CLIMATE CHANGE AND ECONOMIC CHALLENGE - STRATEGIES FOR VINEGROWERS, WINEMAKERS AND WINE ESTATES

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Abstract
For wine areas around the world, nature and climate are becoming factors of production whose endowment becomes a stake beyond the traditional economic factors: labor, capital, land. They strongly influence agricultural and environmental conditions for production. With global warming new production areas are suitable for cultivation of vines with new people embarking on viticulture, preventive relocations are underway as well as land purchases which are anticipated future potential, cultivation practices evolve... A shift towards the poles (north and south) begins to be observed.
The people in charge of wine estates (winemakers, owners, managers,...) have to adjust continually to the impacts of climate change, a key and permanent concern today. In the vineyard as in the winery or in cellars adaptation is unceasing. Moreover, important observations of temporal and spatial variability of climate require unending monitoring in the vineyard, operations vital and costly in time. Simultaneously a strong spatial variability of climate on tight spaces requires responsiveness of winemakers in their plots because of high differences caused by local conditions (topography, soil, subsoil ...) both in the short and medium term.
For wineries individual adjustment strategies, although still implemented through the centuries have become essential or crucial to the future of the working tool. The wide variety of situations (climatic, geographical, economic ...) require new decisions to protect properties from incidents and accidents; the consequences of climate may jeopardize the survival of the wine estates especially the small ones (coverage risks, geographic diversification ...). An individual or collective supervision is required to avoid uprooting of vines followed by losses and shortfalls in earnings over several years. Some recent situations are given as examples; they essentially concern familial estates in Burgundy from the vineyard to the choice of the type of produced wines.
Keywords: climate change, grape, strategies, vignerons, vines, wine, winemakers

1 INTRODUCTION

A large literature begins to analyze the implications of climate change in strategic decisions of *vignerons* during different stages of the cycle of the vine and in the process of wine production (Jones, Web 2010; Mozell, Thach 2014; Bernetti 2012). These choices have to be decided at each step of the production from the plantation of a vine (grape variety, vine planting density...) to commercialization (bulk, bottle...) through the oenological practices or the kind of wine to produce (red, pink, dry, sparkling...) or the time and date of harvest to obtain a great quality of grapes. The choice of harvest date is often a risky bet. If absolutely necessary a reorganization of the vineyards (varieties, orientation of the rows, local or regional movements) is a costly process. Individual experiments of winemakers are common. Moreover, collective decisions become indispensable such as water management, detecting diseases or parasites, phytosanitory treatment, fight against bad weathers such as severe thunderstorms, hail and frost whose probability tends to increase. They can be critical for the survival of the vineyard and the perpetuation of wine estates.
Furthermore the heterogeneity of demand becomes a new concern: consumers have expectations and tastes very different from one end to another in the world (colors, varieties, wine types, ...), opportunities, circumstances and consumption occasions are extremely varied: with or without food, at home or not, during social gatherings or moment of relaxation ... What category of wines produced? Which market? In addition a new challenge is the preparation of consumers (novices, regulars, fans, connoisseur, wine lovers...) to modifications in the organoleptic characteristics of wines; climate change influences the aromatic balance of wines and consumers have to be initiated to accept them.
The aim of these pages is to give a few examples of situations recently encountered by the *vignerons* and managers of estates in Burgundy. By using the decomposition technique of the production cost structure per analysis center (vineyard along the vine growth, harvest and winery, market), the presentation aims to highlight the critical decisions and strategies (technical, economic, managerial, commercial,...) for an individual and collective responsibility of the wine estates. The final objective is to ensure the economic and financial profitability of the estate, a challenge for their sustainability while being attentive to the requirements of customers (individuals, wine shops, restaurants, supermarkets,...) on domestic and international markets. It is important not to forget the new responsibilities in terms of environment and nature protection, and eventually heritage conservation.

