The use of local knowledge relating to vineyard performance to identify viticultural terroirs in Stellenbosch and surrounds

Utilisation des connaissances locales relatives à la performance des vignobles pour identifier les terroirs viticoles à Stellenbosch et aux environs

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Abstract: A terroir represents grouping of homogenous environmental units, or natural terroir units, based on the typicality of the products obtained. Identification and characterisation of terroirs depends on knowledge of environmental parameters, the functioning of the grapevine and characteristics of the final product, which must be placed in a spatial context. Field studies, resulting in point data, are considered to be necessary to investigate the functioning of the grapevine, but the use of representative sites to determine the response of the grapevine to its environment is time consuming and costly and limits terroir studies to research related investigations. We surveyed vineyard managers on their perceptions of the functioning of established Sauvignon blanc vineyards in the Stellenbosch Wine of Origin District. Comparison of data generated with these questionnaires to measured data in commercial vineyards suggested that the vineyard managers were able to characterise the performance of vineyards with respect to vigour, signs of drought stress and yield. Each vineyard was mapped and the responses were linked to modelled environmental variables. This data was used to construct decision trees, which could be applied to environmental data in a geographic information system to determine viticultural terroirs for production of Sauvignon blanc.

Key words: GIS, survey, Sauvignon blanc, vineyard managers, terroir

Introduction

A terroir can be defined as the ecosystem of the grapevine (Seguin, 1986), and it represents the agricultural aptitude of a delimited area. This aptitude results from interaction between the stable environmental features of the site and results in specificity of product (Morlat, 1989). As the product forms an integral part of the definition of terroir, the identification and characterisation of viticultural terroirs requires a thorough understanding of the reaction of the grapevine to its site environment. This entails monitoring the performance of the grapevine at a number of representative sites for an extended period of time, at least seven-years (Vaudour, 2001), to obtain a picture that is representative of the long term.

The Stellenbosch Wine of Origin District is an interesting study area due to its complex topography, geological history, soil distribution and proximity to the ocean. These parameters result in a complex environment for wine production. This region has formed the focus of a number of terroir related studies in South Africa (Carey, 2001; Bonnardot *et al.*, 2002; Conradie *et al.*, 2002). These studies have used reference plots in commercial vineyards, spanning ten years. Such studies are time consuming and costly and limit terroir studies to research related investigations.

Although some studies may be initiated to determine the viticultural potential of virgin areas, many are for existing wine producing regions with a long viticultural history. In the latter, empirical knowledge already exists amongst the producers of the region. A survey amongst producers was performed at a plot level in the Loire Valley to validate the existing identification and characterisation of terroirs and in an attempt to propose a way of simplifying the existing methodology (Thélier-Huché and Morlat, 2000; Bodin, 2003). This paper addresses the usefulness of a survey of the intrinsic knowledge of vineyard managers in the Stellenbosch Wine of Origin District to identify terroirs for production of Sauvignon blanc wines.

Materials and methods

Knowledge of vineyard managers

1. Cultivar and vineyard selection. The study area included the existing Stellenbosch Wine of Origin District. *Vitis vinifera* L. cv. Sauvignon blanc was selected as cultivar. Within the Stellenbosch Wine of Origin District there are 191 farms that cultivate Sauvignon blanc (1,655 ha) (SAWIS, personal commun., 2004). Twenty vineyards were used for field measurements during the 2002/2003 season. These had comparable trellising systems and bud load and were well established (8 to 15 years old).

2. Survey amongst vineyard managers. Questions soliciting a combination of unstructured line scale, multiple choice and free choice answers, were included. The categories included genotype, environmental characteristics (measured and perceived), management practices, perceived vegetative and reproductive performance and expected berry aroma characteristics. A postgraduate student in viticulture facilitated the completion of the questionnaires in an attempt to ensure standardisation of responses. A total of 98 producers completed surveys. This covered 344 vineyards on 113 consolidated farms (1,105 ha).

Field and laboratory measurements

1. Grapevine measurements. Measurements of pre-dawn and midday leaf water potential and visual monitoring of stress symptoms were performed post-véraison. At pruning, cane mass and mean cane length were measured. A 20 kg bunch sample was taken before commercial harvest for sensorial and chemical analyses.

