**Notes in ‘The impact of climate change on the winegrape vineyards of the Portuguese Douro region’**

**Notes in Document**

**'The impact of climate change on the winegrape vineyards of the Portuguese Douro region':**

Highlight : In this paper, we analyse the impact of spring temperature (ST) and soil water (SW) on wine production volume (WPV) for the period 1933 to 2013 in the Douro region. We employ a state-space regression model to capture possible structural changes in wine produc- tion caused by a change in ST and/or SW. We find that the ST explains about 65 % of the variability of WPV. In contrast, the summer SW level increases the Radj-square to 83 % and the Akaike criterion value was lower. We also find interesting dynamic properties of SW and ST. The immediate impact of an increase in SW is negative for WPV, while the SW that is in the ground, i.e. from the previous 2 and 3 years, have a positive effect on actual WPV. Moreover, the individual changes of ST and SW have similar dynamic impact on WPV. Our main finding is that climate change does not only change the variables in question but also the winegrape vineyards adding to the negative impact on WPV levels. As a result we observe a shift of the relative importance away from ST to SW.  *(The impact of climate change on the winegrape vineyards of the Portuguese Douro region, p.1)*

Highlight : Viticulture and wine production is one of the agribusinesses where the impact of any ecological change, especially anthropogenic climate change is particularly noticeable (van Leeuwen et al. 2004; Deschenes and Kolstad 2011; Urhausen et al. 2011) *(The impact of climate change on the winegrape vineyards of the Portuguese Douro region, p.1)*

Highlight : In the Douro region, as in many other wine regions, the last decades were characterized by a large inter-annual fluctuation in wine  *(The impact of climate change on the winegrape vineyards of the Portuguese Douro region, p.1)*

Highlight : production levels (Lobell et al. 2007; Cunha and Richter 2012), which may be further exacerbated by climate change in the future (Jones et al. 2005b), despite noticeable advances in vineyard technologies. *(The impact of climate change on the winegrape vineyards of the Portuguese Douro region, p.2)*

Highlight : governmental agencies, the wine industry and researchers have become more alert to the problems caused by climate variability and are looking for ways to manage them (Cunha et al. 2003; Quiroga and Iglesias 2009; Olesen et al. 2011; Jones 2012; Dunn et al. 2015).  *(The impact of climate change on the winegrape vineyards of the Portuguese Douro region, p.2)*

Highlight : Jones et al. (2005b) compare the average climates of two periods, 1950–1999 and 2000–2049 for the 27 most important wine regions. Their results suggest that temperatures during the growing season could increase by an average of 1.3 °C. The greatest increase in temperature (2.9 °C/50 years) is projected to occur in Portugal. Moreover, they show that many wine regions are at or close to their optimum growing season temperature for high quality and WPV already.  *(The impact of climate change on the winegrape vineyards of the Portuguese Douro region, p.2)*

Highlight : The Douro region is one of the most arid wine regions of the world, with strong and consistent post-flowering water shortages (Jones 2012; Moriondo et al. 2013); hence, if climate change has an impact on dynamic behaviour of WPV *(The impact of climate change on the winegrape vineyards of the Portuguese Douro region, p.2)*

Highlight : The impact of climate change on crop yield has been simulated using general or regional circulation models as well as the crop-growth-monitoring systems. These were then combined with stochastic weather generators to analyse the impact of climate change on crop yield (e.g. Supit et al. 2012; Briche et al. 2014). *(The impact of climate change on the winegrape vineyards of the Portuguese Douro region, p.2)*

Highlight : the perennial nature of the grapevine and its permanent structures (roots and woody stem), which provide carbon and nutrient reserves, are highly influenced by the past years’ agroclimatic conditions (May 2004; Guilpart et al. 2014). *(The impact of climate change on the winegrape vineyards of the Portuguese Douro region, p.2)*

Highlight : many previous studies to assess the impact of climate change on crop yield, have *(The impact of climate change on the winegrape vineyards of the Portuguese Douro region, p.2)*

