

*Full Length Research Paper*

## Climate change impacts on South African hop producer prices

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Climate change impacts caused South Africa to breed unique hop cultivars which are adapted to shorter and warmer winters and shorter day length in summer. However, climate change impacts in South African include further increases in temperature along with noticeable inter-seasonal variation in rainfall patterns. These changes have demanded a re-evaluation of the ability of South African hop farmers to adapt to climate change impacts. In order to assess the adaptive capacity of hop farming operations from a financial perspective, the study assessed the potential inflationary impacts of climate induced water related risk on the production cost of South African commercial hop operations. It was found that the South African hop price model is a cost-based model with fixed returns, which aims to maintain the gross margin above specified cost for hop farmers. This rather unique setup implies that returns on investment are fixed and that inflationary pressure cannot erode the profitability of hop farming operations. Climate induced inflationary impacts will therefore inflate the consumer price of hops since it is almost certain that breweries will pass on any inflationary impacts to the final consumer. We have distinguished between a temperature effect and a rainfall effect of climate change. Given an average dry yield of 1 739 kg of hops per hectare for the study area and a current market price of R51.39/kg for dry hops, the temperature effect will inflate the market price for hops with R1.03/kg, while the rainfall effect will inflate prices with R0.31/kg. The study found that a total increase of R1.34/kg (that is, a 3% increase) in the producer price of hops is therefore required to offset climate induced water-related risk on hop cultivation in the study area.

**Key words:** Climate change, hop farming, production cost model, South Africa.

### INTRODUCTION

Between the late 1990s and early 2000s, the international hops market was over-supplied, causing a worldwide decrease in the price of hops. Consequently, the area under cultivation decreased steadily; falling by approximately 50% during this time (Mozny et al., 2009). This was followed by a volatile price period characterized by stockpiling and speculation. More recently, the market

has stabilized and is set for a period of growth; unless the demand for beer decreases significantly; or, more relevant for the current paper, external factors such as climate change induce water-related risks that threaten the production and supply of hops.

A focused effort was made during the 1980's to grow the South African hops industry because of its strategic

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**Figure 1.** Water management areas in South Africa (provincial boundaries are shown in grey and study area is indicated with arrow).

importance for the South African beer industry. It was expected that the drier South African climate would not only lead to fewer pests as compared to Europe and the United States, but being a labor intensive industry, create much needed job opportunities while savings on foreign exchange (all South African hops was imported at that time). Consequently, an active breeding programme has resulted in some unique South African hop cultivars with unique terroir properties which are sold on the international market. Today, 75% of the area under cultivation is grown by private growers who are contracted to single beer brewing company. This arrangement effectively cancels out marketing risk from the producer side. Producers therefore have a guaranteed buyer for their produce, which implies that producers are not vulnerable to international price variation. This low-risk proposition has been an important consideration for private land owners when considering growing hops under contract.

The South African producer price for wet hops is based on a fixed margin above specified costs, which is reviewed and adjusted on an annual basis. Climate change impacts can affect the cost structure of hop farming operations, but not producer's profitability. This is the first study focusing on quantifying the inflationary impact on input cost specifically due to climate induced water related-risk on the industry. We present the required adjustments in producer price to maintain the profitability of hop farming operations and recommend

changes to hop cultivation practices to better manage climate induced water-related risk on hop farming by applying a pragmatic approach as far as possible to maintain practical relevance. Data were mainly derived from a hop farm survey conducted by the researchers (De Lange and Mahumani, 2010), while industry data was obtained from a leading South African beer company (Conway, 2010; Brits, 2010) and previous reports on hop farming operations in the study area (Kleynhans, 1991; Kassier and Spies, 1988).

