MASTER IN INTERNATIONAL FINANCE

MASTER RESEARCH PAPER

Academic Year 2023 – 2024

The Financial Impacts of Climate Change on Burgundy and Loire Valley Vineyards

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Date 23 / 06 / 2024

Jury: François Derrien, Professor of Finance at HEC Paris

PUBLIC REPORT

Acknowledgments

Foremost, we would like to express our deepest gratitude to our thesis professor, Francois Derrien, for his guidance, continuous support, and insightful feedback throughout the development of this thesis. His expertise and encouragement have been indispensable in helping us navigate the complexities of our research.

We sincerely thank our families and friends for their support, understanding, and encouragement during this journey. Their patience and belief in us have been invaluable.

We are immensely grateful to all the 69 respondents who participated in our poll. Their contributions have proven crucial to the success of our research and provided valuable insights that have helped us draw firm conclusions. We would also like to sincerely thank the individuals we had the privilege to interview: Gilles Cossanteli, Christophe Lanson, and Etienne Neethling. Their insights and experiences have enriched our study and offered precious perspectives.

Thank you all for your support and contribution to our work.

Abstract

Climate change poses significant challenges for the wine industry, mainly because the latter is known for its sensitivity to environmental variations. This paper investigates the financial impacts of climate change on vineyards in Burgundy and Loire, two French winemaking regions, to add to the existing research that primarily focuses on the phenotypical effects of climate change on wine. Using a questionnaire and vineyards’ financial data, this study identifies the main climate-related challenges which winemakers face and relates climate events to key financial metrics like revenue, costs, profitability, and liquidity ratios. Results indicate a considerable increase in the volatility of income statement items and display winemakers' resilience in adapting to new climate conditions, especially severe climate events. These events are also shown to have diverging impacts on the two regions, and existing differences are discussed. The study finally highlights various adaptive strategies implemented by winemakers and underlines that the cost effectiveness and profitability of these methods vary. The paper concludes with recommendations for mitigating climate impacts, emphasizing the need for strategic adaptation to sustain the viability of vineyards in the face of ongoing climate change.

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1 Introduction

It is no mystery that climate change constitutes one of today's most pressing issues, impacting a wide range of sectors, industries, and ecosystems (Abbass et al., 2022, p. 42539), and the wine industry is no exception. Indeed, climate change has far-reaching implications for winemaking activities and wine grapes – which "are some of the most notoriously delicate and vulnerable agricultural products on the planet" (Willcox, 2021) –, affecting physiological aspects such as vine phenology or grape composition (de Orduña, 2010, p. 1844) as well as economic components such as yield, costs, prices, and profits (Ashenfelter & Storchmann, 2016, p. 105) and negatively impacting grape and wine quality (Cook, 2016; Gutiérrez-Gamboa et al., 2020, p. 101). In sum, as stated by Ollat et al. (2016, p. 139), "climate change affects all activities linked to wine production (grape growing, wine making, wine economics, and environmental issues)". As a consequence, wine production may shift away from traditional winemaking regions and towards the poles, where climatic conditions are becoming more suitable for winegrowing (Ashenfelter & Storchmann, 2014, p. 1; Asimov, 2019; Kurtural & Gambetta, 2021, p. 353; Sgubin et al., 2023, p. 808; Speed, 2023; Tamma, 2021; Venios et al., 2020, p. 1), and "wine growers will need to consider changing their practices to a world that is rapidly moving to a place where the old climate rules may no longer apply" (Cook, 2016).

Overall, there exists extensive research regarding climate change and its concerning implications for traditional winemakers, with great focus on physiological impacts on grapes and wines themselves. However, though some authors have noted that climate change affects various financial metrics and while several researchers have listed viticultural and other techniques that can be used to fend off the detrimental effects of climate change, there appears to be a lack of research targeting specific regions to clearly quantify the real effects of climate change on winemakers' key financials in those areas and to suggest closely tailored solutions. Yet, investigating in detail the relationship between phenomena caused by climate change and winemakers' main financial numbers and ratios and identifying affordable solutions that can be implemented as a response can prove very useful to not only better understand how climate change impacts the viability of winemaking activities in particular regions but also come up with a clear and specific adaptation strategy.

This thesis will thus delve into the impacts of climate change on winemakers’ activities, focusing on Burgundy and Loire, two traditional French winemaking regions. It will aim to 1) identify the specific challenges which winemakers in these two regions are facing, 2) quantify the financial impacts of climate change for these winemakers by looking at several key financial metrics, and 3) recommend tailored, effective, and affordable solutions that could be implemented by winemakers to deal with the encountered challenges. To achieve these three objectives, this thesis will rely on a combination of theoretical and empirical research by first conducting a review of the existing literature, before undertaking its own analysis, the details of which are addressed in the methodology section below.

2 Literature Review

A lot of research has been conducted and many papers have been written on the impact of climate change on vineyards and winemaking activities in general, with interesting findings regarding the main challenges faced by winemakers, as well as potential solutions that the latter could implement in order to cope with climate-change-related issues. This part will dive deeper into these insights to build a solid theoretical framework which will serve as a basis against which this thesis' empirical findings will later be compared.

2.1 Challenges

Existing research has identified numerous challenges for winemakers that stem from climate change and need to be actively dealt with to offset the financial burden that these issues may create. According to the IPCC (2022, p. 739), climate change indeed not only has consequences for "decreas[ing] grape quality", but also has led to "wine-growing regions [that] have expanded outside the normal temperature bounds of locally grown varieties." This subchapter will look into several climate-change-induced phenomena – notably higher temperatures, water deficits, precipitation disruptions, and increased frequency of extreme climatic events such as heat waves, frost, or hail – as well as the challenges that they imply for winemakers.

2.1.1 Higher Temperatures

A first crucial issue caused by climate change is higher temperatures (Drappier et al., 2019, p. 14; Venios et al., 2020, p. 1), which could reportedly lead suitable wine-growing regions to shrink by 50% or more (Fecht, 2020). According to de Orduña (2010, p. 1844), advanced temperatures are among the most important effects of climate change on winemakers and their activities. Sgubin et al. (2023, p. 809) likewise claim that "temperature is arguably the most important factor, as it influences grapevine phenology by determining its development, from bud break to fruit maturity." Increased temperatures indeed cause an advancement in grape phenology (Ferrise et al., 2016, p. 88; Ollat et al., 2016, p. 141; Schultz, 2016, p. 190; Sgubin et al., 2023, p. 809; van Leeuwen & Darriet, 2016, p. 152; Venios et al., 2020, p. 1), thus shifting grape ripening – and hence harvesting – to earlier, warmer periods (Amos, 2021; Cook, 2016; Mallet, 2022; van Leeuwen & Darriet, 2016, p. 150) and impacting grapes' composition, as well as their quality (Arias et al., 2022, p. 1; Sgubin et al., 2023, p. 809; Venios et al., 2020, p. 2). Moreover, Mozell and Thach (2014, p. 84) argue that "it is a certainty that a change in climate, no matter how small, will shift grape chemistry for winegrapes currently in place." Increased temperatures thus appear to have numerous impacts on grape physiology, with key implications for winemakers' production processes and finances.

First, research has shown that increased temperatures typically lead to higher sugar concentrations in grapes (Ashenfelter & Storchmann, 2014, p. 5; Ashenfelter & Storchmann, 2016, p. 108; Barriger, 2011, p. 313; Bucur & Dejeu, 2014, p. 339; Chrobak & Zimmer, 2022; de Orduña, 2010, p. 1844; Gutiérrez-Gamboa et al., 2021, p. 3; Mallet, 2022; Mozell & Thach, 2014, p. 84; Ollat et al., 2016, p. 141; Schulz, 2016, p. 185; van Leeuwen & Darriet, 2016, p. 151; Venios et al., 2020, p. 7). As identified by many authors, the main effect of such higher sugar levels is an increase in wines' alcohol content (Ashenfelter & Storchmann, 2014, p. 5; Ashenfelter & Storchmann, 2016, p. 108; Barriger, 2011, p. 311; Bilby, 2023; Chrobak & Zimmer, 2022; Kurtural & Gambetta, 2021, p. 357; Mozell & Thach, 2014, p. 84; Ollat et al., 2016, p. 141; van Leeuwen & Darriet, 2016, p. 155; Venios et al., 2020, p. 7), but this is not the only aspect that is affected by an increase in sugar. Indeed, the latter also typically impacts sensory aspects such as wine flavor and aroma (Kurtural & Gambetta, 2021, p. 357; Mozell & Thach, 2014, p. 84; Venios et al., 2020, p. 7), wine style (Ashenfelter & Storchmann, 2016, p. 108; Bucur & Dejeu, 2014, p. 339; Kurtural & Gambetta, 2021, p. 357), wine balance (Ashenfelter & Storchmann, 2016, p. 108; Venios et al., 2020, p. 7), and wine color (Kurtural & Gambetta, 2021, p. 359). Additional issues are pointed out by de Orduña (2010, p. 1848), who finds that higher sugar concentrations can result in growth inhibition, altered fermentation performance – with an alcoholic fermentation that tends to be both sluggish and stuck –, as well as financial issues. All in all, increased sugar levels thus have important implications for wine quality (de Orduña, 2010, p. 1848; van Leeuwen & Darriet, 2016, pp. 155-

156) and constitute a key consequence of climate-change-induced higher temperatures for winemakers.