2 GENERAL CONDITIONS AND ENVIRONMENT

In recent years the climate changes have played on the nerves of winemakers. Face to various situations, they research to benefit of positive effects (maturity of grapes, sugar content, ...) and to limit the influences of negative effects (frost, hail, thunderstorms, pests, diseases ...). Model of wine estate in Burgundy is a family one with a medium size 5 to 15 ha consisting in 14 to 20 plots located in several villages. In the past, it has been a strategic decision of the village elders to allocate naturally the risks. If a plot was damaged in a village, another one generally was not concerned. In such a situation, needs of each estate are specific with a wide dispersion of the farmed plots. Moreover the same plot may be used by several *vignerons*; e.g. plot "*Clos de Vougeot*" of about 126 acres is owned by 85 owners.

From bud break to fruit maturity via flowering, numerous and various decisions have to be taken by "*vignerons*". Because of a strong spatial variability of climate on tight spaces due to local conditions, decisions are generally specific to the plot and sometimes in different part of the plots (top or bottom, very sunny or not exposure, proximity of a low wall, a wood...). More and more frequently collective decisions for different kinds of protections are necessary, against diseases (observations, treatment...), fight against hail (equipment, meteorological watch), frost (team of watch during night), thunderstorms in order to implement materials (heaters, sprinkling device, wind machine) or drought. These equipments are expensive and concern most of the time several estates.

A great problem will be that of water whose grapes need through the rain during the growth of berries or irrigation in some countries. The yield of the plots can be drastically reduced and production of wine insufficient. Micro-irrigation could be a response but it modifies root system that tends to stay on the surface, the plant will not look in depth the necessary nutrients and water, which affects the quality of grapes and wine. Moreover to water the vines by micro-irrigation is not totally allowed by some regulatory designations in Europe (AOP - Appellation d'Origine Protégée - Protected Designation of Origin) except in Mediterranean area; in other countries it is the lack of water resources and drought that can make disappear a vineyard. Finally the water needs of agriculture are in competition with residential and industrial needs, creating conflicts of use.

3 STRATEGIC CHOICES IN VINEYARD

Vine as perennial plant is object of watchful and greatest care; adaptation to climate change is time-using, time-costly and money-costly. To plant a vineyard is a long term investment (30, 50 years or more) and no income is expected the first three or five years after at least 5 years of fallow without harvest; it means finally 8 to 10 years lack of money. This is why grubbing operations are made by rolling and why an estate has different plots. The choice of a grape variety is important, especially as climate change will alter the characteristics of the grapes and consequently the organoleptic properties of wines that will be produce. Moreover, designation regulation (such AOP or IGP in France) imposes specific varieties to use the name of a particular wine (designation system). A change of variety needs a modification of the specifications "*cahier des charges*" to continue to benefit of the label of origin and appellation; if not the label is lost. Fortunately, the Pinot noir as one of the most climatically sensitive varieties, today seems still perfectly adapted in Burgundy to give great wines. But it needs careful and regular care.

During the vine growth different situations appear that demand the greatest attention and require a capacity to develop responsiveness to climate accidents. In spring the occurrence of severe episodes of frost is the obsessive fear of *vignerons*. April and May of 2016 have been two terrible months for vineyards in France with a repeat of severe frost and hail episodes which destroyed a more or less large part of emerging buds, compromising the future harvest (Cognac, Chablis, Bourgogne, Beaujolais). In case of frost, the nights have been long for *vignerons* who surveyed temperature and decided to launch the collective protective systems that equipped some plots (heaters with paraffin oil, sprinkling water); it does not completely prevent losses. If heaters are polluting and environmentally unfriendly (600 per ha for a good protection), they need a significant work force, are costly but constitute an efficient system in case of emergency. As for the sprinkling water system to protect young buds, it needs a lot of water nearby (which is not the case of all the vineyards) and large water reserves are necessary to provide sprinkled throughout the frost event. It follows that it's necessary to outfit some particularly sensitive springtime frosts parcels and / or those that produce great wines. In other parts of vineyards, some plots are equipped with "wind machine".