#### STUDY AREA AND CLIMATE CHANGE MODELLING

Hops require a cool, moist climate, preferably with summer rainfall, low winter temperatures (about 5 weeks at temperatures below 4°C) to encourage full dormancy, and a frost free growing season with long daylight hours. In addition, winds can cause both delay in growth and physical damage to the ripening cones. Hot gusts around harvest time also cause yield losses because hops become dry and brittle, which causes the cones to shatter in the picking machines. Hop farming operations in South Africa are primarily located in the Waboomskraal area (33°52'20.64"S, 22°21'15.14"E) which is situated in the Outeniqua Mountains, inland of the south coast town of George in the Western Cape Province of South Africa (Figure 1).

The Waboomskraal area is considered a spring rainfall region, with the bulk of its rainfall between September to November; while the driest period is June to July. Average rainfall is 691 mm per year with a standard deviation of 140 mm per year (De Lange and Mahumani, 2010).

Given that hops require approximately 900 to 1000 mm water per

year to serve growth requirements and to account for evaporation losses, the Waboomskraal is therefore considered a marginal area for growing hops compared to most northern hemisphere growing regions where there are ample cold units in winter and long daylight hours in summer. Farmers manage these requirements using supplemental irrigation (a typical irrigation season varies between 16 and 18 weeks, during which farmers irrigate between 25 and 30 mm per week), cultivar selection and breeding programmes, and artificial lighting. There are 13 commercial hops growers cultivating 483 ha of hops in the Waboomskraal district of the George area, and all of them deliver wet hops to directly to a single brewery. Some farms are diversified, but the majority (65%) has hops as a monoculture.

The Cape south coast is considered to be a climatic transition zone, located between the winter rainfall area of the southwestern Cape to the west, and the summer rainfall areas of the interior to the north. As such, the region's climate is affected by changes in the circulation systems of both of the climate regimes bordering the area, which makes it particularly vulnerable to climate change impacts (Engelbrecht, 2010).

During the past century, temperatures in the central interior of southern Africa have been increasing at about twice the global average rate of 0.8°C (Kruger, 2006; Kruger and Shongwe, 2004). This is due to the region's location in the subtropics, in combination with hemispheric changes in circulation systems, primarily the strengthening of the subtropical high-pressure belt over the region (Engelbrecht et al., 2009). In order to assess climate change risk in the Cape south coast, it was necessary to consider long-term historical rainfall and temperature data, and projections of future trends of the same variables by means of regional climate models (Peter et al., 2009).

Six climate simulations were performed by the Council for Scientific and Industrial Research (CSIR) in South Africa during 2010 (Engelbrecht, 2010; Engelbrecht et al., 2009). These experiments applied a variable-resolution atmospheric global circulation model (AGCM) as a regional climate model to simulate future climate conditions over southern Africa. The model was fed with historic (1961 to 2010) and simulated (2011 to 2050) data from six different coupled global circulation models which contributed to Assessment Report 4 of the Intergovernmental Panel on Climate Change (IPCC) (<http://www.ipcc-wg2.gov/publications/AR4/index.html>). The CSIR simulations were done based on the IPCC's A2 emission scenario (<http://www.ipcc.ch/ipccreports/sres/emission/index.php?idp=98>). The AGCM used to perform the simulations was the conformal-cubic atmospheric model (CCAM) of the Commonwealth Scientific and Industrial Research Council (CSIRO) in Australia (McGregor, 2005). The model was first applied at a resolution of 2° in latitude and longitude, whereafter the simulations were downscaled to a resolution of 0.5° for southern Africa. An important feature of the simulations was that the sea surface temperatures of the coupled global simulation models used to drive the regional climate model, were bias-corrected, an approach that leads to improvements in the simulation of regional precipitation and circulation patterns (Engelbrecht, 2010).

A general strengthening of the subtropical high-pressure belt, and southern displacement of the westerly wind regime projected for the southern African region, are expected to decrease frontal rainfall and cut-off lows over the Cape south coast (Kruger, 2006; Engelbrecht et al., 2009). Projections of maximum temperatures over southern Africa suggest that, for all seasons, the largest temperature rise will occur over the western interior, with the strongest warming projected to occur during winter. The coastal areas are expected to warm at a slower rate than areas over the interior, due to the moderating effect of the ocean.

