Viticultural Zoning for the Identification and Characterisation of New Zealand "*Terroirs*" Using Cartographic Data

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Abstract

The paper initially looks at different viticultural zoning traditions as well as modern day approaches, concerns, issues and purposes associated with this form of sectionalisation schemes from a cultural history related development perspective. The empirical studies from literature on this topic and related themes reveal that majority of the still existing traditional viticultural zoning systems relate to a 19th century "French notion" of the well known *Terroir* concept, the latter is said to have originated from Latin many centuries ago. The zoning systems of some generally referred to as "*old world"*, such as France, Spain and Italy, were originally introduced solely to regulate the wine industry especially, to protect winemaker livelihood in already then established wine regions. Interestingly, these old systems and their derivatives portray significantly less reference to geography. In the present day context, many different aspects are managed by zoning a wine producing nation's vineyards and wineries and they are; wine identification and characterisation, vintage labelling, both for implementing regulatory measures over wine marketing strategies with "designated origins" controlled by state institutions, as well as in some instances for irrigation, and are discussed. Consequently, the paper outlines major contemporary approaches being developed and implemented by the *new world*, such as Australia, New Zealand and South Africa, for improving viticulture husbandry practices with scientifically validated technical tweak and know-how obtained by deploying digital data processing and state-of-the-art mapping technologies. Finally, the paper proposes a simple higher level framework at a macro (nation's regional) scale for viticultural zoning to identify and characterise New Zealand *Terroirs* using some basic wine style, climatic conditions required for grapevine growing and altitude data. This framework could be extended for zoning New Zealand wineries using "meso" scale thematic maps, indicators and other essential factors relating to grapevine varietal characteristics, plant growth, local (vineyard site) environmental, climatic and winemaking as well as economic using cartographic data in grid as well as vector formats. This work relates to a wider project called *Eno-Humans* that is aimed at building models to analysing vital associations between different combinations of two major categories of factors, namely; **dependent**, such as grapevine yield and wine quality, the latter generally described in qualitative and rather imprecise forms, often than not perceived as a subjective issue with wine sensory perception descriptors and ratings, and **independent,** such as climate and environmental, available in more precise, quantitative measures and formats. The relevant viticulture factors of both categories are analysed using historic, live and model prediction data sets to better understand and forecast vineyard yield and wine quality outcome scenarios.

Keywords: grapevine, winemaking

Introduction

The popular, centuries-old viticultural zoning practices of Europe originated and evolved presumably in parallel to the development of viticulture and winemaking themselves. The zoning practices were originally introduced by growers of *old world*'s established wine regions solely to protect their livelihood (Stephen Skelton, 2009). Related literature in this domain reveals that the *old world* viticultural zoning approaches have derived from the 19th century's "French notion" of the real "*Terroir*" concept the latter is described to have originated from Latin many centuries ago. The main objective of these zoning

approaches developed based on some form of areal/ territorial demarcation, such as the French *Terroir* units, was to confine a particular taste or character of wine to homogeneous unit/s or "a place" and was used to implicate the unit's "dominant soil features" instead of the grape variety "*cultiva*". Hence, this French notion of very old *Terroir* based wine identification and characterisation could be interpreted as a way of attributing a particular wine label to a "designated origin" or "geographically distinct area". This is seen as an approach used to link a complex phenomenon resulting from the interactions among all aspects belonging to the area i.e., the environment, geography, geology, and "cultural practices" along with spiritual aspects as well that influence grapevine cultivation and wine production. In essence this zoning barred any other region/s from producing that wine style (Douglas, et al., 2001).

Amazingly, the zoning systems of the *old world* still continue to be in use with interesting twists and turns. Related literature reveals further stringent European Union (EU) regulations on labelling has led to the incorporation of GIS features into viticultural zoning approaches and more recently researchers increasingly tend to use state-of-the-art technologies for this purpose. Meanwhile, the signing of General Agreement of Tariffs and Trade (GATT) in 1994 paved the way for intense debate on certain intellectual property clauses pertaining to a term "geographic indications (GIs)" in the agreement. To realistically implement GATT's GI regulations on wine labelling and marketing a global registry is required for identifying a wine label with a single location and this initial thought is being debated for a while now. The reason for the debate being such a registry can cause major impacts on European emigrants in the US, marketing their US wine labels linked to their *old world* wines with world famous Mediterranean rural places. Hence, understandably US officials have been hesitant in establishing such a global registry of product - single place and the issue is seen as having a polarising impact on the wine producing countries since the signing of the agreement (Barham, 2003).

In addition to the kind of wine identification and characterisation, viticultural zoning has been useful in regulating many present day issues and among them are:

1. irrigation, to ensure that the use of water is optimised or justified.
2. improve grapevine growing practices, such as pest management, re-allocation of land, vineyard restructuring operations
3. site-selection for new vineyards

Section 2 of the paper outlines the key concepts surrounding the world's famous *old world* wine countries of Europe, such as France, Spain and Italy, with reference to empirical studies in literature. This is followed by a discussion on some modern methodologies and approaches to developing viticultural zoning of wine regions within a country with an objective to gain insights in viticulture to help grapevine growers for ripening grapes with the right mix of sugar and pro-phenols, the essential ingredients that give the vintage its special appellation properties, such as the colour, aroma and aftertaste, of course the more important refinement depends on the winemaker talent and experience.

