Quantitative Ranking Evaluation of Wine Quality

A. Brunel, A. Kernevez, F. Leclere, J. Trenteseaux

Abstract**—**Today, wine quality is only evaluated by wine experts with their own different personal tastes, even if they may agree on some common features. So producers do not have any unbiased way to independently assess the quality of their products. A tool is here proposed to evaluate wine quality by an objective ranking based upon the variables entering wine elaboration, and analysed through principal component analysis (PCA) method. Actual climatic data are compared by measuring the relative distance between each considered wine, out of which the general ranking is performed.

Keywords—Wine, grape, vine, weather conditions, rating, climate, principal component analysis, metric analysis.

I. Introduction

WINE represents a large market with 2014 total world production of 271Mhl (million hectolitres) and mean yearly consumption around 243Mhl [1], see Fig. 1. Even if Europe remains the largest area for wine, with first three ranking 2014 producers (France, Italy, Spain), other places such as USA and China can no longer be ignored [2], inducing tighter competition amongst producers.

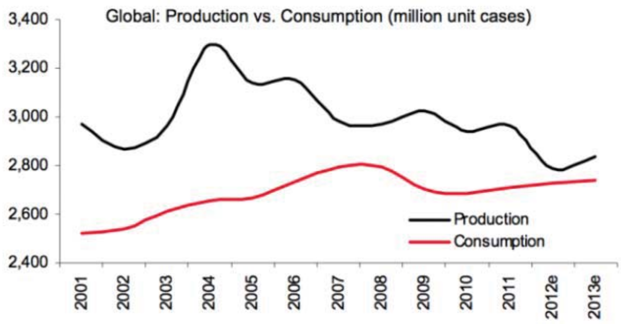

Fig. 1 Progression of Worldwide Consumption and Production since 2001 [1]

Today, wine quality is judged by wine experts. In an enlarging market, their number increases, with their own rating system strongly influencing sales and wine pricing [3]. Ambivalently grades are often used as sale argument by producers and, at the same time, as useful advertising tool for consumers using it as a reference in their purchases. However, this grading, delivered once the wine has been produced, is subjective as it relies on experts tastes [4]. This may lead to unfair pricing compared to intrinsic wine quality. So there is today a lack of "objective" method to assess wine quality even if some parameters can be measured. In this situation it is proposed here to develop such an approach to quantitatively measure wine quality. It is mainly based on selection of driving parameters which can be experimentally evaluated, and on adequate mathematical filtering method to extract a ranking which will be shown to back up usual experts ranking when applied to specific illustrative example of a French Bordeaux wine.

II. Context

Every year, experts taste the new collected vintage and, according to their own rating system, they give the wine a grade. For instance, Robert Parker has a scoring on a 100-point scale [5] with grades spread between 50 and 100, and various wine parameters, such as aroma or colour, are evaluated to lead finally to an idea of its quality. Typically, a grade higher than 96 characterizes an extraordinary wine, and a rating around 70-79 corresponds to an average wine. As actual lowest grade of tasted wines is around 90, this means that every selected wine is an outstanding one. This experts' selection agrees with their role in guiding consumer choice, and at the same time allows maintain independence with respect to industry.

Wine quality is influenced by many parameters such as technological choices, soil nature and weather conditions [6]-[9]. Although first two parameters can have a crucial impact on wine quality [10], [11], present study is devoted to analyse the same wine on an interval of several years. This has the advantage to leave aside technological choices knowing that they have been the same along the studied period.

The influence of soil is a difficult issue as it has been suggested that same technology and same weather could finally come out with equivalent wine quality for different soils. Here by focusing the study on a specific winery, the soil effect can also be ignored in the analysis and only weather conditions can be taken into consideration. Climatic conditions are essential for wine elaboration and especially during vegetative cycle [12]-[16]. From observations of past years, weather evolution is expected to have major observed impact [17]-[21] with important consequences on wine quality and production [22]-[27]. Aside global effect there is also a local effect on each period of wine cycle which conditions future grape quality [28]-[31]. For a specific vineyard, producers are expected to operate with best technological choices, and it can be supposed that corresponding wine quality is directly linked to its grape. Wines go through a well-defined sequence of seven stages over the year for producing the grape harvested at the end of vegetative cycle. The nature of each period has different effects on final

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wine quality [32], and producers often rank their vintage from beginning and end dates of latest maturation stage.