The observed and projected trends in maximum temperature over the study area, for each of the seasons June to August (winter), September to November (spring), December to February

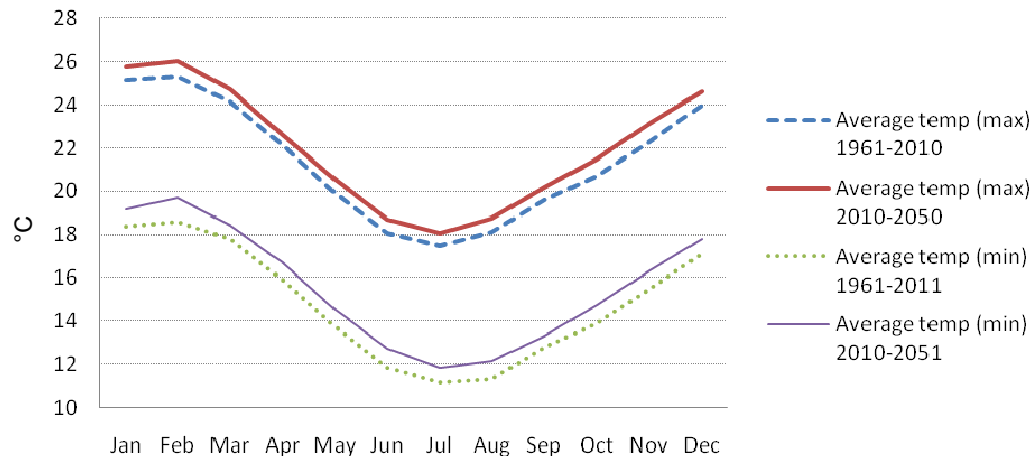
(summer) and March to May (autumn), are presented in Figure 2. The temperature trend analysis was performed using weather station temperature data as well as the above-mentioned projections for the period 1961 to 2050. Although there is variation between models, the models suggest an expected average increase of approximately 0.6°C in the mean annual temperature. However, given that an annualized average does not reveal sufficient detail to derive the impacts on the hop growing cycle, and therefore on hop farming operations in the study area, it became necessary to present temperature changes on a monthly basis (Figure 2) (De Lange and Mahumani, 2010). Of particular interest was a projected increase in the average maximum temperature over the irrigation season (September/October through to February/March) of 0.7°C, while the average minimum temperature is projected to increase by 0.79°C.

Figure 3 presents observed and projected monthly average rainfall totals for the period 1961 to 2050. It is expected that both the total rainfall and standard deviation in rainfall will remain constant at an average of 639 and 116 mm per year respectively (Engelbrecht, 2010). However, certain months will become drier, whilst other will become wetter (Figure 3). The relevance of these expected changes to the hops industry is determined by the impacts of such events on the growing cycle of hops. For example, the expected decrease of 9 mm in October is considered more important as compared to the decrease of 6 mm for May, because the former falls within the beginning of the annual growth cycle, whilst the latter occurs after harvest time.

