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UNPRECEDENTED RAINFALL IN WINE-GROWING REGIONS OF NORTHERN PORTUGAL

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Abstract

Aim: Climate is arguably one of the most important factors determining the quality of wine from any given grapevine variety. High rainfall during spring can promote growth of the vines but increases the risk of fungal disease, while vineyard operations can be disrupted, as machinery may be prevented from getting in the vineyard owing to muddy soils. Conversely, high rainfall during harvest time (August to October) also bears the potential for severe operational disruption and heavy economic losses. To date, the probability of unprecedented rainfall amounts in spring and the harvest season has not been assessed over northern Portugal, specifically the three wine-growing regions of Vinho Verde, Trás-os-Montes and Porto and Douro DOC. In a situation of higher climatic variability, establishing the probable limits of rainfall variation during critical moments of the vine growth cycle will allow for better readiness of farmers as well as higher resilience of the whole value chain.

Methods and Results: Observed rainfall totals for northern Portugal were extracted from version 21 of the E-OBS dataset. Monthly rainfall totals were archived from a series of 16 month-long hindcasts produced with the Met Office's decadal prediction system DePreSys3. These hindcasts begin in November of each year, corresponding to the start of each viticultural campaign. The hindcasts are produced from 1980 to 2017, when satellite data are available for model initialisation. Forty ensemble members are available for each start time, providing 1520 (38 × 40) simulations of spring and late summer rainfall totals. The hindcast and observed rainfall totals are considered indistinguishable if the mean, standard deviation, skewness and kurtosis from the observations are within the respective 2.5th–97.5th percentile ranges from 10,000 model bootstraps. It was necessary to shift the modelled mean for spring rainfall owing to a wet bias in the simulations. The model results showed there was a probability of 0.02 ± 0.01 of an unprecedented rainfall event in spring and summer. However, the chance of another year with an exceptionally wet spring and late summer (as happened in 1993) is extremely small.

Conclusions: Rainfall totals in northern Portugal over the past 38 years have been very high in a few years, but higher values are possible in the current climate. The chance of another year similar to 1993, when both seasons were exceptionally wet, is very low. The uncertainty in extreme rainfall estimates is considerably reduced when the modelled data are used. A year with rainfall equal to the highest observed amounts in one of these two seasons could be expected to occur just once in the next 30-100 years.

Significance and Impact of the Study: This study is the first to assess the probability of unprecedented rainfall extremes over northern Portugal, allowing for a better estimate of the inherent risk. The results help inform the need for costly adaptation investments, such as better availability of spraying machinery and labour, high-gauge drainage, landslide controls or even abandonment of exposed vineyard areas.

Introduction

Climate, together with soil, plant material and cultural practices, is arguably one of the most important factors determining the quality of wine from any given grapevine variety and an important element of the concept of terroir (Gladstones, 2011; Jones and Alves, 2012). Winter rainfall is normally welcome, because it allows the replenishment of the soil water reserves ensuring an even vegetative development. High rainfall during late spring (April to June) can increase the risk of fungal disease and disrupt vine phenology, namely blossom and fruit set, which all occur during this period. This was the case in the Douro valley in 1988, 1993 and 2016, when higher than average late spring rainfall increased the risk of fungal disease, especially downy mildew (*Plasmopara viticola*), among others. There was a need to permanently monitor the vines and apply the necessary phytosanitary treatments while managing canopy development that, because of high water availability, grew excessively (ADVID, 2016). In 1993, 2002 and 2014, heavy rain in mid-September occurred in the Douro valley during full harvest, and caused a reduction in the quality of the grapes, by lowering their sugar, acid, flavour and colour values via dilution phenomena. The rain also promoted outbreaks of fungal rot (*Botrytis cinerea*) that partially destroyed crops, and thus reduced final yields.

