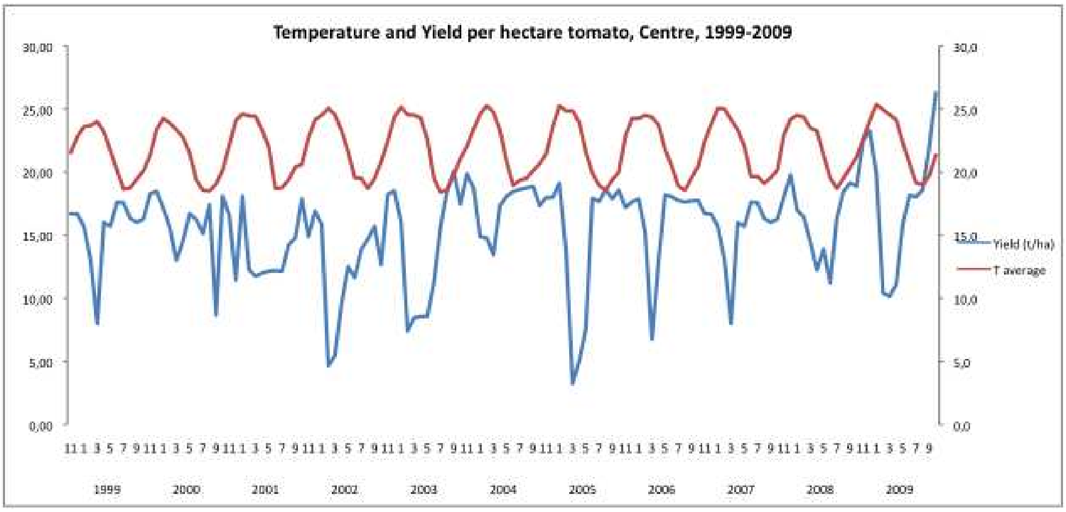

Figure 31: Monthly tomato yields and temperature for the Centre of Mauritius form 1999 to 2009.

[25] The explanation to this could eventually be due to erratic data.

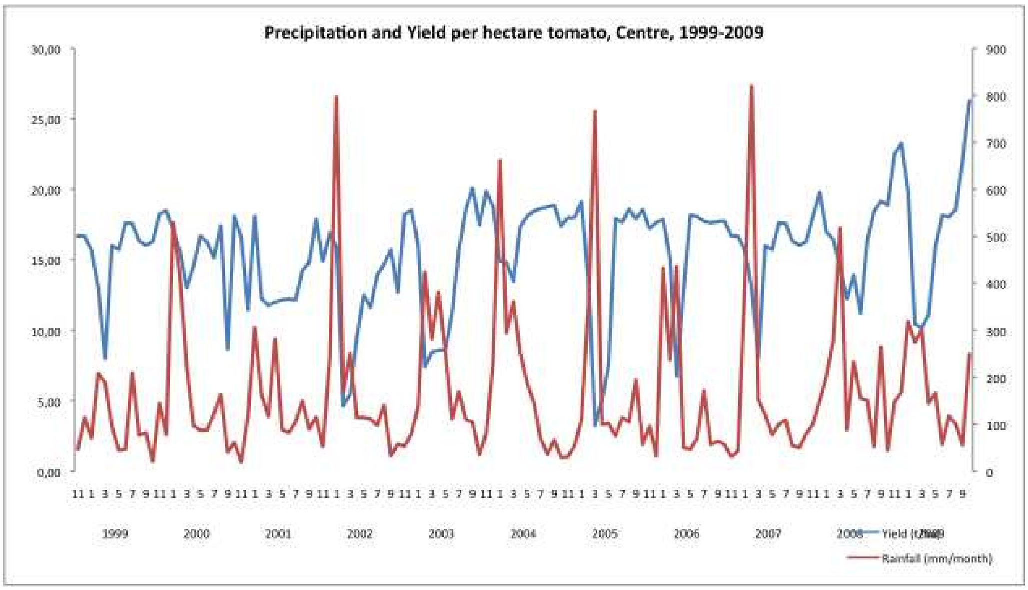

Figure 32: Monthly tomato yields and precipitation for the Centre of Mauritius form 1999 to 2009.

Furthermore, figure 32 shows that with a low level of rainfall, the yields are high and vice versa. Furthermore, figure 33 illustrates that the tomato yields is quite regular regarding the sunshine hours curve. The yields decreases when sunshine hours decrease, which makes sense according to the previous agro-ecological studies (see chapter 4.3, table 12).