2. Must extraction and analyses. Grapes were destemmed and crushed, sulphur dioxide was added at 25 mg/L and the pomace macerated overnight at 15°C. Juice was extracted with a balloon press. Free-run and first-press juice were collected and settled overnight at 15°C with addition of a commercial pectolytic enzyme preparation as per directions, and racked. Must pH, total titratable acidity and soluble solids were determined. Juice was stored in 5 L plastic cans at -20°C. After defrosting at 0°C, the acid was adjusted to 6 g/L by addition of tartaric acid. Free SO_2 and ascorbic acid were adjusted to 30 mg/L. Sensory analyses were performed using generic descriptive analysis on the stored grape juice approximately six months after harvest with no more than five samples tasted in a session. An unstructured anchored line scale was used to describe the aroma of the juice samples.

Spatial data

Vineyard boundaries were digitised from 1:10 000 rectified images (Chief Directorate: Surveys and Mapping, Department of Land Affairs, South Africa). Altitude was determined with a hand-held GPS (Garmin 76s). The dominant soil class per vineyard was determined from a digital soil map compiled from a Peri-Urban Soil Survey (Ellis and Schloms, 1975; Ellis *et al.*, 1976). A 50 m Digital Elevation Model (DEM) was used to determine slope aspect, using Spatial Analyst™ in ESRI®ArcMap™ 8.2. The zonal median value was determined for each vineyard. Spatial climatic data was interpolated from data obtained from an automatic weather station network over a 7-year period in the Stellenbosch Wine of Origin District (F Knight, unpublished data). Zonal statistics in Spatial Analyst™ in ESRI®ArcMap™ 8.2 were used to calculate mean values of pertinent variables for each surveyed vineyard. Natural terroir units were determined by Carey (2005).

Statistical analyses

Vineyards with multiple clones, rootstocks or planting date were recorded with each combination as a separate data row. Correlation matrices were constructed to compare vineyard manager survey results with the respective field measurements (Statistica 6.1, StatSoft, Inc., Tulsa, USA). Classification and regression tree analyses (CART) (Breiman *et al*., 1984) were performed on dependent variables relating to the performance of Sauvignon blanc obtained from the survey. Calculations of variable importance were performed on the complete data set for each dependent variable based on the number of times the variable was used as splitting variable during tree construction and how well it separated the low values from the high values (M Kidd, personal commun.). The data set was then split into a test and a training set. A final tree was built on the training set using predictor variables with the highest relative importance. The model was tested against the test set.

Results and discussion

Comparison of surveyed data with field measurements

It appeared from correlation analyses (table 1) that vineyard managers were able to assess the performance of Sauvignon blanc with respect to vigour, signs of post-véraison water stress and yield. The poor correlation for acidity and ease to obtain sugar may have been due to grape samples being taken before commercial harvest. For some vineyards this resulted in ripeness levels that could be considered below optimal as producers tend to harvest some Sauvignon blanc early in order to obtain strong green pepper and grassy notes for later blending purposes (anecdotal information). The analytical results may, therefore, not be a true reflection of the aptitude of a site for sugar accumulation and maintenance of a good acidity. Significant differences ($p<0.05$) were found between samples with respect to « green » and « fruity » aroma nuances, and when compared to survey data, nine out of 16 entries were considered to be correct with respect to berry aroma as perceived by vineyard managers (data not shown).

