Modelling climate change effects on wine quality based on expert opinions expressed in free-text format: the WEBSOM approach

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Abstract: The motivation for modelling the effects of climate change on viticulture and wine quality using both qualitative and quantitative data within an integrated analytical framework is described. The major constraints and solutions evident when taking such an approach are outlined. WEBSOM is a novel self-organising map (SOM) method for extracting relevant domain-dependent characteristics from web based text and in this case applied to modelling wine quality determined by climate variation, by web text mining a sample of 95 New Zealand wine published descriptions made by sommeliers about this phenomenon. This paper describes experiments using the WEBSOM method with their results.

Keywords: text mining, self-organising maps and artificial neural nets

1 Introduction

Climate change impacts on all forms of agriculture and vegetation. Current awareness of climate change and the phenomenon known as 'global warming' has increased scientific and commercial interest in it and predictions relating to it. The potential influence of climate variation on viticulture and enology is considered as *dramatic* because grapevine crops are among the most sensitive to any small change either in climate or environmental conditions. Historical viticulture records show that the ability of winemakers to produce premium quality wine as highly prone to climate change; short and long term. This historical data is proving invaluable when comparing contemporary data with the past and it is essential for any forecasting or prediction over time. Literature reviewed for this research reveals that viticulturists and winemakers began introducing subtle changes to cultivation practices as well as winemaking processes to overcome short term or annual climate change effects. This can be seen as occurring over centuries to turn climate variation effects to winemakers' advantage, especially to producing finer wine. There is sufficient evidence to support that major shifts of cultivation in whole wine-producing regions as well occurred in the past and as it appears, all these happened in order to produce grapes with a higher percentage of sugar but without comprising the other aroma and colour protein compounds during the berry ripening process. These characteristics of wine quality are considered to be the principal factors relating to the climate of viticulture regions throughout the world. Irrigation, frost, wind and solar influences are also major factors in grape production of course and therefore, are determinants of wine quality [1], [2].

With that introduction to the reasons for using modern knowledge discovery methods to gain a better understanding of climate influence on wine quality, section 2 elaborates on analysing both, qualitative and quantitative data on climate and atmospheric conditions that determines grapevine phenology that in turn determines the sugar and protein components in grapes and its influence on the final wine product. Section 3 outlines the initial results of this research conducted at the Centre for Geoinformatics Research at Auckland University of Technology in New Zealand and already published in [3]. The next section illustrates upon a novel approach being investigated in the Centre for analysing sommelier comments in free text format with the same sample data set, extracted from a web magazine called *Web Enthusiast* [4] for modelling the climate change effects with an unsupervised neural network known as WEBSOM [5]. The final section of this paper proposes future research to model the effects of climate change in greater detail with larger data sets from more grape growing regions and to look at the climate change effects on the world's major wine regions. From this analysis we expect to be able to predict the wine style and appellations suitable for future climate change, short and long term, using data from climate models already developed.

2. The effects of climate change

Climate change is predicted to bring about significant modifications to all forms of agriculture and vegetation on earth [6]. Its potential impact on Viticulture, the world's most expensive cultivated crop and *enology,* is considered by many observers to be *dramatic,* also supported by science that underpins climate change effects as well as historical evidence specific to this crop. Climate change predictions suggest that the variability across the globe to be inconsistent (severe in the northern hemisphere and mild in the southern) and to have a variable effect on different grapevine varieties. Grapevine phenology, such as crop budburst, "*floraison*", "*veraison*", and harvest, greatly depends on weather and climate conditions in different regions, and this is a major factor in determining wine quality. For example, even a single degree centigrade change in temperature is predicted to make the production of the world famous Mediterranean wine appellations

impossible. Grape varieties thrive under significantly narrow climate and environmental conditions, and historical evidence as well suggests that the production of premium quality wine as highly prone to any change in current climate, annual and long term. Research findings with Australian grapevines and wines [7] suggest that a change of grapevine varieties could be a way to overcome the future climate variation effects in that country's major wine regions. This would of course, be an extremely expensive exercise [8], which is why objective scientific analysis for scenario building and prediction is of great significance at the moment.

This paper relates to the second part of the overarching research project called *Eno-Humanas*, (see www.geo-informatics.org and also [9] and [10]) that aims building models based on correlations of dependent variables in the combinatorial set of relationships that comes from data collected relating to climate, atmosphere, soil, terrain, moisture and plant responses (grapevine) in association with wine sensory perception data relating to flavour, odour and fruit robustness. Hence, the title *Eno-Humanas*, is about the combinational analysis of precise ecological data and the less precise qualitative opinion data that comes from wine consumers. This paper relates to the analysis of descriptions (in free text format) of wine quality coming from experts; Master Wine Sommeliers.

3 Previous Research

This section of the paper discusses previous research by others and ours on wine quality and sensory data analysis. It also describes the WEBSOM approach.

3.1 Wine sensory analysis

Literature reviewed for this research on wine quality especially relating to sensory and chemical data analysis can be broadly categorised into the following:

1) *Wine characterisation and discrimination using chemical and sensory properties.* Most of the literature reviewed in wine sensory data analysis falls into this category. They all in essence looked at ways and means that could best identify the differences for developing sub-appellations within major wine appellations such as, champagne, *chardonnay*, and *pinot noir*. For example, a study on a distinctive New Zealand wine style *Marlborough Sauvignon Blanc*, looked at classifying the wine appellation by sensory characterisation and chemical analysis using selected aroma compounds [11]. Another study on red Niagara Peninsula *Bordeaux* style investigated into the differences that might be supportive for designating three sub-appellations with the use of chemical and sensory analysis on forty-one commercially available wines from that region [12]. Similarly, [13] and [14] looked at strategies a) to control champagne wine quality based on sensory and b) red table wine quality characterised by pleasing and complex mouth-feel sensations respectively.
2) *Professional versus novice taster abilities*. There are many studies in this area cited in the literature and another project within *Eno-Humanas* is considering this from an audio-mining perspective to elicit the degree of emphasis (passion) expressed about wine quality in recording of wine tasting by both professionals and novices.
3) *Wine ratings, favourable climatic conditions and price fluctuations*. Research on this subject described in [15] looked at climate and global wine quality factors and discussed a year-to-year comparison over a ten year period. It includes a description of wine quality factors in juxtaposition with prices and vintage ratings. Citing many earlier studies the authors of this work pointed out that the analysis of the relationships between climate variables and wine prices as based on an underlying hypothesis that beneficial climate conditions would improve the wine quality and that in the past, these had in turn led to short term price hikes. They also reflected that unavailability of consistent price data for multiple regions and with different styles over many years was a shortcoming for any analysis on the study of long term effects. They also argued that the vintage ratings to be a strong determinant of the annual economic success of a wine region based on analysis by [16] but then went on to say that the ratings could be determinants of wine quality not necessarily a predictor based on [17] where ratings were described to be reflective of wine in a qualitative manner; they had same weather factors documented to be the determinants of the same wine quality.
4) *Analysis of wine taster descriptions in free-text*. There are not many studies of this kind cited in the literature. Of the studies revealed under this category, two major approaches are outlined herein. In [18] taster comment analysis on different wine experts revealed something about the structure of the language used by the experts to describe wines. In this study, using software called ALCESTE analysts produced groups of word categories from different expert corpuses by calculating the chi square of co-occurrences of words and classified the categories into different classes, such as idealistic, odour, colour, somesthesic, taste and hedonistic. The study concluded that the language structure used by the wine experts as not organised along their sensory dimensions instead with prototypes. When describing wine taste, experts tend to relate it to a prototype rather than stating its properties.

   In another interesting piece of work [19], researchers looked at calculating synthetic liking scores by studying the correlations between pairs of original scores and word groups/counts in free text comments and then compared these synthetic scores with that of the original ones for the sample set of wines studied. The authors used multiple factor analysis to establish the correlations between each pair of comments and their respective liking scores.

Research conducted at University of California Davis [20] found that only 25% of wine liking ratings to be linked to wine sensory descriptive data in a map created with statistical analysis results of the latter on *y* axis and wine ratings on *x* axis. The authors as well found that descriptors, such as "leather" and "sour", as having a

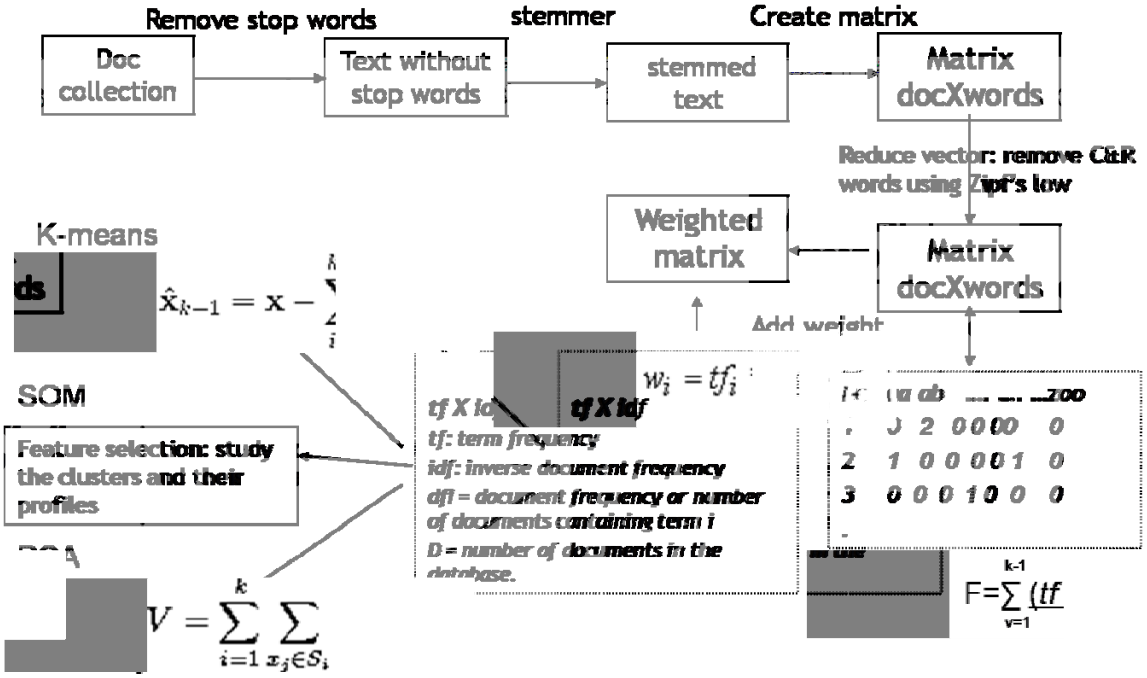


Fig. 1. Diagram on the steps followed to create a word matrix of 95 New Zealand wines being analysed herein.

negative effect on preference and "vanilla/oak" and "canned vegetable", as liked by wine tasters and noted even though 75% of the variations in liking could not be explained, the results should be read with caution.

3.2 WEBSOM applications

WEBSOM provides an efficient methodology for full-text information retrieval and exploration of large collections of documents. It uses Self-Organizing Map (SOM)[1] techniques to statistically analyse any relations between the document collection words based on their co-occurrence in the document set being analysed, and then based on the relationships, creates document maps. As the word co-occurrences are used as basic components for clustering, similar documents get clustered close to each other on the document map. The WEBSOM approach was first developed as a map of documents providing a good basis for search and exploration of documents [21]. WEBSOM applications include unsupervised [22], partially supervised processing of newsgroups [23], browsing interface for web pages for the exploration of document collections [24] and as a method/ tool for data mining in textual databases [25].

In this research, WEBSOM is applied to grouping words based on their co-occurrences in sommelier comments for establishing any year-to-year variations that may exist between the word groups/ descriptors that best describe the wine quality/ wine sub appellations in terms of appearance, aroma and mouth-feel.

3.3 Text mining of sommelier comments using SOM

As a first step in implementing the *Eno-Humanas* concept to model the correlations between climate change effects on grapevine phenology and wine quality with ecological data and sommelier/ wine taster comments, the latter is being investigated using words extracted from sommelier comments (Fig. 1).