To make things more precise, present study focusses on data from Saint-Emilion Cheval Blanc (SECB), near Bordeaux, France, and only concentrates on climatic conditions endured by the wines in this specific environment. Daily data spread over six years from 2005 to 2010 are available. They are divided into five parameters {minimum and maximum temperatures, pluviometry, water loss and sunshine intensity}, here representing input parameter "state" of wine system. During the past twenty years, the harvest has been taking place in September, see Fig. 2. From October to February, the (maturing) wine is resting in storage tanks without impact of weather conditions. So, this period is ruled out in the study.

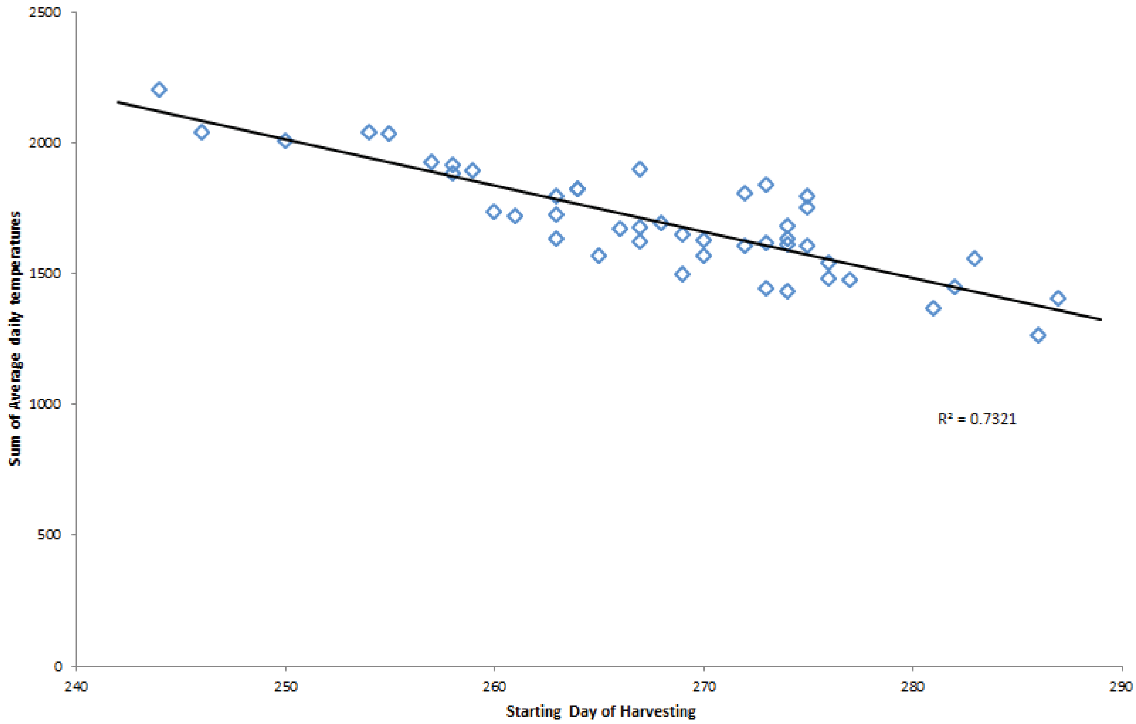

Fig. 2 Correlation between Harvesting Beginning Date and the Sum of Average Daily Temperatures (>10°C) between Years 1960 and 2005 for SECB

For some variables of state vector, missing data have been reconstituted by extrapolation of a moving average on twelve days. For wine quality analysis, only local microclimatic data have been selected, as experience [33] showed that high precision is required for correct judgment on climate influence. In present case, recorded temperatures by Meteo France in downtown Bordeaux are not the same as in vineyards around because of local factors such as pollution. For this reason, the data have been recorded onsite at SECB vineyard weather station.

III. Theoretical Analysis

From available database of collected grape and environmental system parameters, theoretical studies have been developed to evaluate wine (end product) price [34], [35] or to link climate to harvesting dates [36]. Principal Component Analysis (PCA) has been used to determine acid and sugar proportions in various cultivars [37]. This method [38]-[40] will be used here on six files database of daily collected system parameters for Years 2005, 2006, 2007, 2008, 2009 and 2010, which have been split into different subsections. Each subsection has been studied to select relevant variables from possibly noisy ones. Records number has been reduced by taking monthly average instead of rough daily records. Principal Component Analysis (PCA) [21], [22] has been applied on each variable to continue the reduction and, finally, to obtain an overall trend per vintage as a table linking years to climatic variables. PCA is used to point out similarities between files and to create homogeneous groups. In present case, PCA enables highlight a typology of files. A graph of the files has been build up enabling describe them in the same plane without losing inertia of original table. For the variables, PCA indicates links between them and a typology of variables, and allows discover the essential elements in order to realize metric analysis. Metric Analysis (MA) has been used to calculate the likeness between each year, by determining the relative distance between each file. This step has been made for each variable and then for the whole data to obtain a general position. Finally, a general file ranking has been established leaving open the choice of reference year for comparison.

