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Climate change and the future of South Africa's wine industry

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ABSTRACT

An attempt is made to synthesise the lessons from at least four different ways of looking at the South Africa wine industry: economics, climatology, viticulture, and the sociology of work. To this end, the economic performance of South Africa's wine industry since democratisation in the early 1990s is reviewed, as is the effect of climate change on the industry. This is followed by an assessment of possible strategies for building international competitiveness whilst simultaneously coping with the effects of climate change. Here we argue that, while industry systems should allow the marketing of speciality wines (e.g. from a single vineyard, from a single estate), this is not a viable strategy for most wine producers. Furthermore, climate change will lead to volatility in the characteristics that identify different terroirs. For this reason, industry strategies should rather focus on the benefits of diversity, but with a range of adaptations that will also result in better quality wines. These encompass quality; geographic location; viticultural practices; the style of wines and the renewal of skills. In synthesising this argument, we then consider whether such a strategy could enhance or hinder greater international competitiveness for the industry.

Key words: Climate change; wine; South Africa; competitiveness

Introduction

South Africa's wine industry has performed well since the first democratic elections in 1994. Wine exports have increased to 20% of the country's total agricultural exports, and investment and employment in the industry has increased. There is however evidence that the industry has already been affected by climate change, and that this impact will continue in the future. How then should the industry react to the twin challenges of building international competitiveness and coping with the effects of climate change?

In this article, the literature on the impact of wine industries on local economies is reviewed, and then the South African evidence of economic performance is provided. This is followed by a review of the literature on climate change in the industry. In the third section a range of possible strategies for building competitiveness and managing the climate change effects are discussed. In conclusion, the possible effects of these strategies on the competitiveness of the industry are assessed.

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Economic performance

A brief literature review

The economic performance of an industry is measured as the direct plus the indirect and induced impacts of that industry. The direct impact is the value of production, indirect impacts are the result of changes to other industries that result from these changes in production (e.g. more bottles and labels are bought), while the induced impacts arise because wages and salaries in the industry change, which induces changes in downstream industries when these are spent. These impacts are typically measured as the value-added of the industry and the activities that this induces in the wider economy, the latter using multipliers, which are usually based on an accounting matrix. While there are many examples of this type of study in the literature, there are few examples in the wine industry globally. Benito (1998) estimated the economic impact of wineries on the economy of Sonoma County in California using a countywide Social Accounting Matrix, while MKF Research (2005) conducted a similar study for the Napa Valley using similar methods. Full Glass Research (2006) estimated only the direct and indirect impacts of the Oregon wine industry. More recently, Storchmann (2010) used a panel econometric model to examine the impact of growth in the wine industry on the revenues of hotels and restaurants in Oregon State.

In South Africa, the South African Wine Industry Information and Systems (SAWIS) has commissioned research on the economic impact of the wine industry on three occasions over the past decade (Conningarth Economists, 2000, 2004, 2009). In these reports, the consultants also estimated the direct, indirect and induced impacts of the wine industry, in the same manner as the Sonoma and Napa studies, in this case using a regional Social Accounting Matrix as base. The results are discussed later in this article.

The South African wine industry: a profile

Table 1 provides some basic facts about the South African wine industry. The first four rows of the Table show that the number of wineries (cellars) increased from under 300 in 1997 to almost 600 in 2010 (row 4), and that this has largely been the result of expansion in the number of private cellars, which increased from 218 in 1997 to 504 in 2008, but have subsequently declined. The final row in this section of the Table shows that most of these new cellars are small: the proportion of cellars that crush less than 100t of grapes per year has increased from a quarter of the total in 1997 to almost half in the past five years.

The second set of rows in Table 1 shows the trends in new vine planting over the past decade. Since about 2004 the area has stabilised, and is currently declining, while the proportion of vines younger than 4 years has declined consistently since the beginning of the current decade. It would seem, therefore, as if the industry has consolidated with little prospect for future growth in absolute size given the uncertain investment climate in South Africa (see e.g. Sandrey and Vink, 2008).

The last set of rows reflects changes in the size and composition of the wine that is made from grapes harvested in the industry. The industry's capacity to produce wine, distillates and grape juice concentrate increased by some 20%, the proportion of 'good wine' increased from 62% of the total to 80%, and exports increased from some 12.5% of the harvest to 50%.

Table 1: Basic trends in the South African wine industry, 1997 - 2008

	1997	2002	2004	2006	2008	2010
Cellars						
Producer cellars (number)	69	66	66	65	58	54
Private cellars (number)	218	349	477	494	504	493
Producing wholesalers (number)	8	13	18	17	23	26
Total wineries (number)	295	428	561	576	585	573
Cellars that crush 1-100 t of grapes (number)	77	171	272	280	267	265
Cellars that crush 101-500 t of grapes (number)	76	111	114	137	150	151
Cellars that crush 500-1000 t of grapes (number)	32	38	56	41	50	45
Cellars that crush 1000-5000 t of grapes (number)	52	56	60	63	63	57
Cellars that crush 5000-10000 t of grapes (number)	19	24	21	20	15	20
Cellars that crush >10000 to of grapes (number)	39	28	38	35	40	35
% of cellars that crush <100 tons pa	26	40	49	49	46	46
Vines						
Total vine area (ha)	87301	96233	100207	102146	101325	101016
Vines 4 years and older (ha)	76025	79073	85331	89426	92504	93198
Vines younger than 4 years (ha)	11276	17160	14876	12720	8822	7818
Vines < 4 years as % of total	12.92	17.83	14.85	12.45	9.5	7.7
Wine						
Total production (million litres)	881	834	1016	1013	1089	985
Wine production (million litres)	547	567	697	710	763	781
Good wine as % of total wine	62.09	67.99	68.60	70.09	70.06	79.3
Domestic sales (million litres)	402	388	351	345	356	346
Exports (million litres)	46	218	268	272	412	379
Proportion of total (%)	12.60	26.14	26.38	26.85	53.9	48.5
Income from wine as % of total	67.74	76.30	71.52	72.16	75.57	80.1