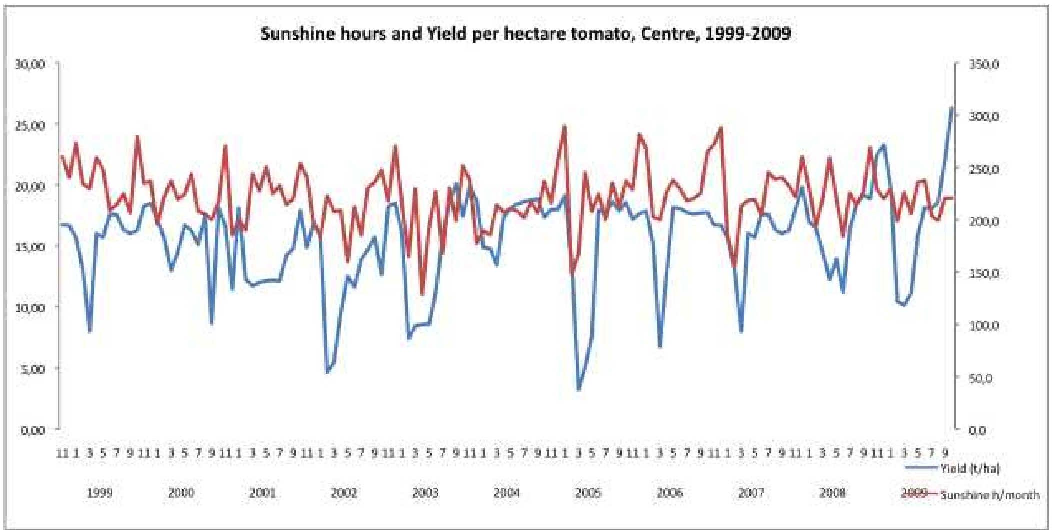

Figure 33: Monthly tomato yields and sunshine hours for the Centre of Mauritius form 1999 to 2009.

Region D: South

The southern region has an annual rainfall between 1500-3200 mm and an average temperature of 24,3°C. The monthly yields per hectare are approximately 13 tonnes. An increase in yields during the years can be observed in the southern region (figure 34). As observed from table 22, the temperature variable did not show any statistical significance. It does however not eliminate the impact of temperature in the Southern region. One could argue that the effect of sunshine also implicates to a certain extent that the effect of temperature since the temperature variable could be considered as an unobservable variable according to Almon's law[26].

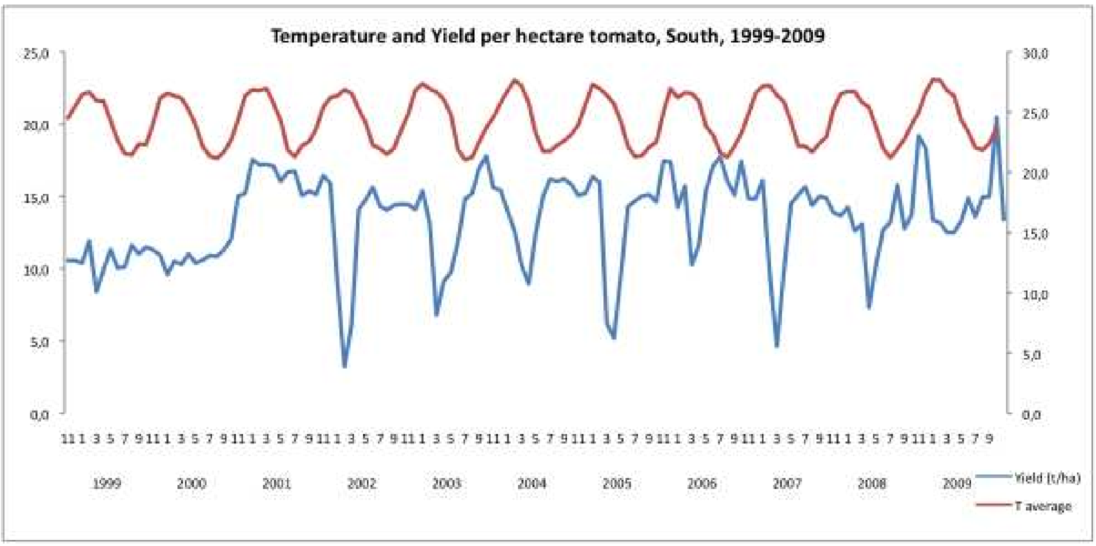

Figure 34: Monthly tomato yields and temperature for the Southern part of Mauritius form 1999 to 2009.