The final section of the paper presents the recent investigation thus far conducted into developing a *Viticultural zoning* system for the identification and characterisation of New Zealand *Terroirs* with thematic maps and factors relating to grapevine growth, phenology, yield, wine quality and economy at a regional (state) scale. It is anticipated that with a mapping of similar kind to the one presented in this paper, but at finer scales, integrated with cartographic data from a range of sources, New Zealand viticulturists and wineries would be able to opt for the best possible outcome among those many available to them that result from a countless number of diverse, complex and non-linear interactions between many related factors. The present day viticulture and wine making activities, such as precision viticulture and wine quality involve many factors, and issues. For example local environmental, seasonal weather conditions and economic viability, the latter with global impacts, represented by multi sourced data sets and at a range of scales in a variety of forms, range from a very subjective wine ratings to more precise weather conditions and are far too complex for analysis with conventional modelling approaches. The complexity involved in modelling modern day viticulture issues, increasingly requires more modern intelligent information processing methods based intuitive approaches to collate, manage, integrate and analyse historic as well as live data streamlined at surprisingly shorter intervals, such as hourly, daily and monthly maximum, minimum and average.

Traditional Viticultural Zoning Approaches

Despite the worldwide popularity spanning several centuries, viticulture and enology until very recently have been largely ignored by "geographers" from both *old* and *new world* wine countries (Unwin, 1996). The majority of the literature describes the significance of wine and vine throughout human history and their roles in economic, social, political, cultural, ideological, developmental and even spiritual as well as emotional aspects of human endeavours in different parts of the world nonetheless geographical aspects have been largely neglected. The Mediterranean countries (see figure 1) consist of the worlds most ancient traditional, economic and many social events linked to viticulture development and vinification, hence arguably most of the academic literature originates from that part of the world. Even in such ancient scholarly work that emanates from France and Germany, the only reference to geography and geographers is seen in the domains of research relating to slope processes in vineyards. Based on literature reviewed and personal communications with individuals considered to be experts in the field, Watkins, et al., (1997) observed a paucity of applications utilising GIS in this area of study.

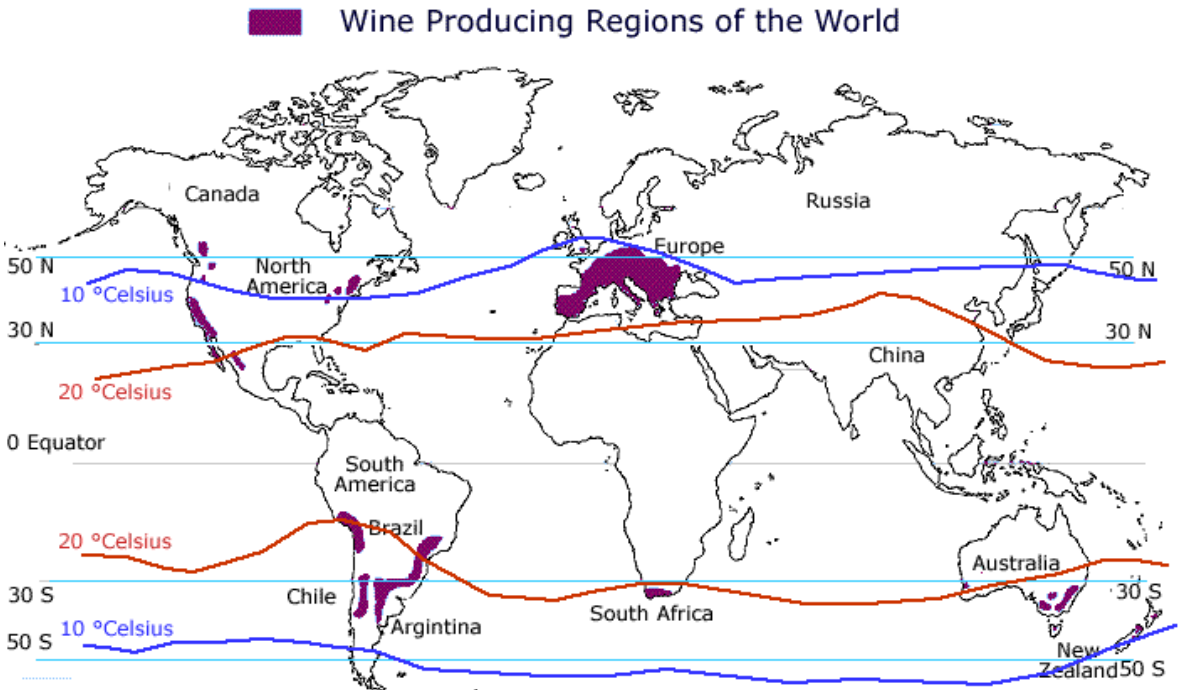


Figure 1. Wine producing regions of the world. Source: *www.thirtyfifty.co.uk/spotlight-climate-change.asp*. from (sallis *et al.,* 2009:3)

Terroir influence and issues in viticultural zoning

Interestingly, the *Terroir* concept has gained wide recognition in modern day viticultural zoning as well, however, there are a few major issues relating to the use of this concept with contemporary approaches and technologies, and the issues are elaborated in this section.