Source: SAWIS, various years. South African wine industry statistics. Paarl, South African Wine Industry Information and Systems

The industry has a strong impact on the South African economy as a whole, as is evident from Table 2 (Conningarth Economists, 2009). The industry had a total turnover of R19bn (US$2.5bn) in 2008, of which R3.3bn (17%) was from primary production and the rest from secondary activities, which includes distilling. Exports contributed R6bn or just on one third of total turnover, while imports are negligible, reflecting relatively high tariff protection.

Table 2: Economic structure and the flow of goods and services in the wine industry

	(1)	(2)	(3) = (1) – (2)	(4)
	Incremental turnover (Rm)	**Exports (Rm)**	**Domestic Sales (Rm)**	**Current Import Level (Rm)**
A Primary				
1. Farming	2 236	893	1343	0
2. Cellar	1084	433	651	0
Total Primary	3320	1326	1994	0
B. Secondary				
Distilling, bottling, etc.	5644	2254	3390	211
Trade, catering, accommodation	6741	2692	4049	26
Taxes (VAT and Excise)	3459	0	3459	0
Total secondary	15844	4947	10898	237
C. Sub-total (A + B)	**19164**	**6272**	**12892**	**237**
D. Tertiary				
Foreign tourism	3463	0	3463	0
Domestic tourism	800	0	800	0
Total tertiary	4263	0	4263	0
Total (C + D)	**23427**	**6272**	**17154**	**237**

Source: Conningarth Economists, 2009

Table 3 shows that the growth in nominal turnover was greatest in the value-adding part of the industry, with farm gate turnover increasing by a mere 37% compared to domestic retail (45%) and export (99%) growth. Interestingly, employment increased by 43%, whereas employment in agriculture generally has declined.

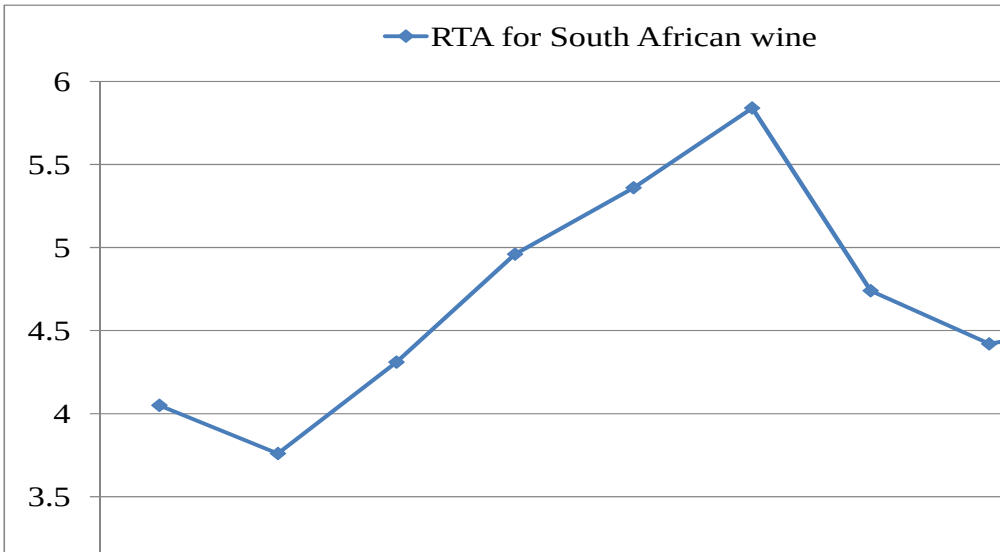
Table 3: Growth rates: 2003 – 2008; main economic components (current prices)

	2003	2008	Nominal change (%)
Primary Production (Rm)	2406	3320	37
Total Turnover (Local Wine Output) (Rm)	10675	19164	79
Manufacturing Production[1] (Rm)	3274	5644	72
Exports (Rm)	3153	6272	99
Taxes/Excise (Rm)	2022	3459	71
Local Sales[2] (Rm)	4223	6113	45
Direct and indirect employment (number)	192252	275606	43

Notes: 1. Before trade and transport margins and taxes; 2. Without taxes
Source: Conningarth Economists, 2004, 2009

However, this performance is less impressive when seen in an international context (Figure 1). International competitiveness is measured as the extent to which the growth in net exports of a product such as wine relative to a benchmark (in this case South Africa's net exports of all agricultural products) is faster or slower than global growth in wine exports relative to all agricultural exports. When the ratio, called the Revealed Trade Advantage (RTA), is greater than one, South Africa's industry is doing relatively better than that of its competitors. Figure 2 shows that South Africa's RTA was greater than one throughout the past decade, but the increase between 2001 and 2004, and that there has been a substantial decline since 2005, most likely the result of the strengthening of the currency.