Such a Spring illustrates in Burgundy some consequences of climate change with a lot of damage such as the black frost (the night April 26-27) grilling many new buds. Unfortunately, rain associated with the morning sun created a "magnifying glass" effect that shattered the buds. Numerous *vignerons* have to deplore a "destructive effect to the vine when it was at its most delicate physiological stage". Months of hard work are reduced till nothing. Due to the heterogeneity of the intensity of the frost in the vineyard, damages concern nearly 10% to 80 or 100% of some plots: yields will be reduced after 3 years of small harvest. For wine estates another source of worry has been the hailstorms in mid-April and May 2016 which have damaged some parcels that had been preserved from frost and destroyed a part of vineyard. Then wind, cold and moisture have limited the recovery and growth of vines. Violent, brutal and devastating thunderstorm (May 27 at the end of afternoon) reached the

plots that had not undergone frost event and destroyed vines. The 2016 vintage will be reduced in some appellations and in the affected areas the vines and woods are so damaged that even the 2017 harvest is compromised. If buds are scratched, much is lost, the operation of pruning will be difficult and harvest of the following year is compromised. The wounds made to the vines make them unsuitable for the production temporarily (lower yields) or permanently (loss of vines by uprooting followed by replanting operation).Thus it appears that climate may jeopardize the survival of the wine estates especially the small ones and there is now anxiety for the sustainability of some estates; moreover it could not have enough work for seasonal workers during 2016. However, care giving is a necessity for a vine that gives nothing but should be ready for next season. Financial consequences appear when small harvest implies loss of income and difficulties to permit the payment for wages, taxes, rents... Consequences of a severe reduction in the volume of the harvest are too for all the environment of the wine industry: bottles, boxes, rent of refrigerated vehicles, taking on grape-picker and particularly for cooperages which cannot sell new barrels they have anticipated and have to find other wineries and market. It's all the local economy which is affected.

To prevent (a part of) the damages, anti-hail guns and installation of new networks have reduced the potential losses. The interest of these guns is based on two factors: a shooting early enough before the arrival of the storm so the system has a defense on the hailstones that they do not reach the ground. But (second factor) the difficulty of in advance and accurate detection of storms is real and a delay in sending the alert message by meteorological services today still limit the effectiveness of such a device. The installation of anti-hail nets is another solution; however, the narrow distance between the rows (1 meter in Burgundy) can make difficult some operations requiring the frequent move of clearance tractors (vineyards tractors) (treatments, operations on leaves, trimming ...); lifting nets takes time. Moreover, the installation cost of such equipment is high and this protection is not clearly allowed (it is supposed to change the *terroir*); experimentation is underway. These climatic accidents and the damage they cause demonstrate that it is vital for *vignerons* to have a subscription of weather report and warning message, and they need to have information **at a very local level, ideally at plot scale.** They also reveal necessity of a collective watch and monitoring, and requirement of solidarity because of sharing plots.

During summer heavy thunderstorms (rain and/or hail) are feared. In the case of sloping vineyards or those which are steep, violent summer storms rain causes gullying, soil losses and nutriment erosion; they can damage the vines by putting the plants bare, vines are blessed (Brenot 2008, Quiquerez 2008), with potential impact on future quality of grapes … and wines. Moreover, the land that has been accumulated at the bottom of the plots should be raised and distributed along the slope.

It is possible to insure some risks but with frequencies of episode (hail, frost, drought, flooding) insurance premium increase and people have to make a compromise between potential loss and equipment of the plots. Because generally installation costs are high, frequently they choose to insure specific plots against hail (with a choice of deductible), more rarely against frost. When they decide to protect them and begin to install equipments, they select especially plots giving best wines or those which are particularly sensitive to frost. Against hail, only 15% of surfaces are insured; the *vigneron* must compromise between potential losses, cost of insurance, installation of equipment and constraints in the practice of some operations in the plots. Insurance is a way to limit the economic impact of a devastating episode. Some estates choose to insure a harvest, the salaries of permanent workers ... It must be emphasized that the repetition of the damage may be associated with the existence of corridors storms and hail which a cause could be the creation of new parcels by deforestation or the construction of new private housing estate.