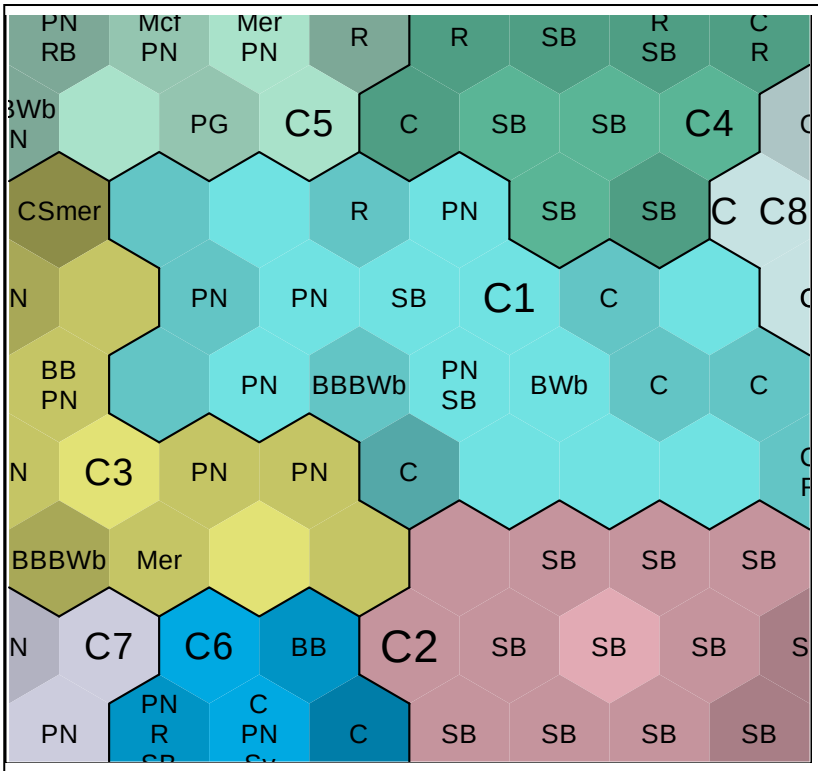
Our initial investigation used a SOM based text mining approach to analyse the comments of 95 New Zealand wine (in free text format) and structured data (name, style, region, year) extracted from a popular web based wine catalogue called *Wine Enthusiast* [3]. After removing stop words, such as a, the, in and etc, and running a stemming program, a matrix of words (*lemmas*) was created from the selected set of wine taster comments. Weights w_i of (1) for the selected words were calculated by applying the well-known information retrieval system called Slaton's vector space model, which is based on a) local information from individual documents and b) global information from the collection of documents [26].

$$w_i = tf_i * log\left(\frac{D}{df_i}\right) \qquad (1)$$

Where,

- *tfi* = term frequency (counts) or number of times a term *i* occurs in a document.
- *dfi* = document frequency or number of documents containing term *i*
- *D* = number of documents in the collection/database.

[1] A SOM (self-organising map) is single layered, feed forward artificial neural network (ANN) that enables the projection of multidimensional data sets onto low (two- or one) displays for easy visualisation and analysis of any correlations within the vectors analysed. The SOMs are well-known for their ability to preserve details embedded in the raw data. Artificial neural networks (ANNs) are collocations of elements called 'neurons' with weighted connections between them. The neuronal structure, the connections, training and recall algorithms define the network architecture. The neurons and ANN structures are imitations of biological (human/animal) nerve and brain cell structures. ANNs became more popular since the 1960s because of their ability to solve problems found to be impossible by conventional algorithmic computing methodologies.



SOM clusters and wine style

C 1: R, PN, PN, PN, SB, C, PN, BBBWb, PN SB, BWb, C, C, C, C

C 2: SB, SB, SB, SB, SB, SB, SB, SB, SB, SB, SB

C 3: CSmer, PN, BB PN, PN, PN, PN, BBBWb, Mer

C 4: R, SB, R SB, C R, C, SB, SB, SB, SB

C 5: PN RB, Mcf PN, Mer PN, R, BBBWb PN, PG

C 6: BB, PN R SB, C PN Sy, C

C 7: PN, PN

C 8: C, C, C

BB: Bordeaux Blend **BBBWb :** Bordeaux white Blend **C**: Chardonnay **CSmer**: Cabernet Sauvignon Merlot **M**: Merlot **MC**: Merlot Cabernet **PG:** Pinot Gris **PN**: Pinot Noir **RB**: Red Blend R:Riesling **SB**: Sauvignon Blanc

Fig.2 SOM 95 NZ word frequency calculated based on Slaton's vector space model using words in wine expert comments. In this SOM of words extracted from expert comments, clusters C1-C8 reflect wine style rather than wine regions of New Zealand (see Figs. 3-5). Clusters C2, C7 and C8 consist of Sauvignon Blanc, Pinot Noir and Chardonnay style wines respectively.