This is confirmed by the growth of wine exports from other New World wine producers, which show that South Africa's export growth is overshadowed by Chile and Australia, and has only recently overtaken the USA, a country with a large domestic market. Given that the South African industry is dependent on the export market (with domestic per capita consumption at only 6.9 litres in 2010, compared to 22.4 litres in Australia and 8.4 litres in the USA) (SAWIS, 2011), this performance is somewhat disappointing.



Source: Faostat, 2010

Figure 1: The Revealed Trade advantage (RTA) for South African wine, 1990-2008

Thus, the political changes in South Africa, the subsequent economic boom and the wine industry's own efforts have combined to allow the wine industry to grow, and to contribute substantially to the economy. However, the greatest vulnerabilities of the industry remain namely a declining domestic market and exports that still consist largely of wine in the basic price categories. While basic wines have been the driving force behind the export performance (and hence international competitiveness), the diversity argument also holds for labels in the 'mid-range' price category. Therefore, diversity of terroir units is what defines most South African wines. The question is to what extent is this threatened by climate change.

Climate change: observed trends

Since 2007 and the release of the IVth Intergovernmental Panel on Climate Change report, global warming has been widely accepted as a real threat, with consistency across observations worldwide (Trenberth *et al.*, 2007). Climate change is a reality and its impacts are increasingly felt in South Africa.

At the **national** scale, an economic study on agricultural impacts, based on three scenarios, indicates that crop net revenues could fall by as much as 90% by 2100, with small-scale farmers affected most severely (Benhin, 2006), although the adoption of mitigation strategies could reduce these negative effects. Other studies also show the potential impacts of climate change on different South African ecosystems, e.g. fynbos (Midgley *et al*., 2002), animals (Erasmus *et al.*, 2002), and dunes (Thomas *et al.*, 2005).

Studies on climate change at the **regional** scale of the South Western Cape, the traditional wine grape-growing area of South Africa, show that climate change has already affected the wine industry. Research shows significant trends in rainfall and air temperature: in a study of 12 weather stations located in the South-Western Cape over the 1967-2000 period, Midgley *et al.*, (2005) found significant warming trends for minimum (around +1°C for December to March) and maximum temperatures for nearly each month of the year. Very warm days have become warmer and have occurred more frequently during the last decade, particularly during January, April and August.

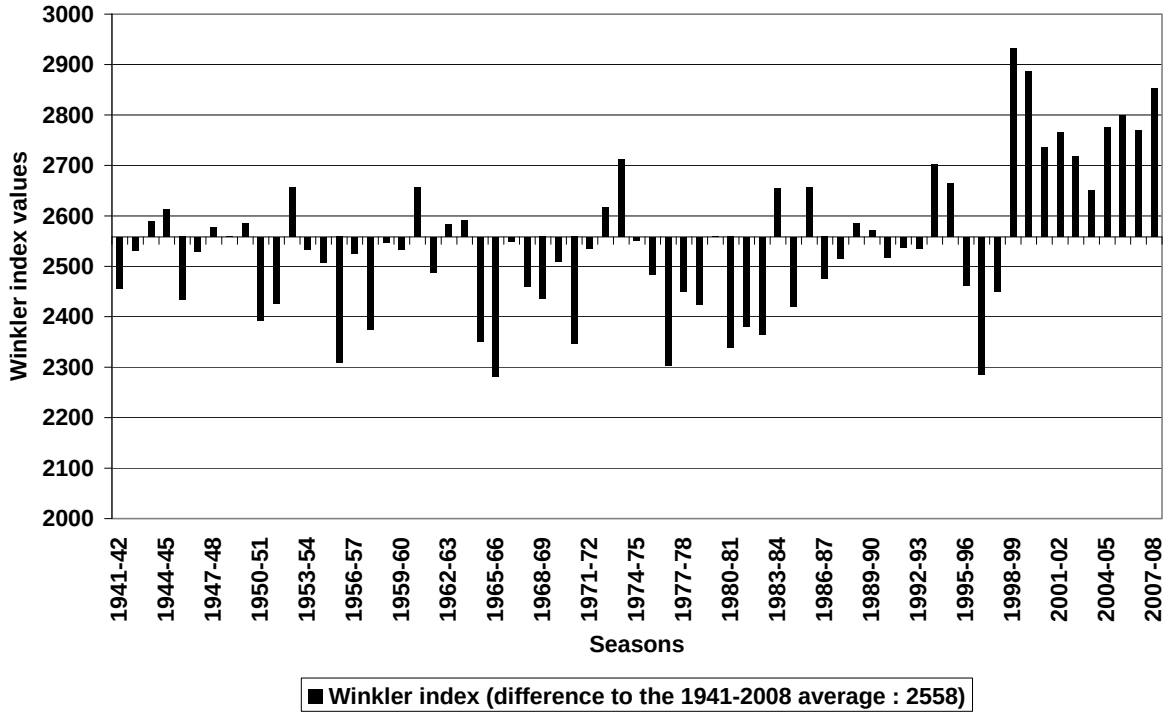
Globally, research on climate change and its impact on viticulture gained momentum with the publication of an article by Schultz (2000). An analysis of weather stations located in South African vineyards over the period 1942-2006, for example, showed that the wine regions of the Western Cape have experienced a significant increase in temperature over the past decades (Bonnardot and Carey, 2008). The annual temperature increase ranged from 0.5°C to 1.7°C (Table 4).

