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**Nathalie Ollat**[1] and Jean-Marc Touzard[2]

[1] UMR EGFV, Bordeaux Sciences Agro-INRA-Bordeaux University, ISVV, 210 chemin de Leysotte, 33882 Villenave d'Ornon. nathalie.ollat@inra.fr, https://www6.laccave.fr
[2] UMR Innovation, CIRAD-INRA-Montpellier SupAgro,2 place Viala, 34060 Montpellier jean-marc.touzard@inra.fr

**Abstract**

LACCAVE was launched within ACCAF metaprogram as a national scientific network aiming at studying and providing knowledges and tools for the adaptation of the French wine industry to climate change. After a brief description of LACCAVE consortium and general objectives, this note illustrates the systemic approach of adaptation developed, by focusing on one main issue related to climate change "how to cope with drought in a sustainable way".

**Keywords**

Grapevine, drought adaptation, climate change, strategic choices, adapted varieties.

Considering the economic and cultural place of the wine industry in France, the LACCAVE project was launched in the frame of Metaprogram ACCAF as a systemic and interdisciplinary approach to study the impacts of climate change and define some adaptation strategies for this sector. Climatic conditions, both from current and previous years, have a large impact on grape production and wine quality, which is already known as the "millesime effect". Vineyard locations, growing practices and annual calendar of phenological stages are also considered as good markers of climatic conditions. Indeed, harvest dates were used to reconstruct climates from the past in several wine areas (Garcia de Cortazar-Atauri *et al*., 2010). In addition, grapevine is a perennial plant, but fruits and wine are produced annually. Consequently, adaptation strategies can combine both short and long term changes. Finally, in more than 70% of French vineyard areas, wines are produced under the rules of Protected Geographical Indications (PGI) which define collectively where and how vineyards can be grown and wines can be elaborated. This system induces very specific conditions to adopt innovations and to manage adaptation. All together these specificities characterize the wine sector as a model to study adaptation to climate change.

LACCAVE adopted a systemic description of the industry as a combination of bio-physical components considered at local scale and highly impacted by climate changes, technical components from the grape growing and wine making systems, marketing components and regulation and organizational policies components along the value chain (Ollat *et al*., 2016). Each component included also a set of levers which could be mobilised to define adaptation strategies. A common definition of adaptation was chosen as "the set of actions and processes which societies must utilize to limit the negative impacts of changes and maximize their beneficial effects" (Hallegate *et al*., 2011). The overall objective of LACCAVE was to design adaptation strategies at local scale, combining technological, spatial and organisational changes, based on expert and participative approaches. The national consortium established involved about 90 scientists and students from 23 laboratories from INRA, CNRS and two universities, with a large range of skills including climatologists, geneticists, plant

physiologists, pathologists, agronomists, oenologists, human science scientists, mathematicians and data managers and economists. Seven pH-D theses were successfully defended. The consortium defines the following operational goals which were i) to establish a network in order to coordinate the already existing studies, ii) to perform new specific studies with both disciplinary and interdisciplinary approaches, iii) to share knowledge about impacts and adaptation, iv) to raise the awareness of the industry and to transfer our collective knowledge to the stakeholders, and v) to elaborate a foresight exercise as a tool for stakeholders to define their own adaptation strategies.

Among others, increased drought problems are a major concern for the industry, especially in the Mediterranean vineyards. Even though grapevine is considered as highly adapted to dry environments, yield is highly related to water status and quality may be negatively affected severe drought. Consequently, one question addressed to LACCAVE was "how to cope with increasing drought, in a sustainable way?". Using simulated climatic data from Meteo-France for the GIEC scenario A2, Lebon and Garcia de Cortazar-Atauri (2014) computed several agro-climatic indices related to vineyard water status in 3 different zones of Languedoc-Roussillon region for the near and far future. Even with large uncertainties for precipitation, and some variability among zones, evapotranspiration, duration and intensity of drought might increase with a high probability during the growth cycle. However, as a consequence of earlier ripening due to increased temperatures, average drought intensity during the ripening period would not be significantly affected. Nevertheless, these more stress-full conditions over the season will require an adaptation of growing practices in order to maintain vineyard sustainability in these regions. Several technical levers, as irrigation, soil management, training systems and more adapted plant material may be considered, and several strategies may be designed according to additional factors. Irrigation is a simple and fairly easy solution to implement at short term if water is available. According to Ojeda *et al.* (2017), the amount of additional water has to be strictly monitored to adjust the plant water status to the levels defined according to the grapevine stage and the targeted quality. Even if the use of alternative source of water is promising, irrigation won't probably be possible everywhere, is expensive both at collective and individual levels, and may become a risky strategy when water resources will become limiting. At medium and long terms, and taking into account the life cycle of a vineyard, more sustainable strategies as training systems and more adapted plant material, varieties and rootstocks, need to be considered seriously. In the frame of LACCAVE, Aude Coupel-Ledru studied the genetic architecture of grapevine responses to drought. Using a combination of quantitative genetics and physiological approaches, as well as the PhenoArch phenotyping platform and vineyard experiments, she detected several quantitative traits loci underlying traits as plant transpiration and hydraulic conductivity, water use efficiency and night transpiration. Among the various traits studied, night transpiration was demonstrated as a good marker of high water use efficiency (Coupel-Ledru *et al*., 2014, 2016). This result is an important piece of knowledge to select more adapted varieties. These varieties may already exist among *Vitis vinifera* genetic diversity and should now be characterized for this trait. New varieties highly adapted to drought may also be bred to combine several performances as resistance to diseases and resilience to high temperature. However, any technical solutions, as the release of new varieties or growing practices, should be experimented in commercial conditions to evaluate their impacts on the whole agronomical performances of the vineyard, and from an oenological point of view with a special interest to yield and wine quality. Conditions of acceptance in PGI areas (AOP or IGP labels) should also been studied. Last but not least, conditions of acceptance by growers, other actors of the industry and consumers have to be taken into considerations as shown by several studies from LACCAVE project (Neethling *et al*., 2017; Fuentes-Espinosa *et al*., 2017).

Adaptation to climate change of the French wine industry will involve strategic choices based on a combination of changes at several scales from the individual plot to the national level. These choices may be difficult to do, taking into account all the actual other challenges for this sector. LACCAVE was

successful to raise the awareness of the industry and provided a foresight exercise as a tool to design its own strategies plans both at local and national scales (Aigrain *et al.*, 2017). Perspectives involve participative approaches to support the actors to implement the required evolutions.

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