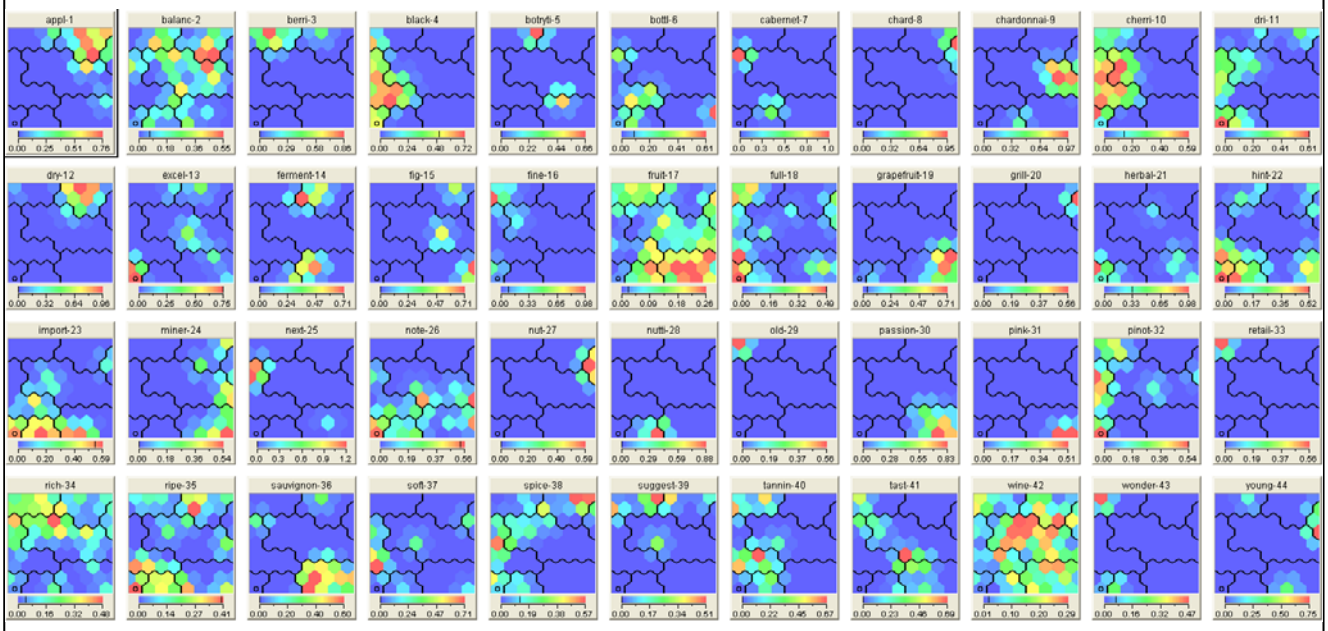


Fig. 3: component planes of SOM (Fig. 2). Cluster 2 of this SOM consists of high word frequencies for Sauvignon Blanc descriptors, such as fruit-17, paasion-30, sauvignon—36 and wine-42. Some of the wines in this cluster consists descriptors miner-24 (for mineral), grapefruit-19, hint-22, import-23, pink-31 and ripe-35.

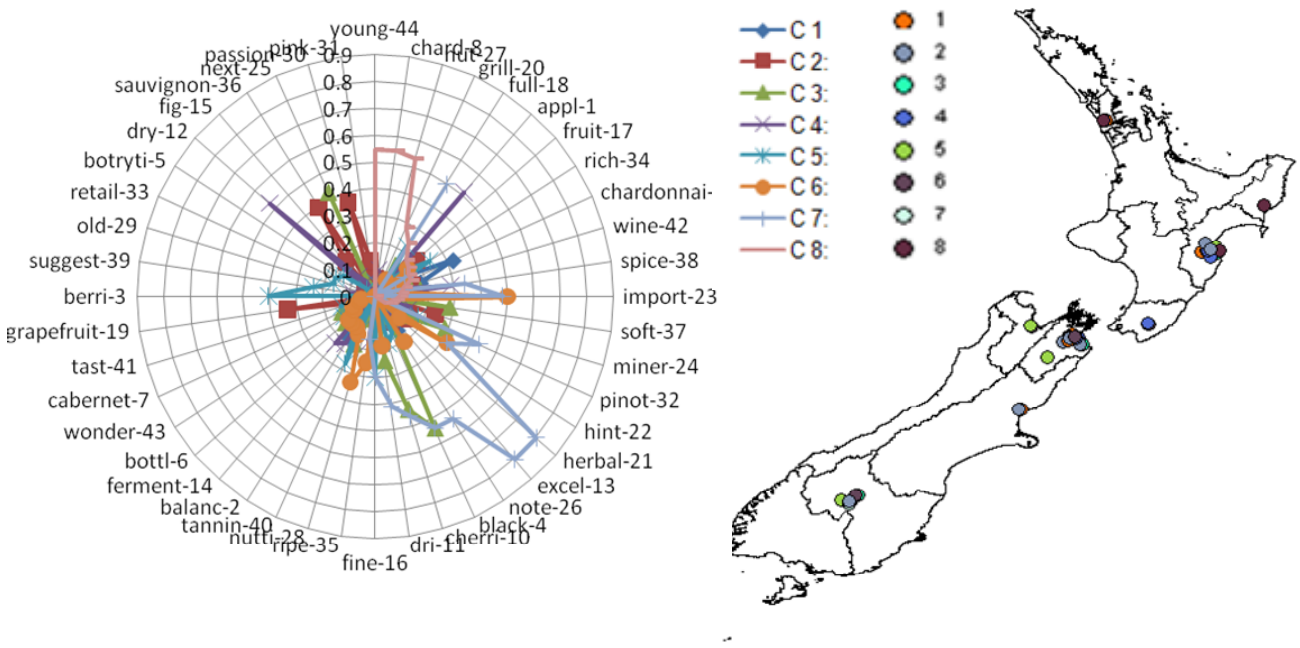


Fig. 4: SOM cluster profile radar (word average values). Cluster 7 wines consist of high weights for herbal-21, excel-13, import-23 and note-26. 4: 95 NZ wine clustering projected on a DIVA map. Wines from far northern New Zealand aren't present in deep southern part of the country and *vice versa.*