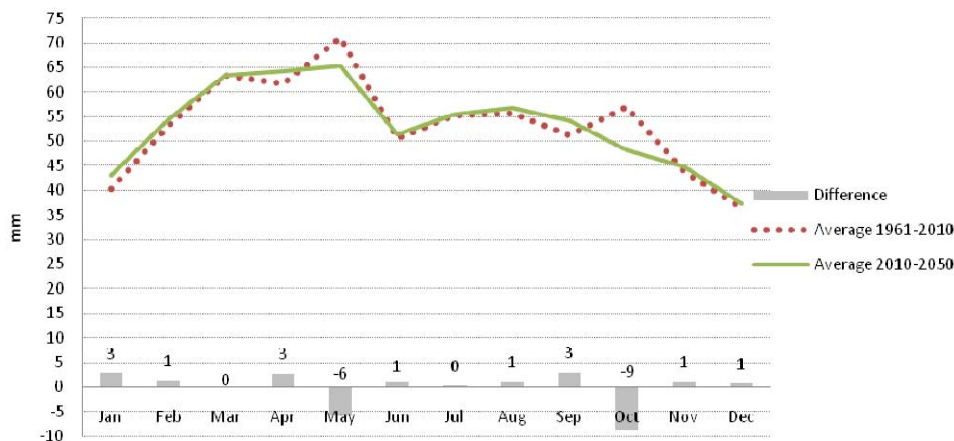
## RELATIONSHIPS BETWEEN CLIMATE AND YIELD/QUALITY

The relative performance of commercial hop growers is measured in terms of yield (tons harvested per hectare) and quality ( $\alpha$ -acid percentage per unit weight, which is the generally accepted indicator of quality for hops). Growers thus aim to optimize growing conditions to maximize performance. Hops is particularly vulnerable to an increase in air temperature during the onset of the reproductive phase, as this not only leads to a shortening of the vegetative period, but also has negative impacts on the yield (quantity) and  $\alpha$ -acid (quality) of the harvest (Brits, 2010). Furthermore, although no field trials are currently available to enable estimation of the exact crop-water production function for hops, it has been reported that hop plants in the Waboomskraal area have a total water requirement of 1 161 to 1 271 mm per hectare per year (Brits, 2010). This implies an irrigation requirement of between 470 to 580 mm per hectare per year (De Lange and Mahumani, 2010) to supplement the average 691 mm of rainfall (Engelbrecht, 2010). Given that 483 ha are currently under commercial hop production, the total water requirement for the industry is estimated at 5.6 to 6.1 million cubic meters per year, of which 2.3 to 2.8 million cubic meters needs to be irrigated. It is clear that hop farming is highly dependent on irrigation, which implies that irrigation management can be used to increase the adaptive capacity of hop farming.

In the absence of field trial data for South African conditions, we turned to international data to establish the relationship between climate change, yield and quality of hops. Surprisingly, few studies were found on this subject, which could imply that climate change is not yet seen as a major production risk in the prominent hop growing areas of the world (Germany, USA, China and the Czech Republic). Only one recent study was found (Mozny et al., 2009). Mozny et al. (2009) simulated the impact of changing weather conditions on yield and quality of Saaz hops in the Czech Republic with a crop production model developed earlier by the same author (Mozny et al., 1993). The model was calibrated with historical production data for a 52 year period, historical records of minimum and maximum air temperatures, relative air humidity, rainfall and solar radiation.



**Figure 2.** Observed and projected average maximum and minimum monthly temperatures for Waboomskraal.



**Figure 3.** Observed and projected average total monthly rainfall for Waboomskraal.

Although this work was done in the Czech Republic, it can at least be used to qualify the relationship between expected changes in rainfall and temperature on the one hand, and the yield and quality of hops on the other. Reliable South African hop production records only go as far back as 1997 (De Lange and Mahumani, 2010), whereas climate data dates back to 1961. Research on the calibration of such a model for South African conditions and South African cultivars such as Southern Star and Southern Promise should therefore be a priority. Mozny et al. (2009) quantified the positive functional relationship between water application and yield; and establish a slope between a decrease in water application (rainfall and/or irrigation) and a decrease in yield of between seven and 10%. This relationship proved **Error! Reference source not found**. relevant to our study area, because an extrapolation of this relationship towards the current average rainfall of 691 mm per annum for the Waboomskraal area closely matched the reported average yield of the area of 1.739 t/ha (standard deviation of 0.21 t/ha) (De Lange and Mahumani, 2010). However, because of higher evapotranspiration rates in South African conditions as compared to Czech conditions, it behooves growers to augment precipitation with irrigation in the former (De Lange and Mahumani, 2010). Furthermore, Mozny et al. (2009) also quantified the negative

relationship between temperature and  $\alpha$ -acid percentage (quality) and found an increase in temperature could decrease  $\alpha$ -acids (and therefore the quality of the hops) by between 13 and 32%, depending on the baseline. We have used these outcomes to support the two working assumptions for our study. For the purpose of this study we can thus assume with a fair degree of confidence that climate changes will affect hop cultivation in the following ways, *ceteris paribus*:

- i) Increasing temperatures lead to an increased water requirement which, if not managed by means of irrigation, will decrease yield;
- ii) Increasing temperatures will, if not managed, decrease quality ( $\alpha$ -acid percentage).

## RESULTS

The extent of the impacts of changes in temperature and rainfall on hop yield and quality are determined by the timing of these events within the hops cultivation calendar (Figure 4).

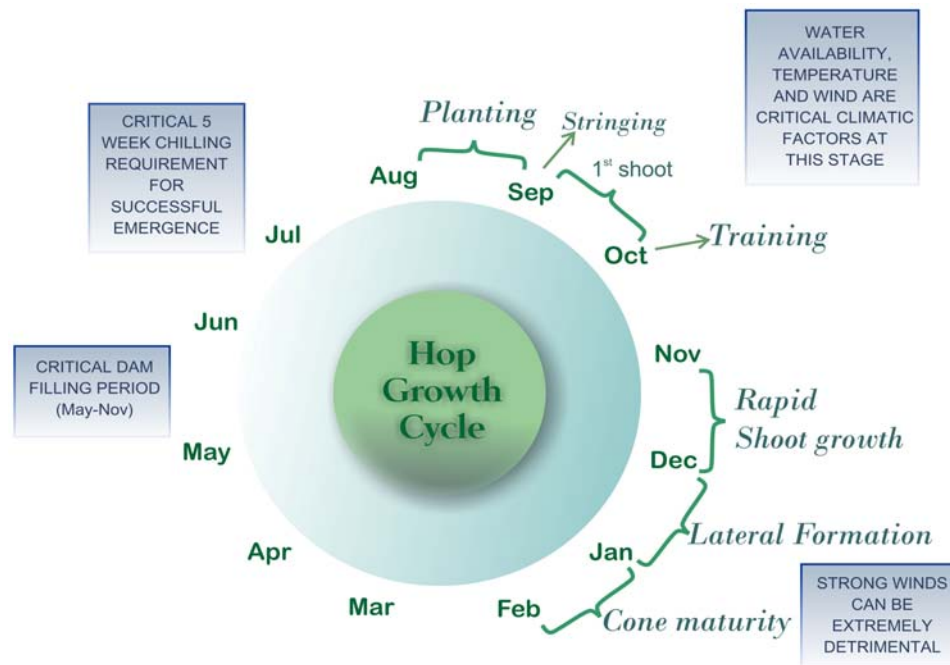


Figure 4. South African hop growing cycle.

(September) could lead to phenological changes to the plants, which could cause an earlier onset of flowering (Brits, 2010). This could have significant impacts on the operations calendar of a farm, particularly if such farm is diversified (like most in the Waboomskraal area (De Lange and Mahumani, 2010)). Furthermore, an increase in the number of hot days during the rapid growth period of early summer (November through to December) will increase the evapotranspiration rates (and hence the irrigation requirement) of the plants (Brits, 2010). Growers can respond to these impacts in various ways, including changes in cultivar selection, changes in cultivation practices (crop rotation, irrigation, soil moisture retention, and temperature control (cooling) regimes), changes in harvest practices, and diversification. The choice of strategy will depend on the expected climatic stress factors (determined by the duration and intensity thereof), and the financial implications of the different interventions.