The major "dilemma" in the *Terroir* concept is that there isn't a specific meaning to the term in viticulture (Vaudour, 2002); throughout the literature researchers tend to convey that even this French word that originally comes from Latin, consists of several "notions" to describe the influence of several vineyards'/ a particular area's conditions on grapes ripened/ distinctive quality or wine characteristics produced from the grapes. But there is a marked difference in the way it is implicated in the *old* and *new world* notions. In the European context, with regards to the *old world* perspective, a homogeneous area's spatial attributes (dominant) along with human/historical aspects, especially the latter, interpreted as the knowledge inherited through generations of viticultural development and vinification, and are given more emphasis. On the other hand, the way it is portrayed in the *new world*, an area is portrayed as a spatial and temporal entity, giving more importance to soil, landscape as well as its base and seasonal climate along with the territory's social, historical and cultural affinities, added to this is

the final technical choices made in winemaking. As stated in (Vaudour & Shaw, 2005), today to evade from any "lexical ambiguity" concerning the term, many tend to prefer phrases, such as "viticulture potentialities", " viticultural zones", soil viticultural environment" to "viticulture *terroirs*" in defining "viticultural zones".

The second major issue is that the *terroir* concept does not comprise a "scale" component attached to it when defining a distinctive area and it could range from a local to broader region (Vaudour, 2002:Vaudour & Shaw, 2005). Smart (2002:1), describes *Terroir* as "both soil and "meso" climate influences on grapevine growth and wine quality" based classification scheme assuming the scale of *terroir* from a few to tens of meters, and very occasionally to hundreds of meters. In general, meso climate is considered to be the optimum scale for monitoring the climate, especially for comparing the variability in climatic conditions across a landscape for disease and frost forecasting when finding the optimal *cultivar* choice/s in specific sites (Bonnardot, Carey, & Strydom, 2000).

Contemporary viticultural zoning approaches

When developing Viticultural zoning systems with modern approaches, researchers in some sense have extended the *Terroir* concept and based on the way the approaches have been applied the research thus far seen could be broadly classified into two major categories as stated in (Vaudour, 2002). All modern research efforts have attempted to establish the geographical differentiation of either 1) products/ raw material or 2) environmental potentialities. Notably, in these *terroir* based viticultural zoning studies researchers while trying to eliminate the mythical/mystical facets in relation to the term by using appropriate rationale along with quantifiable criteria relating to the environmental, grapevine plant growth and winemaking factors, have been extending the confusion and debate surrounding the notions and interpretations of the concept. Except for a few studies none has defined the term or stated in what context it has been used in the zoning. Over the centuries, there have been a variety of ways in which the term has been interpreted and all agreed definitions of the past as well as the currently existing ones for *Terroir* reflect the influence of technology of the time.

Contemporary research into incorporating geo-coded geographical features into viticultural zoning approaches range from simple factors i.e., soil type, climate information and wine style as in (wine fight club, 2010) to that of complex i.e., viticultural agroclimatic indicators i.e., Helio thermic indices (Huglin Index (1978)) along with seasonal rainfall distribution and efficiency, and evapotranspiration (ETP) as in (Deloire, 2008) and some of the significant approaches are elaborated upon in this section.

A simplest viticultural zoning approach could be developed as described in (Vaudour & Shaw, 2005) with a single factor/ variable based on its spatial distribution data. The various approaches in use vary on the way how the spatial data is aggregated/ disaggregated to match the demarcating registration boundaries. In general, a demarcating approach involves the assigning of a boundary to a single pre-existing quantifiable variable with historically or customarily accepted spatial distribution. The spatial distribution data of a variable could represent any one or more aspects relating to climate, grapevine or wine style/ quality, and their respective boundaries at which spatial distribution data of different variables are available. Hence, in more complex approaches with multi factors the task of assigning spatial distribution data to the zoning boundaries becomes confound.

A moderately complex approach by (wine fight club, 2010) interpreted the French notion as common sense implying that the *Terroir* concept after all tends to convey semi-mystical group of forces of the area that in turn produced the wine as special. Furthermore, added humour by producing a formula for this

soil + climate = grapes turned into wine (plus natural/cultured yeast)

Australia has a modern "three tier system" to define its wine regions, starting on the top with "state", then mid way through "zone" and finally at the bottom "region". In some cases, in addition to the three tiers there are sub-regions defined by Wine and Brandy Corporation's Geographical Indications Committee (GIC). For instance, Australia's Adelaide Hills wine region within the Southern part of the country's Lofty zone, has two sub regions, namely, Piccadilly Valley and Lenswood. Similarly, High

Eden is defined as a sub region of the Barossa Valley. Interestingly, a new region only declared in 1997 consisting of roughly an area of 15 by 30 kilometre stretch with 6,800 hectares of vineyards, even though GIC has not officially declared any sub regions within it, there are 6 regions defined unofficially and they are; Seaview, Willunga Plains, Sellicks Foothills, McLaren Flat, McLaren Vale/Tatachilla and Blewitt Springs, all of them used by winemakers to describe vineyard blocks/locations based on temperature change during different seasons i.e., grape berry ripening. The system is seen as a significant marketing ploy that enables McLaren's less known producers to charge higher prices which could in turn reinvested to improving vineyards as the region has a higher price expectation. In fact, within this region Tatachilla is seen as a good area.

Highly complex models of viticultural zoning so far developed basically attempted to use multiple key variables at micro scales and these models could be classified into two major approaches. They are: a) formulate a complex index by adding appropriately weighted vital factors that are considered as most influential in grapevine growth and berry ripening. Such highly complex models seem to look at meso scale data projected onto a national map. 2) study the correlation between selected key variables and most of them at micro scale (precision viticulture) within a vineyard.