Otherwise 2015 on a part of Burgundy is a good example of the situation of millerandage and drought: rain and cold at flowering causes imperfect fertilization of the flower that gives small berries, drought in August at the moment of véraison did not allow the grains to grow. The grapes mature with small bays that is the pledge of a good concentration in polyphenol, the presence of aromatic compounds and a nice color. It is expected very high quality and great wines but unfortunately in small quantities, favorable to outstanding wine of great structure with ageing potential (long-keeping wine) much sought-after by connoisseurs and wine lovers. Price increases reached by the vintage 2015 in auction charity sales ("early to market wine") of 228 liters casks owned by estates Hospices de Beaune (November 15, 2015 with an increase in the average price compared to the 2014 vintage 27% for red wines, 32% for white wines) and Nuits-Saint-Georges (March 20, 2016, up from the 2014 vintage of 54% for red wines, 73% for white wine) illustrate the consequences of a summer season characterized by drought. Prices seem not to stop international buyers and wine lovers who were present in large numbers at these two events.

During flowering and véraison periods, diseases and pests have to be carefully watched; new pests are appearing last years in Burgundy vineyards with migration of parasites from the south. It needs to fight against vectors responsible for disease distribution; a patient and scrupulous monitoring of the vineyard became time consuming. A particularly dangerous fly is the Scaphoideus titanus, vector of "golden flavescence"; it develops in case of not enough cold winter temperature (may be Winter 2015-2016?) and attacks with irreparable consequences for continuity of vines or eventually vineyard as it was the case with phylloxera. In France, any case of golden flavescence must be declared to the Plant Protection Services and the affected vines must always

be pulled out. The regulations require the uprooting of plots where the proportion of vines is above a certain threshold (20 or 30% in general). In contaminated area (defined by regional administration) the fight against the insect vector is mandatory. Collective and mandatory action in search of parasites has been implemented with official and regional decision of compulsory treatment; absence of treatment endangers the vines of area (plots and eventually vineyard village); in case of no treatment, legal action could be taken against the grapegrower. A systematic struggle is based on 3 insecticide treatments during vegetation period These three compulsory treatments are problematic in organic farming; only careful and regular visits of the plots by a group of grapegrowers of the village can limit the damage caused by this insect.

Since 2008 in Europe, a second new parasite is the fly "Drosophila suzukii" that wreaked havoc in laying eggs in healthy berries of black grapes (pinot noir), fruit that becomes unfit for making wine because of the rot. The presence of this parasite requires the installation of monitoring and trapping systems; it's essential to destroy and bury the damaged fruit including those who fell to the ground. Because of losses of grapes on the plots and consequent lower yields, this fly becomes a real scourge for red wines and for grapegrowers and winemakers with a significant reduction of volumes for the vintage. Chemical control is currently inefficient and some products are banned from use since February 2016. Some research programs are started but it will take time to find environmentally and economically satisfactory solutions

A new challenge has emerged with climate change in the late 80s . First, there is no more bad vintages. Second, the increase in CO2 concentration has led to a growing weight of bunch of grapes and performance of the plant. Measurements made by the technicians of the BIVB (*Bureau Interprofessionnel des Vins de Bourgogne* - Burgundy Wine Board) point out that the unit weight of the bunches of grapes increased for Chardonnay and Pinot noir: more bunches, more berries per bunches, more voluminous berries. For example, the bunch of pinot noir in Côte d'Or grew from 35g in 1994 to 50g in 2006. It may be necessary to pay attention to the respect of yields required by specifications of the labels and decide a new performance strategy.