Table 1 - A comparison between perceptions of vineyard managers of Sauvignon blanc in Stellenbosch and field measurements from selected vineyards

Survey variables	Field and laboratory measurements	R^2
Acidity	Must pH prior to maceration	-0.38 (n=19)
	Titratable acidity prior to maceration (g/L)	0.15 (n=19)
Ease to obtain sugar	Total soluble solids prior to maceration (°B)	-0.41 (n=19)
Vigour in dry seasons	Cane length (m)	**0.60**[y] (n=19)
	Internode length (mm)	0.37 (n=19)
	Cane mass (g)	**0.47** (n=19)
	Number of lateral shoots per cane	0.39 (n=19)
Vigour in wet seasons	Cane length (m)	**0.59** (n=19)
	Internode length (mm)	0.35 (n=19)
	Cane mass (g)	**0.47** (n=19)
	Number of lateral shoots per cane	0.41 (n=19)
Shoot homogeneity	Cane length (m)	**0.51** (n=19)
	Cane mass (g)	0.29 (n=19)
	Number of lateral shoots per cane	**0.49** (n=19)
Signs of post-véraison stress	Predawn LWP (MPa)	**0.58** (n=18)
	Midday LWP (MPa)	0.31 (n=18)
Yield	Yield / ha (ton/ha)	**0.65** (n=18)

[y]Bold type indicates correlation coefficients that are significant at $p \leq 0.05$

Interaction of Sauvignon blanc with the environment

The wine style or quality of Sauvignon blanc vineyards in the Stellenbosch Wine of Origin District appeared to be closely related to perceived ambient temperature during ripening. Cooler locations were associated with premium wine, while warmer locations were associated with a trend towards good wine production. Comparison of the Winkler Growing Degree-day Index for the two terminal nodes showed a significant difference ($p \leq 0.05$) (data not shown).

For grape-berry aroma the predictor of perceived wind exposure was selected for the final classification tree. The node associated with reduced wind exposure (scores on an unstructured line scale <0.9) was associated with significantly warmer perceived ambient temperature during ripening (results not presented) and was represented by predominantly tropical fruit aroma characteristics. The two nodes associated with moderate and high wind exposure were both associated with lower mean perceived ambient temperatures. Cooler temperatures with moderate wind exposure were associated with berries with predominantly green aroma characteristics. The effect of temperature during ripening on methoxypyrazine concentrations is well documented (Marais *et al*., 1999). A greater exposure to wind was associated with complex aromas (i.e. a combination of green and fruity aroma characteristics). Smaller leaves resulting from exposure to moderate to strong winds and flustering of the leaves may have resulted in increased sunlight penetration and higher levels of fruity and tropical aromas as monoterpenes and C13-norisoprenoids concentrations have been found to increase with increased sunlight penetration in the canopy (Marais *et al.*, 1999).

Vineyards that were situated on well-drained soils (generally red and yellow apedal to neocutanic soils) were associated with less seasonal variation in aroma characteristics (confirmed on the test data, $p \leq 0.0001$). Well-drained soils receive predominantly conservative irrigation, which together with their depth, drainage and water retention characteristics provide a constant environment despite seasonal climatic fluctuations. Wet (generally medium-deep duplex soils) and dry (predominantly rain-fed) soils were associated with increased seasonal variation, suggesting that conservative irrigation is a necessity for residual and apedal to neocutanic soils to ensure consistency in berry aroma characteristics under the climatic conditions of the Stellenbosch.

Berry juice acidity was predicted by air temperature and soil type in the final regression tree (confirmed on the test data set, $p \leq 0.0001$). The first split occurred at a perceived ambient temperature during ripening of 2.7 (score on a 10-point unstructured line scale). Mean modelled values for the Winkler Growing Degree-day Index, as adjusted for South African conditions (Le Roux, 1974), differed significantly ($p \leq 0.0001$) between the two nodes (data not shown). At higher perceived ambient temperatures, soil type played a complementary role in determining acidity. The lowest acidity levels were perceived for medium-deep, wet duplex soils and poorly drained alluvial soils, while higher acidity levels could be achieved for predominantly deep red and yellow apedal to neocutanic soils and residual soils. These soils are associated with higher altitudes (> 200 m above sea-level) than medium-deep, wet duplex and poorly drained alluvial soils. A positive association between altitude and wine acidity has been found in mountainous areas (Falcetti *et al.,* 1990) and the relationship found in the regression tree may therefore be an indirect effect of altitude.

