Development of an application (INDITES software) that allows to integrate spatial and temporal information of a vineyard for the development of the digital terroir.

S. Best; G. Gatica, L.F. León G. and R. Quintana
Chilean Agricultural Research Institute (INIA),Precision Agriculture Program, 515 Vicente Méndez Av., Chillán, Chile.
sbest@inia.cl, ggatica@inia.cl, lleon@inia.cl, rquintana@inia.cl.

ABSTRACT

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 “Digital Terroir ". This paper proposes a methodology to develop the “digital terroir" through use of emerging technologies, as current procedures that should be use for the study and define of terroir which suffer from having replicable protocols. The study took place in Valdivieso Vineyard, Curicó, Chile, during the 2012 and 2013 seasons, under the Var. Cabernet Sauvignon, Merlot and Carmenere. The Ferari index (MULTIPLEX RESEARCH ™, FORCE- A), was used for the grapes quality quantification, which was obtained from field samples by a high density grid (20x20 m). 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). From the fruit quality index distribution curve (Ferari), 7 rated strata was developed 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 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 95 %, 90 % and 80 %, of well classified area (R^2>0.9 and Mean Absolute Error < 0.1) for *Var.*Carmenere, Cabernet Sauvignon and Merlot, respectively. Finally, the well defined grape quality area develop could be used for differential harvest and could be use for vineyard management when increase the yield it is the main goal. The described procedure and results are a keystone for the application of INDITES software presented on this work.

Keywords:Digital terroir, precision viticulture, fruit quality index, machine learning.

1. INTRODUCTION

The 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 et al., (2005) 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. On this sense, is for the inclusion of cultural attributes, implied in the region of origin that makes something so difficult to quantify terroir. Many authors (Deloire,

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2003) have assessed the impact of a single parameter of the terroir in the quality of the grapes: the climate, the soil, crop, rootstocks, or water. Meanwhile, other studies have investigated the combined effects of two parameters in the terroir such as, soil and climate (Deloire, 2003), soil and varieties (Van Leeuwen, 1995).For his part, VanLeeuven (2004) by studying three variables (soil, climate and cultivate) simultaneously in the definition of terroir, found that the effects of climate and soil on the vine development and the grape composition can be explained largely by its influence on the water status of the vineyard.

The 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 terroir at a block level, is solved by using the term "Digital Terroir" for identified areas. As the name suggests, a digital terroir is a “modeling” terroir. 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 "digital terroir". The preciseness of this model depends on the accuracy and validity of input data. Thereby, the digital Terroir is essentially an alternative term for a zone or differential management class. 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. Digital terroir can then be addressed from a performance perspective (quantity), as well as the qualities of the different areas and finally the quality of produced wines. At present, it is proposed to solve the implementation of emerging technologies through the “digital terroir” development and management, given that the current procedures which are used for the study and definition of management areas in viticulture, suffer from own replicable protocols, where the entry information is quantitative and focused on the different variables that occur at the vineyard level.

2. MATERIALS AND METHODS

The study took place Valdivieso Vineyard in Curicó, Chile, during the 2012 and 2013 seasons, under a commercial vineyard, on Cabernet Sauvignon, Merlot and Carmenere varieties. For each variety was defined a block on the vineyard, on which information was taken from the field, plant and fruit quality as described below.

2.1. Evaluation of vegetative characteristics using spectral information and automated analysis of those.

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 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 AnalyzerSystem), which among other functions (such as a selection of samples location, feedinggeneration of files for the database, among others) serves for the canopy segmentation and vegetation index creation (IV), such as NDVI and RFI (Radiometric FoliarIndex), which allows you to get these IV at the plant level without distortion of its surrounding condition. The proper development of maps without distortions, allows to get a proper classification of predial areas, a very important factor for a clear definition of input variable in the digital model of the terroir. In Figure 1, we can visualize the classification done by using ICAS in the vineyard in study.

2.2. Evaluation of edaphic conditions in the area under study

The interaction with the performance and quality go beyond the composition of the foliage, there is a high influence of factors of the site associated with the soil and its composition (spatial variability), topography and other factors make this kind of images, even though they are useful in defining changes, are not sufficient to carry out a clear definition of terroir of the vineyard. It is particularly noticeable in the case of Chile, where the soils of the central valley areof alluvial origin, presenting 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 to the integrated into the already exposed have direct influence on the product both in performance and in quality, and finally in 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 is 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 exhibition planes (inclination of the land), significant value in its association with the solar radiation differentiated level that the areas have, in particular when they are on hillsides, in which case was the trial area.