IV. Results

This part gives the results obtained by PCA and Metric Analysis (MA).

A. Principal Component Analysis

The aim is to progressively reduce the volume of studied data in order to examine only essential ones. First, data are reduced to monthly average for each variable. The wine is known to rest from October to February. During this period, it stays in a dormancy state and climatic conditions do not have a real effect except if an exceptional event occurs. March has also been discarded out because it is the "bleeding" period where buds are just appearing and are not much affected by weather conditions.

With "R-studio" software, PCA has been developed for each variable. Some results are particularly relevant, such as pluviometry, see Fig. 3, and sunshine intensity, see Fig. 4.

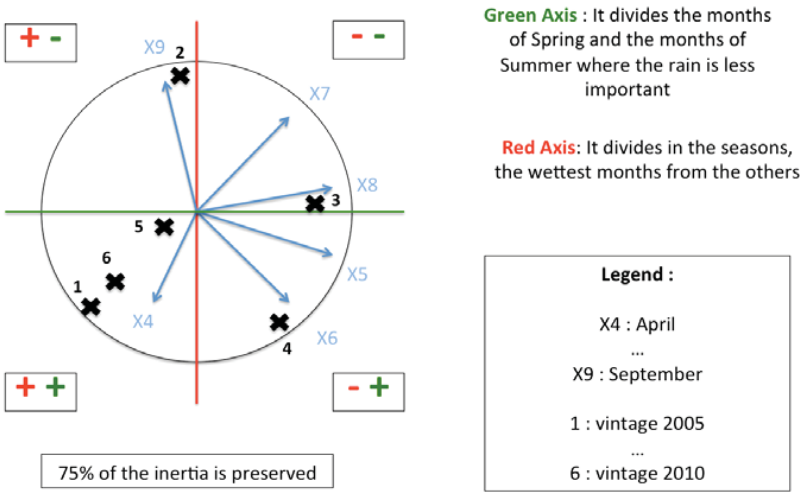

Fig. 3 Pluviometry from PCA

It is observed that months are distributed all over the circle. This means that pluviometry is not correlated between the different months and that, consequently, every month has to be kept for this variable. So 75.78% of initial data inertia can be kept.

Years 2005, 2010 and 2009 are very close. Indeed, these years suffered from an important hydric stress. On the graph, the three years are on same half-circle corresponding to not particularly rainy summer period. They are mainly influenced by a rainy April month but quite dry months after. Years 2007, 2008 and 2009 are scattered on the graph. Year 2006 had a very dry season except during September which was very rainy hence its place on the graph. Year 2007 was generally cold but September was dry which improved wine quality before harvest.

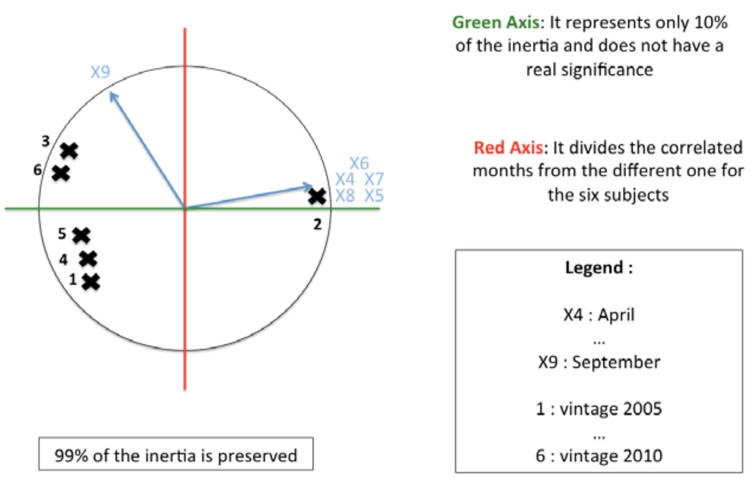

Fig. 4 Sunshine from PCA

The graph of sunshine is particularly helpful. It highlights the point that, except September, data are almost identical for every year and every month. In addition, there exists an obvious opposition between Year 2006 and the others years. Indeed, Year 2006 had a wonderful but very rainy season and, consequently, not particularly sunny month of September. For MA, one could try to select only two variables, the average sunshine in September and the average sunshine during the five others months.