Numerous trade-offs are present in adaptation strategies to climate changes. For example, because commercial farmers aim to provide optimum growing conditions for the hops, the probability of applying deficit irrigation as a medium to long term response strategy to a water shortage, is unlikely and farmers will rather take hectares out of production and ensure that the remaining hectares are irrigated optimally (De Lange and Kleynhans, 2007). This implies that if climate projections suggest a decrease in rainfall, the number of hectares under cultivation could decrease, as opposed to a decrease in yield per hectare. Furthermore, if a grower

decides to increase water use efficiency by upgrading his irrigation system to for example drip irrigation, the benefits of overhead sprinklers in terms of countering temperature spikes (through the cooling effect of such sprinklers) will be lost. The choice between different management practices is thus determined by the risk profile of the grower, which is in turn, affected by the time frame under consideration. For example, a seasonal drought will leave little time for growers to respond to such an event. Consequently, most will cover their short term risks by means of short term crop insurance instead of changing their cultivation practice.

Medium and long term temperature forecasts suggest that daily maximum temperatures in the study area during September/October through to February/March will increase by 0.7°C on average, while daily minimum temperatures will be 0.79°C higher. This temperature increase will increase the demand for irrigation water during the irrigation season with approximately 6 mm/month (or 60 m<sup>3</sup>/ha/month) to maintain field capacity, implying a total additional 30 mm (or 300 m<sup>3</sup> of irrigation water per hectare) for the five month growing cycle (Chapman, 2011). This implies an additional 144 900 m<sup>3</sup> of water on an industry level over the growing period. Furthermore, Figure 3 suggests an expected decrease in rainfall of approximately 9 mm for October (the beginning of the rapid growth period of hops). This is considered a significant change which will need to be accounted for in irrigation scheduling (a further 6 mm decrease is expected for May, but this falls outside the irrigation season). The current irrigation requirement for October is

**Table 1.** Production cost structure for hop farming operations in the Waboomskraal area. Data sourced from hop farms survey report (De Lange and Mahumani, 2010).

Description	Production cost (R/ha/yr)
Annual re-plant @ 1.5%	313
Wages	15 955
Pesticide	2 754
Twine	1 340
Fertilizer	4 530
General maintenance	10 486
Fuel	5 627
Electricity	4 437
Research levy	438
Insurance	2 636
Communication	943
Manager salary	8 420
Equipment hire	535
Licenses	331
Fees	897
Interest on overdraft	2 971
Current cost depreciation	9 350
<b>Total</b>	<b>71 964</b>

rainfall for October decreases by 9 mm, this deficit will need to be supplemented by irrigation, which implies that the total irrigation need for October will become 72 mm. The overall increase in the demand for irrigation water (resulting from the expected increase in temperature in addition to the decrease in rainfall) implies an increase in irrigation costs in the production budget for hops (Table 1 shows the 2010 production cost structure). Given that borehole water costs approximately R5.99/m<sup>3</sup> (as calculated in De Lange and Mahumani, 2010) (operating, maintenance and depreciation included), it is estimated that the temperature increase (above-mentioned 300 m<sup>3</sup>/ha) will increase the production cost by R1 798/ha; while the decrease in rainfall in October (additional water requirement of 90 m<sup>3</sup>/ha) will add R540/ha. A total additional cost of R2 338/ha over-and-above the current total production cost of R71 964/ha is expected.

Given an average yield of 1 739 kg of dried hops per hectare and a current market price of R51.39/kg for dried hops (Conway, 2010), the increase in temperature will require a price increase of R1.03/kg (that is, R1798 / 1739 kg), while the decrease in October rainfall will require an increase of R0.31/kg (that is, R540 / 1739 kg) (total price increase of R1.34/kg), to maintain the current margin above specified cost.

## Conclusion

Changing climate patterns have operational and structural impacts on the capacity of commercial agriculture. This changing environment implies that the adaptive capacity is determined by the flexibility of commercial agricultural production systems, and is an increasingly important component of successful commercial farming practice. This study focused on the adaptive capacity of commercial hop farming operations in South Africa and illustrates the inflationary impact of climate change impacts on hop producer prices.