In addition to fostering sugar accumulation, higher temperatures also impact another essential wine-making component by causing a reduction of grapes' acidity levels or, equivalently, an increase in their pH levels (Ashenfelter & Storchmann, 2014, p. 5; Ashenfelter & Storchmann, 2016, p. 108; Barriger, 2011, p. 311; Bucur & Dejeu, 2014, p. 339; Cabot, 2022; Chrobak & Zimmer, 2022; de Orduña, 2010, p. 1845; Di Carlo et al., 2019, p. 512; Gutiérrez-Gamboa et al., 2021, p. 1; Mallet, 2022; Ollat et al., 2016, p. 141; Schultz, 2016, p. 185; van Leeuwen & Darriet, 2016, p. 151; Venios et al., 2020, p. 7). Indeed, while tartaric acid – the main acid contained in grapes – does not vary much following temperature changes, the latter do play an important role when it comes to malic acid – grapes' other major acid –, which typically decreases with warmer temperatures (de Orduña, 2010, p. 1845). This is a very important element, as decisions regarding grape harvest time heavily depend on whether grapes have achieved the required acidity level for a premium wine (Di Carlo et al., 2019, p. 511). Furthermore, this decrease in acidity or increase in pH may, in turn, affect wine taste (Venios et al., 2020, p. 7), alter fermentation (Gutiérrez-Gamboa et al., 2021, p. 4; Mozell & Thach, 2014, pp. 86-87), result in a lack of freshness (Ashenfelter & Storchmann, 2016, p. 131; Barriger, 2011, p. 311; van Leeuwen & Darriet, 2016, p. 156; Venios et al., 2020, p. 7), impair wine stability (Cabot, 2022; Gutiérrez-Gamboa et al., 2021, p. 4; van Leeuwen & Darriet, 2016, p. 156), prove detrimental to wine quality and typicity, i.e., wine style (Ashenfelter & Storchmann, 2016, p. 130), impact wine color (De Toda & Balda, 2014, p. 17; Gutiérrez-Gamboa et al., 2021, p. 4), and lead to wine spoilage due to the facilitated development of a problematic microorganism called Brettanomyces (Ashenfelter & Storchmann, 2016, p. 131; De Toda & Balda, 2014, p. 17). De Orduña (2010, p. 1850) even describes low pH levels as "a cornerstone of microbiological stability," arguing that an increase in pH values bears the risk of increasing microbial contamination.

In sum, as highlighted by Gutiérrez-Gamboa et al. (2021, p. 4), higher temperatures may increase the costs of wine-making processes as winemakers are forced to add tartaric acid in their wines to try and foster microbial stability while offsetting the various adverse effects caused by a decrease in grapes' acid content, coupled with higher sugar levels. Furthermore, these temperatures favor the development of diseases, both bacterial and fungal, which can also prove costly as significant efforts are required from winemakers in order to cope with them (Ashenfelter & Storchmann, 2016, pp. 112-114). All in all, increasing temperatures have important adverse effects on viticulture, with not only short-term consequences such as negative impacts on wine quality but also long-term concerns as some grape varieties may become unsuitable and certain traditional wine-making regions unviable for viticulture (Venios et al., 2020, p. 1).

2.1.2 Water Shortages and Precipitation Disruptions

Another major consequence of climate change is **water shortages** (Mozell & Thach, 2014, p. 83), which can significantly impact wine-making activities. Wagner et al. (2023, p. 5) identify water availability as one of the most critical elements impacted by global warming, as it influences yield and grape and wine quality. Schultz (2016, p. 182) likewise argues that "water shortage is probably the most dominant environmental constraint" in existing production domains and claims that water could end up being "the decisive factor for positive or negative yield development in the future" (p. 185). In fact, the observed combination of high temperatures and water deficits is likely to cause a large number of classical wine-making regions to lose a big proportion of their vineyards (Schultz, 2016, p. 187). These comments highlight the extent of this environmental phenomenon's operational and financial challenges for winemakers.

More specifically, water shortages typically cause a decrease in yields (Tamma, 2021) as well as a modification of grapes' composition (van Leeuwen & Darriet, 2016, p. 150). Not only do they harm photosynthesis, but they can also impair shoot growth, damage leaves, and alter grape ripening, while reducing berry size, thus impacting grape composition, especially regarding tannin and anthocyanin levels (van Leeuwen & Darriet, 2016, p. 152). The concentration of thiol, one of the volatile compounds that make up grape and wine aroma (Gutiérrez-Gamboa et al., 2021, p. 6), is also influenced – namely, reduced – by water shortages (Schultz, 2016, p. 186). Barriger (2011, p. 313) also notes that the probability of grape desiccation increases with water deficits when these are not dealt with through the use of irrigation techniques.

Related to the question of water shortages is the issue of **precipitation disruptions**, another consequence of climate change (Ashenfelter & Storchmann, 2016, p. 118; Di Carlo et al., 2019, p. 508; Schultz, 2016, p. 181), where too much or not enough rain can adversely affect wine quality (Scott, 2022). According to Ashenfelter and Storchmann (2016, pp. 112-113), precipitations are among the key factors that determine a vine's water balance, and the overall amount of precipitation over a given year as well as its distribution between the growing and nongrowing seasons are essential for vines that are not equipped with an irrigation system, which is most often the case in Europe. Indeed, both too little precipitation and excessive rainfall can have detrimental effects, the former typically leading to a potentially severe reduction in grape productivity while the latter increases the likelihood of diseases and pests (Sgubin et al., 2023, p. 809).

Research finds that such irregularities are becoming increasingly common. Indeed, similarly to Ashenfelter and Storchmann (2016, p. 113), who write that water deficiencies are expected to increase in most wine-making regions, Wagner et al. (2023, p. 3) find that precipitations are becoming more uneven and extreme, which directly affects the suitability of wine-making regions, alters grape phenology and composition, and may therefore cause these regions to lose their varietal identity. This, along with the higher potential for disease development associated with precipitation perturbations, are key issues that need to be actively addressed by winemakers to ensure the viability of their operations (Wagner et al., 2023, p. 3). Similarly, Di Carlo et al. (2019, pp. 508-509) note that precipitations are getting increasingly intense, damaging vineyards and causing agricultural loss, landslides, and flooding, while affecting grape phenology and exacerbating the adverse effects of temperature increases on grapevines. Under a warming climate, this rise in precipitation intensity may make it even more difficult to grow certain grape varietals in classical wine-making regions (Di Carlo et al., 2019, p. 512). In fact, "for wineries that want to use the same cultivation techniques they have had for decades or centuries, with minimal fertilization and irrigation, producing premium wines could become more difficult or even impossible," given the observed rise in heavy rain events (Di Carlo et al., 2019, p. 512).

2.1.3 Extreme Climatic Events

Extreme climatic events constitute another crucial consequence of climate change for winemakers (van Leeuwen & Darriet, 2016, p. 152; Venios et al., 2020, p. 1; Wagner et al., 2023, p. 1). They may ruin entire harvests (Chrobak & Zimmer, 2022) and are likely to increase in frequency (van Leeuwen & Darriet, 2016, p. 150). For instance, as noted by Thach (2021), the extreme heat, floods, and devastating frosts that hit European vineyards in 2021 caused significant damage to wine grapes and resulted in an estimated $2bn loss in wine sales. The rise in excessive rainfall events addressed above is only one example of such drastic climatic events, which notably include extreme temperatures causing either heatwaves or frosts, as well as hailstorms.

Extreme temperatures, whether high or low, are a first excessive climatic phenomenon that can heavily impact winemaking activities. Indeed, **excessively high temperatures and heatwaves**, which are becoming increasingly common (Venios et al., 2020, p. 1), can result in significant heat damage to grapevines, causing sunburns while impairing growth, ripening, and photosynthesis (Ashenfelter & Storchmann, 2016, p. 110). These changes to vine metabolism may, in turn, negatively impact both wine aroma and color (Ashenfelter & Storchmann, 2016, p. 116; de Orduña, 2010, p. 1844), while harming both grape yield (Sgubin et al., 2023, p. 821; Venios et al., 2020, p. 2) and grape quality (Venios et al., 2020, p. 2). Very high temperatures that occur during floral initiation may also cause buds to be unfruitful (Gutiérrez-Gamboa et al., 2021, p. 2). On the financial side, Sgroi and Sciancalepore (2022, p. 4) find that extreme heatwaves can cause a reduction in both revenues and margins.

Extremely low temperatures are just as harmful. Indeed, they can cause so-called **spring frost** – with notably frost occurring after buds have burst – which has recently become more frequent (Sgubin et al., 2023, p. 821) and may damage developing shoots (Ashenfelter & Storchmann, 2016, p. 109) as well as buds (Sgubin et al., 2023, p. 821), injure vegetal tissues (Gutiérrez-Gamboa et al., 2021, p. 11; van Leeuwen & Darriet, 2016, p. 151), negatively affect bud fertility (van Leeuwen & Darriet, 2016, p. 151), severely reduce crop yield (Ashenfelter & Storchmann, 2016, p. 109; Gutiérrez-Gamboa et al., 2021, p. 3; Sgubin et al., 2023, p. 821), harm grape quality (Sgubin et al., 2023, p. 821), and simply destroy grapevines overnight (Yeginsu, 2021). And, according to an article published in rfi (2021), "episodes of unseasonably late frost, like the one that damaged French vineyards in April, are likely to happen more often because of climate change."

Hailstorms are another typical environmental event favored by climate change (van Leeuwen & Darriet, 2016, p. 150), which winemakers have to deal with every year (Sgroi & Sciancalepore, 2022, p. 5). These storms can have devastating consequences for winemakers, having the potential to decimate the vineyards that they hit (Mozell & Thach, 2014, p. 87). A recent example is the hailstorm that ravaged the Chablis vineyards in the French region of Burgundy on May 1, 2024. With hailstones described as being the size of ping pong balls, the storm led to losses as high as 85%-90% in the most affected areas (Reuters, 2024; Swissinfo, 2024).

To sum up, it appears that climate change fosters harmful environmental phenomena that create crucial issues with regards to wine production and can prove very costly for winemakers, hence putting their operations at a high risk. This context calls for swift adaptation by winemakers in order to ensure the long-term viability of their businesses by mitigating the detrimental effects of climate change on their activities, from wine production to commercialization. The following part will focus on potential solutions identified by existing research, which winemakers may implement to address these adverse effects and enhance the profitability of their businesses. It will also address the crucial tradeoff that winemakers are facing between implementing new production methods to try and counter the harmful effects of climate change and avoiding a further increase in the financial burden that the latter are causing.