2.3. Segmentation quality developed and considered elements.

The analysis of fruit quality (and in particular of grapes), has afundamental importance to the time of making the leading segregations to the objective differentiation of areas that have a wine production potential associated to a greater or lesser potential in relation to their quality to consumer-level, understanding this concept from the point of view of organoleptic quality andnutraceuticalhave had major impacts.On the other hand, it is a key element in the definition of the optimal harvest time.Fluorescence is one of the most recent techniques of optical detection proposed for grapes quality evaluation and obtaining maturity index.Among its advantages are the nature of the non-destructive method, is its speed (milliseconds) and the possibility of analyzing bunches as a whole (Cerovic et al., 2008; Cerovic et al., 2007) or layers of continues berries (Ben Ghozlen et al., 2008). The method is designed to measure flavonols and anthocyanins in the epidermis, on the basis of chlorophyll fluorescence, have been successfully used in vineyards (Cerovic et al., 2008; Ben Ghozlen, et al., 2008). As well, to carry out the definition of quality of grapes, were performed anthocyanins and index of Ferari evaluations levels, through multiplex equipment (MULTIPLEX RESEARCH, FORCE-A) for the definition of these areas.

2.4. Segmentation quality developed and considered elements.

As it was already mentioned, there were evaluations of quality of grapes (Index of Ferari levels) using multiplex equipment for the definition of these areas. On the other hand, the sectors were discussed and tested by the company staff in the gustatory evaluation of these having a full coincidence.Thus generated crop planes 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).

2.5. Ferari Index Spectral Analysisand Quality Stratification

Figure 3 shows an example of the distributions, density, of Ferari index probability of the seasons 2012, 2013, 2012-2013 integration in a single one (201X), for the Carmenere variety, taking these curves for all the varieties under study. 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. Andso 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, but in the time it had become clear that this is not the case. Therefore, the integration of levels was sought through the use of multivariate analysis of information.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 (Ferari Index), it is to integrate the site information (EM38, topography, aspect, and NDVI Index of Ferrari).

2.6. Training and Calibration.

It is to train 9 Ferari 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 that is called INDITES (INIA DIGITAL TERROIR SOFTWARE).

3. RESULTS AND DISSCUSION

In figure 4, you can see the evaluation of the results of the model incorporated into the software INDITES, where are the field results of the Ferari Index estimated and actual, in addition to displaying a fit curve of the Ferari Index modeling Carmenere variety.This way, in Table 1, we will be able to evaluate the estimation done with the model INDITES for different varieties in study and according to the classification of a defined quality. It should be noted that the model performs an estimated job quite acceptable with errors less than 10% but in most cases on the quality stratification is lower than the 5 %. *Ense, the classification results were 95 %, 90 % and 80 %, of well classified area (R^2>0.9 and Mean Absolute Error < 0.1) for Var. Carmenere, Cabernet Sauvignon and Merlot, respectively (Figure 5, carmenere 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-Indurkhya whose results are shown in Figure 6.

Of 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 thetheory of the terroir is defined by variables in situ, can be integrated to improve the understanding of the behavior of vineyardsthat will lead to a 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 INDITES platform goes for the integration of captured information between seasons for generation of the sectors whose behavior is a common pattern or similar (digital)terroir, and within each of the seasons allow the automated sectors segmentation for differentiated crop.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 onbeing 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.

Finally, it is necessary to emphasize that as these segmentations or productive space trends obtained early in the season, will lead to the implementation of different management measures to these different "zones or terroir of the blocks", which would allow to make changes to the productive trends. 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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6. FIGURES

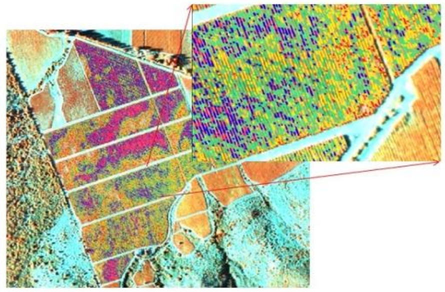

Figure 1. Analysis of the multispectral information obtained from the land in study with the ICAS software, and detail of segmentation performed by plant.

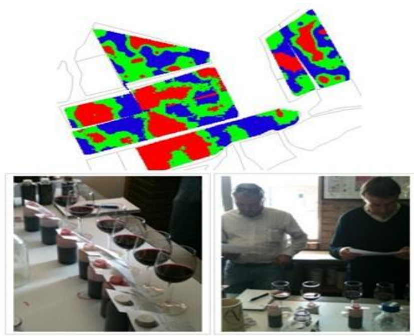

Figure 2. Map of segmentation of the quality of grapes for harvest and wine tasting developed from segmented areas (Lontue Plant Laboratory, Viña Valdivieso S.A.)

