



Development of a Differential Grape Harvesting Methodology

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The Terroir has been recognized as an important factor in wine quality and style, especially in European vineyards. There is currently a need for quantification of the factors that influence the definition of terroir, incorporating indexes that quantify variables such as soil, plant and climate, which has led to the definition of quality zone for differential harvesting. This paper proposes a methodology to develop the "digital information" through use of emerging technologies, which should be used for the study and definition of quality zones on vineyard which allow differential harvesting with replicable protocols. The study took place in Valdivieso Vineyard, Curico, Chile, during the 2012 and 2013 seasons, under the Var. Cabernet Sauvignon. The use of the multispectral images and analyze by ICAS Software (INIA Developed) integrated with ferari index (MULTIPLEX RESEARCH™, FORCE- A), was used for the point sampling and grapes quality quantification using grid model base en NDVI maps. Moreover, the soil and plant information was obtained by the use of equipment as follows, electrical conductivity (EM38), topography and exposure (RTK) and NDVI (Tetracam ADC and ICAS analyze). From the fruit quality index distribution curve (Ferari), 7 rated strata was develop by variety and year, which was used for training the respective model classification of the variables associated with the site. The classification algorithms were based on qualifying Boosting and super vector machines (SVM). For model training, 75 % of the data was used and allowed the remaining 25 % to verify the calculation error (control data). The classification results were 90 %, of well classified area ($R^2 > 0.9$ and Mean Absolute Error < 0.1). Finally, the well-defined grape quality area develop was used for differential harvest and wine developing. Finally, this development could be used for vineyard management when increase the quality of wines it is the main goal.

1. Introduction

The Grape Quality Zone or Terroir of an area has been recognized as an important factor in the quality of the wine and the style, especially in Europe's vineyards. According to Best (2005) the terroir can be defined as the combination of all the attributes, historical, geographic, human, biological or environmental, of a (delimited) region contributing to the individuality of the wines produced there, is for the inclusion of cultural attributes, implied in the region of origin that makes something so difficult to quantify terroir. Many authors (Deloire, 2003) have assessed the impact of a single parameter in the grapes quality, such as: the climate, the soil, crop, rootstocks, or water. Meanwhile, other studies have investigated the combined effects of two parameters in the grape quality such as, soil and climate (Deloire, 2003), soil and varieties (Van Leeuwen, 2004). For his part, Van Leeuwen (2004) by studying three variables (soil, climate and cultivate) simultaneously in the definition of grapes quality zone, found that the effects of climate and soil on the vine development and the grape composition can be explained in largely by its influence on the water status of the vineyard. Consideration of quantitative variables into the establishment of a (digital) optimization capture level, storage and analysis of information has as its first references in Australia (Taylor, 2004), where the problem of the definition of grapes zones at a block level, deals with using the term "Digital Terroir" for identified areas. As the name suggests, a digital terroir is a "modeling" quality grapes zones. The model seeks to identify areas of different environments based on edaphoclimatic variable. Thereby, having information about the local soil, terrain and climate, a vineyard can be mapped in terms of grapes quality definition. The preciseness of this model depends on the accuracy and validity of input data. Thereby, the success to define grapes quality zone

is essentially an alternative for develop a differential harvesting by quality classes. In this regard, the management philosophy of these areas is closely related to handling a specific site (Cupitt and Whelan, 2001), and therefore a precision viticulture.

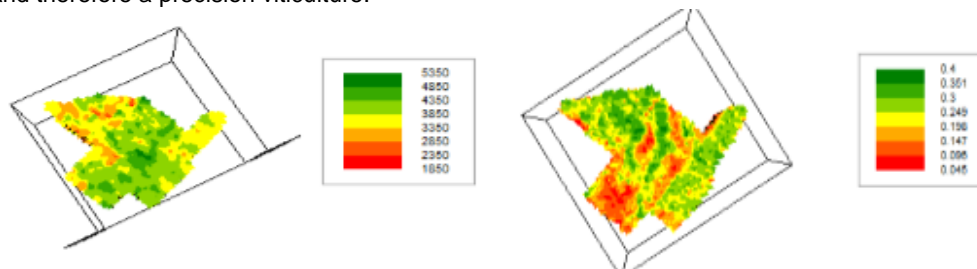


Figure 1. Comparative of Grapes Quality (left) and NDVI map (right) in which we see that there are not much correlation.