Table 4: Temperature changes in the Western Cape, 1964-2006

Wine regions, districts or wards	Increase in annual max temp (°C)	Increase in annual min temp (°C)	Increase in Growing Degree Days (Sept-March)	Period of record	Duration of records
Stellenbosch	+1.7	+0.7	+150	1967-2006	40 years
Paarl	+1.1	+0.5	+200	1970-2006	36 years
Worcester	+1.0	+1.1	+150	1967-2006	40 years
Olifants River	+1.1	+0.8	+240	1973-2006	34 years
Robertson	+0.5	+1.1	+150	1964-1994	30 years
Constantia	+1.0	+1.0	+180	1967-1999	32 years
Overberg	+1.6	+1.1	+180	1964-1994	30 years
Walker Bay	+0.8	+0.5	+100	1977-1990	13 years

Source: Bonnardot and Carey, 2008

According to Bonnardot and Carey (2008), the first signs of warming were higher winter maximum temperatures starting in the late 1960s, while a significant break in the annual temperature series occurred in the mid 1980's, with a warming acceleration since 2000. This is similar to trends found in the literature (Laget *et al*., 2008). The increase in mean temperature was calculated as 1.8°C for the months of February and July and the increase in growing season mean temperature was calculated as +0.7°C for Stellenbosch district over the 1967-2010 period (Bonnardot et al., 2011). The calculation of the Winkler index for viticulture using a longer data series (1941-2008) from the Bien Donne weather station in the Paarl Wine of Origin district clearly confirms the increasing rate of warming over the last decade (Figure 2) (Bonnardot *et al.,* 2009).



Note: Average and standard deviation for the 1941-2008 period were 2558 and 168 respectively**.**
Source: Adapted from Bonnardot *et al.,* 2009

Figure 2: Winkler index (1941-2008) for Bien Donne in the Paarl district

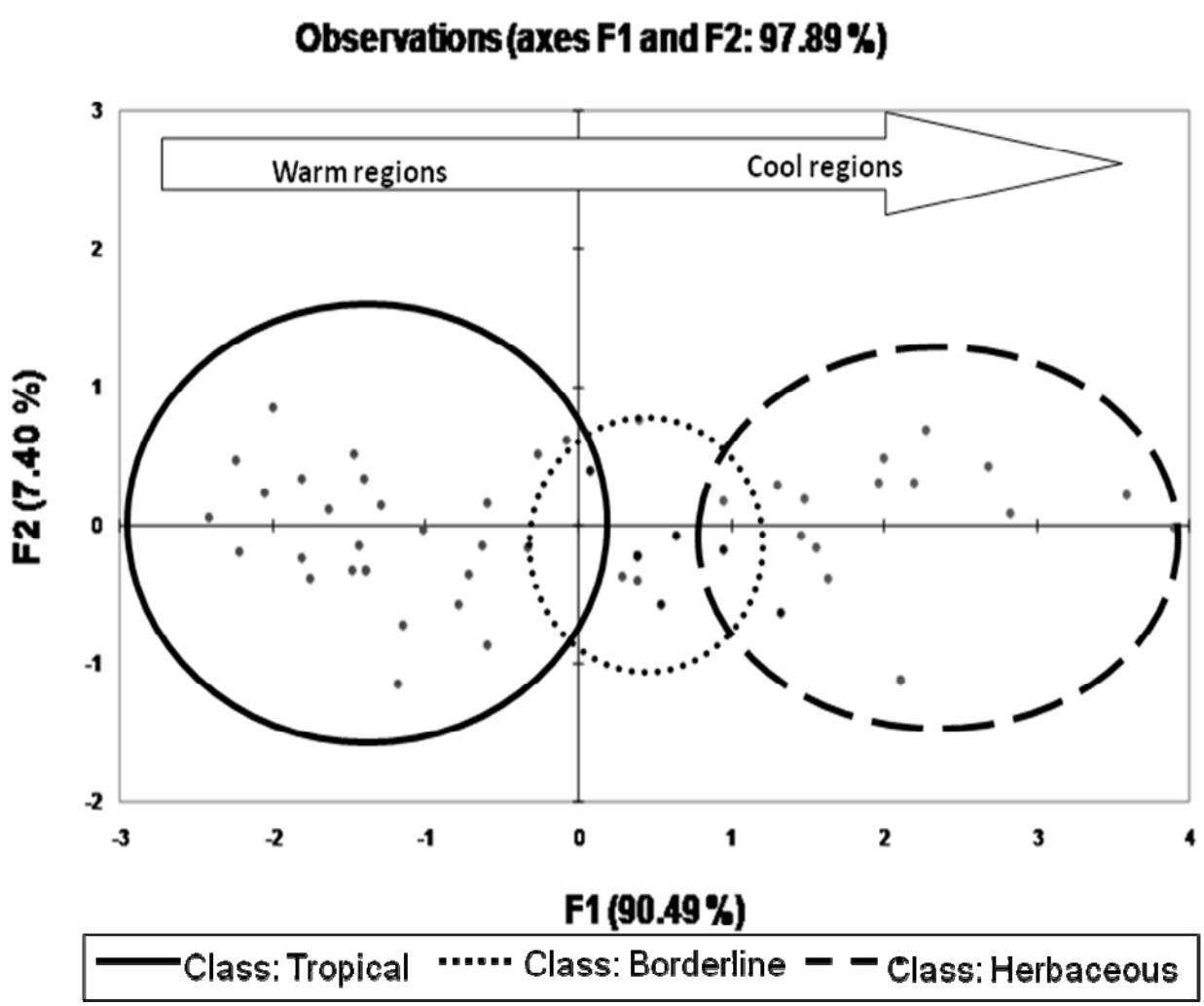
Studies on future expected climate conditions for South Africa show that temperatures can be expected to rise everywhere in the South Western Cape, with the smallest increases in areas adjoining the coast. Typical increases range from ~1.5ºC at the coast to some 2-3ºC inland of the coastal mountains by 2050 (Midgley *et al*, 2005). Based on 30-year control climate (1961-1990) of Global Climate Models, rainfall projections for mid century (2046-2065) over the Stellenbosch, Paarl and Franschhoek wine regions show diminished winter rainfall, particularly in early winter (Carter, 2006). Generally speaking, one can expect warmer and drier conditions for vineyards.