Figure 35 illustrates the quadratic relationship between monthly yields and precipitation for the North. Table 22 shows the statistical link between *Y*, precipitation and precipitation^2. The quadratic variable demonstrates that rainfall during the first of the production cycle is impacting upon yields. The quadratic variable represents, as for temperature, a hill-shaped function. The elasticity measures show that tomato yields are likely to decrease by a small percent with a precipitation decrease.

[26] Almon's approach explains that, from the original variables X, of which Y is constructed upon, the variable Z could be derived as an unobserved parameter. In this case, temperature.

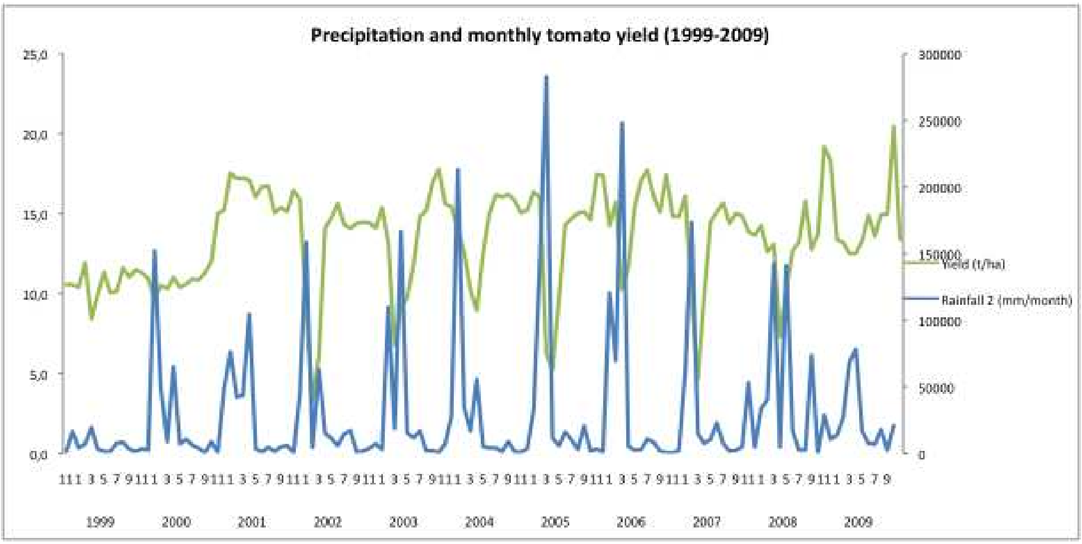

Figure 35: Monthly tomato yields and Rain[2] for the Southern part of Mauritius form 1999 to 2009.

Furthermore, monthly sunshine hours indicated a significant relationship for the third month of every production cycle. The parameter of sunshine hours does not have a quadratic relationship to the dependent variable *Y*. The yields are not likely to decrease by the impact of a change in sunshine hours by itself. It could be examined in figure 36, where the yields seem to decrease with a decline in sunshine hours. One also has to consider, as mentioned earlier, Almon's law, where the temperature variable could have an input and influence on the yields regarding sunshine hours.