The quality differential zones can then be addressed from a performance perspective to produced differential wines that could maximize the winery profit. At present, it is proposed to solve the implementation of emerging technologies associated to precision viticulture for the development and management, moreover, the current procedures which are used for the study in the definition of quality areas, suffer from own replicable protocols, which we start to testing in others vineyard to validate the result of this study under different productive conditions.

2. Materials and Methods

The study took place Valdivieso Vineyard in Curio, Chile, during the 2012 and 2013 seasons, under a commercial vineyard, Cabernet Sauvignon variety. For this variety, 2 block was selected on the vineyard, on which information was taken from field, and aerial images process by ICAS software to define plant and fruit quality as described below.

2.1. Precise Vegetation Index Evaluation using ICAS Software

The uses of vigor maps are used to date in Chile in the detection of abnormalities within the orchard or vineyard (Best et al., 2005 and 2009), as well as an evaluation tool for variables that would affect the production. As we have already mentioned, for the areas segmentation that may be linked to a differentiation of areas, it is necessary to count with the maximum radiometric type information of the vineyards, as a high-resolution image, this because the main problem is the analysis of such images are found in the information between rows (soil, rocks, weeds, etc.) greatly distort the final result and hence its possibility of a good definition of areas, and therefore those must be removed from the analysis, a factor that can only be performed with high-resolution images. To eliminate from the analysis the distortion areas can be done with several software (ENVI, ERSI, ERDAS, etc.) but with a high working level, and even more, if it requires a definition of treetops level to each plant. This need, was remedied by the use of the ICAS software (INIA Canopy Analyzer System, Best and Leon; 2009), which among other functions (such as a selection of samples location, feeding generation of files for the database, among others) serves for the canopy segmentation and vegetation index creation (IV), such as NDVI and RFI (Radiometric Foliar Index or $NDVI \times \text{Canopy Area}$), which allows us to get these IV at the plant level without distortion of its surrounding condition. The proper development of maps without distortions, allows us to get a proper classification per plant basing, a very important factor for a clear definition of input variable in the digital model that was developed.

2.2. Soil Spatial Definitions under the study area

The final yield and grapes quality are not always related to the foliar composition and physiological activity obtained from vegetation index (NDVI Maps) as some precision viticulture companies have try to sell the vineyards, sometimes there are correlation and in another cases not much (Figure 1). Moreover, there is a high influence of factors of the site associated with the soil and its composition (spatial variability), topography and other factors that defining changes on the plant, are not sufficient to carry out a clear definition of grapes quality of the vineyard. It is particularly noticeable in the case of our country, where the soils of the central valley to be alluvial nature, present a great spatial variability mainly in terms of texture, depth, and topography, variables that have great impact on the development of the vineyards and finally in both yield and in quality, that hit the vineyards profitability. A tool for the subdivision of soils in areas of similar properties is the electrical conductivity of the soil (EC). In this study was used the Geometrics EM38-MK2 equipment (Geonics,

Canada), connected to an RTK-Geodetic (Topcon HiPer Lite Plus+, L1 L2 Glonass RTK GPS) to obtain electrical conductivity maps of soil and at the same time the precision topography. From the topography drawings, there were generated the aspect maps (inclination of the land), that have significant impact in its association with the differentiated solar radiation that the areas have, in particular when they are on hillsides, in which case was the trial area.