Despite these observed regional trends, the best strategy for surviving climate change seems to be to deal with diversity. The diversity in soil type and depth, and in climate (mainly at the meso climate level) in the South African viticulture regions, including the proximity of the Atlantic and Indian oceans, allows growers to plant a wide variety of cultivars. This is

important considering that these regions are able to produce different wine categories, types and styles. A wine region is not seen as able to produce only one typical type or style (as in the French appellation system) but several, including by blending the same cultivar from different terroir units in different regions. The potential to move into new territories is also a new challenge for the South African wine industry and a provides a strong competitive advantage against countries using the system of “appellation d’origine protegee”.

For this reason, it becomes necessary to experiment with cultivars based on their potential tolerance to temperature and/or drought and on their disease tolerance or resistance. The key to surviving climate change firstly requires an understanding of climate at different scales, including the microclimate (plant level) and the mesoclimate (vineyard level), in order to correctly adapt according to the location-specific potential for viticulture – for example to adapt the training system, row orientation and cultural practices such as irrigation, soil and canopy manipulation. Studies dealing with climate at different scales have shown, for example, the effect of inter-annual microclimatic variability on Sauvignon Blanc wine aroma (Marais, *et al.,* 1999; Deloire *et al*., 2010), or the effect of proximity of the Atlantic Ocean and complex topography on local air circulation (sea and slope breezes) resulting in interesting spatial climatic variability for viticulture (Bonnardot *et al*., 2001; Carey *et al*., 2003; Bonnardot *et al*., 2002; Hunter and Bonnardot, 2002; Conradie *et al*., 2002). The cool night index (Tonietto and Carbonneau, 2004) recently calculated for the 2008-2009 season at locations situated in the Overberg (Elgin), Stellenbosch and Paarl wine of origin districts clearly confirms macro and meso-climatic effects, with differences of up to + 6°C over a 40 km distance from the Atlantic ocean (Deloire *et al*., 2009).

The current diversity of climatic and soil conditions in South Africa allows the elaboration of different types of wine (rosé, red and white wine, port, sparkling and sweet wine) of different styles. Sauvignon Blanc, for example, illustrates the effect of climate on the yield potential and the style of wines (tropical or green/herbaceous characteristics with different levels of wine complexity), which is mainly related to the climate of a specific region (warm-hot versus temperate-cool), bunch microclimate (light and temperature; sea breeze effect), and/or vintage. This is illustrated by the results of a recent study as illustrated in Figure 3. Principal component analysis of 52 Sauvignon Blanc wines shows that the style of wine, in terms of intensity of tropical and/or green characteristics, seems mainly related to the thermal condition of the regions at the macroclimatic level (warm versus cool). At the bunch level (microclimate), light and temperature in a specific mesoclimate will influence berry composition and the style of wine, increasing the diversity of wine styles. Factor 1 (F1) indicated by the horizontal axis explains 90.49% of the variance in the data and factor 2 (F2) indicated by the vertical axis explains 7.40% of the variance in the data set.



Note: The authors thank Ms Leanie Louw and Ms Sulette Malherbe of Distell in Stellenbosch for these results from a sensorial analysis of Sauvignon Blanc wines

Figure 3: Principal component analysis of 52 Sauvignon Blanc wines in the Western Cape Province of South Africa

Furthermore, the vintage-to-vintage variation is an important factor for wine style (Jones, 2007). For the Western Coastal area in South Africa, the heat wave periods, which are not predictable and which occur during the berry growth and ripening stages, can change the berry aromatic profile and the style of wine (Conradie *et al*., 2002; Bonnardot *et al*., 2005; White *et al*., 2006; Deloire *et al*., 2009; 2010; 2011).