The major constraint encountered when incorporating GIS data into precision viticulture systems is that finding a process/es to aggregate spatial information where resolution and precision are not the same and in most of the cases this is resolved using geostatics and kriging. Through a krining process, all the data is transformed into the same grid allowing for classical data analysis or queries at different layers as seen in (Paoli, et al., 2005). In this study the authors modelled the correlations between spatial variability in vigour, elevation, sugar content and soil resistivity using hertrogeneous precision viticulture data by applying uncertainty theories (fuzzy sets, possibility theory and Choqiet integral).

Research based on the "precision viticulture" methods, is a refined field of domain that consists of highly advanced technologies. Contemporary precision viticulture studies use high resolution aerial imagery and micro climatic data acquired using networks of wireless/ wired sensors/ probes to identify the different zones within a block. For example in (Buss, *et al.,* 2004), to understand the complex dynamic relationships between site, soil, water, phenological stages, vine variety and wine quality, in order to manage the vineyard daily operations efficiently, key variable interactions, such as the effective soil-water storage, plant rooting depth, onset of water stress, and daily vine water use, were studied. For this purpose, soil-water monitoring based on near-continuous profiling data was gathered using "EnviroSCAN® technology" introduced by Sentek Pty Ltd. In recent times, since the beginning of the last decade the technology has become an important tool in vineyard water management, especially in Australia.

Another study by (Tesic, *et al.,* 2010) elaborated upon Cabernet Sauvignon phenology, from observations of cropping and fruit characteristics at six vineyard sites in Hawke's Bay (New Zealand). The study conducted over three seasons, produced a numerical model to characterise environmental conditions of a vineyard site. The model was based on air temperature in October and January, seasonal rainfall, rooting depth, gravel percentage and clay-to-silt ratio in topsoil. A "site index" or "SI" calculated using the stated variables was described to the significantly correlated with soil temperature and volumetric soil moisture content, the latter in turn described to be closely linked with clay-to-silt ratio, air temperature and rainfall. Similarly, vegetative growth, canopy characteristics, precocity of *veraison*, total anthocyanins, TSS and malic acid concentrations in grapes were found to be significantly correlated with SI values in the six sites over two seasons. The study concluded SI correlations between particular viticultural variables to be stronger with five climatic indices for the sites studied and descried SI index as a potential gauge for use in vineyard zoning and site selection evaluation purposes.

Martinovich, *et al.,* (2010) described the Hungarian Ministry of Agriculture and Rural Development (MARD) efforts to generate a geo-coded Vineyard Registry to fulfil the European Union (EU) and professional inland requirements in order to secure EU funding and exercise wine quality control policies as well as regulate wine marketing by protecting "designated origins" for the whole nation's vineyards. The efforts initiated in 2001 involved the Institute of Cartography Geodesy and Remote Sensing (FÖMI) and Remote Sensing Centre in the development of a Geographic Information System (GIS)

supported Vineyard Register (VINGIS) from an existing HEGYIR vineyard databases for all the vineyard communities in the country, through this FÖMI project. The project was set out to develop a map of potential sites for vineyards from analogue maps of site suitability, developed and maintained by the Viticultural and Enological Research Institute (SZBKI). The existing analogue maps were created with onsite observation data, using the technology of older times hence does not provide accurate information sufficient enough for decision making with regards to implementing new policies laid by EU. Hence, it was decided to update the old analogue maps with GIS technology and this led to the development of a more efficient information system called VINGIS for the protection of vines with "designated origins".

A novel GIS based vineyard support system developed to test, match and map *cultivars* to the landscape of untested terrains and climates of the Northern Great Plains, before planting to avoid vineyard failures is elaborated upon in (Waltman, *et al.,* 2004). The system also provides a better understanding of vineyard sustainability within the Northern Great Plains considered as being a region with marginal vineyard settings. The system is novel in that it attempted to capture the concept of "genotype x environment" (GxE) and build a "sense of place" using landscape and climate characteristics (as georeferenced information) integrated with the human dimensions of vineyard management.

A regional scale study from Casitlla-La Mancha, Spain reported in (Riquelme & Ramos, 2005) described a tool developed to support decision making on vine growing areas at larger scales using georeferenced data. The system results were found to be useful in zoning the region's grapevine farms based on physiographic farming capability and vine varietal factors. It provided a means to study the region's environmental, social and economic aspects in managing the land and water use in consideration of different stakeholder perspectives.

In (Galetto, et al., 1998) elaborated upon some early 1990s efforts by the Italian government and a number of academic institutions to integrate geospatial data with a prototype of wine-viticulture cadastre for managing agricultural development planning based on a three tier (level) structure. The publication, titled "GIS on network" details on the development of a national database integrated with GIS for taxation and planning. The three tier structure was adopted to incorporate detailed information at Provincial, Regional and National level planning and at appropriate scales. An Internet Map Server called "MapObject" was used to create an interactive map browser for the Wine-viticulture Cadastre's GIS. The system was planed to include GIS data in different formats, such as parcels, TIN, MESH, etc. along with Alfa-numerical archives (the properties, the registry, the production and wine types) that were to be managed on different Servers (Oracle Servers, SDE-Servers, SDO-Servers).

