Chapter 6: Summary and Conclusions

This study made an attempt to evaluate the impact of climate change on sugarcane production in South Africa. The analysis utilized the Ricardian methodology that captures farmer adaptations to varying environmental factors.

Data from 11 districts for the period 1976/77 to 1997/98 were analyzed to explain farmer-adapted responses to climate variations across seasons and production zones. Three main seasons (winter, summer and harvesting) and two main production zones (irrigated and dryland) were considered for the study. Out of the 11 sample districts, nine were selected from the dryland farming contributing 80 % of the total sugar production while; the remaining two districts were selected from the irrigated north, which contribute the remaining 20 % of the total production.

Based on pooled analysis, district level net revenues per hectare were regressed on temperature, rainfall, soil type, altitude, dummies for irrigated and dryland areas and time trends. It was found that climate has a non-linear and significant impact on net revenue per hectare. The soil type, which affects productivity and altitude, which proxies solar energy, were also statistically significant. The dummies for irrigation and dryland including time trends, which were included to compare the trends of climate change on net revenue per hectare for both farming zones were also statistically significant.

The total and partial impacts of increasing temperature and precipitation, keeping other factors constant, were also simulated based on the estimated regression coefficients of the empirical model. The total impact was simulated for a 2^{0}C rise in temperature and a 7% increase in precipitation, a scenario associated with the doubling of carbondioxide for the whole world. Increasing temperature by 2°C and precipitation by 7 % (Doubling of CO_2) have negative impacts on sugarcane production in all zones. As expected, this impact is not equally distributed between the irrigated and dry farming region. The average loss in net revenue indicated that the dryland farming sustains more damaged under this climate change scenario. The reduction in average net revenue per hectare amounts to 26 % in the case of the irrigated farming, while it is 27 % in the dryland farming. This indicates that with irrigation, the damage from changing climate can be reduced not significantly though. The partial impact of increasing only temperature or precipitation across all seasons was also simulated to evaluate the impact of increasing temperature or precipitation on sugarcane production. The partial impact of increasing temperature was evaluated for the most likely scenario of a 2.75^0C rise in temperature on average for South Africa. Additionally, seasonal impacts were also simulated to evaluate the seasonal effects of changing temperature and precipitation levels.

Increasing temperature across all seasons, keeping other factors constant, reduce net revenue per hectare by 30 % in the irrigated farming and by 29 % in the dryland farming. These figures show that both the irrigated and dryland regions are almost equally affected by increasing temperature across all seasons. Increasing precipitation by 7% increase net revenue for the irrigated farming by 0.35% and reduce net revenue per hectare by 1.5 % for the dryland farming, a result that contradicts expectations and warrants further research.

The seasonal effects of a rise in temperature (2.75°C) and rise in precipitation (7%) were also analyzed to find out the impact of changing a specific season's temperature or precipitation on net revenues of both production zones. It was found that increasing winter and harvesting temperatures are damaging to both irrigated and dryland farming, while increasing summer temperature is beneficial to both farming zones. Additionally, increasing winter and harvesting precipitations were found beneficial whereas increasing summer precipitation was damaging to both farming zones.

To summarize, the yearly changes in net revenue per hectare caused by changes in temperature and precipitation were averaged over the 22 years period for both irrigated and dryland farming to get the average impact at each season (Table 6.1)

Table 6. 1: Average change in net revenue per hectare (1995 R) for irrigated and dryland farming for increasing temperature by 2.75°C and Precipitation by 7%.

Climate variables	Winter		Summer		Harvesting		Total
	Irrigated	Dryland	Irrigated	Dryland	Irrigated	DryLand	
Temperature	-844.69	-495.82	591.8	260.54	-211.3	-183.86	-893.33
Precipitation	5.13	9.5	-36	-89	4.3	1.2	-104.87
Total	-839.56	-486.32	555.8	171.54	-207	-182.66	-998.2

As showed in table 6.1, increasing temperature and precipitation across all seasons have negative impacts on sugar farming. Based on the most likely climate change scenario of increasing temperature by 2.75°C across all seasons, the contribution of sugar farming to agricultural GDP and to the overall economy decrease by 6 % and 0.2 % respectively. This clearly indicates that increasing temperature has a negative impact on the contribution of sugar farming to the South African economy.

Based on critical damage point analysis, it was found that increasing winter temperature beyond 18°C and decreasing summer temperature below 23°C were found damaging to sugarcane production. Winter precipitation levels beyond 94mm were damaging, whereas summer precipitation levels beyond 354mm were beneficial. Additionally, increasing harvesting temperature beyond 19°C was beneficial while increasing precipitation level more than 4mm was damaging to sugarcane production in South Africa.

Moreover, the critical damage points were compared with agronomic optimum temperature and precipitation levels for South African sugar farming to give more realistic interpretation of the results. Most of the critical damage points identified were found consistent with and fall within the agronomic optimum ranges. The likely impact of climate change on sugarcane production in South Africa was analyzed based on this critical damage point analysis compared to where current temperature and rainfall levels are. The critical damage points (temperature and precipitation) identified for each seasons were compared with the average current temperature and precipitation levels to evaluate the likely net revenue impacts of marginal changes in temperature and precipitation levels. It was found that winter and summer temperature levels are currently very close to the critical damage points identified for these seasons indicating the high sensitivity to winter and summer temperatures. The case however was different with rainfall as current rainfall levels are far from the identified critical damage points providing better range of tolerance to future rises in precipitation.

These results suggest a priority to intervention and adaptation strategies that target mitigation of increased temperature impacts. Therefore, future research has to focus on cost-effective methods of controlling yield-reducing factors associated with increased temperature especially during the winter growing season and the availability of sugarcane varieties, which are relatively not sensitive to increased temperature during ripening and harvesting.

While the general agreement is that arid and semi- arid regions of the world are more vulnerable to warming, management options, such as irrigation, are thought to provide an adaptation mechanism. This however, was not the case for sugar farming in South Africa, as irrigation did not reduce the harmful impacts of climate change significantly. As the result includes only one crop, generalization for the whole country cannot be made. Therefore an overall study, which includes all crops and other sub-sectors like livestock, should be conducted to get the full picture of the impact of climate change on agriculture and design mitigation strategies. Moreover, the model adopted for this study does not include the corbondioxide fertilization and price movements' effects, which if included could highly improve our understanding of the likely impacts of climate change on agriculture in South Africa.