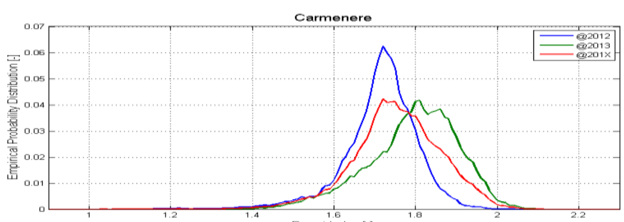

Figure 3. Distribution of probability density of Ferrari index (Quality Index) in Carmenere variety, season 2012, 2013 and 201x.

Table 1 .Table of errors control for each variety.

Variety	High Quality	Medium Quality	Low Quality
Cabernet Sauvignon	7,01%	10,81%	2,21%
Malbec	1,89%	5,63%	3,57%
Carmenere	4,97%	6,38%	1,03%

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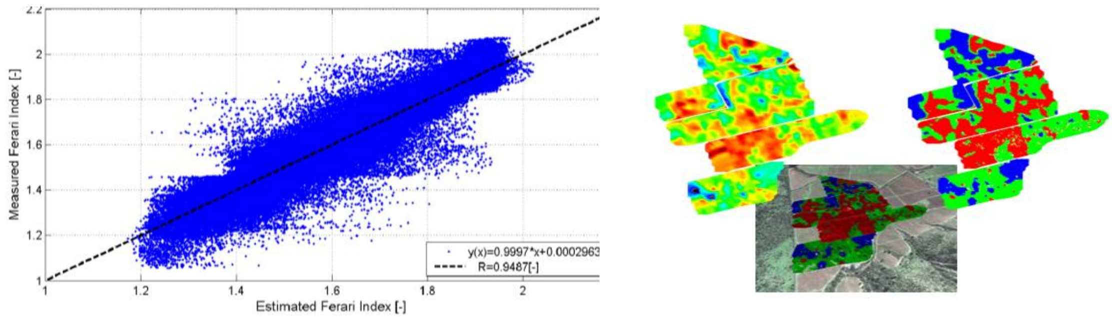

Figure 4. Ferari Index calibration: Carmenere, training data 2012 and 2013, and comparison of the results obtained with Ferari Index map. Left graphic: Ferari Index map; Right graphic: quality clusters.

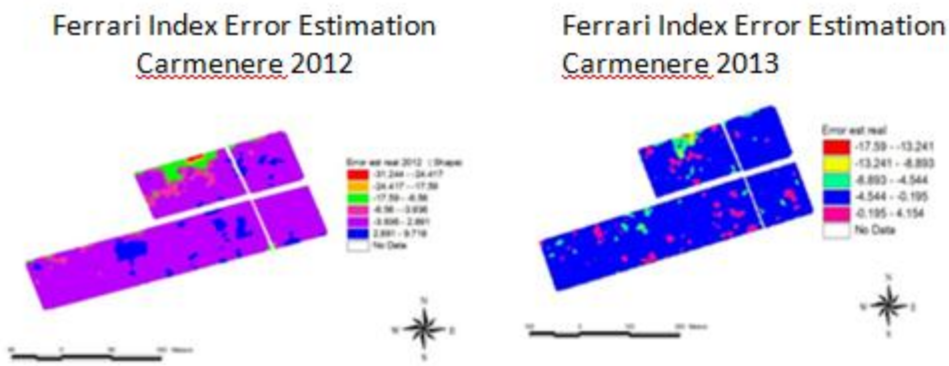

Figure 5. Comparison in the estimation of the Model (INDITES Software) in relation to the Ferrari Index obtained in the field for two seasons of work (maps show an error of the order of 4% in most of the blocks).

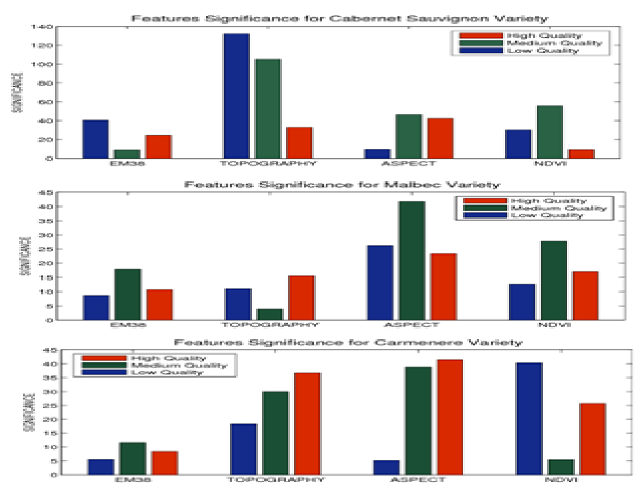

Figure 6. Significance of Patterns for the Cabernet Sauvignon, Malbec and Carmenerevariety, respectively.