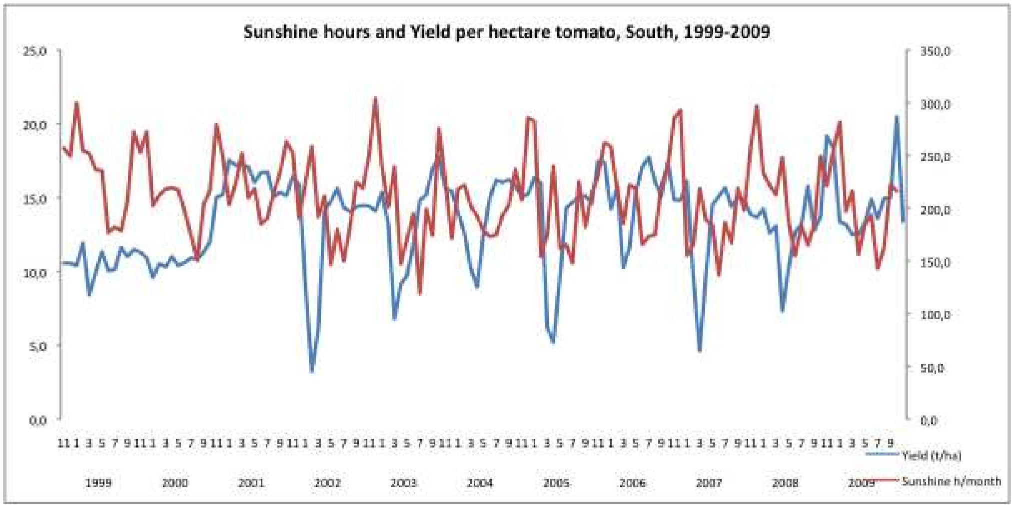

Figure 36: Monthly tomato yields and sunshine hours for the Southern part of Mauritius form 1999 to 2009.

Region E: East

The Eastern area of Mauritius disposes of the approximate climatic characteristics as the Southern part of the island. The yearly rainfall varies between 1500-2300 mm with an average temperature of 23.2°C and a monthly yields of roughly 15 tonnes per hectare. According to table 20, as for the North there is a significant quadratic and non-quadratic relationship between the dependent variable *Y*, precipitation and temperature. The quadratic variable is the most interesting one, where the variable of $T^2_{(t-2)}$ indicates a negative relationship during the second month of the production cycle, denoting a hill-shaped function, which can be examined in figure 37. When the temperature increases, forming a hill-shaped function, yields decrease.

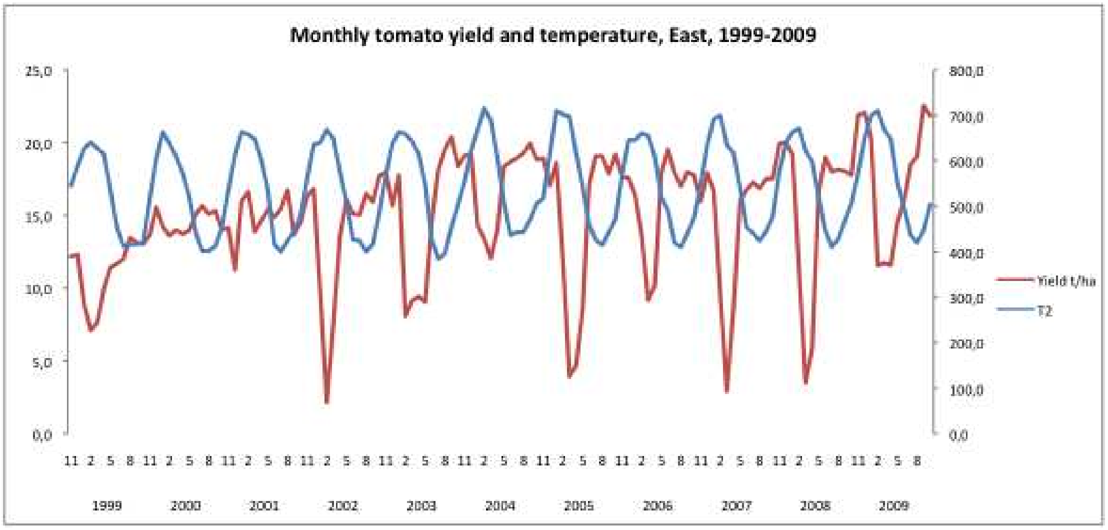

Figure 37: Quadratic relationship between monthly tomato yields and T^2 for the Eastern region from 1999-2009.

Furthermore, the temperature estimate is the variable affecting most importantly the monthly yields. The observations can be studied in table 25, which shows the impacts of climate change in monthly yields. A temperature increase of 1°C for instance, would decrease the monthly yields by 6%. On a seasonal or yearly basis, this could be detrimental for the Eastern based farmers.

Figure 38 demonstrates the quadratic relationship between monthly yields and precipitation for the East. Table 20 shows the statistical link between *Y*, precipitation and precipitation^2. The non-quadratic as well as the quadratic variable demonstrates that rainfall during the first and third month of the production cycle is impacting upon yields. The quadratic variable represents, as for temperature, a hill-shaped function. It is here likely that yields decreases by a small decrease in rainfall. Nonetheless, according to the figure, the yields equally seem sensitive to heavy rainfall or extreme rainfall, such as cyclones.