Recent advances in remote sensing and access to satellite imagery have led to the use of airborne multispectral and hyperspectral imagery in precision viticulture with greater flexibility especially in yield mapping integrated with soil or disease properties (Ferreiro-Arm´an *et al* 2006). The paper discussed of a French research effort, beginning with an introduction to the most recent developments in this area of spectral characterisation of vine canopy, varietal mapping. The recent capability to discriminate plant species could be used as a tool in the certification of wine productions at regional as well as vineyard scales in detecting mis-planting and managing inner species variability. Subsequently, the paper investigated the use of three main approaches namely, multiple-layer perceptrons, radial basis function neural nets and support vector machines for varietal mapping. Most recent developments in this field include the use of fuzzy logic (in satellite imagery pixel analysis) and delineation of vine parcels by segmentation of high resolution (in aerial images) (Costa *et al* 2007: Paoli *et al* 2005)

Viticultural Zones of New Zealand

As far as New Zealand Viticulture and Wineries are concerned the growth has been very rapid during the last two decades and is outlined briefly in this section.

New Zealand being one among the new wine producing countries, its growth has been remarkable and unprecedented especially over the last two decades. The country's grapevine cultivation area spread

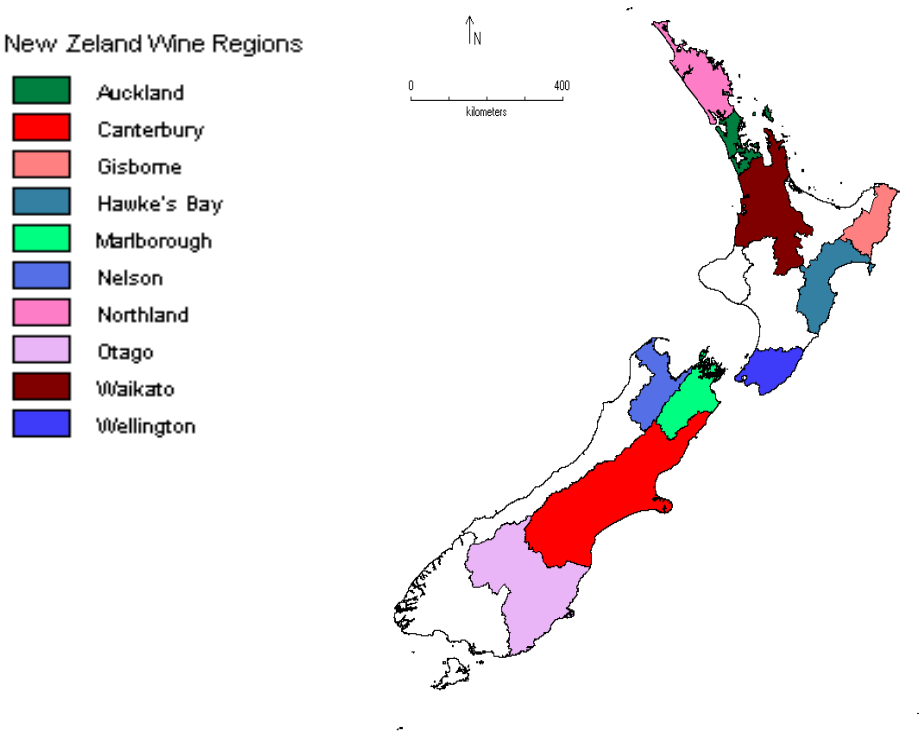
across the country (figures 2 and 3) increased from 4,880 hectares in 1990 to 31,002 projections for 2010. This means wine production of 200 Million litres (for 2008) was estimated from 582wineries consisting of 50% for the domestic and 87.8 Million litres for export markets, and with an import of 40 million litres into the country. The value of New Zealand grape wine export for 2008 was 773.9 Million dollars. It is also interesting to note that 76.1 % of the export (by volume for June 2008) comprised of Sauvignon Blanc, the main export destinations being 34.6 % UK, 27.6% Australia and 21.5% USA.

Methods for investigation

Based on the nature of the data available for analysis, the following methods are being investigated:

1. point based: the method is used to integrate data relating to vineyards/ wines and the variability in the different attributes among the point based entities are analysed.
2. region based: wine regional scale attributes are analysed for studying the variability using geocorded data at this scale.

For both methods attributes in vector as well as grid formats are used.



Figures 2: Wine regions of New Zealand.