One major issue for assessing the risk of extreme rainfall events is the relatively short period of observations available. It is difficult to assess the probability of extreme events from a short data series, as the number of events may be under-sampled. Using a large ensemble of decadal climate predictions provides considerably more simulations of the recent climate than are available from the observations (Kent *et al.,* 2017). The decadal forecast model, if it is skilful, is capable of sampling more extreme rainfall events, allowing the identification of unprecedented rainfall events and assessing their likelihood in the real world (Thompson *et al.,* 2017). In this study, the probability of unprecedented rainfall totals over northern Portugal is assessed in two critical periods of vine phenology (Fraga *et al.,* 2017): budburst and flowering (April to June) and grape maturation and harvest (August to October). These periods will be referred to as spring and summer respectively.

Materials and Methods

In this study, unprecedented rainfall amounts over northern Portugal are assessed within a region defined as 8°50'W and 6°30'W, and 40°30'N to 42°N, which includes the wine-growing regions of Vinho Verde, Trás-os-Montes and Porto and Douro DOC. Simulated daily rainfall totals were taken from the Met Office's decadal climate prediction system DePreSys3 (Dunstone *et al.,* 2016). The model is initialised with atmospheric, oceanic, and sea-ice observational data and current anthropogenic and natural forces, so that the simulations are representative of current real world climate. These hindcasts begin in November of each year, corresponding to the start of each viticultural campaign. The hindcasts were produced from 1980 to 2017, when satellite data are available for model initialisation. Forty ensemble members are available for each start time, providing 1520 simulations of spring and late summer rainfall totals. The six and ten month lead times allows the forecasts from the ensemble members to diverge, producing a wide range of plausible extreme rainfall events, some of which will not have been observed (Kent *et al.,* 2017). DePreSys3 is able to skilfully predict European summer rainfall (Dunstone *et al.,* 2018). Monthly rainfall totals from DePreSys3 were summed to produce seasonal totals for spring (April to June) and summer (August to October) over northern Portugal.

Observed rainfall totals over northern Portugal were calculated from gridded daily rainfall amounts in v21 of the E-OBS dataset (Cornes *et al.,* 2018). Rainfall amounts in E-OBS are calculated on a regular 0.1° grid (12 km) via interpolation of station-derived meteorological observations. Daily rainfall totals were extracted from E-OBS for 1980-2017, which corresponds to the hindcast period of DePreSys, and aggregated to the same spatial resolution. Series of rainfall totals for spring and summer over northern Portugal were calculated from the aggregated data.

Results and Discussion

Climate Model Evaluation

The fidelity of the DePreSys3 hindcasts is assessed over the study area of northern Portugal. Rainfall totals for spring and summer were calculated from the hindcasts. For each 3-month period, 10,000 bootstrapped samples of length equal to the observations were sampled from the modelled rainfall series. The modelled and observed rainfall totals are considered indistinguishable if the mean, standard deviation, skewness and kurtosis from the observations are within the central 95% of the model bootstraps (Thompson *et al.,* 2017; Kent *et al.,* 2017). For both 3-month periods, the observed standard deviation, skewness and kurtosis lay within this percentile range. The observed mean rainfall for summer lay within the range of the modelled distribution (Figure 1), but there was a clear wet bias in the mean of the modelled rainfall for spring (not shown). It was necessary to shift the mean of the modelled distribution for this latter period to correct the bias. All the observed metrics now lie within the central 95% of the model distribution (Figure 1); therefore, the model is considered to be statistically indistinguishable from the observations (Thompson *et al.,* 2017).