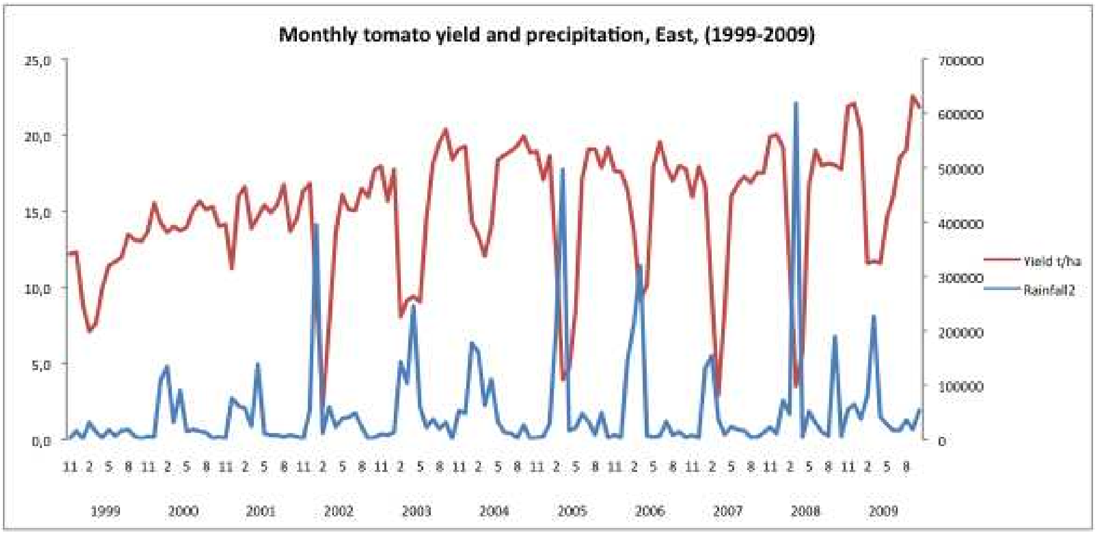

Figure 38: Monthly *Rain*^{2} and tomato yields, Eastern region.

As for the predicted impacts of climate change, where the prognosis suggests a decrease in rainfall does not seem to have a large negative effect upon yields for the East. For a precipitation decrease by 10%, yields would decrease by 0.5% monthly (table 25). However, what is interesting to analyze is how the yields reacts with a temperature increase and precipitation decrease. In table 25, it is foreseen that with a 2°C temperature increase and 10% rainfall decrease the yields would decrease by 16.2% monthly. It is however the temperature parameter the does have the largest negative effect upon yields.

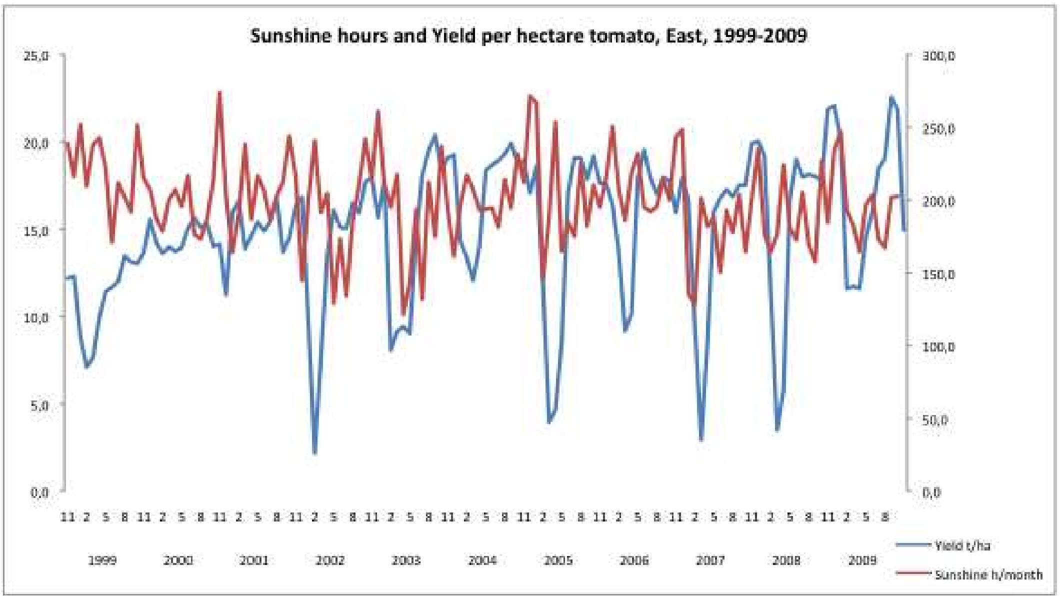

Figure 39: Monthly sunshine hours and yields per ha for tomato production in the Eastern part of Mauritius.