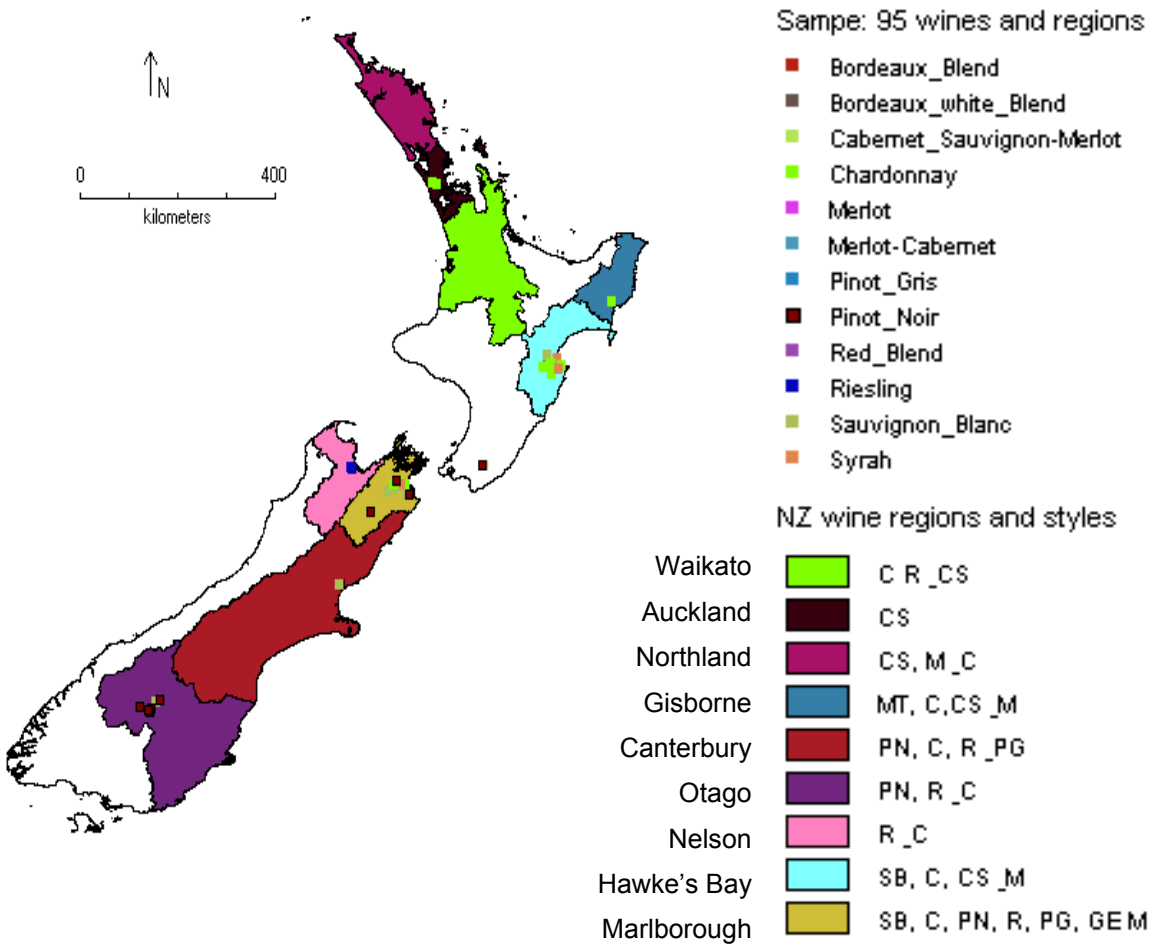


Figure 3: New Zealand wine regions and the styles within a sample of 95 wines from (www.winemag.com). C: Chardonnay, GEM: Gewurztraminer, CS: Cabernet Sauvignon M: Merlot, PN: Pinot, PG: Pinot Gris, R: Riesling, S: Syrah, SB: Sauvignon Blanc.

Results

Initially, wines/ vineyards were geo-coded and displayed in a layer in DIVA-GIS (www.diva-gis.org/) environment. The layer is then overlaid with New Zealand wine regions as shown in Figure 3. Climate and altitude data for the 95 wines was then extracted from world climate data provided by (Hijmans 2005). The graphs produced from the data extracted show the niche climatic conditions required for the different wine styles produced in New Zealand. For example, figure 4 graph shows the altitude of the vineyards of the 95 New Zealand wines; Based on this graph, it is clear that all the Chardonnay (C) come from under 200m altitude. Meanwhile, Pinots (PN) from Otago are from over 600m altitude however, in Marlborough Pinot wines are grown from 100-1200m altitude. Again, Marlborough Sauvion Blanc wines come from anything between 50-800m altitudes.

The graphs of altitude and climate data extracted for three different wine styles, namely Sauvignon Blanc (Marlborough), Cabernet Sauvignon-Merlot (Waipara) and Sauvignon Blanc (Otago) illustrate interesting attributes required to grow these grapevine clones. As seen in figures 5 and 6 a-c Sauvion Blanc at Otago's high altitude (700 meters) is more tolerant to winter cold. As far as the monthly minimum and maximum temperatures are concerned the Sauvignon Blanc (Marlborough), Cabernet Sauvignon-Merlot (Waipara) clones grow under the same temperature ranges but differ in monthly rainfall. Marlborough and Waipara region vines are grown in highest and lowest monthly rainfall respectively of the three wine regions analysed in this work.