2.3. Quality segmentation developed

The analysis of fruit quality, has a fundamental importance to evaluate the areas that have a wine potential associated to a greater or lesser quality to consumer-level, understanding this concept from the point of view of organoleptic quality and nutraceutical have had major impacts. On the other hand, it is a key element in the definition of the optimal harvest time. Fluorescence is the most recent technique of optical detection proposed for grapes quality evaluation and obtaining maturity index. Its main advantage, the nature of the non-destructive method, is its speed (milliseconds) and the possibility of analyzing bunches as a whole (Cerovic et al., 2008) or layers of continues berries (Ben Ghazlen et al., 2008). The method that is used to measure flavonols and anthocyanins in the epidermis, on the basis of chlorophyll fluorescence shield, has been successfully used in vineyards (Cerovic et al., 2008; Ben Ghazlen, et al., 2008). As well, to carry out the definition of quality of grapes, we use the index of Ferrari Index evaluations (highly correlated to anthocyanins), with multiplex equipment (MULTIPLEX RESEARCH, FORCE-A) for the definition of quality areas. On the other hand, the sectors were discussed and tested by the company viticulture and enology in the gustatory evaluation of these having a full coincidence. Thus using a NDVI maps developed with ICAS we develop sampling scheme that was used during the grape harvest, generating a segmented vintage and were vinified obtaining a clear differentiation of the wine developed for both seasons (Figure 2). Figure 3 shows the Ferrari index distributions, of the seasons 2012, 2013, 2012-2013 integration in a single one (201X), for the Cabernet Sauvignon variety. From the analysis of the distribution curves presented, it is clear the temporary effect on the quality of the grapes, a very important factor in knowing to evaluate before harvest due to that allows you to optimize the harvest and finally the wines that will be produced in this. And so the above mentioned drawings are searched, in a combination and statistical analysis, which allows to finally give a combined plane which is expressed in crop differentiated areas, this is because the information on a map as the NDVI, electrical conductivity (EM38), topography, etc. alone are not sufficient to define homogeneous zones, a factor that has been one of the problems within the productive sector as it was expected this when were introduced. Therefore, the integration of levels was sought through the use of multivariate analysis of information.

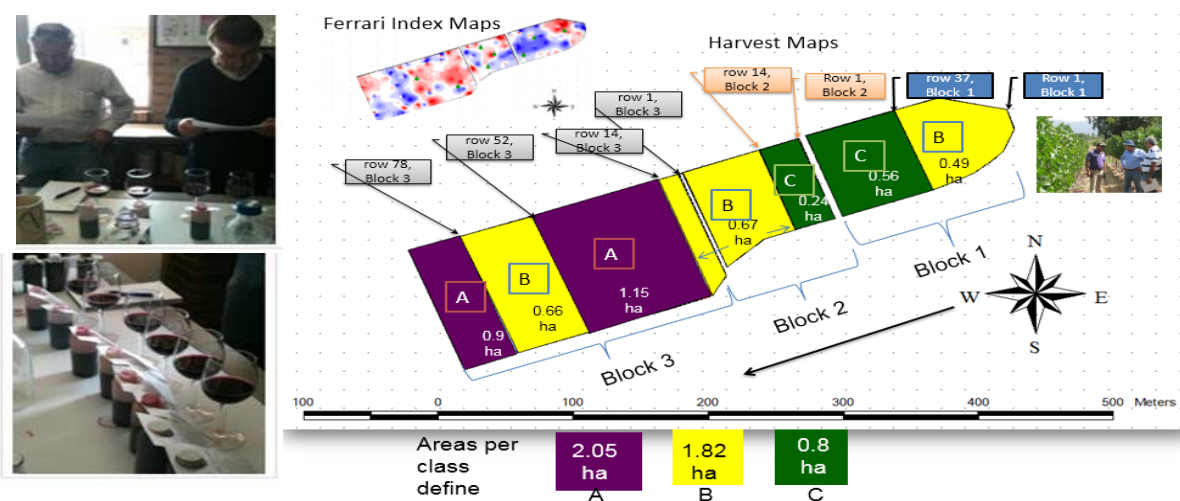


Figure 2. Map of segmentation of grapes quality for harvest (a) anthocyanin maps (b) model developed (c) and wine tasting developed from segmented areas (Lontue Plant Laboratory, Viña Valdivieso S.A., left images) for one of the cabernet sauvignon area in study.

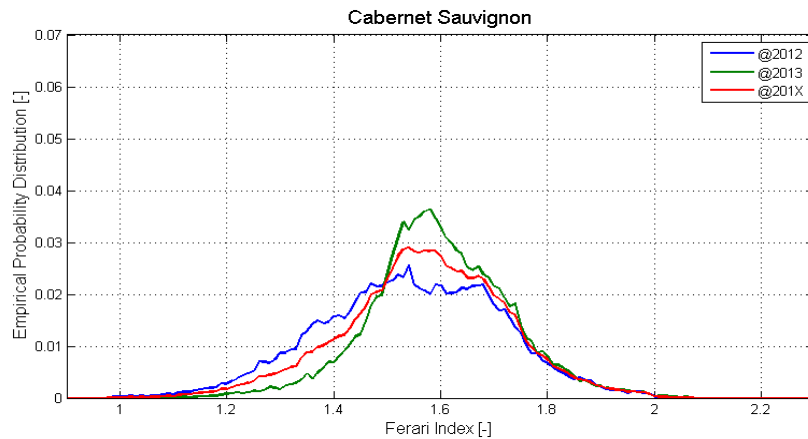


Figure 3. Distribution of probability density of Ferrari index (Quality Index) in Carmenere variety, season 2012, 2013 and 201x.