Strategies to mitigate the impact of climate change

Historically, the South African wine industry has been characterised by its diversity, but this is threatened by climate change. When a warm region, for example, becomes a hot region, diversity in the type and style of wine that can be produced becomes limited. On the other hand, the industry is situated in an area where there is still potential for further expansion into temperate and cool areas, for changes in viticultural and oenological practices, and for changes in wine styles, all factors that could enhance diversity.

The 'quality' of South African wine and climate change

Although the industry has seen improvement or 'upgrading' over the last 15 years (Ponte & Ewert, 2009), most South African wine is still sold in the basic price category, both here and abroad. Here 'basic quality' refers to wines characterised by three elements: (1) intrinsics and packaging; (2) food safety codes (and to some extent environmental and social concerns); and (3) logistics. With regard to intrinsics and packaging, retailers tell suppliers what to bottle, what kind of label and cork to use, the weight and shape of the bottle, and the recycling possibilities. Specifications in 'intrinsics' can generally be measured or described easily, and include levels of alcohol, total acidity, volatile acidity, sulphur dioxide content, residual sugar content, methods of protein and cold stabilization, a flavour profile, and general wooding regime (unwooded, lightly wooded, etc). In order to list with a retailer, a supplier needs to deliver on intrinsics at the specific price point (e.g. £4.99), which could mean, for example, 'fruit forward, clean, easy drinking wine in the right packaging … and consistency year by year' (Ponte & Ewert, 2007). In the UK market, all wines sold under £5 per 750 ml bottle fall into this category. In continental Europe, this applies to all wines sold under €7. In 2005 the average sales price of a bottle of South African wine in the UK was £3.77, while in 2008 the average price per litre (off trade) that South African wine fetched in the UK was £5.04 (ACNielsen, 2008)

Secondly, most of the 'basic quality' wine that goes into popular labels is sourced from a variety of producers and cooperatives, spread all over the Cape winelands, and 89% of wine produced by cooperatives ends up in the bottles of wholesalers and exporters (PWC, 2010: 13). In other words, wine in these bottles is a blend of a number of different and divergent regions or 'terroir units'.

This is evident from the wines certified by the Wine and Spirits Board (WSB). For instance, of the 333 million litres certified in 2005, most (69%) originated from a broad geographical unit (e.g. 'Wine of South Africa' or 'Wine of Western Cape'). More specific origins under the Wine of Origin scheme applied to 29% of total certified wine, while 'estate wine' accounted for only 2% of total certifications (SAWIS, 2006). It is these wines, made only from grapes grown on a single farm or neighbouring farms, that come closest to the classic meaning of 'terroir' or 'terroir units'.

Ironically, these cellars that have the most to fear from climate change, because as 'estates' they have the least flexibility to compensate for the possible impact of climate change on their vineyards. Private cellars, producing wholesalers, exporters and cooperatives on the other hand, can compensate by sourcing grapes from different growers within the same region, or from growers spread over a whole range of different regions. Thus, given the reality of climate change, the appropriate strategy for the future of the South African wine industry may lie in maintaining this flexibility by exploiting the *diversity* in its vineyards.

Geographic shift

Climate, soil surveys and water availability assessments are important factors in establishing new locations for grapevines, selecting cultivars, assessing the viability and profitability of the vineyard and managing vineyards. Climate change holds implications for changes in wine styles due to changes in berry ripening processes and altered cultural and oenological practices. Furthermore, climatic change may already have contributed to the development of new wine regions in South Africa. The search for cooler locations towards the coast, where

the moderating effect of the ocean is expected to temper increasing summer temperatures, or at altitude, as well as the development of vineyards towards the eastern part of the Western Cape Province with a more evenly distributed rainfall are existing responses to climate change (Bonnardot & Carey, 2008).

Viticultural practices

Worldwide, interval lengths between the main grapevine phenological stages have declined, with bud break to bloom, veraison or harvest dates shortening by 14, 15 and 17 days respectively (Jones, 2007). According to Jones (2007), grapevine phenology shows a 3-6 day response per 1°C of warming over all locations and varieties over the last 30-50 years.

High temperatures increase grapevines' evapotranspiration, which could, in the long term, lead to an increased demand for irrigation water at a time when agricultural use of water is coming under increased pressure (Chaves *et al*., 2010). Thus the concept of precision viticulture and precision irrigation is important, as water has to be saved if viticulture is to be pursued in a sustainable manner.

However, adapting the training system to drier conditions will necessarily lead to a reduction in grape yield per vine and per hectare, which could in turn impact on the profitability of wine grape production, and have an impact on the type and style of wine that can be produced (i.e. also on the profitability of wine production). Without irrigation, the climatic conditions of a terroir unit will influence the choice of the training and pruning systems and dictate the yield per vine and per hectare. In this regard table 5 provides an overview of possible changes to viticultural practices that could arise as a result of climate change in South Africa.

