CHAPTER 1 : INTRODUCTION

1.1 Background

Human activities during recent decades have contributed largely to the increased emissions of carbon and other greenhouse gases in the atmosphere. The atmospheric concentration of carbon dioxide (CO_2) has increased by 31% since 1750 and the rate of increase has been about 1.5 ppm[1] (0.4%) per year over the past two decades. Also, the atmospheric concentration of other gases such as methane (CH_4) and nitrous oxide (N_2O) have increased by 1060 ppb[1] (151%) and 46 ppb (17%), respectively since 1750 and continue to increase (IPPC, 2001a). Scientists agree that the increase of these emissions will change the world's climate. Forecasts of climate change from General Circulation Models (GCMs) indicate that a doubling of atmospheric CO_2 will increase the global average temperature from 1.5 to 4.5 degrees Celsius (^{0}C) by 2060[2], as well as alter precipitation amounts and frequency (Rosenzweig, 1989).

The global change of climate is a serious concern to the international community because it may affect prospects for sustainable development. Global warming poses a significant threat to future economic activities and the well being of a large number of human beings (Jepma and Munasinghe, 1998). Among all economic sectors, the agricultural sector appears to be the most sensitive and vulnerable. Plant production is influenced by climate factors such as temperature and rainfall. Each crop has its optimal conditions for growth. Therefore, any change in the climate can have serious impact on the crop production sector. World agriculture, whether in developing or developed countries, remains very dependent on climate resources and conditions.

Various studies have been done to assess the impact of climate change on agriculture. It has been shown that at a global level, the impacts will be small since production reduction in some areas is balanced by gains in others (Kane *et al.*, 1991). The

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[1] ppm (parts per million) and ppb (parts per billion) measure the ratio of the number of greenhouse gas molecules to the total number of molecules of dry air in million and billion units, respectively.

[2] This was the most accepted scenario before the new estimates of IPCC (2001), which reported a range between 1.4 to 5.8 ^{0}C over the period 1990 to 2100.

Intergovernmental Panel on Climate Change (IPCC) studies on climate sensitivity of agriculture across the globe, concluded that the tropical areas seem to be more likely to suffer negative consequences, while temperate climate and polar zones will gain in productivity. Developing countries agricultural systems are vulnerable to climate change because they tend to be less capital and technology intensive and because they tend to be in climate zones, which are already too hot and will likely get hotter (Mendelsohn, 2000). Many countries in tropical regions are expected to be more vulnerable to warming because additional warming will affect their marginal water balance.

Thus, the changes in climate will affect agriculture either negatively or positively depending on the location. There is a wide concern that the agricultural sector in Africa will be especially sensitive to future climate change and variability (Mendelsohn *et al*., 2000). In the Southern African region, the effects of climate change could be further exacerbated due to its high risk cropping environment and the marked intra-seasonal and inter-annual variability of rainfall (du Toit *et al*., 2002).

South Africa, as part of Southern Africa is predicted to be vulnerable to climate change due to the combined effects of the following factors:

- South Africa is energy and carbon intensive economy and among the top twenty greenhouse gas emitters in the world (Scholes *et al*., 1999).
- South Africa is a semi-arid country where the bulk of farming is practised on marginal land
- Frequent occurrence of droughts
- Scarcity of water, which is exacerbated by a high temporal and spatial variability of rainfall.

IPCC (2001a) forecasted the following key impacts in South Africa:

(i) A complete loss or displacement of succulent Karoo biome projected under climate change and many species losses in other biomes

(ii) Intensity of extreme events will significantly increase in South Africa; biome shifts will favour horticulture over plantation forestry and malaria risk areas projected to expand southward.

(iii) The dependence of production and crop yield on intraseasonal and interannual variation of rainfall.

1.2 Problem Statement and Motivation

The population of South Africa has been increasing over the years. South Africa's total population as per the 1996 census was 40,583 million and in 2001 the estimation of the population is about 43,586 million (SSA, 2002a). The growth in population increased the demand for food and the use of resources needed to feed this growing population. South Africa is also a major source of food for the rest of the region. Generally, South Africa has been meeting its food requirements with domestic production for most items. However projections show that although South Africa is currently meeting its consumption requirements, the growing population, rise in income levels and change in preferences may lead to increased demand for food (NDA, 2000). The ability of the agricultural sector to feed this increasing population will not be an easy task as South Africa is largely semi-arid with secluded sub-humid areas and with a large variation in soil types and physiography. With the threat of climate change, food insecurity in the country and in the region is expected to be worsening in the future without any proper policies actions.