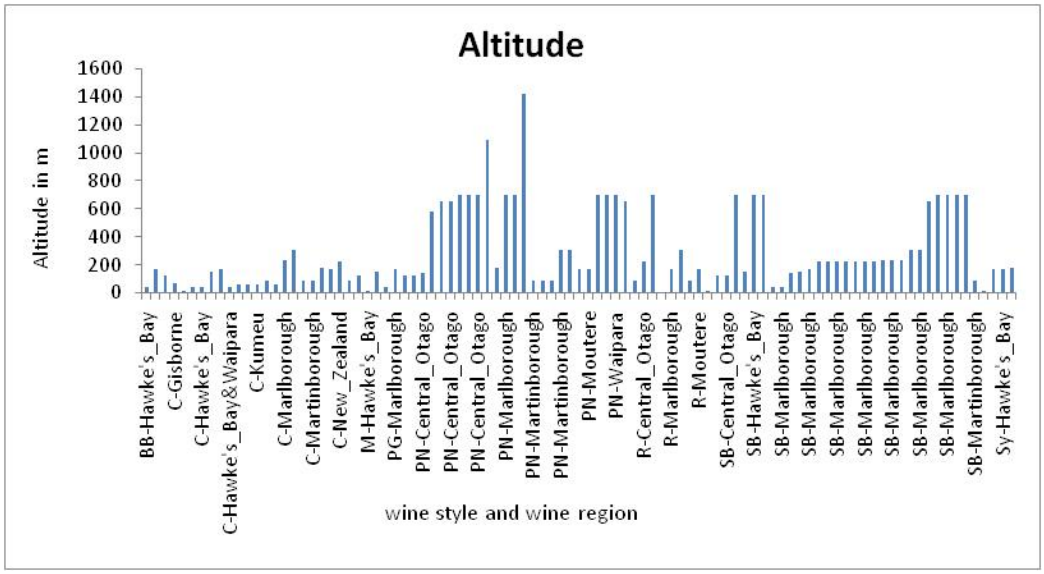


Figure 4: Graph showing the altitude of the 95 New Zealand wineries (figure 3) and the difference in altitudes that different wine styles (and regions) require to grow. The climate and altitude data was extracted from (Hijmans 2005) using DIVA-GIS. BB: Bordeaux Blend, C: Chardonnay, PN: Pinot, R: Riesling, SB: Sauvignon Blanc and Sy: Syrah.

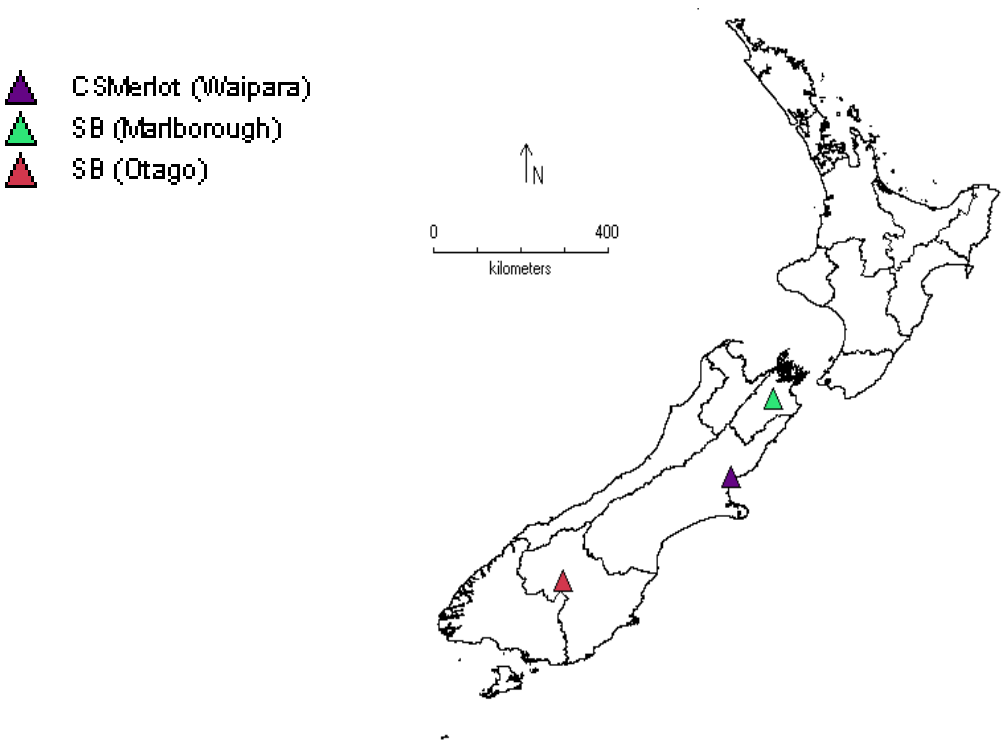
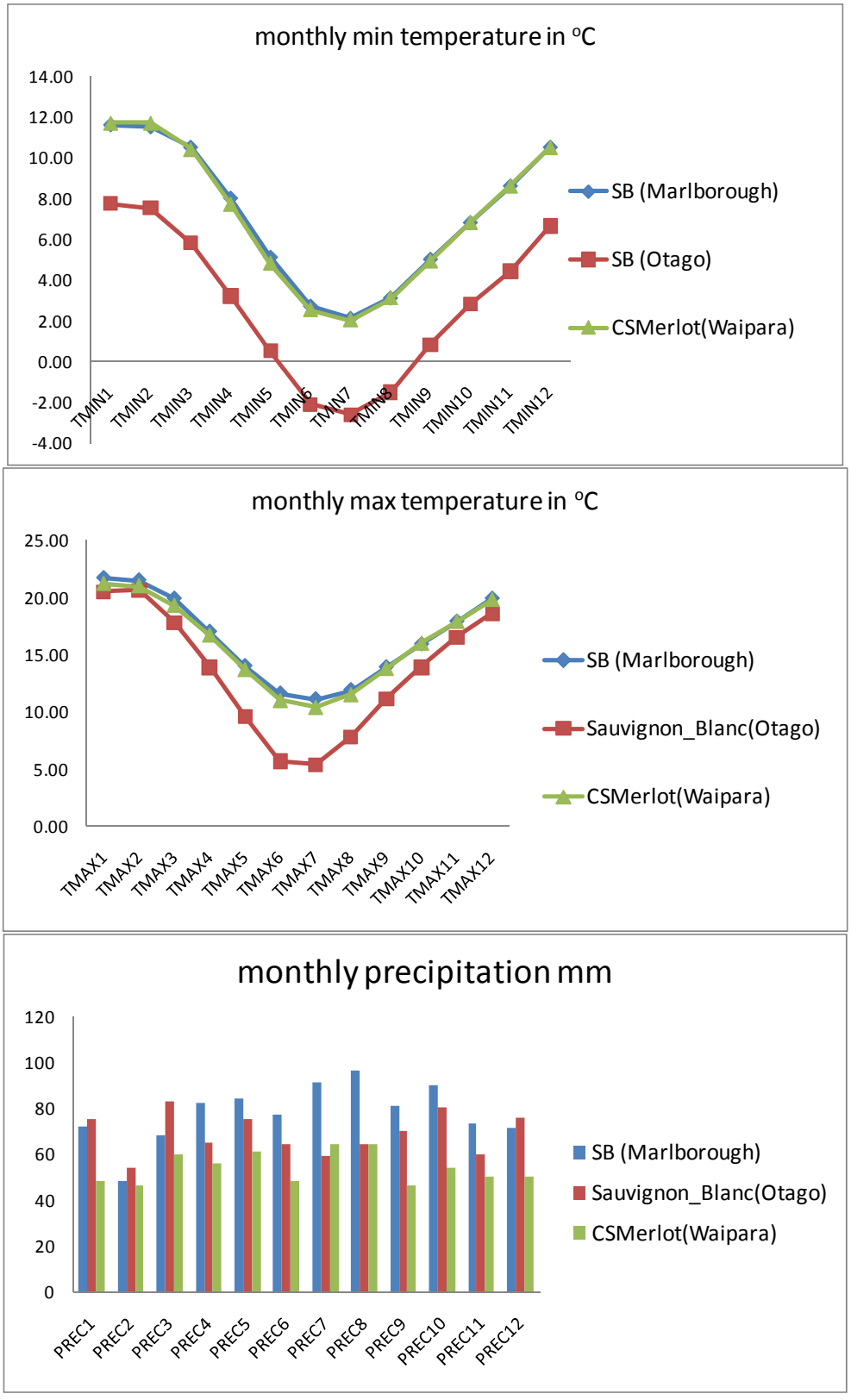