Graphs related to temperatures are difficult to analyse because months are strongly correlated and file distribution does not follow wine logic. Consequently, the meaning of the axis given by PCA cannot be analysed.

B. Metric Analysis

1. Ranking

After PCA, a metric analysis has been developed and a matrix has been built up for each file. Starting from all collected data, they have been first reduced to the only months of vegetative cycle. Though some variables were not weighted because it is important to look at complete cycle, MA has been performed after normalization of 5 parameter daily recorded variables. The resulting ranking is shown on first column of Table I. These first distance measurements are an indicator for vintage hierarchy as best overall year, Year 2009 has been used as the ranking reference but results do not look correct. Indeed, 2005 vintage was second before last in the rating whereas it is recognized as one of best years. For this first ranking, calculations have been made with 5 variables on 182 days span. Results are very sensitive to daily variations. As the gap between two days can be significant, it has been necessary to increase the period of study and restrict the amount of used variables. Performing the same operations with arithmetic weekly data average (26 weeks instead of 182 days) limits results sensitivity, erases daily gaps, and allows focus on each vintage own trends. Results are more logically organized than previous ones, see column 2 of Table I. However, relative distances between vintages are particularly small. Indeed, there were still residues in the data. Once again, the study has been restricted to monthly data in order to focus on overall displacement of variables during the years and to set aside small weekly changes, see column 3 of Table I.

TABLE I
SUMMARY OF YEARS DIFFERENT RANKING (FROM TOP TO BOTTOM)

Daily	Weekly	Monthly	PCA
2009	2009	2009	2009
2008	2005	2005	2005
2010	2008	2008	2008
2007	2010	2010	2010
2005	2007	2007	2007
2006	2006	2006	2006

TABLE II
METRIC ANALYSIS FOR MONTHLY AVERAGE DATA

Month	2005	2006	2007	2008	2009	2010
2005	0	1.0722	0.9985	0.9877	0.6264	0.7560
2006	1.0722	0	1.0695	1.2345	1.0183	0.9558
2007	0.9985	1.0695	0	0.6627	0.8945	0.6570
2008	0.9877	1.2345	0.6627	0	0.6598	0.8161
2009	0.6264	1.0183	0.8945	0.6598	0	0.7522
2010	0.7560	0.9558	0.6570	0.8161	0.7522	0

From Table II, two groups can be distinguished among the files:

- 2009, 2005, 2008 and 2010
- 2007 and 2006

These two groups respectively correspond to exceptional and good quality vintages.

2. Link to PCA

Principal components have been selected according to Kaiser criterion which states that the study can be reduced to data whose components have a principal value above one, see Fig. 5. It is seen that two main components dominate in the system.

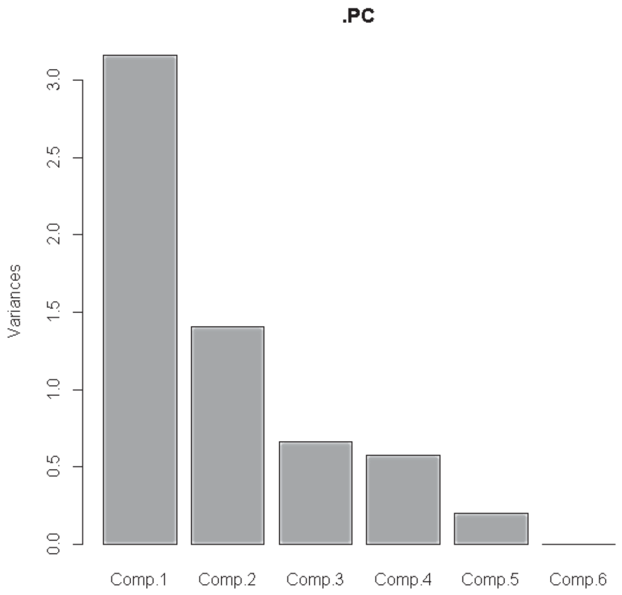

Fig. 5 Eigenvalue for Maximum Temperature

Calculations have been made for each variable to select the significant components. A matrix has been constructed based on these elements (preserving 85% of the inertia). After normalization the same ranking as the one from monthly analysis (column 3 of Table I) has been found. Finally, new PCA has been performed on the matrix. Thus, the three axes best preserving inertia have been isolated.