4 STRATEGIC CHOICES DURING HARVEST AND AT THE WINERY

The choice of the first day of harvest is crucial and the maturity of the grapes is followed from day to day; in some plots, several harvests may be necessary.With harvest very early in September and high temperature during the day, the main objective for *vignerons* is to maintain the freshness of the grapes. Some of them decide to make nocturnal harvest or to begin harvesting very early at the end of the night in order to get the grapes in the winery before 8 or 10 AM. It's also more comfortable for grape-picker (manual or machine harvesting). To respect harvest, *vignerons* use crates of small size to avoid crushing the bunches of grapes, with holes to eliminate juice and avoid a beginning of fermentation before being placed in the fermentation tank. Moreover, more and more frequently they use to rent refrigerated trucks to keep fresh grapes until they arrive at winery (a trip per hour); it needs sometimes a double equipment: the first one at the vineyard, the second one for transport between vineyard land (plot) and winery; this last one has to be very carefully washed (specially crates) before returning at vineyard for a new trip. The cleanliness and hygiene of equipment is paramount, requiring frequent washing and a careful workforce. At the entry of the winery, the crates are gently emptied on a sorting table and three or four people observe the bunches of grapes and the berries with the utmost attention to eliminate the damaged berries; it's a condition to make great wines. After such inspection, grapes are put into tanks which are carefully kept watch during alcoholic fermentation. It needs sometimes 6 or 7 persons to ensure all these operations in winery each day during harvest time, and a big quantity of water to wash all the material.

With the risk of experiencing high temperatures during the harvest period, new and recent fermenting rooms are air-conditioned and temperature controlled vats are connected to electronic monitoring that alerts the grower (day and night) to intervene. After alcoholic fermentation, wine is transferred into casks or barrels for the rearing period in old fresh storage cellars or in new air conditioned room.

5 STRATEGIC CHOICES OF WINE TYPES

What kind of wine produce and offer to buyers and consumers? With climate change, rising temperatures have a significant effect on the grape and wine industry (Mira de Orduña 2010) With summer high temperatures in the long term and with acceleration in the last twenty to thirty years, the degree of alcohol of many wines has increased. If choice of selected plants and cultivation methods has played a role, it is also the result of the rise in temperature at the time of ripeness, leading to a higher sugar content of grapes. In the middle of the nineteenth century and in the Bordeaux area, the wines of "chateaux" (which were not yet classified) measured 8.7 to 9.3% alcohol by volume. Since 1960, experts estimate that the French wine takes additional near 1% per decade. Where consumers used to purchase wines from 10 to 12%, it is necessary today to have wines from 13 to 15% and buyers are surprised by the new alcoholic volume of wines; moreover with recent political decisions on security (driving), on health and welfare, they hesitate to drink too much wine (and alcoholic beverages) so that winemakers are accustomed to advise to drink in moderation.

Winemakers seek to limit the alcohol volume and experiment different solutions. Thus, some of them harvest before complete maturity; thereby they preserve acidity and ensure the ability of aging. Face to the dilemma

"sugar / acid", the winemaker is confronted with different situations for pinot noir, chardonnay and other varieties, with concerns in terms of quality, sale price and acceptance on the market. Another possibility for *vignerons* who use yeasts is to choose whose which gives less alcohol (Tilloy et al., 2015). Otherwise, partial dealcoholisation process is conceivable; wine studies on winemaking techniques, sensory perceptions, marketing and management help to understand the technical possibilities, the conspicuity of the reduction, the acceptance of such products, the quantities consumed and consumer reactions purchase. Technical solutions remain expensive (to add water remains banned). Acceptance of partially dealcoholised wines does not appear to be particularly marked by the refusal as the reduction remains in the region of 2 to 3° (Meillon et al, 2010). If a VDQA quality wine (*Vin De Qualité à teneur réduite en Alcool* - quality wine with reduced alcohol content) appears as a new market it needs to train and inform the buyer and the consumer. If such a process is acceptable for premium wines, it is less or not considered by fine wine producers who prefers other solutions. Furthermore, depending on the climatic year and quality of the grapes, the winemaker may decide the most suitable wines to produce: wines to drink quickly, wines with or without label, great fine wines, wines to keep a long time...