Furthermore, monthly sunshine hours indicated a significant liaison for the first month of every production cycle. The parameter of sunshine hours does not have a quadratic relationship to the dependent variable Y. What could be observed in figure 39 is that yields seem to decrease with a decline in sunshine hours. It is however important to point out the fact that this would most likely be due to a combined effect of the three climatic variables.

Appendix 5: Questionnaire of the survey

Impacts of Climate Change upon Agricultural Food crops in the Republic of Mauritius
UNDP, Madeleine Jonsson, mad.jonsson@gmail.com

Date: __/__/____
N° of questionnaire:

Geographical area:
- ☐ North
- ☐ North West
- ☐ South
- ☐ East
- ☐ West
- ☐ Central Plateau

Profile of the Mauritian farmer

1) **A.** Age
- ☐ < 20
- ☐ 21-30
- ☐ 31-40
- ☐ 41-50
- ☐ > 50

B. Sex
- ☐ M
- ☐ F

C. Are you cultivating in the area you live?
- ☐ Yes
- ☐ No

If no, is the reason due to:
- ☐ Better agricultural land
- ☐ Climatic factors
- ☐ Less expensive
- ☐ Other____________

D. Have you always been cultivating in the same region?
- ☐ Yes
- ☐ No

If no, is the reason due to:
- ☐ Change in climate
- ☐ Other access to land
- ☐ Less expensive
- ☐ Other____________

E. What is your level of education?
- ☐ Primary
- ☐ Secondary
- ☐ Tertiary

2) For how long have you practiced as a farmer?
- ☐ ≤ 5 years
- ☐ 6-10 years
- ☐ 11-20 years
- ☐ > 20 years

3) For how long do you intend to continue agricultural practice?
- ☐ ≤ 1 year
- ☐ 2-5 years
- ☐ 6-10 years
- ☐ 11-20 years
- ☐ > 20 years

4) Is this your land or rented?
- ☐ Owner
- ☐ Rented
- ☐ Both

If owner, how many employees do you have?
- ☐ 0
- ☐ 1-3
- ☐ 4-7
- ☐ 8-10
- ☐ >10

Agricultural production, business & climate

5) **A.** How much land do you produce on?
- ☐ < 2 ha
- ☐ 2-5 ha
- ☐ 6-10 ha
- ☐ > 10 ha

B. During the last ten years that you have used your land, has it:
- ☐ Increased
- ☐ Decreased
- ☐ Remained the same

C. If it had increased **OR** decreased, are the changes due to:
- ☐ Less cultivable land
- ☐ More cultivable land
- ☐ Climate is favourable for the food crops
- ☐ Climate is unfavourable for the food crops
- ☐ Other___________

6) **A.** What vegetables **have** you grown?
- ☐ Tomato
- ☐ Potato
- ☐ Onion
- ☐ Carrots
- ☐ Cabbage
- ☐ Chou-chou
- ☐ Other

B. Have you changed food crops since you started farming?
- ☐ Yes
- ☐ No

If yes, are the changes due to:
- ☐ Prices
- ☐ Weather changes
- ☐ Some food crops are more tolerant then others
- ☐ Demand
- ☐ Other___________

7) **A.** What variety are you growing?

Tomato
- ☐ Sirius
- ☐ Hybrid
- ☐ Calora
- ☐ MST32/1

Potato
- ☐ Spunta local
- ☐ Spunta imported
- ☐ Delaware
- ☐ Mondial
- ☐ Other___________

Onion
- ☐ Local Red
- ☐ Véronique
- ☐ Sivan
- ☐ Bellarose
- ☐ Star 5517
- ☐ NLN 7272
- ☐ Rio Santiago
- ☐ Z 516
- ☐ Noflaye

B. Have you shifted the variety?
- ☐ Yes
- ☐ No

If yes, are the reasons due to:
- ☐ Prices
- ☐ Climate
- ☐ Yield and revenue
- ☐ Consumer preferences
- ☐ Other_____________

8) Is your production:
- ☐ Rain fed
- ☐ Rain fed with traditional irrigation
- ☐ Overhead irrigation
- ☐ Drip irrigation
- ☐ Fertilized inorganically
- ☐ Fertilized organically
- ☐ Chemical pest management[1]
- ☐ Organic pest management

9) **A.** Have you changed the way you water your production?
- ☐ Yes
- ☐ No

If yes, when did you change?
- ☐ < Then one year ago
- ☐ 2-5 years ago
- ☐ > Then five years ago

[1] Chemical pest management is per definition where the farmer uses a chemical type of pesticide to fight different types of hostile cultures, such as fungus, insects and Acarids. The chemical fertilizer includes; active material, a dilutant and an adjuvant.