2.4. Quality Stratification, Training and Calibration

On the basis of the distribution curves generated a classification of 7 tiers for each variety and year, on which is used a classifier of high range (Boosting), for their respective training of classification associated with the variables of a site. Once chosen the stratification of the quality variable (Ferrari Index), it is to integrate the site information (EM38, topography, aspect, and NDVI Index of Ferrari). It is to train 9 Ferrari Index classifiers from the site information obtained, each of them chosen in through the Rapper methodology, in order to choose the most appropriate qualifying structure. Where the classification algorithm was based on boosting and supports vector machines SVM. For the training it took 75% of the data and leaves the remaining 25% to verify the error calculation (control data). Then generated 3 classes of grape quality, according to the experience gained in the field and wine developed, defining high, medium and low quality, which cover the classifiers developed before mentioned. Once ready the qualifying practices proceeded to implement a neural network to the classifier output. Finally, integrating all the above-mentioned procedures in an application to automatize the process of the modeling.

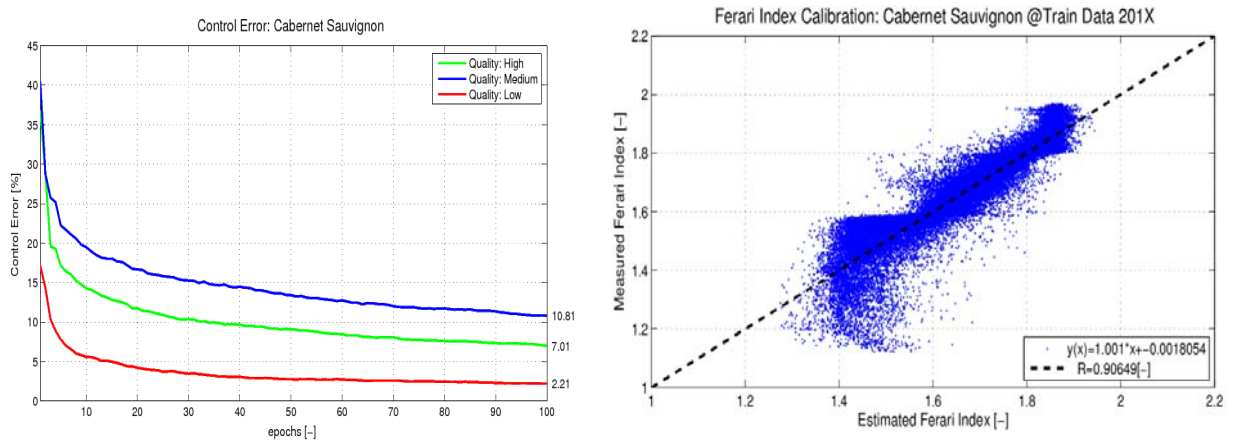


Figure 4. Comparison in the estimation of the Model and real Ferrari Index obtained in the field for two seasons of work (right) and maps of estimation error for both blocks.

3. Results and Discussion

In Figure 4, we can see the evaluation of the results of the model incorporated into the software developed, where the field results of the Ferrari Index from estimated and actual, in addition, to displaying a fit curve of the Ferrari Index errors in modeling for Cabernet Sauvignon variety. It should be noted that the model performs an

estimated job quite acceptable with errors less than 10% (Figure 4) but in most cases on the quality stratification is lower than the 5 %.