2.2 Potential Solutions

2.2.1 Adapt Vineyard Placement

First, many authors propose interesting solutions to climate change effects with regards to vineyard placement. Indeed, in order to respond to climate change effects and foster grape quality, winemakers may try to relocate vineyards to cooler areas (Barriger, 2011, p. 314; Hertsgaard, 2010; Ollat et al., 2016, p. 139; Venios et al., 2020, p. 2). Moreover, according to Gutiérrez-Gamboa et al. (2020, p. 1261), adequately choosing vineyards' orientation, slope, and altitude can help mitigate negative climate change impacts. Indeed, selecting a vineyard's orientation and slope so that solar radiation exposure is limited – i.e., a northern orientation for vineyards located in the Northern hemisphere – can help reduce sugar amounts in grapes while fostering a less warm canopy microclimate and helping avoid soil drought (Gutiérrez-Gamboa et al., 2020, p. 1264). Ashenfelter and Storchmann (2016, p. 130) also find that adapting vineyard orientation is an effective way to shield grapes from radiant heat exposure. Furthermore, setting up vineyards at higher altitudes allows to reduce the temperatures to which grapes are exposed, thus fostering grape quality (Arias et al., 2022, p. 5; Gutiérrez-Gamboa et al., 2020, p. 1262; Venios et al., 2020, p. 2). It notably permits the obtention of grapes with lower alcohol, higher acidity, and enhanced aromatic quality (Gutiérrez-Gamboa et al., 2020, p. 1262). Ollat et al. (2016, p. 143) similarly state that higher altitudes and their cooler climate become increasingly suitable for the production of wines of high quality. Likewise, Arias et al. (2022, p. 5) note that "higher altitude regions have become a recognized alternative for maintaining current high-quality winegrowing of traditional varieties in future climate scenarios." However, it should be noted that higher altitudes are also associated with high economic costs and that vines located in higher altitudes are typically more exposed to radiation, which increases the risk of sunburn (van Leeuwen and Darriet 2016, pp. 162-164). Soils can also be poorer, water scarcer, and extreme climatic events such as hailstorms and frosts are just as threatening (Asimov, 2019).

2.2.2 Delay Grapevine Ripening

According to Gutiérrez-Gamboa et al. (2020, p. 1266), achieving higher vineyard altitude and better orientation can also help delay grape ripening. Indeed, though peak temperatures may not be significantly cooler at higher altitudes, periods of intense heat are shorter, and temperatures during the night lower, helping slow down grape ripening and hence extend the ripening phase (Asimov, 2019). This is a critical feature, as an increasingly advanced ripening is causing it to take place under higher temperatures (Gutiérrez-Gamboa et al., 2021, p. 2), with negative consequences for fruit quality (van Leeuwen & Darriet, 2016, p. 161).

However, managing vineyard altitude and orientation is far from the only strategy which winemakers can adopt to delay grape ripening. According to Gutiérrez-Gamboa et al. (2020, p. 1266), the most efficient way to delay ripening alongside aiming for higher altitudes is to choose later grape varieties, potentially delaying ripening by about twenty days. The authors indeed note that grape variety can have a significant influence on berry ripening, as the difference between the earliest- and latest-ripening grape varieties can reach two months (p. 1264). The importance of choosing suitable grape varieties has been particularly emphasized in recent research, with, for instance, Sgubin et al. (2023) explaining that "climate conditions establish the degree of appropriateness of a specific grapevine variety to a specific site" (p. 809) and that "reallocating better-suited grapevine varieties to warmer conditions may be a viable adaptation measure to cope with the projected suitability loss over the traditional regions" (p. 808). Merrill et al. (2020, p. 2) likewise argue that winemakers could use the wide diversity of existing grape varieties by planting some that are better suited to changing climatic conditions. Similarly, Wagner et al. (2023, p. 20) state that growing new, resilient grape varieties constitutes a crucial element to respond effectively to climate change.

Gutiérrez-Gamboa et al. (2020, p. 1266) then put vineyard orientation in second position, together with choosing later rootstocks, which may lead to a delay of about four days. The third position is occupied by training systems. Indeed, adapting training systems is considered an effective way to delay grapevine phenology (Gutiérrez-Gamboa et al., 2021, p. 2; van Leeuwen & Darriet, 2016, p.

162). While the "gobelet" or "bush vine" training system fosters resistance to high temperatures and drought without negatively impacting economic sustainability – indeed, though this training system typically leads to lower yields, it also provides an easy and cost-efficient way of producing and cultivating grapes – (Gutiérrez-Gamboa et al., 2020, p. 1265; van Leeuwen & Darriet, 2016, p. 163), adapting the training system to raise trunk height can help delay ripening by about one day per 10 centimeters of increased height (Gutiérrez-Gamboa et al., 2020, p. 1266).

Moreover, Gutiérrez-Gamboa et al. (2021) identify several other viticultural techniques that can help delay grapevine ripening, ranging from canopy management methods such as apical leaf removal to severe shoot trimming and minimal or late pruning (p. 13), and argue that the most interesting strategy is to force bud regrowth, as this can delay ripening by more than two months (p. 1). Finally, increasing crop load can help delay grape ripening, pushing fruit maturation to cooler times (Mozell & Thach, 2014, p. 86) and positively modifying grape composition (Wagner et al., 2023, p. 3).

2.2.3 Irrigation Practices

Other potential solutions to climate change effects focus on adapting irrigation practices, with notably increased irrigation (Gutiérrez-Gamboa et al., 2021, p. 10; Mallet, 2022; Ollat et al., 2016, p. 139), which can help reduce the damage caused by extreme heat (Ashenfelter & Storchmann, 2016, p. 130). Increasing irrigation frequency can typically enhance water conservation, thus improving water use efficiency (Gutiérrez-Gamboa et al., 2021, p. 10). Other ways to increase water use efficiency to ensure sufficient yield provision and vineyards' economic viability include deficit irrigation and modern irrigation technologies such as drip irrigation (Wagner et al., 2023, p. 12). Indeed, historical and low-tech irrigation techniques typically result in important losses of water use efficiency, while deficit irrigation strategies such as partial rootzone drying allow to improve this efficiency while fostering grape quality (Wagner et al., 2023, pp. 12-13). Mozell and Thach (2014, p. 86) likewise argue that drip irrigation helps offset water supply issues by allowing more effective irrigation with minimized delivery loss and that deficit irrigation, with methods such as sustained deficit irrigation, partial root drying, and regulated deficit irrigation, fosters water use efficiency and wine quality, thus also helping with water shortage issues. However, Leeuwen and Darriet (2016, p. 163) note that irrigation should not be winemakers' first choice when responding to water deficits, as it "has an economic, environmental, and social cost." Indeed, though the authors recognize that when irrigation is absolutely necessary, deficit irrigation can allow to save water while optimizing fruit quality, they explain that irrigation may foster the accumulation of salt in vineyard soils, which can make the latter unsuitable for growing grapes (pp. 163-164).

2.2.4 Sugar-Reducing Methods

One of the key negative consequences of climate change identified above is increased grape sugar content and, subsequently, alcohol levels. Some methods exist that can help mitigate this phenomenon, including reverse osmosis and ultrafiltration (Mozell & Thach, 2014, p. 86), as well as spinning cones or even water addition to the wine in some cases (Ashenfelter & Storchmann, 2016, p. 131). However, as noted by Gutiérrez-Gamboa et al. (2020, p. 1261), these filtration techniques and physical processes aimed at wine dealcoholizing can be perceived as too artificial. Some vintners indeed prefer more natural solutions, reducing sugar levels indirectly by focusing on delaying grapevine ripening, using the various techniques highlighted earlier, such as the introduction of better-suited grape varieties and more suitable rootstocks or the adaptation of vineyards' placement with regards to altitude, orientation, and slope (Gutiérrez-Gamboa et al., 2020, pp. 1261-1263).

2.2.5 Other Methods

Mozell and Thach (2014) list several additional techniques that can be implemented to address the negative consequences of climate change and, in particular, higher temperatures and water shortages. First, the authors provide some solutions to counter rising temperatures, such as leveraging canopy management to create additional shade and hence improve soil-water balance, decrease sugars, and increase acid levels (p. 85). Canopy management can also help protect grapes from excess radiation, heat waves, and resulting sunburns (Ashenfelter & Storchmann, 2014, p. 25; van Leeuwen & Darriet, 2016, p. 164; Wagner et al., 2023, p. 3). In addition, Mozell and Thach (2014) encourage nighttime harvesting and a prompt delivery of harvested grapes to the winery in order to achieve cooler grape temperatures and avoid spoilage (p. 85), as well as "the use of cooling equipment to assure completed primary and malolactic fermentations" and a reinspection of cellar practices to ensure optimal temperatures in the winery (p. 86).

Second, Mozell and Thach (2014, p. 86) address the issue of water shortages, which can be dealt with by improving soil-water balance through not only drip irrigation but also the use of cover crops, which foster a better soil erosion control and storage of nutrients, and by resorting to deficit irrigation, as already mentioned earlier. The authors also vouch for water recycling and reuse, which may minimize waste while "reducing the costs of water usage and removal" (pp. 85-86). Then, Mozell and Thach (2014, pp. 86-87) mention acidification as a means to offset acidity reduction and thus foster microbiological and microbial stability while rendering stuck fermentations less likely. They also promote the benefits of new blending techniques, such as blending wines from several regions and terroirs, in order to mitigate vintage variability, especially regarding wine style and complexity (p. 87).