B. Are the reasons for adapting due to:
- ☐ Increased amount of land
- ☐ Decreased amount of land
- ☐ Climatic conditions
- ☐ Higher demand on the market

10) Based on what recommendations to you fertilize and pesticide your production?
- ☐ Recommendations made by AREU/MSIRI
- ☐ Personal knowledge and experience

If based on personal knowledge, is it due to:
- ☐ Recommendations are not possible to follow up
- ☐ Lack of economy
- ☐ Climatic situation is too harsh

11) Which are the factors affecting the yield of the crop? (Number ranking where 1 is the most influencing factor)
- ➢ Heat waves ____
- ➢ Flash-flooding ____
- ➢ Droughts ____
- ➢ Lack of fresh water ____
- ➢ Pests ____
- ➢ Insects ____
- ➢ Salt water intrusion ____

12) A. Does the yield differ regarding different seasons?
(**ONLY** applicable for all year food crops)
- ☐ Yes
- ☐ No

If yes, is the yield:
- ☐ Higher in summer
- ☐ Lower in summer
- ☐ Higher in winter
- ☐ Lower in winter
- ☐ More profitable in summer
- ☐ More profitable in winter

B. Have you noticed or observed any changes in seasonal yield during the last 10 years?
- ☐ Yes
- ☐ No

If yes, is this due to:
- ☐ Increased weather uncertainty
- ☐ Pollution
- ☐ Soil changes
- ☐ Heat waves
- ☐ Humidity changes
- ☐ Increased drought
- ☐ Other_________

13) What are the constraints of agricultural practice on Mauritius? (Number ranking where 1 is the most influencing factor)
- ➢ Temperature _____
- ➢ Rainfall _____
- ➢ Land (area) _____
- ➢ Soil types _____
- ➢ Input costs _____
- ➢ Varieties _____
- ➢ Labour _____

14) Have you noticed any changes in weather patterns?
- ☐ Yes
- ☐ No

If yes, has this affected your food crops?
- ☐ Yes, positively
- ☐ Yes, negatively
- ☐ No

Personal

15) What is your household income per year (in Rupees)? **(OPTIONAL)**

- ☐ 0 – 60 000
- ☐ 61 000-120 000
- ☐ 121 000-240 000
- ☐ 241 000-360 000
- ☐ > 360 000

16) What is your monthly income per food crop? **(OPTIONAL)**

- ☐ 0-15 000
- ☐ 16 000-25000
- ☐ 26 000-35 000
- ☐ > 35 000

Appendix 6: Underlying theories and motivations behind the survey questions

The survey has been divided into three main sections in order to distinguish the importance of the three topics with regards to the objective of the survey. The profile of the Mauritian farmer is, as mentioned, the first of the three treated areas where it is necessary to determine to whom the questionnaire is addressed to, who is the Mauritian farmer, how does he/she work, what are his/her production tools and how does he/she relate his/her yields to climate? (Astner & Johansson, 2005).

Primarily, the geographical area is of interest due to the different microclimates on Mauritius. The production differs depending on the region. (Cheeroo-Nayamuth & Nayamuth, 1999). Further, the sex is an important factor in order to determine if there is a gender division and if gender and age perceives climatic changes upon their yields differently. The educational question could illustrate if there are any relationship as well as differences amongst famers when it comes to climatic knowledge, perception and adaptation (Pers. com. Shimadry, 2010). Followed by this are questions related to the history of the farmer since it is important to understand whether the cultivator has practiced on the land for a long time or not. (Pers. com. Ramnauth, 2010). The reason behind the second question of the questionnaire is to ascertain climatic changes during the last twenty years and the farmer's past experience of climate related to his or her production. It is yet important to assume that the production might be a family business. Here it is important to point out that it is the head person of the business that should be interviewed.

