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Mortality and vigour based indicators for an early diagnosis of vineyard decline

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Similar to the forestry industry, the winegrowing sector has experienced a grapevine decline phenomenon over the last twenty years, so that decline is now considered an increasingly widespread problem in many vineyards across the world[1]. In this work, the relationships between yield, mortality and vegetative vigour were investigated, in both temporal and spatial terms, to identify early diagnosis indicators of vine decline.

Vineyard decline is a complex multifactorial issue

Grapevine decline is a major global viticulture issue defined as a multi-year decrease in vine productivity and/or increase in vine mortality. Although grapevine trunk diseases are one of the most studied causes, decline is multifactorial and rather complex since it has been associated with more than 70 factors, including abiotic and biotic hazards. Decline is assumed to result from the exposure level (time and severity) of grapevines to some environmental hazards combined with genetics and management factors conditioning vineyard susceptibility. Because of the complexity of such interactions, a global and systemic approach should be adopted to study vine decline[2 3]. The present study aims to characterise the temporal dynamics of grapevine decline by focusing on three key indicators: yield, mortality and vegetative vigour. Farm surveys, historical analysis and field measurements in declining plots were conducted simultaneously to shed light on the relationship between farmers' perceptions of decline and its objective characterisation based on the plant indicators measurements.

Winegrowers' perceptions of decline

The winegrowers' survey showed that decline was a major concern in the three French regions studied. All the interviewed winegrowers identified grapevine decline in their plots and it was mostly observed in plots that were at least 10 years old (decline diagnosis mainly when plots were between 11 and 15 years old). Decline was attributed to vine mortality, which ranged from 5 % to 20 %, rather than to yield decrease. The yield issue was considered more in terms of inter-annual variability than of a regular decrease over time.

FIGURE 1. Detection of absent and dead (A/D) vines from old orthoimages (IGN June 2012) in the Languedoc_7_Chard plot. The yellow circles indicate the A or D vines, without distinction; the white lines correspond to the studied subplots.

Progressive spreading of vine mortality over the years

The historical analysis of mortality in the plot network (15 to 30 years old vines), based on orthoimages (figures 1 & 2), was consistent with the winegrowers' perceptions of grapevine decline as being a long term phenomenon mostly driven by increasing the proportion of non-productive vines.

Mortality progressively spread over the studied plots, year after year (figure 2). However, a large degree of within-plot variability was due to non-productive vines being distributed irregularly within each vineyard.

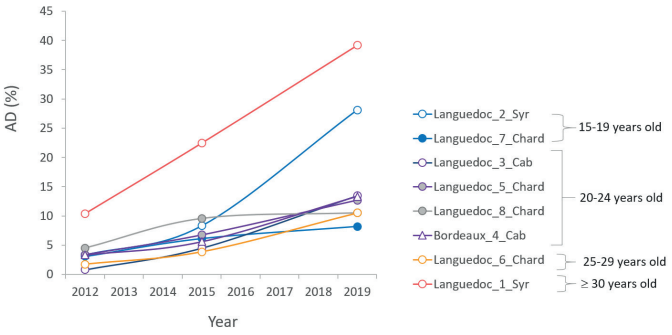

Figure 2. Rates of absent (A) and dead (D) vines (AD%) in 2012, 2015 and 2019 according to the age class of the plots.

No clear link between mortality and yield loss

Although no clear yield loss was observed in any individual vineyard plot at the time of the study, yield tended to be negatively correlated with the rate of non-productive vines within our whole network (figure 3). Additionally, the dynamics of productivity indicators, i.e. yield and/or Yield Achievement Ratio (YAR), were less precise grapevine decline markers than the mortality rate, principally because of their

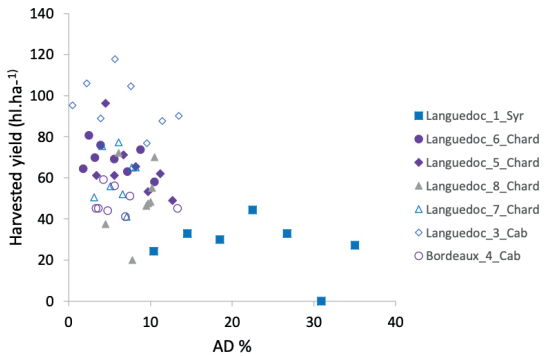

FIGURE 3. Harvested yield as a function of mortality at plot scale (AD%) over the 2012–2019 period in two of the three studied regions (Bordeaux and Languedoc).