Highlight : assumed an historical probability distribution (e.g. Vossen and Rijks 2001; Santos et al. 2010; Lorenzo et al. 2013). The use of such distributions assumes stationarity of the data-generating process and typically assumes a constant linear trend *(The impact of climate change on the winegrape vineyards of the Portuguese Douro region, p.3)*

Highlight : Although this linear trend describes the overall long-term trend in production, it does not reflect the implicit structural breaks in production and the information contained therein (Chen and Chang 2005; Quiroga and Iglesias 2009). *(The impact of climate change on the winegrape vineyards of the Portuguese Douro region, p.3)*

Highlight : The climate in general affects wine production directly, but as production technology changes, there is a non-constant impact (or spillovers) of climate onto WPV, which translates into changing lead/lag relationships between WPV and climate. Therefore the detection of structural changes in crop production time series should take this into account, especially in models where climate plays an important direct or indirect role (Quiroga and Iglesias 2009); *(The impact of climate change on the winegrape vineyards of the Portuguese Douro region, p.3)*

Highlight : This paper provides a dynamic analysis of the impact of spring temperature (ST) and soil water in summer (SW) on WPV from 1933 to 2013 in the Douro region. *(The impact of climate change on the winegrape vineyards of the Portuguese Douro region, p.3)*

Highlight : Wine production has always been volatile in terms of output variance. The time-series of WPV in the Douro region from 1933 to 2013 are presented, showing evidence of an upward trend in WPV (see ESM1). Additionally, this time series contains changes in its Btypical^ cyclical behaviour (in terms of increasing variance), which may be caused by structural breaks (which in turn may be caused by climate effects). In any case, this variation makes a common regression very difficult, as we need to distinguish systematic changes from random ones; the Kalman Filter is able to detect these structural changes (trend included).  *(The impact of climate change on the winegrape vineyards of the Portuguese Douro region, p.4)*

Highlight : At the end of the sample (2013), the current ST as well as the STs of the previous 2 and 3 years have a significant impact on the WPV. However, the impact differs with the lag: the current ST has a positive impact and the ST of the previous years have a negative impact on WPV (Table 1); note that the first and the 5th lag of WPV are significant.  *(The impact of climate change on the winegrape vineyards of the Portuguese Douro region, p.5)*

Highlight : the effects of SW level on WPV for the last point in time 2013. In comparison to the model for ST, the Radj-square is now higher (83 %). *(The impact of climate change on the winegrape vineyards of the Portuguese Douro region, p.6)*

Highlight : our result is that SW is clearly more important to WPV than ST when it comes to predicting WPV. It is worth noting that the AIC is also not constant over the time. *(The impact of climate change on the winegrape vineyards of the Portuguese Douro region, p.6)*

Highlight : The Douro is one of the most arid wine regions of the world with strong and consistent post-flowering water and thermal stress (Chaves and Rodrigues 1987). Since most of the vineyards in the Douro region are non-irrigated and most of the rain occurs outside the vegetative growth cycle, SW should be an important factor of the temporal variation of WPV in Douro. *(The impact of climate change on the winegrape vineyards of the Portuguese Douro region, p.10)*

Highlight : The in-season ST is directly correlated with WPV and could explain about 65 % of its inter-annual variability (Table 1). The simulation results suggests that actual ST in Douro is generally below the optimum level of the main grape temperature-dependent physio- logical processes related with crop yield that occurs during spring such as flowering development, anthesis and fruit-set (May 2004; Vasconcelos et al. 2009; Cunha et al. 2016). Also, high ST plays an important role in triggering the different phenological stages, with great impact on SW stress avoidance and, consequently on WPV (Urhausen et al. 2011). Further, high ST is negatively correlated with late frosts spells (Briche et al. 2014). The positive effect of in-season ST on WPV agree with the previous studies on the Douro region (Gouveia et al. 2011; Santos et al. 2013) and, northwest Portugal (Fraga et al. 2014), Spain (Lorenzo et al. 2013), Germany (Bock et al. 2013) and California (Lobell et al. 2007).  *(The impact of climate change on the winegrape vineyards of the Portuguese Douro region, p.10)*

**Notes in Workspace:**