The following question within this section of the survey is more presently related to the farmer, where the justification for question 2C and D are due to the fact that depending on where the farmer is cultivating, he/she could provide additional information of the different microclimates on Mauritius and if some regions are better suited for agricultural production than others and moreover if it has always been that way or whether a shift in climate had been noticed. (Pers. com. Ramnauth, 2010). The next question implicates the future, linking long-term production and eventually sustainability matters. The question illustrates whether there exists future motivation for agricultural farmers, for which it would then be interesting to analyze how the impacts of climate change are perceived, if they actually are noticed and if the farmers have future interest within Mauritian agriculture or if the climatic factors, for instance, makes it to difficult for the future agricultural practice. (Pers. com. Goolaub, 2010).

It is moreover important to verify if the land belongs to the farmer or not and if the business disposes of external employees with regards to how long the farmer intends to continue the agricultural business and also how many persons could eventually be involved and more or less depend upon in the agricultural industry in terms of revenue. (Pers. com. Goolaub, 2010). Furthermore, the land owner could eventually have a different perception of the importance of land concerning different impacts affecting the yields whereas a farmer that rents the land might have other sources of income or accord less importance to the land and might therefore not be as attentive to what really affects the land in question.

The reason behind the fifth question is to firstly compare small scale against larger scale and whether they distinguish climate changes differently. (Pers. com. Goolaub, 2010). Moreover, an eventual reduction or increase in land could be interpreted in such way that there exists an

interest/disinterest in agriculture enhancing certain opportunities or threats, such as reduction in land due to change in climate the last decade.

The sixth question is asked about the past form because of the historic interest of production since it is important to understand why the farmer decides to make production or crop changes. (Le Guide Agricole, 2004). It is by this climate related, where different food crops are more or less tolerant to higher or lower temperatures as well as increase or decrease in precipitation (Le Guide Agricole, 2004). What comes next is the question of varieties and whether the farmer has shifted variety during his practice over time and why. (Meeting with AREU, St Pierre, 2010). The Agricultural Research Unit (AREU) recognized this question as an important one, since it is related to the understanding of production and the reasons behind the choice of crop and variety. Is it due to climatic changes or are the other main players?

Further, whilst discussing with AREU, the eighth question covers a possible change in water production related to adaptation strategies related mainly to the changes in precipitation. (Meeting with AREU, St Pierre, 2010). The answers to this question would further be interesting to analyse which farmers have perceived changes in for instance weather patterns (question 14). The first part of question 8 is then related to question 9, also related to adaptation strategies and how climatic variables are perceived in relation to this matter. The second part of question number eight goes into fertilization and pesticide use, equally related to adaptation strategies when it comes to usage of organic or chemical pesticides, whereas question 10 is directly related to pesticide and fertilisation. The objective of question 10 is to verify if the farmers are able to follow the recommended fertilizer and pesticide recommendations or not and why. The question has been structured in a fairly neutral way due to the fact that according the AREU, questions concerning usage of chemical products is of a sensible nature. (Pers. com. Ramnuth, 2010). If the question would then be asked in a direct manner such as *"How many do you chemical products are you using per month upon your production?"* The risk here would be that the interviewee would not give an honest answer.

Question number 11 is the first ranking question of the questionnaire involving different climatic effects as well as insects upon yields. (Pers. com. Ramnuth, 2010). This question gives information concerning the true issues for the farmer and his production and could moreover be linked to chemical usage. Furthermore, the variables that where chosen was firstly climatic with regards to the variables analyzed in the econometric study. Besides, the socio-economic variables where included to, as mentioned, complete the missing.

Question 12 verifies the seasonal differences in yields and how the seasonal yields shift according to the climate. (Pers. com. Ramnuth, 2010). This question is then linked to question 13, where, from an historical perspective, the farmer has perceived a shift in seasonal production and what the precise climatic reasons for this could be. The purpose of the "other" option is to give the farmer an opportunity to express him-/herself in case none of the proposed options is of experienced as an issue. Furthermore, the variables that were analyzed are for the same purpose as for question 11.

Question 14, as mentioned above, is directly linked to climatic changes, where the answer of this question is of interest to compare the other answers in order to categorize the farmers and verify whether it is uniquely actually the impacts of climate change that are affecting their production or if there are other factors, variables affecting their production (Pers. com. Ramnuth, 2010).

Question 15 and 16 were placed at the end of the survey due to their sensitivity of the questions. According to Astner & Johansson (2005), questions related to private matters should in general be placed as last questions because they could cause unease for the interviewee, where a radical way of reacting to private questions could be to refuse to further cooperate. However, these questions are yet of an importance, which is why they are asked. The yearly income per household as well as monthly income per food crop gives the author an idea of the economic situation related to the full-time farmer and whether his/her production is profitable or not.