The ease with which sugar is obtained was predicted by perceived wind exposure. The vineyards that were best able to ripen their grapes ($p \leq 0.01$ for the test data) were vineyards that had a greater perceived exposure to wind, predominantly south-easterly winds. Exposure to wind limits growth and results in smaller primary and secondary leaves (Bettiga *et al*., 1997). This increased exposure to wind implies a smaller canopy, concomitant reduced shading in the bunch zone and reduced vegetative competition for photosynthates.

Vigour in dry years was predicted by slope aspect, with the cooler easterly, southerly and south-easterly slopes being associated with increased vigour. This split was, however, only significant at $p \leq 0.1$ for the test data. Vigour in wet years was predicted by slope aspect and perceived ambient temperature during ripening. Higher temperatures were associated with reduced vigour. This model was significant ($p \leq 0.01$ for the test data) but the relative importance of the variables used in the model was fairly low (<70%). The first split (perceived ambient temperature during ripening = 4.8 on a 10-point unstructured line scale) was significantly associated with differences in altitude ($p \leq 0.001$).

Signs of post-véraison water stress were predicted by dominant wind direction, which appeared to relate to the zonal mean value of wind exposure determined for each vineyard. Higher values for wind exposure (>65%) were associated with winds from the SE, SW and S (data not shown). Vineyards where the dominant winds were from the SE and SW had fewer visual symptoms of water stress. These vineyards will be expected to experience moderate to strong, cool wind on most days of the ripening period due to prevailing synoptic (South Africa Weather Bureau, 1996) and local (Bonnardot *et al.*, 2002) winds. Kobriger *et al.*. (1984) found that exposure of shoots to moderate or strong winds under controlled conditions resulted in higher leaf water potential measurements for Carignane compared to control shoots. Similar results have been obtained under field conditions for Chardonnay by Freeman *et al.* (1982).

Altitude strongly predicted the earliness of the growth cycle. Higher vineyards (>247 m above sea-level) had a significantly later growth cycle than vineyards below this altitude.

Shoot length homogeneity was predicted by altitude and perceived wind exposure of vineyards (confirmed on test data, $p \leq 0.0001$). Canopies with a large number of shoots shorter than 60 cm were associated with vineyards with little wind exposure and poorly drained alluvial soils, but were represented by very few cases (5.8%). Increased exposure to wind, and altitudes higher than 126 m above sea-level, were also associated with a large number of shoots shorter than 60 cm. In this case the vineyards may have had less variability in shoot length, but generally shorter shoots.

Yield was predicted by perceived ambient air temperature during ripening and dominant wind direction. Neither of these variables had a high relative importance and the first split did not result in significant differences in mean yield.

Identification of viticultural terroirs for Sauvignon blanc wine production

Based on the results obtained with the CART analyses of perceived variables and the observed relationships with climate and soil digital data, the variables of Winkler Growing Degree-day Index, wind exposure, altitude and soil type were used to determine terroir units for Sauvignon blanc wine production using the categories given in table 2. Natural terroir units were characterised according to these categories (zonal median values) and homogenous NTUs grouped, resulting in 58 viticultural terroirs, 39 of which were represented by the surveyed vineyards.

Table 2 - Categories used for environmental variables in the prediction of viticultural terroirs in the Stellenbosch (no relationship on the horizontal level)

Winkler Growing degree-day Index	Wind exposure (%)	Altitude (m)	Soil type
≤1867	≤65	≤130	Shallow (<0.5 m), residual soils on hard or weathering rock
>1867	>65	>130, ≤247	Red and yellow freely drained structureless or weakly structured soils
		>247	Dry duplex soils
			Medium-deep (0.5 m-1.0 m), wet duplex soils
			Shallow (<0.5 m) complex of wet duplex soils
			Well-drained, deep (>1.0 m), alluvial sands
			Poorly drained, alluvial soils

Comparison of means of the survey data for each of the viticultural terroirs represented by the surveyed vineyards showed that these viticultural terroirs differed significantly in the expected viticultural response of Sauvignon blanc (results not shown).
Further study is required to test the validity of the delimitation with sensory analysis of commercial wines.

Conclusions

This study suggests that the intrinsic knowledge of vineyard managers may be useful as a first attempt to characterise the viticultural aptitude of an established viticultural region.

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