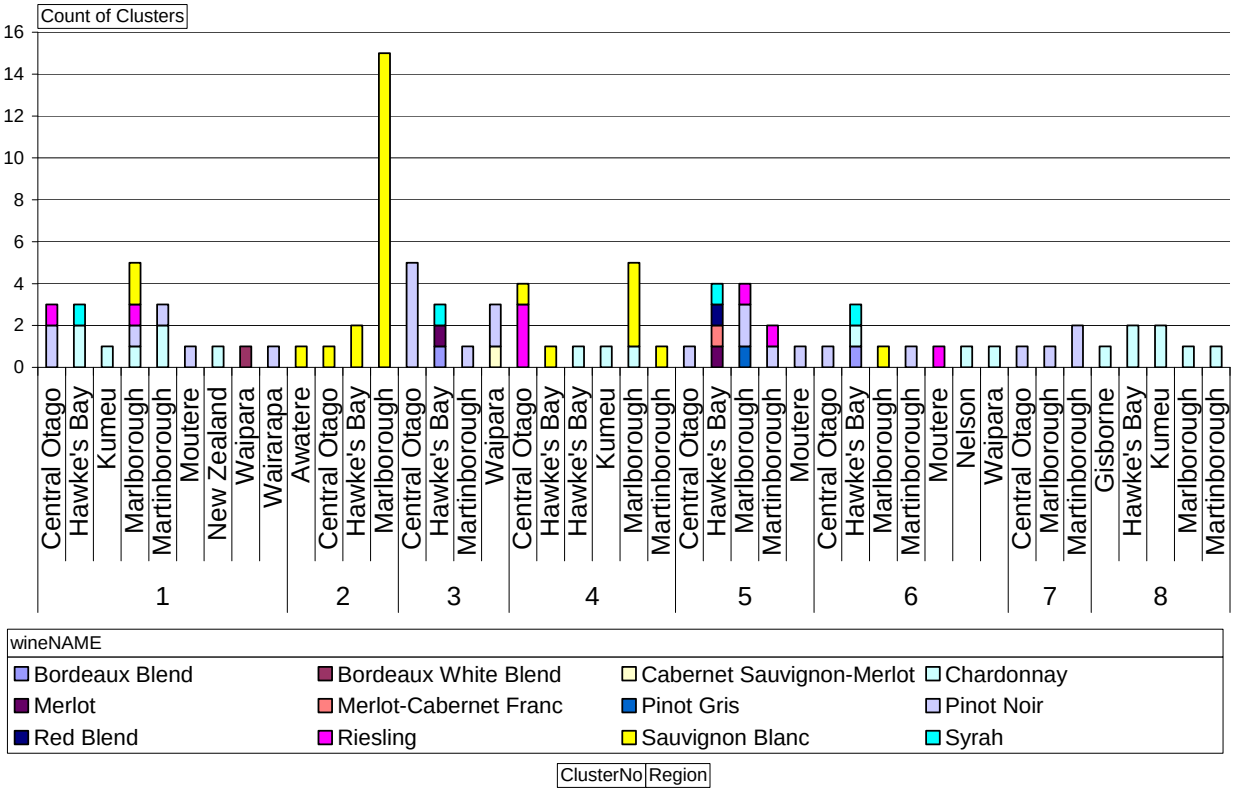


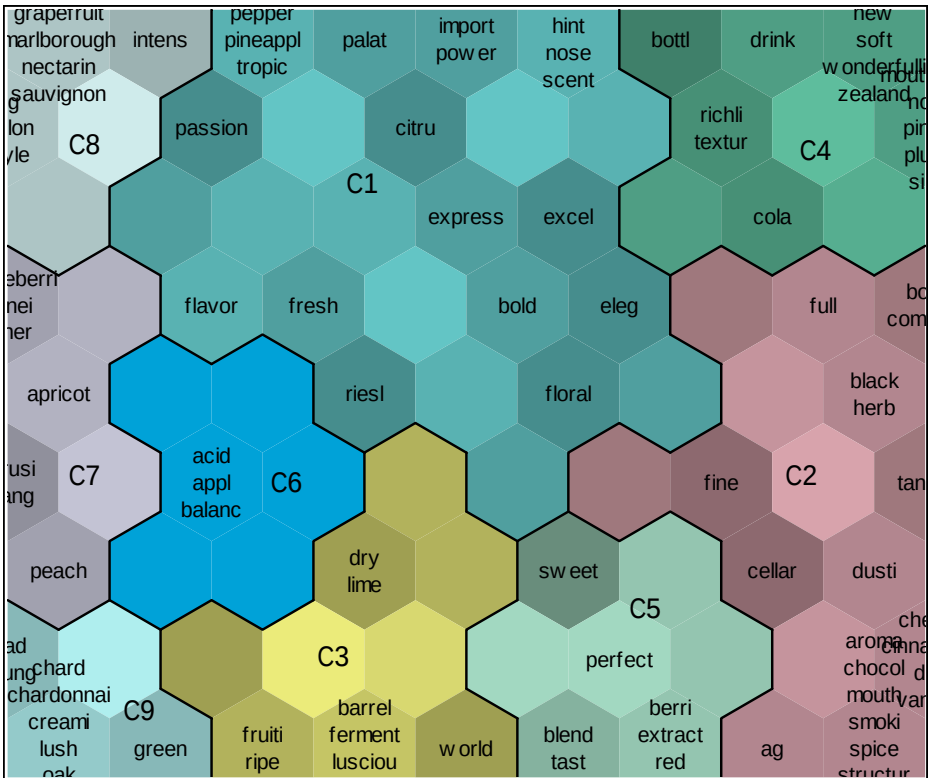
Fig. 5: Histogram showing the number of wines in different clusters (*y* axis) and regions (*x* axis) in the 8 clusters of the SOM created with 95 NZ wine word matrix. In this, cluster 8 consists of *Syrah* wine from Gisborne, Hawks Bay, Kumeu, Marlborough and Martin borough. However, wine appellations from Central Otago could be seen in all SOM clusters except for cluster8. The SOM clusters of word weight frequencies against wines tend to show the variations in wine appellations rather than that of regional.

4 The WEBSOM approach to text mining sommelier comments

The WEBSOM approach to analysing sommelier comments in this study aims to establish any annual variations in the quality of these 95 New Zealand wines, using selected keywords/descriptors from the same set of word matrix calculated for the initial investigation using conventional text mining/ word counting and weight calculation of wine expert comments (Fig. 1). In the WEBSOM approach, SOM clusters of co-occurring words in the 95 NZ wine comments and their cluster profiles are analysed to see the regional, wine style and annual variations embedded within these wine taster comments.

4.1 WEBSOM results

The groups of wine words/descriptors from the WEBSOM approach based on the word co-occurrence in the comments of 95 New Zealand wines being analysed are listed in Fig. 5. Of these groups, C1 words (pepper pineappl tropic, palat, import power, herbal hint nose scent, passion, citru, express, excel, flavor, fresh, bold, eleg, riesl, floral) are used in most of the wine comments hence, this cluster could be classified as common descriptors. These words contribute to the broader categorisation/ at higher levels in a tree/dendrogram) and some discretion is needed in the selection of words to make the wine descriptor grouping more focused, if not such words may force wine comments into not so meaningful groupings.