Finally, other potential solutions highlighted in the literature include "the genetic modification of the grapevine itself to produce heartier, more resilient vines" (Barriger, 2011, p. 315), the development of genotypes that are resistant to environmental stresses (Venios et al., 2020, p. 11), the reduction of grapes' pH levels by combining training systems such as vertical shoot positioning and free cordon with leaf-thinning treatments (De Toda & Balda, 2014, p. 17), and the use of the insurance market to mitigate climate change risks and foster long-term vineyard profitability (Sgroi & Sciancalepore, 2022, p. 1). More generally, Mozell and Thach (2014, p. 87) also highlight the importance of developing and implementing a "system of planned change" in order to better anticipate future climatic events, thus decreasing vulnerability and promoting competitiveness and operational viability.

There therefore seems to be a wide range of techniques and strategies that winemakers can put to use to try and deal with the various challenges created by climate change. However, at least some of these solutions can prove quite costly. Initial costs for implementing some solutions are high, and the investment is sometimes only justified for large vineyards (Neethling et al., 2017). These initial costs thus add to the already considerable financial burden imposed by climate change on winemakers, as the latter are forced to invest potentially significant amounts in new production methods and strategies to try and solve the issues caused by climate change. This also means that the solutions highlighted above may not be accessible to everyone in the field and that choosing an appropriate response to climate change issues depends not only on vineyards' geographical location, altitude, orientation, main grape variety cultivated, etc., but also heavily on winemakers' financial means.

3 Methodology

Having detailed the main climate-change-related challenges faced by winemakers as well as potential solutions that could be implemented to deal with those issues as identified by existing research, this thesis will now turn to its own analysis, focused on Burgundy and Loire, which aims to quantify the effects – if any – of climate change on winemakers' key financial metrics, identify which climatic phenomena have the most significant impact in that respect, and propose some methods that could be applied to respond to the risks caused by climate change.

The first part of the analysis aims to establish relationships between climate events and financial indicators of the Burgundy and Loire regions. The analysis relies not only on the Orbis database, which notably provides a rich set of data on French winemakers' financials – with balance sheet, income statement, and cash flow statement items, as well as financial ratios –, but also on meteorological data ranging from precipitation amounts to the number of days above or below a given temperature, retrieved from government sources (i.e., meteo.data.gouv). Additionally, the production outputs of each region studied were extracted from the Agreste database.

For the purpose of this analysis, only the vineyards located in Burgundy and Loire and with sufficient data were kept, as some vineyards lacked data across a few years and were thus excluded from the observed sample. "Valid" vineyards' financial data were then averaged out for each region to obtain comparable financial numbers for Burgundy and Loire. As meteorological data were given on a per-department basis, averages for each region were computed as weighted averages based on the number of valid vineyards per department to avoid overweighting (underweighting) departments with few (many) valid vineyards. Regarding the timeline, the analysis focuses on the years 2013 to 2022, i.e., a span of ten years until the most recent year with extensive data at hand, in order to look at the current situation while investigating how recent climatic evolutions have impacted winemakers' financials and productivity. However, some meteorological data from 2010 to 2013 were also retrieved to assess the longer-term impact of climate events.

The investigation includes three main steps, starting with a comparison of vineyards' income statements between the more and less recent years, i.e., between the periods 2013-2017 and 2018-2022, in order to better understand the evolution over time of winemakers' income-related financials. It was important to regroup several years to avoid misinterpreting some outliers' years that could distort the overall analysis (i.e., 2021, probably the most challenging year of the past decade). Simple averages of yearly financial results were computed for each period to enable the comparison. Additionally, the volatilities of income statement items and production data percentage changes over the 2014-2018 and 2018-2022 periods were compared. The period is slightly different from the previous analysis as the volatilities were based on percentage changes, with the first data set being the 2014 to 2015 percentage change.

Second, regression analyses were conducted to determine the relationship between production per region and various climate events that were selected to match the challenges faced by winemakers with regards to climate change, as identified in the literature review. A first set of regressions was made over the whole period with available data – i.e., from 2010 to 2022 – to narrow down the selection to the eight meteorological aspects that display statistical significance in explaining vineyards' financials. Further regressions were then conducted – going back this time to the focus period of 2013-2022 – to investigate the relationship between these eight meteorological items and winemakers' financials not only in the same year but also with time lags of one, two, and three years. The goal here is to understand whether climate-change-induced phenomena could explain potential changes in production and whether these potential effects are observable immediately or a few years later.

A similar analysis was then conducted as a third step, looking at the relationship between the same eight climatic events and all key financial numbers and ratios available over different time lags. The financial metrics chosen aimed to grasp different aspects of the vineyard's businesses, aspects that are usually considered in the finance industry when analyzing a business' global financial health. The indicators chosen notably include liquidity, profitability, and solvency ratios and will be discussed further in the analysis.

The second part of this study is based on a questionnaire (see Appendix 1), combining quantitative and qualitative questions, sent to winemakers across the Burgundy and Loire regions. The purpose of this questionnaire was to gather information at the very source, trying to understand practitioners' points of view by asking them about the main environmental challenges that are impacting their activities, how their key financial metrics – revenue, profit, number of sales, production costs, and bottle prices –, as well as their productivity, have been affected as a consequence, how they have reacted to these issues, how much the strategies adopted as a response have costed them, and how much of a positive impact these strategies had. The questionnaire also asks respondents about their annual revenue as well as the surface of their vineyards, in order to get a sense of how size and available financial means may influence the ability of winemakers to adapt to climate change issues. Winemakers' answers will be analyzed in detail and compared with existing literature insights and findings from this thesis' quantitative analysis to either substantiate or adapt the previously obtained results.

Eventually, the overall findings will be synthesized and combined in order to not only provide final answers regarding the main challenges caused by climate change for Burgundy and Loire vineyards and the financial impacts that these issues have on winemakers' activities in these two regions, but also come up with some best practices and solutions that can be implemented to respond to these various challenges.

4 Results

4.1 Financial Analysis

This analysis aims to understand the financial conditions of winemakers and identify the factors influencing the financial indicators of vineyards in Burgundy and Loire. Multiple layers of analysis were used to gain a clear understanding of the situation, including the impact of meteorological events on production and the domains’ financial health.

4.1.1 General Financial Outlook

The initial layer of analysis provides a general overview of the current state of the winemakers. This analysis focuses primarily on income statements, aiming to identify the differences between 2013-2017 and 2018-2022 and between the studied regions.

4.1.1.1 Income Statement Analysis

The income statement analysis (see Appendix 2) presents six income statements constructed using the average income statements of vineyards from the studied regions. This analysis compares the harmonized income statements of the two regions over the periods 2013-2017 and 2018-2022.

In the **Burgundy** region, the revenue, material costs, and employee expenses have increased by 21.5%, 22.6%, and 19.2% respectively, from 2013-2017 to 2018-2022. On the contrary, other operating expenses decreased by 7.9% over the same period, contributing to an increase in EBITDA (Earnings Before Interest, Taxes, Depreciation, and Amortization) from 6.7% to 7.5%.

In addition, the increase in depreciation and amortization aligns with the revenue increase, showing a 24.7% rise compared to a 21.5% increase in revenue. However, financial loss (the net loss from the difference between interest earned on deposits and interest paid) has risen, primarily due to a slight upward trend in interest paid and a downward trend in interest earned on deposits. Overall, profit before tax increased from $772,000 to $1,128,000 between the 2013-2017 and 2018-2022 periods, corresponding to 3.4% and 4.1% of revenue respectively, and representing a 46.2% increase in profit before tax for Burgundy winemakers. Lastly, vineyards' production output in the region has increased by only 1.5%, and the implied theoretical price, which corresponds to the revenue of an average Burgundy vineyard divided by the total production output of the region, increased by 19.7%. This substantial increase in the implied theoretical price primarily accounts for the 21.5% rise in revenue for regional winemakers.

For the **Loire** region, revenue substantially increased by over 38.7%, closely aligning with the 39.1% rise in material costs. Similarly, employee expenses increased by only 27.2%, which helped offset the significant 90.8% increase in other operating expenses. Overall, vineyards in this region maintained an EBITDA above 8.0% of revenue, slightly decreasing from 8.3% to 8.0%. The 65.3% increase in depreciation and amortization underscores the substantial investments made by this region's winemakers in recent years, as does the interest expense, which increased by slightly more than 30%, now representing more than 1% of revenue. These increases in revenue and expenses complicated the efficient tracking of profitability, as evidenced by the decline in profit before tax, which now represents 4.2% of revenue for 2018-2022, compared to 4.8% for 2013-2017. To counterbalance rising expenses and stagnating production output, which grew by only 1.6% over five years, Loire vineyards adjusted their prices upwards, increasing more than 36% during this time frame.

Comparing the financial evolutions in the **Burgundy and Loire** regions reveals large discrepancies. The first notable difference lies in revenue growth. As previously highlighted, revenue in Burgundy increased by 21.5%, while the Loire region experienced a 38.7% increase. These increases in both regions are primarily attributed to price adjustments, as production output remained relatively unchanged. The second significant difference pertains to depreciation and amortization. In Burgundy, the increase in depreciation and amortization aligns with the revenue growth. However, in the Loire region, the increase in these costs nearly doubled the increase in revenue, indicating substantial investment in long-term assets by Loire winemakers. Lastly, and most critically, is the comparison of vineyard profitability. During 2013-2017, owning a vineyard in the Loire region was more profitable on average, with profit before tax at 4.8% of revenue compared to 3.4% in Burgundy. However, this trend has shifted. Profitability in the Loire region declined to 4.2% of revenue, whereas Burgundy's profitability significantly increased, to 4.1%.

4.1.1.2 Volatility of Income Statement Items

The second analysis (see Figure 1 below) aims to elucidate the evolution of uncertainty in income statement items over the periods 2015-2018 and 2019-2022 by examining the volatility of these items.