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higher inter-annual variability. A high infra-plot variability was also noticeable among the three subplots monitored in every plot (data not shown, see source scientific article for more details). Since yield is an integrative variable of all practices and abiotic/biotic stresses, during the two years of yield elaboration, such inter-annual yield fluctuations are not surprising[4 5 6].

Early indicators of grapevine decline based on mortality and plant vigour

Two key vine vigour indicators, based on normalised difference vegetation index (NDVI), were measured on three pre-selected subplot in every field. They were NDVI_N, measured on normal vines only, and NDVI_tot, measured on all vines (Figure 4). Interestingly, NDVI_N-tot and NDVI_tot were linearly correlated to the mortality rate and YAR, respectively (figure 5).

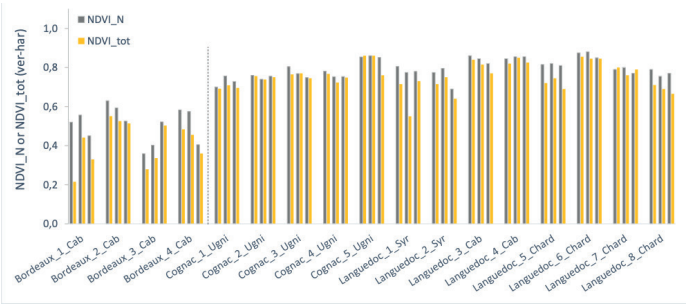

FIGURE 4. Normalised difference vegetation index (NDVI) indicators measured over the veraison-harvest period (ver-har) in each subplot of all vineyards in Bordeaux, Cognac and Languedoc: NDVI_N (measured on normal vines only) and NDVI_tot (measured on all vines). Each bar corresponds to one subplot.

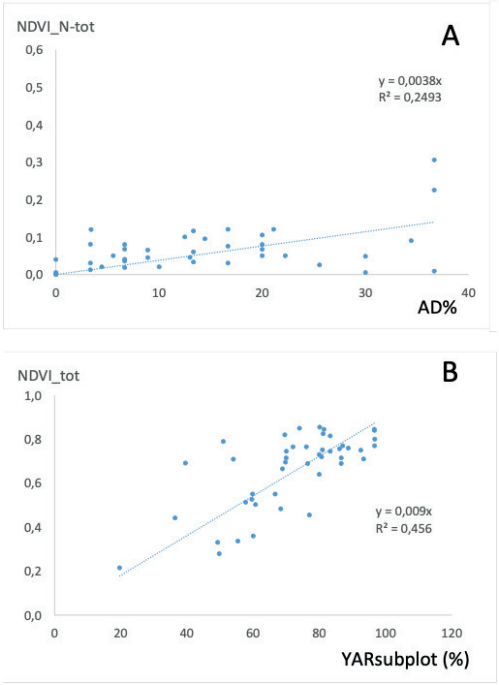

FIGURE 5. Relation between NDVI indicators, mortality and yield. A) Significant linear regression between the decline indicator AD% (dead and absent vines) and the NDVI indicator NDVI_N-tot, i.e., the difference between the normal-vine NDVI and the total NDVI. B) Significant linear regression between the yield achievement ratio indicator (YAR) and the NDVI indicator NDVI_tot, assessed by including every vine in the vineyard subplot monitored: each point represents each studied subplot.

Therefore, the vigour indicator including all vines (NDVI_tot) allowed us to propose a new, easy-to-obtain, field indicator of grapevine decline that may inform also on the yield loss. Furthermore, the NDVI indicators and mortality rate were earlier indicators of grapevine decline than yield loss.

Take home messages

- Winegrowers' associated decline to vine mortality rather than to yield decrease, although yield inter-annual variability also appeared to be of major economic concern.
- Vine mortality, yield and NDVI-based indicators were all shown to be relevant to address and characterize the decline phenomenon, but not at the same time according to the plot lifetime. In accordance with winegrower's perception, mortality and NDVI indicators permitted earlier diagnosis of decline than yield loss.
- At the regional and plot scales, historical series of orthoimages were shown to be both powerful and cost effective to detect absent and dead vines and to characterize the spatial and temporal evolutions of vine mortality in the long term.
- The analyses at infra-plot (subplot) scale were complementary to regional and plot-scale analyses. It allowed us to point out and assess clearly the specific rate of normal productive vines compared with other productive vines but symptomatic ones and/or with one lacking arm. The role and importance of the non-productive vines were also shown and quantified by considering the absent, dead plants or newly planted vines. Thus, we put forward new sensitive and easy-to-measure indicators, based on NDVI assessments by including all vines, or focusing solely on the normal productive plants. ■

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