C 1: pepper pineappl tropic, palat, import power, herbal hint nose scent, passion, citru, express, excel, flavor, fresh, bold, eleg, riesl, floral
C 2: full, bodi complex, black herb, fine, tannin, cellar, dusti, cherri cinnamon dri vanilla, ag, aroma chocol mouth smoki spice structur
C 3: dry lime, fruiti ripe, barrel ferment lusciou vineyard, world
C 4: bottl, drink, layer new soft wonderfulli zealand, richli textur, mouthfeel noir pinot plum silki, cola
C 5: sweet, perfect, blend tast, berri extract red rich
C 6: acid appl balanc
C 7: gooseberri honei miner, apricot, citrusi orang, peach
C 8: blanc grapefruit marlborough nectarin sauvignon, intens, fig melon style
C 9: load young, chard chardonnai creami lush oak smoke toast, green

Fig. 6: SOM created using wine descriptors as variables. SOM clusters C1-C9 of words within wine expert comments, show the groups of words based on these word co-occurrences / combinational use in expert descriptions of 95 New Zealand wines being analysed herein. For example, C6 words (acid, appl (lemma for apple) and balance (for balance)) occur together in sommelier comments

no	Wno	C 1:	C 2:	C 3:	C 4:	C 5:	C 6:	C 7:	C 8:	C 9:	year	wtype	Regior	Cluste	price	year	rate	Comments
75	w75	0.19	0	0	0	0	0	0.31	0.13	0	2004	Sauvig	Awate	1	20	2004	91	bell pepper and
57	w57	0.04	0.05	0	0.02	0	0	0	0	0.04	2002	Pinot_	Centra	1	0	2002	91	the region this is the
60	w60	0.03	0.07	0	0.11	0	0	0	0	0	2002	Pinot_	Centra	2	43	2002	91	the bottle in a slightly
58	w58	0.03	0.1	0	0	0.09	0	0	0	0.06	2002	Pinot_	Centra	4	0	2002	91	this is a
62	w62	0.14	0.29	0	0.01	0.18	0	0	0	0	2003	Pinot_	Centra	5	62	2003	91	and no it-s not
61	w61	0.05	0.23	0	0.06	0	0	0	0	0	2004	Pinot_	Centra	2	60	2004	91	bacony edge to broad
63	w63	0.08	0.09	0.04	0.23	0	0	0	0	0.04	2005	Pinot_	Centra	2	63	2005	91	of reduction on the
25	w25	0.02	0.36	0	0.33	0.07	0.21	0	0	0	2005	Pinot_	Centra	4	35	2005	92	award winner back in
59	w59	0.02	0.22	0	0.46	0	0.2	0	0	0	2005	Pinot_	Centra	1	40	2005	91	wonderfully silky
26	w26	0.02	0.11	0	0.18	0	0	0	0	0.04	2006	Pinot_	Centra	4	42	2006	92	change from
64	w64	0	0.24	0	0.36	0	0	0	0	0	2006	Pinot_	Centra	5	63	2006	91	structured this is the
71	w71	0.07	0	0.31	0	0.06	0	0.03	0.06	0.01	2001	Rieslir	Centr	2	21	2001	91	peaches and
32	w32	0.42	0.07	0.12	0.01	0.12	0	0.13	0.06	0	2002	Rieslir	Centr	5	23	2002	92	expression of Riesling
72	w72	0.14	0.11	0.11	0	0	0.69	0.02	0	0.1	2002	Rieslir	Centr	2	23	2002	91	Riesling is loaded
73	w73	0.04	0.08	0	0.02	0.05	0.37	0.19	0	0	2006	Rieslir	Centr	1	27	2006	91	the sugars are amply
11	w11	0.09	0.02	0.28	0	0.19	0.49	0.07	0	0.23	2001	Sauvig	Centra	1	16	2001	93	s no oak aging or
76	w76	0.12	0	0	0.06	0	0	0	0.3	0	2004	Sauvig	Centra	1	20	2004	91	requisite pea pepper