Figure 1: Evolution of the averages and volatilities of income statement items

Item	Average 2015-2018	Average 2019-2022	2015-2018 Volatility	2019-2022 Volatility
Production Burgundy	2'381	2'079	20.2%	44.7%
Production Val-de-Loire	2'638	2'343	31.0%	39.5%
Revenue Burgundy	22'990	27'999	17.8%	7.5%
Revenue Val-de-Loire	19'403	25'617	4.9%	11.3%
Material Costs Burgundy	17'851	21'664	18.7%	7.5%
Material Costs Val-de-Loire	15'261	19'787	2.7%	10.8%
Cost of Employees Burgundy	2'553	3'074	28.5%	5.2%
Cost of Employees Val-de-Loire	2'084	2'714	15.1%	13.9%
Depreciation & Amortization Burgundy	640	877	24.9%	9.7%
Depreciation & Amortization Val-de-Loire	531	849	18.3%	28.4%
Theoritical Price Burgundy	10	14	26.0%	54.1%
Theoritical Price Val-de-Loire	8	11	26.0%	53.1%

In the **Burgundy** region, production volatility increased significantly, rising from 20.2% during 2015-2018 to 44.7% in 2019-2022, indicating greater uncertainty in production outputs. Despite this growing uncertainty, revenue volatility was not adversely affected; instead, it decreased from 17.8% to 7.5% over the same periods. Given that both production and price influence revenue, and that price volatility doubled from 26.0% to 54.1%, it suggests that winemakers increasingly used pricing strategies to stabilize their income. On the cost side, the volatility of material and employee costs, which constitute the most variable costs, also decreased similarly to the volatility of the revenues (from 18.7% to 7.5% and 28.5% to 5.2%, respectively). Finally, the volatility of depreciation and amortization also decreased from 24.9% to 9.7%, reflecting greater stability in capital expenditures and investments in long-term assets.

Production volatility increased by approximately 50% in the **Loire** region, rising from 31.0% to 39.5%. Similarly, the price volatility doubled, increasing from 26.0% to 53.1%. Those two observations combined likely contributed to the rise in revenue volatility from 4.9% during 2015-2018 to 11.3% in 2019-2022. Based on these figures, it is challenging to determine whether poor price management or production volatility is more responsible for this region's revenue volatility increase. Regarding costs, material cost volatility increased significantly, reaching 10.8% compared to 2.7% in the initial period, aligning with the evolution of revenue volatility. In contrast, employee cost volatility remained stable across both periods, indicating effective management, as winemakers could adapt to production variations over the years. Lastly, depreciation and amortization volatility increased by nearly ten percentage points, from 18.3% to 28.4%.

Comparing the **Loire and Burgundy** regions over the 2015-2018 and 2019-2022 periods reveals both similarities and differences. Both regions experienced a similar increase in production volatility and theoretical price volatility, highlighting the challenge of adapting to more uncertain conditions in wine production. To address the increased production volatility, which resulted in greater variability without a corresponding increase in overall output, winemakers in both regions relied on price adjustments (increases) to compensate for revenue uncertainties. However, the impact on revenue volatility differed between the two regions: the Loire region saw an increase in revenue volatility whereas Burgundy experienced a decrease. Although this could indicate superior pricing management by Burgundy's winemakers, caution is warranted, as consumer preferences may also have positively influenced the prices of Loire's wines, thereby increasing their volatility. Another significant difference is observed in the main variable costs (material and employee costs) and the volatility of depreciation and amortization. Despite the growing uncertainties inherent in production, Burgundy vineyards managed to reduce most of the volatility associated with these costs, whereas Loire winemakers seemed to struggle more with adaptation. Additionally, the higher volatility of depreciation and amortization in the Loire region could underscore more significant investments by vineyards in new equipment, potentially destabilizing their financial stability and increasing the risk profile of their domains.

4.1.2 Climate Events’ Impacts on Production

This second layer of analysis provides further guidance on the different climate events impacting the production output of vineyards in the two regions studied. For this purpose, the study regresses the production output with different climate events as potentially explanatory variables, as follows:

Indicator	Meaning
RR	Monthly total precipitation heights (in mm)
NBJRR30	Number of days with total precipitation heights ≥ 30.0 mm
NBJTXS32	Number of days with maximum temperature ≥ 32°C
NBJTN5	Number of days with minimal temperature ≤ -5°C
NBJGELEE	Number of days with frost
TMM	Monthly average of daily mean temperatures (in °C)
NBJTMS24	Number of days with daily mean temperature ≥ 24°C
GLOT	Monthly total of daily global radiation (in J/cm²)
NBJNEIG	Number of days with snowfall
NBJGREL	Number of days with hail
LATE_FROST	Number of days with late frost (occurring in May and June)

4.1.2.1 Immediate Impacts

This sub-analysis aims to identify the key climate events influencing production output in the two regions over the longest feasible period (2010-2022). Extending the period further could potentially distort the results due to the closure of some weather stations and the opening of new ones within specific departments. However, it is also crucial to utilize long-term data frames to ensure that the regressions are as precise as possible.

Regarding **Burgundy**, the single-factor regressions summed up in Figure 2 below show that only the LATE_FROST is significant at a 90% confidence level. Such events are negatively correlated with the production output of the same year (harvest usually takes place in September compared to this event occurring in May and June).

Figure 2: Individual regression of factors of the production output against climate events

Correlations with Production	**Burgundy**	**Val-de-Loire**
RR	- 0.284	- 0.248
NBJRR30	- 0.255	- 0.243
NBJTXS32	0.282	0.048
NBJTN5	- 0.180	0.005
NBJGELEE	- 0.419	- 0.134
TMM	0.435	0.109
NBJTMS24	0.220	- 0.037
GLOT	0.414	0.061
NBJNEIG	- 0.153	0.267
NBJGREL	0.063	- 0.167
LATE_FROST	- 0.479	- 0.667

P-values with Production	**Burgundy**	**Val-de-Loire**
RR	0.348	0.414
NBJRR30	0.401	0.424
NBJTXS32	0.351	0.876
NBJTN5	0.556	0.987
NBJGELEE	0.154	0.662
TMM	0.137	0.724
NBJTMS24	0.470	0.903
GLOT	0.159	0.843
NBJNEIG	0.618	0.379
NBJGREL	0.838	0.587
LATE_FROST	0.098	0.013

On the other hand, the multi-factor regression (see Figure 3 below) seems way more promising. Indeed, eight weather events – namely, NBJRR30, NBJTXS32, NBJGELEE, NBJTMS24, GLOT, NBJNEIG, NBJGREL, and LATE_FROST – explain Burgundy's production output at a 95% confidence level.

Figure 3: Regression of Burgundy's production output against climate events

Regression Statistics	
Multiple R	0.999955968
R Square	0.999911938
Adjusted R Square	0.99894326
Standard Error	11.64258858
Observations	13

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	11	1539124.862	139920.442	1032.243285	0.024272565
Residual	1	135.549869	135.549869		
Total	12	1539260.411			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	38693.29836	1344.872348	28.77098219	0.022118244	21605.07496	55781.52175	21605.07496	55781.52175
RR Burgundy	1.122255708	0.153714815	7.30089491	0.086658262	-0.830876198	3.075387614	-0.8308762	3.075387614
NBJRR30 Burgundy	-1649.437587	49.2528816	-33.48915907	0.01900408	-2275.254784	-1023.62039	-2275.25478	-1023.62039
NBJTXS32 Burgundy	210.8885279	10.6455865	19.80994921	0.032109111	75.62352626	346.1535295	75.62352626	346.1535295
NBJTN5 Burgundy	-19.2319554	3.07582644	-6.252613983	0.100961556	-58.31403588	19.85012507	-58.3140359	19.85012507
NBJGELEE Burgundy	-97.40262447	2.936761428	-33.1666793	0.019188745	-134.7177164	-60.0875325	-134.717716	-60.0875325
TMM Burgundy	898.8452892	83.02788974	10.82582361	0.058639264	-156.1240767	1953.814655	-156.124077	1953.814655
NBJTMS24 Burgundy	-172.5079306	9.382023579	-18.38707067	0.034589154	-291.717843	-53.2980181	-291.717843	-53.2980181
GLOT Burgundy	-0.082918921	0.002382212	-34.80753863	0.01828468	-0.113187788	-0.05265005	-0.11318779	-0.05265005
NBJNEIG Burgundy	74.57097657	1.346561976	55.37879274	0.011494483	57.46128442	91.68066873	57.46128442	91.68066873
NBJGREL Burgundy	-305.9041569	10.1480651	-30.14408696	0.021111483	-434.8475498	-176.960764	-434.84755	-176.960764
LATE_FROST Burgundy	-78.64138054	2.711245368	-29.0056302	0.021939455	-113.0910193	-44.1917418	-113.091019	-44.1917418

According to that regression, the higher the number of days with total precipitation heights greater than or equal to 30.0 mm, the lower the production output, implying that the vine is sensitive to being overwhelmed by excessive water. The higher the number of days with maximum temperatures equal to or greater than 32°C, the larger the production output, implying that high temperatures favor vine development. The higher the number of days with frost, the lower the production output, indicating that frost adversely affects vine health and productivity. The higher the number of days with a daily mean temperature equal to or greater than 24°C, the lower the production output, indicating that although high temperatures might be acceptable for the vine, consistently high average temperatures are detrimental. The greater the monthly total of daily global radiation (in J/cm^2), the lower the production output. The greater the number of days with snowfall, the larger the production output, which may imply that snow provides beneficial moisture or protective insulation for the vines. The greater the number of days with hail, the lower the production output, reflecting the damaging impact of hail on vines and grapes. The greater the number of days with late frost, the lower the production output, highlighting the catastrophic effects of frost occurring later in the growing season.

Focusing now on the **Loire** region and looking at the single-factor regression p-values (see Figure 2 above), it appears that only LATE_FROST is significant at a 90% confidence level. With a p-value of 0.013, late frost is highly relevant in studying the production output of the Loire region, as this explanatory factor is also significant at a 95% confidence level. However, when considering all factors together, the late frost variable and all other factors become insignificant, as shown in Figure 4 below. In this part of the study, none of the climatic events in the Loire region are significant at a 90% confidence level in explaining the production output.