Figure 5: New Zealand map showing the locations of three selected wine style and regions studied. SB: Sauvignon Blanc, CSMerot: Cabernet Sauvignon-Merlot.



Figures 6 a, b and c: Graphs showing the variablity in monthly minimum, maximum temperatures and monthly rainfall for the three wine regions of New Zealand. SB: Sauvignon Blanc, CSMer: Cabernet Sauvignon-Merlot.

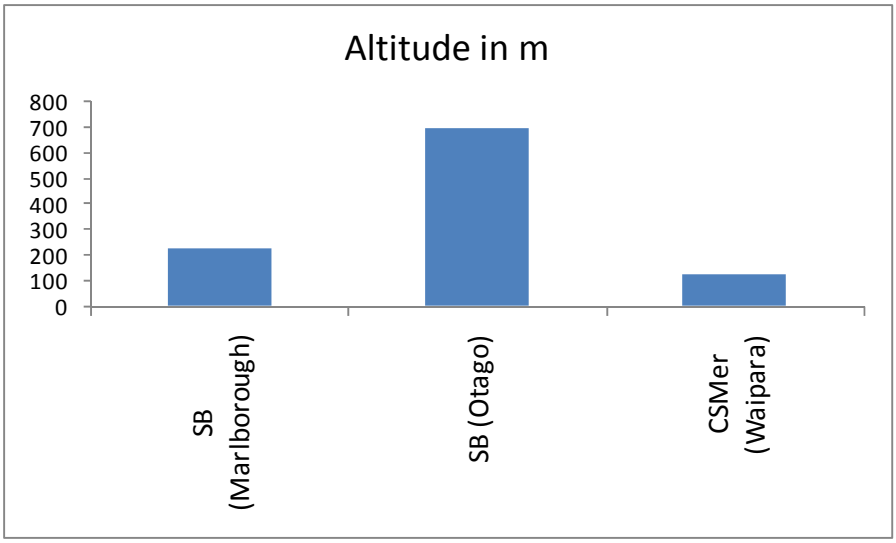


Figure 7: Graphs showing the variability in altitudes at which the three selected wine clones from Marlborough, Otago and Wairarpa are grown SB: Sauvignon Blanc, CSMer: Cabernet Sauvignon-Merlot

Conclusions

The paper looked at literature relating to viticultural zoning and similar modern day processes developed and used in *Old* as well as *New world* wine countries. Interestingly, the French notion of a popular term *Terroir* once said to be introduced in Latin seems to have a greater influence in both wine producing nations. The issues, concerns and purposes relating to the ancient and modern approach based cultivating territory classification systems have vital influence in the marketing wines more than anything else. However, the two major issues relating to the term, 1) exact definition of the term 2) appropriate scale for the term have been dealt with only a few users of this term and all of such applications reflect the technology of the time. Furthermore, it is also obvious that the old systems make no reference to geography whatsoever except for studies in vineyard slope processes and its influence in grapevines.

Finally, the paper presented results of the initial investigations conducted in zoning vineyards and wineries for the identification and characterisation of New Zealand *Terroirs* using cartographic data. The work is ongoing and currently more New Zealand wine style, quality rating information, climate and environmental data sets at regional scale have been gathered and more rigorous statistical tests are being conducted to characterise New Zealand *Terroirs*.

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