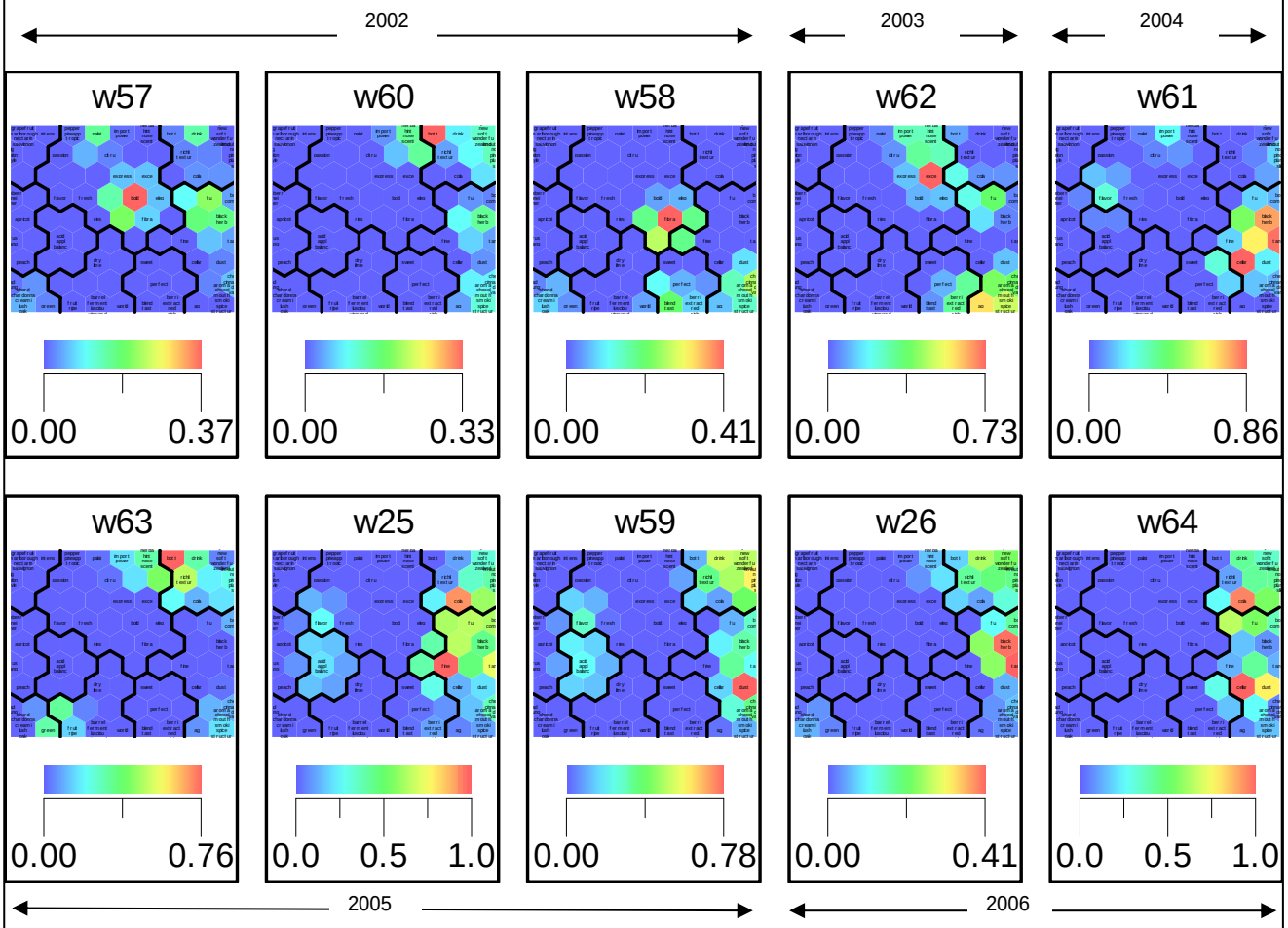


Fig. 7a: Table showing the different descriptors embedded in wine taster comments that reflect regional, wine style and annual variations. In this example, *Pinot Noir* and *Riesling* wines from Central Otago are presented to see whether the word co-occurrences could be used to see any inter annual variations resulting from changes in climatic conditions. The *Pinot Noir* wines from Central Otago do not consist of C7 or C8 words whereas, *Riesling* wines from Central Otago do. In the former group, two of 2005 wines consist of C6 in addition to C1, C2, C4 & C5 words. b: SOM component planes of the wines shown in table 7a.

no	Wno	C 1:	C 2:	C 3:	C 4:	C 5:	C 6:	C 7:	C 8:	C 9:	year	wtype	Regior	Cluste	price	year	rate	Comments
74	w74	0.16	0.02	0	0	0.15	0.48	0	0	0	2006	Rieslir	Marlbc	1	35	2006	91	modest alcohol
38	w38	0.07	0.02	0.01	0	0.18	0	0.22	0.14	0	**1999**	Sauvig	Marlbc	1	35	1999	92	and it shows in
34	w34	0.01	0.01	0.2	0.1	0	0	0.08	0.13	0	**1999**	Sauvig	Marlbc	2	15	1999	92	wine was 25% barrel
82	w82	0.18	0.1	0	0.01	0	0	0	0.34	0	2001	Sauvig	Marlbc	3	13	2001	91	passion fruit form the
85	w85	0.06	0	0.12	0.05	0	0.68	0.28	0.14	0.01	2001	Sauvig	Marlbc	3	17	2001	91	of Marlborough from
12	w12	0.05	0.1	0.22	0	0.15	0.68	0.16	0	0	2001	Sauvig	Marlbc	1	29	2001	93	explosion of lime
80	w80	0.02	0	0	0	0.15	0.48	0	0.2	0.09	2001	Sauvig	Marlbc	7	0	2001	91	extraordinarily
35	w35	0.01	0.03	0.05	0	0.07	0.44	0.24	0	0	2001	Sauvig	Marlbc	2	18	2001	92	complete and
88	w88	0	0	0	0	0.31	0.21	0	0.14	0	2001	Sauvig	Marlbc	3	18	2001	91	very slightly sweet
91	w91	0.13	0.08	0	0	0	0	0.07	0.07	0	**2003**	Sauvig	Marlbc	3	23	2003	91	with complex aromas
86	w86	0.06	0	0	0	0	0	0.03	0.14	0	**2003**	Sauvig	Marlbc	1	18	2003	91	and intense packed
90	w90	**0.25**	0.02	0.01	0	0.23	0	0	0.12	0	2004	Sauvig	Marlbc	1	21	2004	91	style like an arrow to
81	w81	0.13	0.05	0	0.04	0	0	0.27	0.1	0.1	2004	Sauvig	Marlbc	3	0	2004	91	vines in the Awatere
92	w92	0.12	0	0	0	0.03	0	0.06	0.3	0	**2005**	Sauvig	Marlbc	3	25	2005	91	this benchmark wine
84	w84	0.09	0.04	0.03	0.03	0	0.1	0.03	0.06	0.01	**2005**	Sauvig	Marlbc	3	16	2005	91	filled with grapefruit
36	w36	0.07	0.01	0.03	0.04	0	0	0.17	0.43	0.01	**2005**	Sauvig	Marlbc	5	21	2005	92	capable guidance of
37	w37	**0.27**	0.03	0	0.08	0	0	0.07	0.06	0.01	2006	Sauvig	Marlbc	1	27	2006	92	perfumed almost
39	w39	0.18	0.06	0	0.07	0	0.1	0	0.11	0	2006	Sauvig	Marlbc	1	35	2006	92	expressive NZ
87	w87	0.13	0	0	0.11	0.07	0	0.13	0.32	0	2006	Sauvig	Marlbc	3	18	2006	91	Valley this is an
94	w94	0.11	0.04	0.08	0.01	0	0	0.31	0.23	0.08	2006	Sauvig	Marlbc	3	30	2006	91	that this wine is
89	w89	0.02	0.08	0.11	0.05	0	0	0.12	0.32	0	2006	Sauvig	Marlbc	2	20	2006	91	formerly of Lawson-s
93	w93	0	0.03	0	0.05	0	0	0.07	0.32	0	**2007**	Sauvig	Marlbc	3	26	2007	91	usually features
83	w83	0.06	0	0.06	0	0	0.41	0.34	0.47	0		Sauvig	Marlbc	3	16		91	Sauvignon Blanc but
4	w4	0.06	0	0	0.13	0.28	0	0.12	0	0.17	1997	Chard	Martin	7	26	1997	93	regarded as New