6 CONCLUSIONS

"Humans have had a seemingly millennia long love affair with alcoholic beverages around the world" (McGovern 2011). Wine is an important product for human since more than 6 millennium. Indeed, the Areni-1 winery is a 6100-year-old winery that was discovered in 2007 in a complex of caves in the village of Areni (Armenia). For the first time, a complete archeological picture of wine production was found; the winery consisted of fermentation vats, a wine press, storage jars, pottery shards; in addition were found grape seeds, remains of pressed grapes, prunes, walnuts, and desiccated vines as well as drinking cups. To test whether the vat and jars had held wine, the team chemically analyzed pottery shards for telltale residues; they had been radiocarbon-dated to between 4100 B.C. and 4000 B.C. Some years before, McGovern had uncovered chemical and archaeological evidence of wine, but not of a winery, in northern Iran dating back some 7,000 years, around a thousand years earlier than the new find. The new discovery was a proof that the vine had been domesticated (McGovern, 2011). During the next millennium, from the Caucasus region, vines invaded the world and today it is cultivated in the 5 continents, including a priori improbable areas such as the equator and the tropics. Over the centuries, grapegrowers and winemakers have experimented despite climate change that has appeared. Different kind of wines has been elaborated, improved, kept, tasted, appreciated...

Analysis of climate and its numerous changes (Le Roy Ladurie 2007) show that over the very long term *vignerons* and vineyards have adapted to make wine. Adaptability of the vine is well known by professional but it's sometimes necessary to help it. Viticulture managers and producers need to continue to consider a wide variety adaptation methods if they want to preserve their wine's quality, identity and profitability (Mozell, Thach, 2014). From numerous discussions, it appears that *vignerons* are great observers of nature and have a perfect knowledge of their plots, their strengths and their weaknesses, their limits and what they can give or offer. In the vineyards, many experiments are underway. In case of climate change, some of them envisage to move a part of the vineyard in altitude (they have first to buy the necessary land) and make new plantations. This can be too a response to the withering of the vineyard with vines which have often 70 to a hundred years. Moreover, the winemakers can no longer escape a growing commitment to the protection of the environment, sustainable development with all the constraints that involve regulations; it's an individual and collective responsibility of the wine estates. Only wine merchants with an activity of producers and financial capacities can buy vineyards or land in the areas likely to host vines for producing quality wines (purchase of land, buildings and facilities, technical equipment, plantation...).

The *vignerons* will have to manage climate-related risks and opportunities with a main objective: to ensure the economic and financial profitability of the wine estates, a challenge for their sustainability as the viticultural map is changing. They also have the responsibility of protecting biodiversity for varieties (back to ancient vines). Neethling et al. (2016) propose a lighting schematic representation of climate change adaptation strategies, with decisions in short term (winemaking techniques, harvest, soil and canopy management, pest and disease control), then medium term (pruning techniques, rootstock varieties, planting systems, site selection) and finally long term (grapevine varieties and irrigation). Face to climate change and climatic accidents, *vignerons*'s decision-making play a significant role as their adaptive responses to climate conditions. By using the latest connected equipment (through new investments), precise information will be collected to reveal easily the potential adaptive capacity of vine to the climate change; it's time for a precision viticulture.

The recent inclusion on the UNESCO World Heritage List (July 2015) of "Climats, terroirs of Burgundy" as "outstanding example of grape cultivation and wine production developed since the High Middle Ages", imposes a new responsibility to Burgundy *vignerons*; they have to continue to offer great fine wines despite climate change. Wine lovers, connoisseurs, regulars will have to adapt probably to new organoleptic characteristics.

With the help of *vignerons*, their sense of observation, their attentive presence in the plots, their adaptability and experimentation capacity, their extreme vigilance, experience, know-how and expertise, I wish us to have pleasure to continue to share and to taste fine and great fine wines!

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