In addition to being an important source of food supply, South African agriculture contributes almost 9% of the formal employment and 3.2% the Gross Domestic Product (GDP). Agriculture is also an important earner of foreign exchange for the country. Moreover, the agriculture sector has strong backward and forward linkages into the rest of the economy, such that the 'agro-industrial sector' is estimated to comprise 15% of the GDP (Van Zyl *et al.*, 1988; McDonald *et al.*, 1997; Townsend, 1997; GOVZA, 2001; Hassan, 1998). Consequently, any factor affecting the agricultural sector, like climate change, may have serious consequences for the rest of the economy. Van Zyl *et al.* (1988) showed that the overall impact of changes in agricultural production resulting from drought is almost twice on the general economy than its direct impact on the agricultural sector. Furthermore, given an estimate of 3 million farmers who produce food primarily to meet their family's needs, rural poverty in South Africa could be worsening with climate change. Indeed, due to their low income and lower technological and capital stocks, subsistence farmers are predicted to have limited options to adapt to climate changes (Mendelsohn, 2000; IPCC, 2001b and 2001c).

Although there are well-established concerns that climate change has the potential to affect crop production seriously, there is little quantitative information concerning how serious these effects will be in terms of economic losses and social welfare impacts in the case of South Africa. There have been limited agronomic studies conducted in field stations scattered across the country, which mostly examined how individual crops behave in controlled experiments, focusing on grain crops and mainly maize. These studies covered only a small part of the country (Schulze *et al.* 1993; du Toit *et al.*, 2001; du Toit *et al.*, 2002; Kiker, 2002 and Kiker *et al.*, 2002) and fail to account for farmers' adaptation strategies. Thus, as Wit (2000) states in his survey of climate change research in South Africa, there is specific need to determine the economic impacts of global climate change in South Africa. A study by Poonyth *et al.* (2002), using a Ricardian model to explore the agriculture sector performance with respect to climate change concluded that, rising temperatures will be detrimental to agricultural production without proper adaptation by farmers. With only 2^0C increase in temperature, the net revenue per hectare is expected to reduce by 25%. Poonyth *et al.* (2002) study used time series agricultural data and yearly climate variables. By doing so, the results of the study may have reflected weather variations rather than long-term climate change impacts. Moreover, by using aggregate provincial level data the study have neglected the climatic and geographical diversity within the province. Furthermore, given the semi-arid nature of the country where water resources are very sensitive to climate variability and change, Poonyth *et al.* (2002) study suffers from the same criticism levelled against earlier Ricardian studies of agriculture for the non-inclusion of water supplies and availability in the analysis. The present study re-examines Poonyth *et al.* (2002) study results by using cross-sectional agricultural data gathered at district level and with the inclusion of irrigation to re-assess the economic impact of climate change on agriculture in the Republic of South Africa. The effects of climate change on agriculture in South Africa may therefore not be as worse as envisaged by Poonyth *et al.* (2002) study if the role of irrigation in adapting to unfavourable conditions were also considered and much more spatial variability is allowed in the analysis.

1.3 Research objectives

The main objective of this study is to develop and apply empirical methods and procedures to assess the economic impact of climate change on the South African field crops. Indeed, field crops occupy, on average, 80% of the total cultivated land and contributed about 40% of the gross revenue of the total agricultural sector (AAS, 2002).

The study pursues the following interrelated specific objectives:

i. To develop and estimate an empirical model to assess the potential impacts of climate change on South African field crops.

ii. Use the estimated model to predict the range of impacts on agriculture under various climate change scenarios

iii. Evaluate alternative courses of actions in terms of available policies and strategies for mitigation of likely climate change impacts.

1.4 Approach and methods of the study

This study will use an adapted version of the Ricardian approach following the modifications applied by Sanghi *et al.* (1998) in India. This modified model is adopted to evaluate the economic impact of climate change on South African field crops. Based on cross-sectional data, the present study will identify the contribution of environmental variables such as climate variables on farm income.

The Ricardian Method examines how climate in different places affects the net rent or value of farmland. This approach evaluates how profit–maximising farmers respond to various climatic conditions. By regressing farm values on climate, soil and other control variables, the method enables measuring the marginal contribution of each variable to land value. Due to imperfect land markets and weak documentation of agricultural farm values in South Africa, in the current study, net revenue per hectare rather than land value was used as the response variable. This formulation assumes that land prices reflect expected future net revenues.

The analysis was based on district level agricultural, climate, and edaphic data for 300 districts in South Africa, to examine farmer-adapted responses to climate variations across the country. Seven field crops (maize, wheat, sorghum, sugarcane, groundnut, sunflower and soybean), which comprise 80% of the field crops land and contribute about 80% of field crops gross revenues, have been studied.

1.5 Outline of the study

The study is presented in six chapters. Chapter one introduces the research problem, objectives and methods. Chapter two presents the structure of agriculture and climate patterns in South Africa. Chapter three presents a review of relevant literature on climate change and agriculture and empirical approaches to measuring the impact of climate change. The approach and methods applied in this study are presented in chapter four. Chapter five presents and discusses the empirical results and outcomes of the simulations of various scenarios of climate change. Chapter six derives the conclusions and implications of the study.