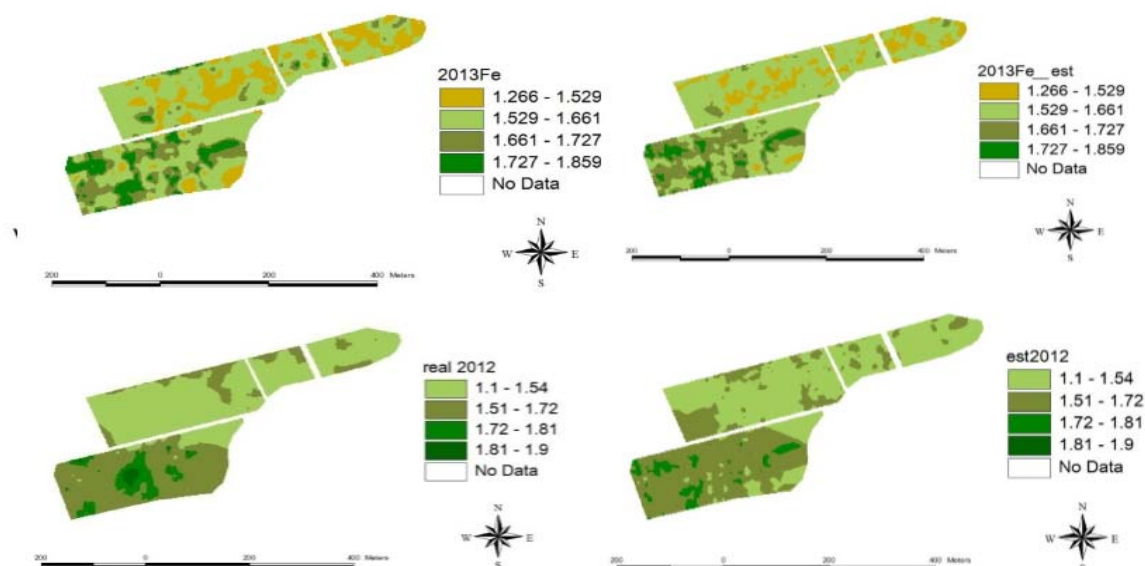


Figure 5. Ferari Index calibration: Cabernet Sauvignon, training data 2012 and 2013, and comparison of the results obtained with Ferari Index map.

Left graphic: Real Ferari Index map; Right graphic: Modeled Ferrari Index Maps.

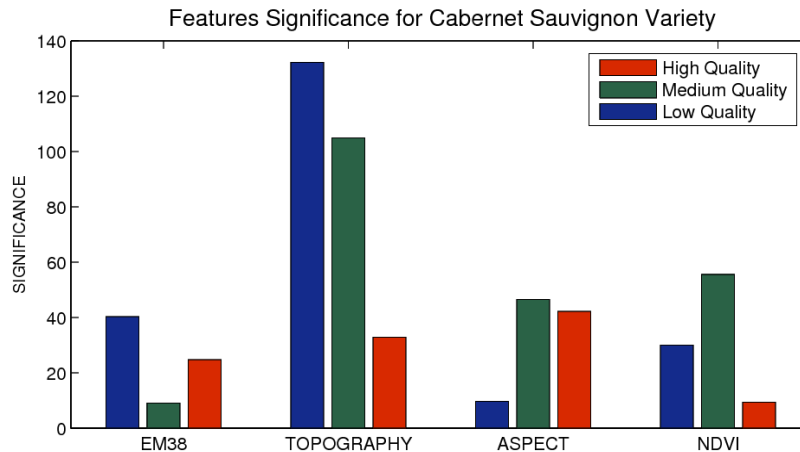


Figure 6. Significance of Patterns for the Cabernet Sauvignon, Malbec and Carmenere variety, respectively.

Ense, the classification results were 90 % of well classified area ($R^2 > 0.9$ and Mean Absolute Error < 0.1) for Var. Cabernet Sauvignon (Figure 5, example for season 2012 y 2013). On the other hand, in order to evaluate the incidence of variables on the fruit quality was a test of significance proposed by Weiss-Indurkha whose results are shown in Figure 6. From the analysis of significance it can be evaluated that the weight of the different variables do not maintain a stable pattern but rather is local, giving further support to the theory of the terroir is defined by variables in situ, can be integrated to improve the understanding of the behavior of vineyards to made better management.

4. Conclusions

As it has already been mentioned in the previous analysis, the generation requires of a common architecture for the integration of digital information both spatially and temporally. So, the model developed goes for the integration of captured information between seasons for generation of the sectors whose behavior is a common pattern or similar zones of quality, and within each of the seasons allow the automated sectors segmentation for differentiated harvesting. This way, the working structure of this multivariate model space - temporary, in the developed context segmentation in each season, shows satisfactory results, which must keep on being evaluated to validate the model, however, demonstrates that the wine zoning must be made with more than one variable such as has been done to date. The previous thing, in contrast to the traditional statistics, make it possible to locate the places where such management be optimized, and thus profitability in search of the desired quality, that is finally the main objective of any vineyard.

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