Figure 4: Regression of Loire's production output against climate events

Regression Statistics	
Multiple R	0.992190175
R Square	0.984441344
Adjusted R Square	0.813296127
Standard Error	202.580931
Observations	13

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	11	2596658.817	236059.8925	5.752082144	0.315266495
Residual	1	41039.03361	41039.03361		
Total	12	2637697.851			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	-11999.03246	8322.506833	-1.441756997	0.38605673	-117746.5082	93748.44327	-117746.5082	93748.44327
RR Loire Valley	1.367988635	2.492209633	0.548905926	0.680415065	-30.2985372	33.03451447	-30.2985372	33.03451447
NBJRR30 Loire Valley	-318.4848921	226.5975512	-1.405508976	0.393681328	-3197.67977	2560.709986	-3197.67977	2560.709986
NBJTXS32 Loire Valley	-37.8319508	107.1045778	-0.353224405	0.783839291	-1398.724645	1323.060743	-1398.724645	1323.060743
NBJTN5 Loire Valley	-51.46036439	52.01987088	-0.98924437	0.503442101	-712.4354941	609.5147654	-712.4354941	609.5147654
NBJGELEE Loire Valley	-8.033684472	46.8452849	-0.171493983	0.891875341	-603.2594653	587.1920964	-603.2594653	587.1920964
TMM Loire Valley	413.1642649	1466.884762	0.281661025	0.82521712	-18225.37385	19051.70238	-18225.37385	19051.70238
NBJTMS24 Loire Valley	-20.98301932	156.0351177	-0.134476262	0.91490028	-2003.597171	1961.631132	-2003.597171	1961.631132
GLOT Loire Valley	0.020991487	0.028870493	0.727091389	0.599771364	-0.345842909	0.387825883	-0.345842909	0.387825883
NBJNEIG Loire Valley	73.50321106	19.10838137	3.84664769	0.161915831	-169.2917948	316.298217	-169.2917948	316.298217
NBJGREL Loire Valley	-29.73749565	118.6530339	-0.250625666	0.843666913	-1537.367237	1477.892246	-1537.367237	1477.892246
LATE_FROST Loire Valley	-102.761546	67.81271087	-1.515372924	0.371344026	-964.403734	758.880642	-964.403734	758.880642

The financial data in the database spans from 2013 to 2022, providing ten years of observations. Due to the lack of data from earlier periods, as most domains are privately held companies, regressions can only be performed if the number of potential explanatory variables is fewer than the number of observations. Consequently, only Burgundy's relevant variables will be retained for analysis as the ones for the Loire Valley were statistically insignificant. Specifically, the analysis will utilize the following eight potential explanatory variables: NBJRR30, NBJTXS32, NBJGELEE, NBJTMS24, GLOT, NBJNEIG, NBJGREL, and LATE_FROST.

4.1.2.2 Long-Term Impacts

The initial sub-analysis, which regressed production against weather events, aimed to explain the output for a given year. However, climate events might influence production outputs in subsequent years as significantly as they affect the current year. In this second sub-analysis, the climate events of previous years will be regressed against production outputs. For example, a regression denoted as T= +1 will correlate climate events occurring at t = 0 (i.e., 2012-2021) with production outputs at t + 1 (i.e., 2013-2022). Three regressions per region were conducted for T = +1, T = +2, and T =+ 3, as the T = 0 analysis was already performed in the previous part, with more data.

For **Burgundy**, the three regressions conducted for T=+1, T=+2, and T=+3 are shown in Appendices 3, 4 and 5, respectively. Since none of the p-values in these regressions is significant at a 90% confidence level, we can infer that based on the collected data and the regressions performed, none of the climate events have a long-term impact on vine production in Burgundy.

Out of the three **Loire**-focused regressions conducted for the three time periods (Appendices 6, 7 and 8), one displayed a p-value that is significant at a 95% confidence level. Indeed, the number of days with frost negatively impacts the production output for the next year (T = +1). This observation indicates that frost adversely affects vine production in the current year and has a lingering negative impact on production in the following year.

4.1.3 Climate Events' Impacts on Financial Indicators

The previous analysis showed that some climate events significantly impact vineyard production output, corroborating previous findings (De Orduña, 2010, p. 1850; Schultz, 2016, p. 186). Building on this, the current study aims to assess the impact of these identified climate events (as discussed in part 4.1.2) on financial indicators. This approach seeks to establish a direct relationship between climate events and financial metrics.

Among the array of possible financial indicators, the study focuses on a select set that assesses business viability, particularly the ability to be profitable in accounting terms, provide returns to equity holders, and meet interest and debt obligations. To evaluate these business imperatives, 13 financial indicators were regressed against each of the region's eight identified climate events over different time frames (T=0, T=+1, T=+2, and T=+3) to capture both short-term and long-term impacts: Current Ratio, Profit Margin, ROE (Return on Equity), ROCE (Return on Capital Employed), Solvency Ratio, EBITDA, EBIT (Earnings Before Interest and Taxes), Interest Coverage, Stock Turnover, Collection Period, Cash and Cash Equivalents, Working Capital, and Operating Revenue. The indicators were directly extracted from the Orbis database, and no adjustment was made. In total, 52 regressions were performed for each region. The complete set of regressions can be found in the accompanying Excel file.

4.1.3.1 Regressions Between Climate Events and Burgundy's Financial Ratios

Burgundy's vineyard **current ratio** appears to be influenced by the climate events occurring in the region, as the regression analysis shows increasing significance from T = 0 to T = +3. At T = 0 and T = +1 (Appendices 9 and 10), the significance is around 0.97, indicating a 97% probability of observing the data given the null hypothesis. However, at T = +2 (see Appendix 11), the significance of the model decreases to 0.6, and it further decreases to 0.04 at T = +3 (see Figure 5 below), meaning that the current ratio of Burgundy's vineyards is impacted three years after the year of production.

Figure 5: Regression of Burgundy's current ratio against climate events for T = +3

Regression Statistics	
Multiple R	0.999829765
R Square	0.999659558
Adjusted R Square	0.996936024
Standard Error	0.055731029
Observations	10

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	8	9.120179114	1.140022389	367.0449579	0.040347966
Residual	1	0.003105948	0.003105948		
Total	9	9.123285061			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	-320.1135853	22.38576626	-14.29987169	0.044446906	-604.5517145	-35.67545603	-604.5517145	-35.67545603
NBJRR30 Burgundy	10.09086615	0.710945573	14.19358462	0.044778649	1.057446142	19.12428616	1.057446142	19.12428616
NBJTXS32 Burgundy	-0.383976117	0.080294738	-4.782083191	0.131234937	-1.404217497	0.636265263	-1.404217497	0.636265263
NBJGELEE Burgundy	0.658684744	0.048432368	13.60009371	0.046725868	0.04329316	1.274076328	0.04329316	1.274076328
NBJTMS24 Burgundy	-0.23139103	0.041967525	-5.513573419	0.114222438	-0.764638995	0.301856934	-0.764638995	0.301856934
GLOT Burgundy	0.000571345	3.92421E-05	14.55951137	0.04365679	7.27276E-05	0.001069963	7.27276E-05	0.001069963
NBJNEIG Burgundy	-0.305465096	0.023821396	-12.82314025	0.049545892	-0.608144625	-0.002785567	-0.608144625	-0.002785567
NBJGREL Burgundy	2.028659233	0.145912718	13.9032379	0.045710601	0.174662362	3.882656103	0.174662362	3.882656103
LATE_FROST Burgundy	-0.988396617	0.038099241	-25.94268498	0.024527328	-1.472493378	-0.504299856	-1.472493378	-0.504299856

Examining the results of the T = +3 regression more closely, it appears that several independent variables significantly explain the current ratio three years later at a 95% confidence level. These variables are NBJRR30, NBJGELEE, GLOT, NBJNEIG, NBJGREL, and LATE_FROST. According to the regression, an increase in the number of days with total precipitation heights greater than or equal to 30.0 mm, in the number of frost days, in the monthly total of daily global radiation (in J/cm²), and in the number of hail days, correlates with a higher current ratio. Conversely, an increase in the number of snowfall days and in the number of days with late frost (occurring in May and June) correlates with a lower current ratio.

This regression indicates that the current ratio is affected three years after production, suggesting that winemakers can initially mitigate the immediate financial impact of climate events, but that this mitigation may not be sustainable in the long term.

Regarding Burgundy's **profit ratio**, only the regression using data at T = 0 was significant enough to be analyzed. The significance of this regression is 0.08, indicating an 8% probability of observing the data given the null hypothesis (see Figure 6 below), whereas the other regressions display significance levels above 0.1.

Figure 6: Regression of Burgundy's profit margin against climate events for T = 0

Regression Statistics	
Multiple R	0.999300926
R Square	0.998602341
Adjusted R Square	0.987421069
Standard Error	0.243663596
Observations	10

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	8	42.42019346	5.302524183	89.31026152	0.081666091
Residual	1	0.059371948	0.059371948		
Total	9	42.47956541			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	469.3025973	27.72534812	16.92684237	0.037566409	117.0186477	821.5865469	117.0186477	821.5865469
NBJRR30 Burgundy	-14.39457822	0.955872548	-15.05909784	0.042212787	-26.54009052	-2.249065927	-26.54009052	-2.249065927
NBJTXS32 Burgundy	1.910007086	0.15558672	12.27615755	0.05174398	-0.066909632	3.886923804	-0.066909632	3.886923804
NBJGELEE Burgundy	-0.996187428	0.057112096	-17.44266961	0.036457932	-1.721865417	-0.270509439	-1.721865417	-0.270509439
NBJTMS24 Burgundy	-1.235968777	0.150718985	-8.200485002	0.077250559	-3.15103506	0.679097506	-3.15103506	0.679097506
GLOT Burgundy	-0.000800253	4.78454E-05	-16.72580998	0.038016864	-0.001408187	-0.00019232	-0.001408187	-0.00019232
NBJNEIG Burgundy	0.542518412	0.029775851	18.22008114	0.034905536	0.16418036	0.920856465	0.16418036	0.920856465
NBJGREL Burgundy	-3.252479664	0.191933282	-16.94588674	0.037524288	-5.691223245	-0.813736083	-5.691223245	-0.813736083
LATE_FROST Burgundy	0.171503636	0.056423953	3.039553712	0.202344239	-0.545430663	0.888437935	-0.545430663	0.888437935

Examining the results of the T = 0 regression more closely, one can observe that several independent variables significantly explain the profit ratio for the year at a 95% confidence level. These variables are NBJRR30, NBJTXS32, NBJGELEE, GLOT, NBJNEIG, and NBJGREL. According to the regression, an increase in the number of days with maximum temperatures equal to or greater than 32°C and in the number of snowfall days significantly increases the profit margin. Conversely, an increase in the number of days with total precipitation heights equal to or greater than 30.0 mm, the number of frost days, the monthly total of daily global radiation (in J/cm²), and the number of hail days correlates with a lower profit margin.