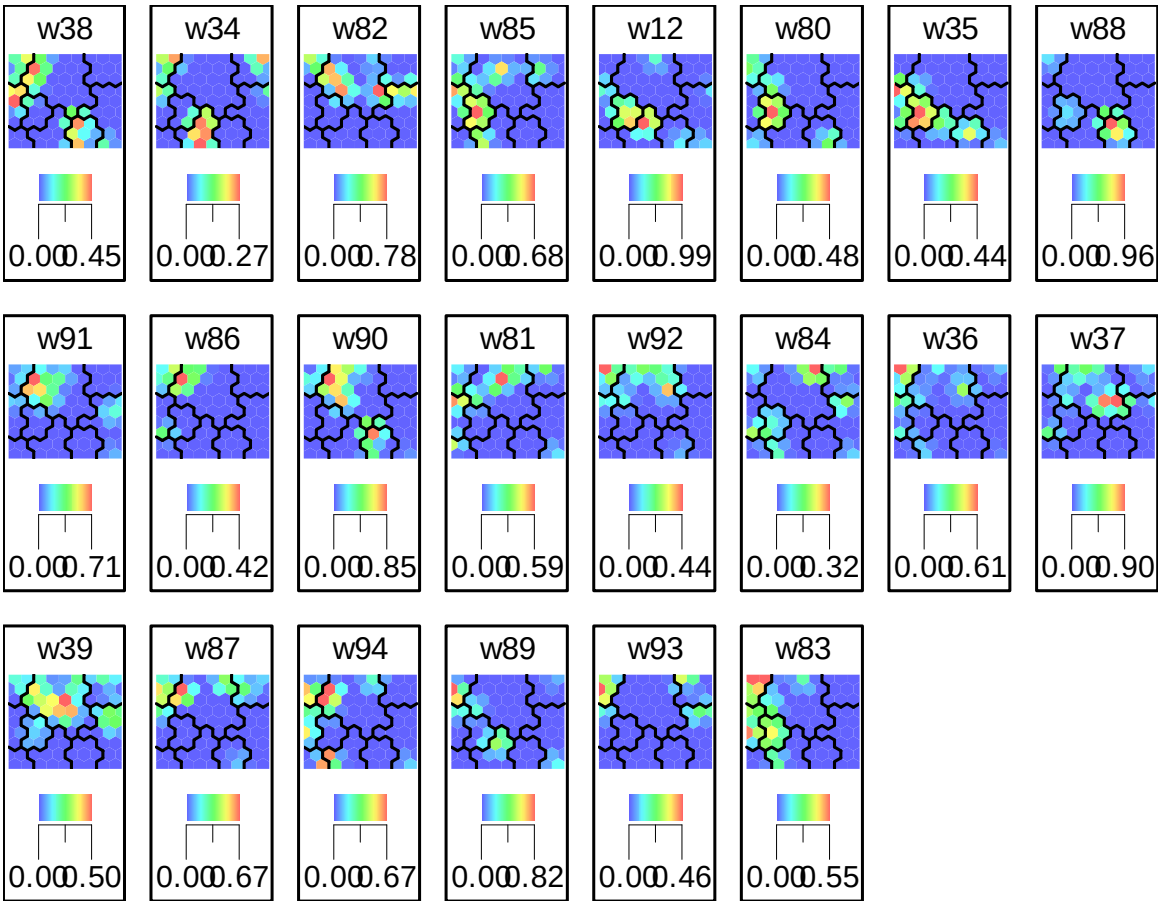


Fig. 8a: Table showing the different descriptors embedded in wine taster comments for *Sauvignon Blanc* style wines from Marlborough region, This group of consist of hardly any C9 words (load young, chard chardonnai creami lush oak smoke toast, green). Of this block 5 out of 6 wine from 2001 have high weight frequencies for C6 words (acid, appl and balnac) and none of the wines from the following years do has. It is also evident that most of 2005 and 2006 wines have high weight frequencies for C8 words (blanc, grapefruit, Marlborough, nectarin, sauvignon, intens, fig, melon and style). **b**: SOM component planes of the wines shown in table 8a.

In figs. 6 a & b, 2001, Marlborough region, *Sauvignon Blanc* wines, all of them have descriptors grouped in SOM cluster C6 words (acid, appl and balanc). Similarly, most of the 2006 wines have high values for C8 descriptors (blanc grapefruit marlborough nectarin sauvignon, intens, fig melon style). In these wines, the use of cluster C9 descriptors (load young, chard chardonnai creami lush oak smoke toast, green) are rare.

In figs. 8 a & b , *Sauvignon Blanc* from Marlborough 1999 wines do not have words from cluster 6 (acid appl balance), however, 5 out of 6 wines of year 2001 have high weight frequencies and none of the wines analysed from the following years do not have. It is also evident that most of 2005 and 2006 wines have high frequencies for C8 words (blanc, grapefruit, Marlborough, nectarin, sauvignon, intens, fig, melon and style).

This shows that the analysis of words/ wine quality descriptors carefully selected could lead to useful word groupings that could in turn point to the inter annual climate variations within the wine expert comments.

5 Conclusion and future work

The initial results of the WEBSOM approach to discerning the descriptors that have the potential to transform the free-text wine comments into quantitative data on wine quality appear convincing. These could be used to analyse the correlations between wine quality and climate change effects. More experimental work is needed though if we are to select appropriate wine quality descriptors and confirm the correlations between these descriptors and other wine factors, such as wine liking scores/ ratings and price. The literature (and history) shows that adjustments are continually being made to grape growing practices in order to produce the best quality crops and thereafter, the best quality wine. We contend that continued work of a scientific nature such as reflected in this paper, will provide useful insights into the dynamics of the interaction between environment and plant growth such that better informed decisions can be made by the growers, especially at this time when global climate change is providing much angst among both wine producers and consumers alike.

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