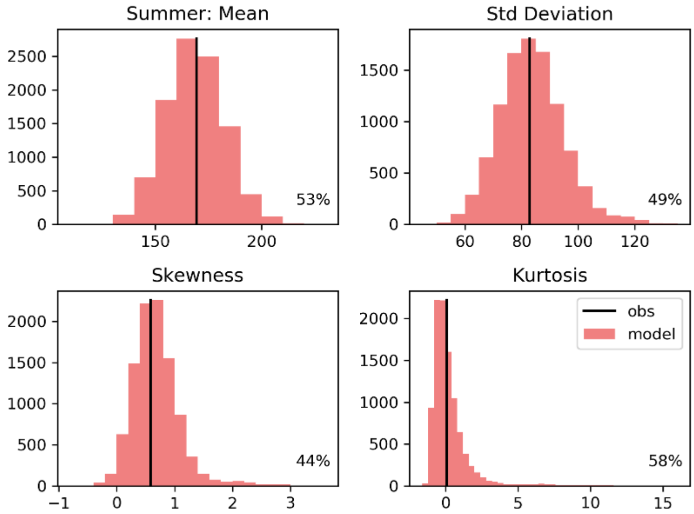

Figure 1: The distributions of the mean, standard deviation, skewness and kurtosis of the sampled modelled time series (light red) compared with the observed values (black vertical line) for summer (August to October). The vertical scales indicate the number of values in each of the histogram bins. The percentile of the observed value in the sampled model distribution is shown at the lower right of each panel.

Unprecedented Rainfall Events

The highest observed rainfall totals are 353 mm in spring and 376 mm in late summer. The observed rainfall series are reproduced in Figure 2 (solid black lines), and the highest observed rainfall totals are indicated by the horizontal dashed lines. The red lines show the rainfall totals from all 40 members of the decadal hindcasts.

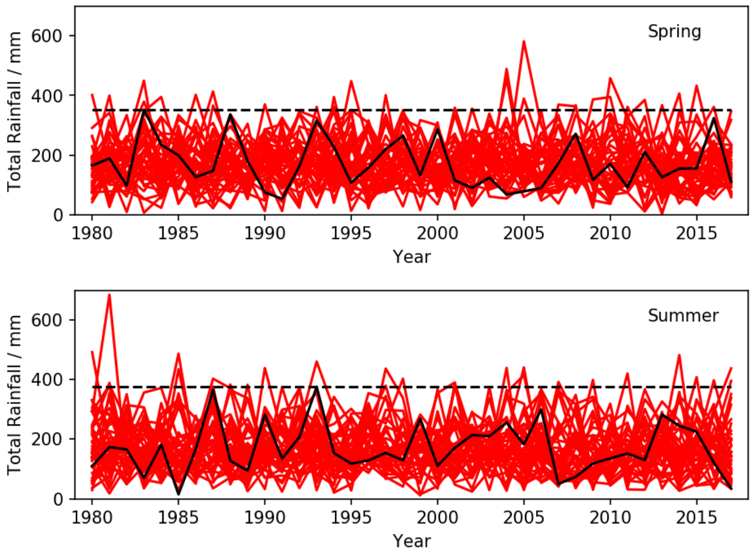

Figure 2: Unprecedented seasonal rainfall totals for spring and summer in northern Portugal from 1980 to 2017. The solid black lines show rainfall totals from observations, and the dashed black lines indicate the highest observed values. The red lines represent rainfall totals from the hindcasts (40 members). Unprecedented rainfall totals are apparent when the modelled rainfall totals lie above the dashed black line in each panel.

Unprecedented events occur when rainfall totals in the hindcasts exceed the highest observed totals. From Figure 2, the highest observed rainfall totals are exceeded in a small number of years in both seasons. It is assumed that the unprecedented events occur with probability P, which can be estimated as the number of events divided by the sample size (Kent *et al.,* 2017). The probabilities of unprecedented rainfall in spring and summer are 0.02 ± 0.01. These results show that the probability of an unprecedented rainfall event over northern Portugal is low, and only one such event might be expected in the next 30-100 years.

From the observed rainfall data, the only year when both the spring and late summer were exceptionally wet during the study period (1980-2017) was 1993. Similar events were searched for in the hindcasts, using a threshold of 300 mm for both seasons. Only nine years (out of 1520) had very high rainfall totals in spring and late summer, which corresponds to a probability of ≈0.005. The chance of a year similar to 1993 reoccurring in the present climate is therefore extremely low.

Conclusions

Unprecedented rainfall totals are possible under the current climate in northern Portugal during spring and late summer. The probability of these unprecedented events is 0.02 ± 0.01 in spring (April to June) and summer (August to October). A year with rainfall equal to or larger than the highest observed amounts in one of these two seasons would be expected to occur just once in the next 30-100 years. The probability of another year similar to 1993, with very high rainfall in both spring and summer, is extremely low.

Acknowledgments

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