These results perfectly corroborate the findings of part 4.1.2: a greater number of snowfall days and days with maximum temperatures equal to or greater than 32°C are associated with higher production output. Furthermore, a greater number of days with total precipitation heights equal to or greater than 30.0 mm, frost days, higher monthly total of daily global radiation, and hail days are associated with lower production output. This observation suggests that production output is an intermediate variable between climate events and profit margin.

The **ROE** is often considered one of the most important financial indicators to assess a company's profitability for equity holders. Regarding the relationship between climate events and the ROE of Burgundy's vineyards, only the T = +3 regression was statistically significant (see Figure 7 below), with a significance level of 0.04.

Figure 7: Regression of Burgundy's ROE against climate events for T = +3

Regression Statistics	
Multiple R	0.999826914
R Square	0.999653857
Adjusted R Square	0.996884715
Standard Error	0.157789061
Observations	10

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	8	71.90318561	8.987898201	360.9976398	0.040684163
Residual	1	0.024897388	0.024897388		
Total	9	71.92808299			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	-976.4579155	63.37993608	-15.40642001	0.041263836	-1781.776359	-171.1394715	-1781.776359	-171.1394715
NBJRR30 Burgundy	29.33023659	2.012872129	14.57133624	0.043621472	3.754271215	54.90620197	3.754271215	54.90620197
NBJTXS32 Burgundy	-1.096505232	0.227335321	-4.823294622	0.130144741	-3.985074366	1.792063902	-3.985074366	1.792063902
NBJGELEE Burgundy	2.092629385	0.137124651	15.26078183	0.041656511	0.350295492	3.834963278	0.350295492	3.834963278
NBJTMS24 Burgundy	-1.224169523	0.118820996	-10.30263641	0.061598968	-2.73393343	0.285594383	-2.73393343	0.285594383
GLOT Burgundy	0.001744594	0.000111104	15.70227905	0.040488466	0.000332877	0.00315631	0.000332877	0.00315631
NBJNEIG Burgundy	-0.937392236	0.067444577	-13.89870444	0.045725459	-1.794356834	-0.080427638	-1.794356834	-0.080427638
NBJGREL Burgundy	6.019235182	0.413116917	14.57029458	0.043624581	0.77008705	11.26838331	0.77008705	11.26838331
LATE_FROST Burgundy	-1.232327169	0.107868878	-11.42430695	0.055583353	-2.602931214	0.138276876	-2.602931214	0.138276876

Examining the results of the T = +3 regression more closely, one can see that several independent variables significantly explain the ROE three years later at a 95% confidence level. These variables are NBJRR30, NBJGELEE, GLOT, NBJNEIG, and NBJGREL. According to the regression, an increase in the number of days with total precipitation heights greater than or equal to 30.0 mm, the number of frost days, the monthly total of daily global radiation (in J/cm²), and the number of hail days correlates with a higher ROE. Conversely, an increase in snowfall days correlates with a lower ROE.

These results differ somewhat from those observed in the analysis of Burgundy's profit margin at T = 0, not only because the period considered is different but also because equity holders significantly influence this ratio, as they can affect the company's capital structure.

Burgundy's vineyard **ROCE** displayed a significant relationship for T = +3 only. The significance of this regression is 0.043, indicating that the null hypothesis can be rejected at a 95% confidence level (see Figure 8 below).

Figure 8: Regression of Burgundy's ROCE against climate events for T = +3

Regression Statistics	
Multiple R	0.999805083
R Square	0.999610205
Adjusted R Square	0.996491841
Standard Error	0.496876362
Observations	10

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	8	633.1266068	79.14082584	320.5559966	0.043171504
Residual	1	0.246886119	0.246886119		
Total	9	633.3734929			

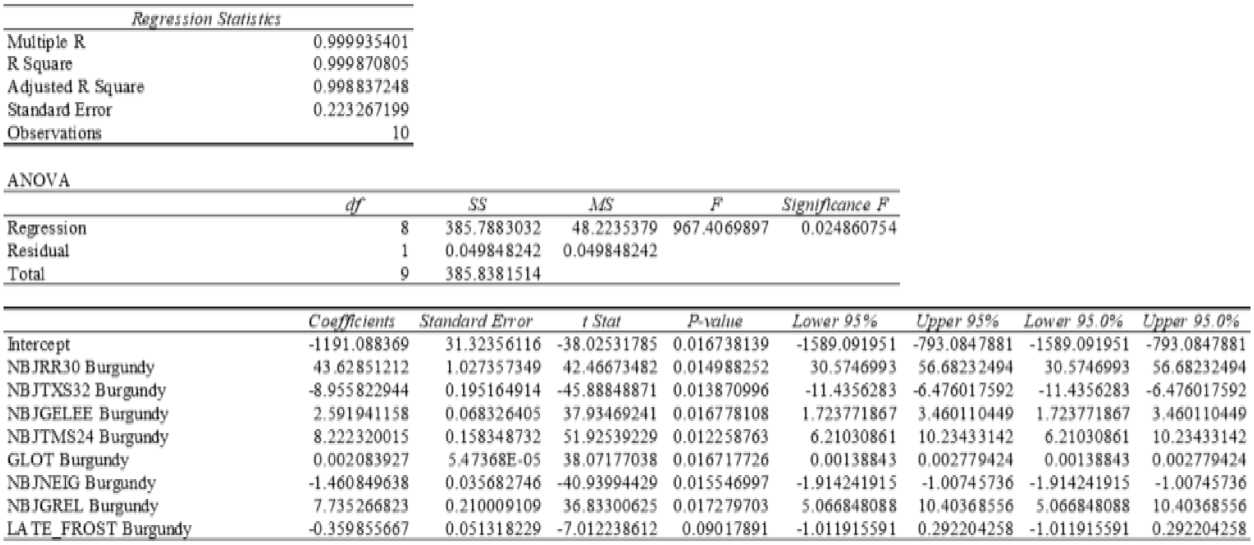
	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	-1178.243932	199.58286	-5.903532655	0.106823098	-3714.184613	1357.69675	-3714.184613	1357.69675
NBJRR30 Burgundy	35.77731058	6.338516591	5.644429586	0.111628956	-44.76117896	116.3158001	-44.76117896	116.3158001
NBJTXS32 Burgundy	-2.840944214	0.715876922	-3.968481348	0.157147396	-11.93702296	6.255134528	-11.93702296	6.255134528
NBJGELEE Burgundy	2.488758043	0.431804318	5.763624724	0.109366019	-2.997836027	7.975352114	-2.997836027	7.975352114
NBJTMS24 Burgundy	0.749878798	0.37416627	2.004132542	0.294641932	-4.004354436	5.504112032	-4.004354436	5.504112032
GLOT Burgundy	0.002067509	0.000349867	5.909414668	0.106718752	-0.002377973	0.006512992	-0.002377973	0.006512992
NBJNEIG Burgundy	-1.027843503	0.212382377	-4.839589409	0.129718595	-3.726417469	1.670730463	-3.726417469	1.670730463
NBJGREL Burgundy	7.378400624	1.300901531	5.671759503	0.111101942	-9.151120576	23.90792182	-9.151120576	23.90792182
LATE_FROST Burgundy	2.134785824	0.339678145	6.284731163	0.10045415	-2.181234232	6.450805879	-2.181234232	6.450805879

Despite the model being statistically significant, none of the independent variables was so, even at a 90% confidence level. Therefore, no meaningful analysis can be drawn from this observation.

The **interest coverage ratio** is crucial for businesses because it measures a company's ability to meet its interest payments on outstanding debt, reflecting its financial health. A higher ratio indicates a stronger financial strength – hence, the likelihood that a lender might consider providing additional debt to cover short-term obligations is higher. Maintaining a strong interest coverage ratio is particularly important for winemakers, who are highly subject to weather conditions and might use revolvers (short-term debt) to face production variabilities.

Regarding the relationship between climate events and the interest coverage ratio of Burgundy's vineyards, only the T = +2 regression was statistically significant (see Figure 9 below), with a significance level of 0.02. Although the T = +3 regression was close to being statistically significant, its significance level exceeded 0.1, indicating that the impact of climate events is less certain after three years compared to two years later.