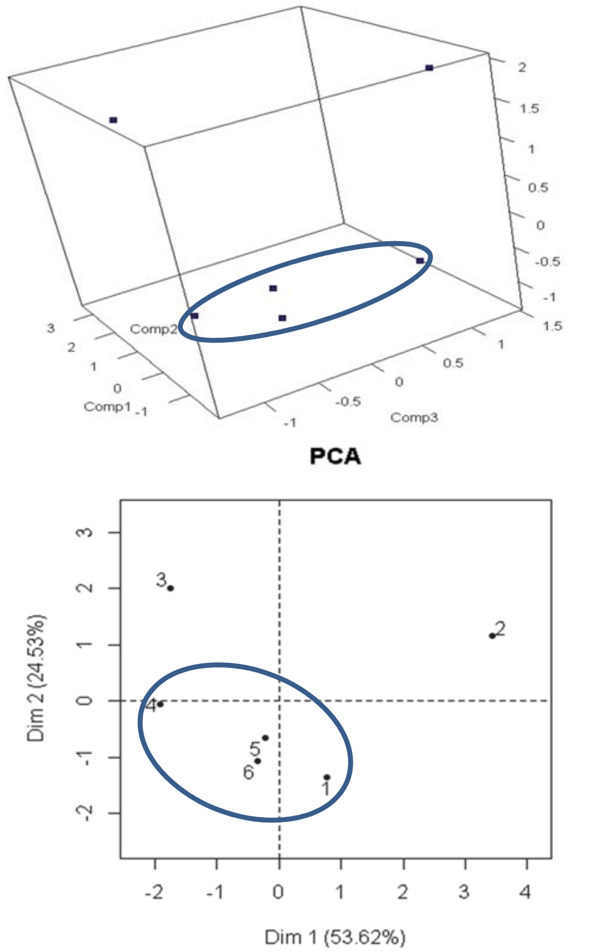

Fig. 6 PCA on Matrix M1 in 2 and 3D (3D: 91.93% of M1 Inertia is Preserved (~77% of Monthly Data); 2D: 76.05% of M1 Inertia is Preserved (~ 65% of Monthly Data))

Now vintage clustering is becoming much more precise. Year files can be split into three classes, see Fig. 6:

- The three vintages with hydric constraint: 2005(1), 2009(5) and 2010(6)
- The vintage 2008(4), near the first three
- 2007(3) and 2006(2), obviously further

Vintages 1,5 and 6 (the best ones), mark out an interesting cluster for the position of a future vintage. This new step enables have a graph highlighting the position of each vintage compared to the rest of selected years. Experts point out Year 2007 as the worst vintage among selected years. However, Year 2006 is always at the bottom in present ranking. According to experts, the difference between these two vintages appears in September. Indeed, this month was particularly rainy during Year 2006 and, on the contrary, it was especially dry during Year 2007. Thus, after a good start, September decreased the quality of Year 2006 vintage whereas in Year 2007 after a quite cold season, this month moved back up harvest quality.

3. Specification on the Model

Looking forward to establish arbitrary notes for each vintage, matrix of monthly distances will be used. Relative distance from a vintage represents the differences that may exist between them. As data are normalized, the Euclidean distance between five variables recorded on 6 months could at best be:

$$D_{max} = 5 \times \sqrt{6} = 12.247 \quad (1)$$

Its ratio to the relative distance allows obtain a percentage of differentiation, P_{diff} and its complement to 1 represents likeliness percentage P_{lik}

$$P_{diff} = \frac{\text{Matrix Distance}}{D_{max}} \qquad P_{lik} = 1 - P_{diff} \quad (2)$$

Once P_{lik} are calculated, the year to be taken as the reference (in present case, Year 2009) is set, and the new grades are calculated according to [19]. Quarin Rating has been used to reveal percentage errors. The rates are close enough to each other, with still greater errors on less good vintages, such as Years 2006 and 2007. However, other years, such as Year 2005, stand out great with almost no gap. To draw a parallel with previous reduction steps, calculations on daily and weekly matrices have been performed retaining Quarin notation and Year 2009 as reference year, see Fig. **7**. These results are consistent with the intention to develop an analysis based on larger step to isolate the overall trend of studied wine quality.