Table 5: Climate change and possible evolution in viticulture and oenology

Problems that could occur due to climate change	**Possible causes**	**Possible solutions**	**Bibliography**
Delayed or uneven bud break	- deficiency of winter cold temperature - inappropriate spring temperature and wind speed (macro and meso climates) - inappropriate soil temperature - deficiency of soil water content	- cultivar – climate adaptation - pruning calendar	Carbonneau *et al*., 2007 ; Myburgh and van der Walt, 2005; Seguin *et al*., 2005; Horvath *et al*., 2003 ; Huglin, 1986; Buttrose, 1970.
Change in phenological stages	- increase in temperature (macroclimate) - inappropriate soil temperature - deficiency of soil water content - choice of pruning date	- cultivar – climate adaptation - pruning calendar - Irrigation	Bonnardot & Carey, 2007; Hunter & Myburgh, 2001; Jones & Davis, 2000.
Yield reduction	- increase in temperature (decrease in bud fertility, uneven flowering and flower fertility) - deficiency of soil water content (less or uneven rainfall distribution, increase in evapotranspiration, scarcity of water for irrigation) - uneven bud break	- choice of cultural practices (precision irrigation, canopy manipulation, cover crop) - choice of canopy architecture (training system: large vs. small canopy) - choice of plantation density according to the soil vigour (number of buds per	Van Zyl, 1984; Bindi *et al*., 1996; Bindi *et al*., 1997; Ojeda *et al*., 2001 ; Deloire *et al*., 2004.

		hectare)	
Change in harvest date	- increase in temperature (macro and meso climates) - deficiency of soil water content - choice of pruning date - change in cultural practices (irrigation vs. dry land) - change in canopy manipulation (bunch and canopy micro climate)	- cultivar – climate adaptation - choice of new cultivars - pruning calendar - precision irrigation - canopy manipulation x row orientation x training system	Carey, 2001 ; Bonnardot *et al*., 2002; 2001; Ojeda *et al*., 2002.
Change in wine type and style	- increase in temperature and evapotranspiration (macro, meso, micro climates) - deficiency of soil water content (soil types and depth) - change in bunch and canopy microclimate.	- cultivar – climate – soil adaptation - choice of new cultivars - precision irrigation - canopy manipulation x row orientation x training system	Deloire *et al.*, 2010; Bonnardot *et al*., 2009 ; Carter, 2006 ; Myburgh, 2006 ; White *et al*., 2006 ; Jones *et al*., 2005 ; Chuine *et al*., 2004 ; Carey *et al.*, 2003, Tate, 2001.

Style of wine

The average alcohol content of wines has been increasing, but in the face of consumer trends that favour more healthy lifestyles. While this does not seem to have had an impact on the wine industry thus far (either globally or in South Africa), it is clear that this is a trend that needs to be taken into account. The reasoning that considers berry ripening only in relation to the brix evolution is no longer relevant. From a certain level of brix it is necessary to stop berry sugar accumulation and to stabilise berry volume evolution to be able to achieve the berry ripening process without an important increase in brix. New indicators such as berry sugar loading (for red cultivars) or berry colour evolution (for white cultivars) which allow determination of the berry aromatic sequence during ripening, should help in controlling this process in the vineyard and in choosing the optimum harvest window in relation to the desired style of wine (Deloire *et al*., 2008; 2009; 2010; Deloire, 2011). Another interesting solution is to select cultivars and clones those that are able to ripen berries at a low level of brix.

The wine making process could be adapted to the harvest potential in terms of berry composition, including de-alcoholization and the possible use of new strains of yeasts (Cambon *et al*., 2006; Malherbe *et al.*, 2003; Erten and Campbell, 2001). Another indirect consequence of temperature increases could be the use of more energy in the cellar to cool down the harvest and to store the wine in tanks, which could adversely affect the carbon footprint of the cellar.

Finally, inter-annual/seasonal climate variability still exists and affects the characteristics of the berry composition and wines of a specific region, which could lead to the so-called vintage effect, because variations between vintages in the Western Cape Province are mainly due to the unpredictable heat waves.

Human resources and the renewal of skills

At the farm level the production of better quality wine requires the implementation of particular technical measures in the vineyard, such as correct soil preparation, cultivar-terroir adaptation, canopy manipulation, yield control, and environment-friendly production. This, in

turn, requires that workers possess skills that are different from those applicable to mass production (Pastre, 1999; Thevenot, 1998; Montmollin, 1986).

Cultivar-terroir adaptation is an essential element of the production of grapes for quality wines. Because cultivars are often new and the terroir quite diverse, growers are forced to build up spatial data bases of various kinds, enabling the identification of plants' agronomic behaviour and the oenological results of grapes according to their annual variability in the different parts of the vineyards (Carey, 2001).

In addition, the control of plant vigour, i.e. the achievement of balance between vegetative growth and yield on a per vine basis is one key factor in the berry composition and its concentration of sugar, organic acids, aroma precursors, phenolic components and other elements that are basic to the successful production of high quality wines. Thus, it is crucial to monitor the individual behaviour of vines due to the strong heterogeneity of soil type, depth, water content and topography. This precise monitoring is meant to adapt each action on the vine to its actual needs (Archer, 2001). As a result, in the quality era, pruning, suckering, leaf removal, and other aspects of canopy manipulation have to be executed in accordance with the specific condition of the vines and the related style of wine. The same goes for yield control. In addition, environment-friendly techniques are increasingly defined as an additional attribute of 'quality' (e.g. reduced use of chemicals, carbon footprint, water saving).