The South African hop producer price model is cost-based with fixed returns, and aims to maintain gross margins above specified cost. This rather unique setup is due to the small size of the industry and the unique production and processing setup in South Africa; whereby local growers do not dry their hops but deliver wet hops directly to breweries for drying and processing. The fact that returns on investment are fixed, provides the assurance that cost increases and inflationary pressure cannot erode the profitability of hop farming operation. The study estimated that an increase of R1.34/kg in the producer price of hops is required to offset climate induced water-related risk on hop cultivation practice in the study area. This figure was estimated via a cost-based approach employing a crop production model based on crop production functions from the literature and was used to simulate the functional relationships between changes in temperature/rainfall and irrigation requirements. The

increase that will maintain profitability.

Crop production models are consequently useful tools for assessing the vulnerability and response of crops to climate change. This study highlighted the fact that such a model does not currently exist for the South African hops industry. The study presents the need for a dedicated study to calibrate hops production functions for South African conditions and South African cultivars which can serve as basis for regression based models for future climate change scenarios.

### Conflict of Interest

The authors have not declared any conflict of interests.

### REFERENCES

- Brits G (2010). Personal communication. Cultivar breeding programme, SAB Hop Farms Pty Ltd, George.
- Chapman RA (2011). Personal communication. OneWorld Sustainable Investments, Cape Town.
- Conway L (2010). Personal communication. Farm manager, SAB Hop Farms Pty Ltd, George.
- De Lange WJ, Kleynhans TE (2007). Towards more inclusive long-term bulk water resource management. *Agrekon* 46(3):371-397.
- De Lange WJ, Mahumani BK (2010). An agricultural economic perspective on water related risk to hop farming operations in George, South Africa. CSIR report number: CSIR/NRE/RBSD/IR/2011/0049/A, Stellenbosch.
- Engelbrecht FA (2010). The physical basis for climate change over southern Africa. IN DRAPER, P. & MBIRIMI, I. (Eds.) *Climate change and trade: The challenges for southern Africa*. Pretoria, Fanele (an imprint of Jacana Media) in association with the South African Institute for International Affairs, ISBN: 978-1-920196-28-8.
- Engelbrecht FA, McGregor JL, Engelbrecht CJ (2009). Dynamics of the conformal-cubic atmospheric model projected climate-change signal over southern Africa. *Int. J. Climatol.* 29:1013-1033.
- Kassier WE, Spies PH (1988). An agro-economic study of the George District with special reference to hop production. Institute for Futures Research, University of Stellenbosch, Stellenbosch.
- Kleynhans TE (1991). An agro-economic study of the George District with special reference to hop production. Department of Agricultural Economics, University of Stellenbosch, Stellenbosch.
- Kruger AC (2006). Observed trends in daily precipitation indices in South Africa: 1910-2004. *Int. J. Climatol.* 26:2275-2286.
- Kruger AC, Shongwe S (2004). Temperature trends in South Africa: 1960-2003. *Int. J. Climatol.* 24:1924-1945.
- McGregor JL (2005). C-CAM: Geometric aspects and dynamical formulation. CSIRO Atmospheric Research Technical paper, Report number: P. 70, Canberra.
- Mozny M, Krejci J, Kott I (1993). CORAC hops protection management systems. *Comput. Electr. Agric.* 9:103-110.
- Mozny M, Tolasz R, Nekovar J, Sparks T, Trnka M, Zalud Z (2009). The impact of climate change on the yield and quality of Saaz hops in the Czech Republic. *Agricultural and Forest Meteorology* 149:913-919.
- Peter C, De Lange WJ, Musango JK, April K, Potgieter A (2009). Applying Bayesian modelling to assess climate change effects on biofuel Prod. *Clim. Res.* 40:249-260.