Average error is 2% and never larger than 5% with other experts' ratings, such as S. Tanzer [41] or R. Parker [5]. So empirical approach based on calculation of distances and similarities leads to a good accuracy with estimation of expert grades.

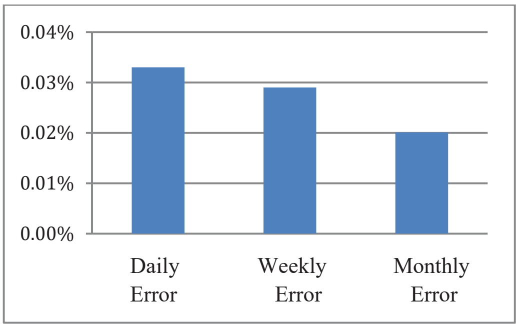

Fig. 7 Error vs Chosen Step

4. Monthly Evolution

From this good accuracy at maturity, it is interesting to follow evolution of proposed ranking gradually during periods of the cycle. Significant failovers, when and where they occur, are retained to determine at what month the ranking freezes and then, to calibrate a predictive model.

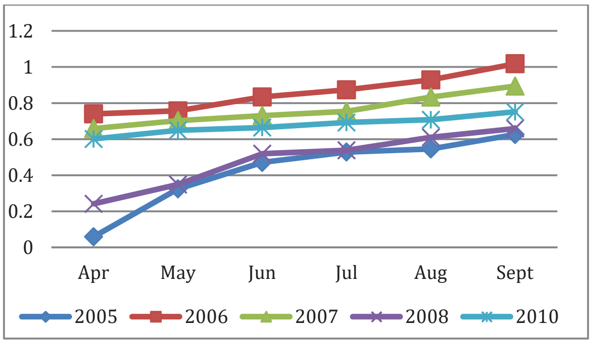

Fig. 8 Evolution of Distances Compared to Year 2009 during Vegetative Cycle

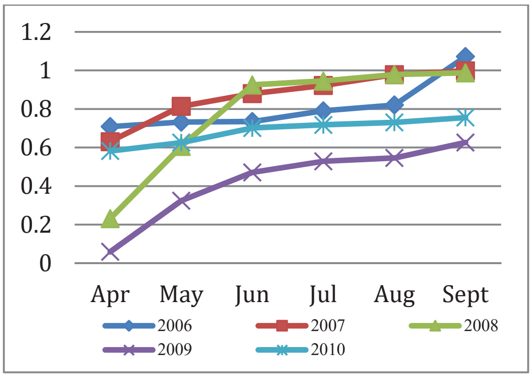

Fig. 9 Evolution of Distances Compared to Year 2005 during Vegetative Cycle

On Figs. 8, 9, the formation of both groups indicated previously, clearly appears in the representation of evolution cycle. Moreover, once the ranking is established in April, it will remain the same until cycle ends. No intermediate nor even final crossing is observed. Compared to Year 2009, Years 2006 and 2007 are still relatively close throughout the cycle and detach from Year 2010 during the last two months. During Years 2006 and 2007, the rainfall was higher than in the other years. Then, they did not undergo the same hydric stress. Thus, these vintages are characterized by smaller aging potential (about 10 years) than those of Years 2009 and 2005 (30 years).

The clustering between vintages is observed with better accuracy on second graph. Year 2006 could have been a member of the high hydric stress vintage group without a bad month of September. The correction of Year 2007 is also visible with a flattening of the distance rise curve at cycle end. Independent of chosen reference year, no evolution is to be observed between June and August. The period from April to June and September are crucial in establishing the ranking. The maturation phase (end of August to late September) is the step where the impact of climate on the wine is largest. It is also during this period that values of climate variables are the most volatile.

A future work is to establish a model for variables evolution one by one on a daily basis using a trend curve based on previous vintages data, assuming that the process is cyclical and that future can be modeled by previous years. These predictions can be made from June to estimate a rating at maturity (i.e. September)

V. Conclusion

A ranking of vintages elaborated from observed climatic data has been established in present analysis. It fits with expert analysis, based on their own rating systems. When specializing to local climatic conditions, it is possible to set a vintage ranking on a specific production domain. It is shown that the same grades as experts' ones can be evaluated with average error smaller than 10%.

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