Workers now have to be sufficiently trained to respond to novel ('abnormal') situations in the vineyard. Workers now have to diagnose the state of the vine in its environment and act upon the vine in a way that brings the biological system to a state of balance. They need to be able to distance themselves from the 'template', and to understand the situation within a framework of rules that are less straightforward than under mass production. As Pastré (1999) puts it, 'the labour process evolves from one of repetitive gestures on undifferentiated objects, to action upon dynamic systems'. In the 'quality era', observation and diagnosis are of key importance in the vineyard, and workers are required to make considered judgements and to exercise discretion.

Since the mid-1990s South Africa has made major strides in quality management in the vineyards, including management on the basis of separate blocks (i.e. 'block grading'). Learning has taken place on most wine farms, no doubt assisted by the fact that most viticulturists and winemakers are the holders of a tertiary degree or diploma. However, it is generally agreed that on the viticultural side there still is considerable room for improvement (Ponte & Ewert, 2007). Amongst others, there is a need for stronger multidisciplinary integrated research programs and more attention to detail (so-called 'precision viticulture').

This implies that there is not only a need for the 'upgrading' of farm worker skills, but for a new way of transferring these new skills. Amongst training providers, there is broad agreement that most wine grape growers still need to make a mind shift with regard to the training of their workers. Even today, workers are taught only the most basic rules regarding vineyard practices (for example, 'leave two eyes per grower'), and training very seldom includes education about the physiology of the vine (Brown-Luthango, 2007). This has a number of consequences. For example, workers do not know what impact a particular action is likely to have on the plant as a biological system, while when the worker is confronted with a situation for which standard rules make no provision he/she has to wait for the farmer's instructions. Furthermore, most farm workers do not get much exposure to different ways of doing things as training is mostly done by the farmer/manager.

One of the ways in which this situation could be rectified is for growers and cellars to arrange training sessions at a central venue in every wine region to which producers could send their workers (this does happen in some wine regions, e.g. Robertson). Here the latter could be exposed to outside training providers and to workers from other farms and cellars. Practical demonstration of lessons learned in class could take place at a variety of vineyards and cellars, increasing the exposure to novel situations even further.

In facing the training and education challenge sight should not be lost of the fact that a significant percentage of the labour force (still) suffers from social pathologies such as alcohol abuse, tuberculosis and HIV/Aids. Therefore, in the South African situation, the focus can never be on technical training alone. The latter has to go hand-in-hand with 'human development' (e.g. personal development like enhanced self-esteem, literacy, health care). As it stands, the comparative cost of labour on South African wine farms may be lower than in some of the other wine producing countries, but it is also less skilled, less productive and less geared to the 'quality era'. Although the temptation is always there to cut labour costs before anything else, producers would be well advised to invest in the education, training and personal development of their workers - for one simple reason, viz. it is very difficult to produce 'world class' wine without an educated labour force.

Synthesis

The South African wine industry has experienced a boom period since the end of *apartheid* and regulation some 17 years ago. This manifested itself in a rapid growth in the number of wineries, a considerable growth in wine exports, and increased employment. Yet the export performance has not been as strong as that of Australia and Chile, while both domestic sales and per capita consumption of wine is declining. Furthermore, bottled wine exports have been dominated by blended wines of a 'basic' quality.

Research on climate change shows that a sharp increase in temperature is already being experienced in the Western Cape Province. Future climate projections show that this upward trend is expected to continue and rainfall is expected to decline or to be distributed differently throughout the seasons. In this regard, South Africa's wine grape growing regions are characterised by diversity (in climate, topography, soil type, etc.), and for most farmers diversity is the key to managing the effects of climate change, mainly in terms of increasing wine complexity brought by blending wines from different terroir units/regions.

These observations form the basis of an assessment of the impact of climate change on the industry, and of steps that can be taken to manage this impact. The dimensions of the impact relate to geographic shifts, viticultural practices, the style of wines produced and the need to improve the skills of farm workers. In brief, the South African wine industry has already shown considerable flexibility in shifting geographically to new production areas that are characterised by cooler climates, in adapting viticultural practices to wine styles, and upgrading the skills of farm workers. However, regarding the latter more needs to be done.

Whether the resultant pursuit of diversity in the production of wine will strengthen or weaken the international competitiveness of the industry will depend on a number of factors. First, diversity may be threatened by climate change unless appropriate strategies are put in place. Second, climate change could have consequences for the industry that are not yet fully understood (e.g. in the form of logistical challenges in the new areas, over-capacity in infrastructure in existing areas, etc.). Third, greater diversity should increase the demand for a

wider combination of wine varieties, vintages, wine styles and terroir characteristics, which could lead to a greater number of (branded) products that have the prospect of fetching higher prices than more undifferentiated wines. Fourth, there is likely to be greater demand for wines with lower alcohol levels, especially as health concerns become more important in shaping consumer choice. Finally, consumer choices are also driven by concerns over the sustainability of agricultural production. Where the exploitation of natural diversity leads to a smaller environmental impact, greater social responsibility toward farm workers, etc. producers will also benefit. Ultimately, however, the impact of the pursuit of greater diversity on competitiveness will depend on whether this will result in higher quality products moving the industry away from its reliance on 'basic' and bulk wines.

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