Figure 9: Regression of Burgundy's interest coverage against climate events for T = +2



Regression Statistics	
Multiple R	0.999935401
R Square	0.999870805
Adjusted R Square	0.998837248
Standard Error	0.223267199
Observations	10

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	8	385.7883032	48.2235379	967.4069897	0.024860754
Residual	1	0.049848242	0.049848242		
Total	9	385.8381514			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	-1191.088369	31.32356116	-38.02531785	0.016738139	-1589.091951	-793.0847881	-1589.091951	-793.0847881
NBJRR30 Burgundy	43.62851212	1.027357349	42.46673482	0.014988252	30.5746993	56.68232494	30.5746993	56.68232494
NBJTXS32 Burgundy	-8.955822944	0.195164914	-45.88848871	0.013870996	-11.4356283	-6.476017592	-11.4356283	-6.476017592
NBJGELEE Burgundy	2.591941158	0.068326405	37.93469241	0.016778108	1.723771867	3.460110449	1.723771867	3.460110449
NBJTMS24 Burgundy	8.222320015	0.158348732	51.92539229	0.012258763	6.21030861	10.23433142	6.21030861	10.23433142
GLOT Burgundy	0.002083927	5.47368E-05	38.07177038	0.016717726	0.00138843	0.002779424	0.00138843	0.002779424
NBJNEIG Burgundy	-1.460849638	0.035682746	-40.93994429	0.015546997	-1.914241915	-1.00745736	-1.914241915	-1.00745736
NBJGREL Burgundy	7.735266823	0.210009109	36.83300625	0.017279703	5.066848088	10.40368556	5.066848088	10.40368556
LATE_FROST Burgundy	-0.359855667	0.051318229	-7.012238612	0.09017891	-1.011915591	0.292204258	-1.011915591	0.292204258

Examining the results of the T = +2 regression more closely, one can observe that several independent variables significantly explain the interest coverage ratio two years later at a 95% confidence level. These variables are NBJRR30, NBJTXS32, NBJGELEE, NBJTMS24, GLOT, NBJNEIG, and NBJGREL. According to the regression, an increase in the number of days with total precipitation heights greater than or equal to 30.0 mm, the number of frost days, the monthly total of daily global radiation (in J/cm²), and the number of hail days correlates with a higher interest coverage ratio. Conversely, an increase in the number of days with maximum temperatures equal to or greater than 32°C and the number of snowfall days correlates with a lower interest coverage ratio.

These results differ from previous observations, where precipitation and hail negatively impacted the profit margin and, consequently, EBIT, which is part of the interest coverage ratio formula. However, since this regression occurs at T = +2, it could be inferred that Burgundy's vineyards had time to recover from the climate events and eventually improve their financial health in reorganizing their interest repayment schedule.

Investors often prioritize examining the cash on the balance sheet among all other financial indicators. Regarding the impact of Burgundy's climate events on **cash and cash equivalents**, only the T = +1 regression indicated a significant relationship (see Figure 10 below). Although the regression's significance is not low enough to be considered at a 95% confidence level, it can be considered at a 90% confidence level with a significance of 0.06.

Figure 10: Regression of Burgundy's cash and cash equivalents against climate events for T = +1

Regression Statistics	
Multiple R	0.9995659
R Square	0.999131988
Adjusted R Square	0.992187893
Standard Error	28.49080248
Observations	10

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	8	934343.4229	116792.9279	143.8822373	0.064392305
Residual	1	811.7258257	811.7258257		
Total	9	935155.1487			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	-79966.34045	3832.327057	-20.866262	0.030486201	-128660.6727	-31272.00825	-128660.6727	-31272.00825
NBJRR30 Burgundy	2685.551572	130.5324834	20.57381811	0.030918867	1026.979112	4344.124031	1026.979112	4344.124031
NBJTXS32 Burgundy	-473.425877	25.36058319	-18.66778352	0.034070027	-795.6626393	-151.1891148	-795.6626393	-151.1891148
NBJGELEE Burgundy	177.0076789	7.789810687	22.7229757	0.027998501	78.02874949	275.9866084	78.02874949	275.9866084
NBJTMS24 Burgundy	358.5479356	23.12236037	15.50654561	0.040998134	64.75049076	652.3453805	64.75049076	652.3453805
GLOT Burgundy	0.139469378	0.006511557	21.41874509	0.029700984	0.056732202	0.222206553	0.056732202	0.222206553
NBJNEIG Burgundy	-88.07110226	4.006384505	-21.98268842	0.028940099	-138.977044	-37.16516049	-138.977044	-37.16516049
NBJGREL Burgundy	594.1051608	31.14038811	19.07828376	0.033338309	198.4290139	989.7813077	198.4290139	989.7813077
LATE_FROST Burgundy	-12.28842259	6.713827155	-1.830315602	0.318335074	-97.59568499	73.01883981	-97.59568499	73.01883981

Examining the results of the T = +1 regression more closely, it appears that several independent variables significantly explain cash and cash equivalents one year later at a 95% confidence level. These variables are NBJRR30, NBJTXS32, NBJGELEE, NBJTMS24, GLOT, NBJNEIG, and NBJGREL, similar to the T = +2 regression for the interest coverage ratio. According to the regression, an increase in the number of days with total precipitation heights greater than or equal to 30.0 mm, the number of frost days, the monthly total of daily global radiation (in J/cm^2), and the number of hail days correlates with higher cash and cash equivalents. Conversely, an increase in the number of days with maximum temperatures equal to or greater than 32°C and the number of snowfall days correlates with lower cash and cash equivalents.

These results align with the findings from the interest coverage ratio regression, indicating that only extreme temperatures and snowfall negatively affect the company's financial position. However, caution is required in interpreting these results. This observation does not imply that the company is in a better financial position when it hails, but rather that it has more cash the year following a year with a high average number of hail days. This phenomenon could be explained by winemakers taking on additional debt, liquidating stocks or investing less to cover losses incurred from hail-damaged production.

Furthermore, it is important to note that the regression is for the T = +1 period, indicating that cash collection occurs the year after production. Considering the growth profile of grapes, this observation is logical, as wines cannot be sold immediately after harvest and must undergo fermentation to produce the necessary alcohol content for commercialization.

Burgundy's vineyard **working capital** only displayed a significant relationship for T = 0. The significance of this regression is 0.045, indicating that the null hypothesis can be rejected at a 95% confidence level (see Figure 11 below).

Figure 11: Regression of Burgundy's working capital against climate events for T = +0

Regression Statistics	
Multiple R	0.999784284
R Square	0.999568614
Adjusted R Square	0.996117529
Standard Error	138.3699891
Observations	10

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	8	44364002.73	5545500.341	289.6389221	0.045414399
Residual	1	19146.2539	19146.2539		
Total	9	44383148.98			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	-546473.3945	15744.478	-34.70889252	0.018336618	-746525.9554	-346420.8336	-746525.9554	-346420.8336
NBJRR30 Burgundy	15965.65559	542.8142592	29.41274169	0.021636019	9068.546481	22862.7647	9068.546481	22862.7647
NBJTXS32 Burgundy	-1511.570288	88.35350518	-17.10820963	0.03716907	-2634.208014	-388.9325622	-2634.208014	-388.9325622
NBJGELEE Burgundy	1183.312841	32.43242036	36.48549284	0.017444205	771.2198677	1595.405814	771.2198677	1595.405814
NBJTMS24 Burgundy	253.5329937	85.58924977	2.962206052	0.207266383	-833.9815371	1341.047524	-833.9815371	1341.047524
GLOT Burgundy	0.978581661	0.027170125	36.01682614	0.017671081	0.633352493	1.323810829	0.633352493	1.323810829
NBJNEIG Burgundy	-453.2620553	16.90890304	-26.8061183	0.02373804	-668.1100391	-238.4140714	-668.1100391	-238.4140714
NBJGREL Burgundy	3779.306208	108.9937384	34.67452592	0.018354782	2394.409453	5164.202964	2394.409453	5164.202964
LATE_FROST Burgundy	-585.5317685	32.04164229	-18.2740873	0.034802584	-992.6594356	-178.4041015	-992.6594356	-178.4041015

Examining the results of the T = 0 regression more closely, one can note that several independent variables significantly explain the working capital for the same year at a 95% confidence level. These variables are NBJRR30, NBJTXS32, NBJGELEE, GLOT, NBJNEIG, NBJGREL, and LATE_FROST. According to the regression, an increase in the number of days with total precipitation heights greater than or equal to 30.0 mm, the number of frost days, the monthly total of daily global radiation (in J/cm^2), and the number of hail days correlates positively with higher working capital. Conversely, an increase in the number of days with maximum temperatures greater than or equal to 32°C, snowfall days, and late frost days (occurring in May and June) correlates negatively with the working capital of Burgundy's vineyards.

The results of this regression are very similar to those of the regression for cash and cash equivalents at T = +1. Hail and recurring events that might be exacerbated from one year to another seem to impact winemakers' financial health significantly. This phenomenon might be linked to producers' perception that recurring events will likely persist over the long run. In contrast, sudden events like extremely high temperatures and late frost might be seen as less relevant in the long term.

However, there is one notable difference. This regression was conducted for the T = 0 period, indicating that climate events have an "instant" impact on the working capital of winemakers. In contrast, the effect on cash was only statistically significant at T = +1. This observation suggests that it might be more challenging for winemakers to generate immediate cash and that they might rely on rescheduling short-term debt repayments (like account payables).

Finally, none of the regressions indicate any statistically significant relationship between climate events and either the **solvency ratio**, the **EBITDA margin**, the **EBIT margin**, the **stock turnover**, the **collection period**, or the **operating revenue** of Burgundy's vineyards.

4.1.3.2 Regressions Between Climate Events and Loire's Financial Ratios

Regarding Loire's **ROCE** relationship with climate events, only the T = +1 regression was shown to be statistically significant (see Figure 12 below). Although the regression's significance is not low enough to be considered at a 95% confidence level, it can be considered at a 90% confidence level with a significance of 0.087.

Figure 12: Regression of Loire's ROCE against climate events for T = +1

Regression Statistics	
Multiple R	0.999211124
R Square	0.998422871
Adjusted R Square	0.985805838
Standard Error	0.582120475
Observations	10

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	8	214.5225868	26.81532336	79.13293754	0.086735494
Residual	1	0.338864248	0.338864248		
Total	9	214.8614511			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	7.245935601	24.86383927	0.291424648	0.819473063	-308.6790967	323.1709679	-308.6790967	323.1709679
NBJRR30 Loire Valley	-0.845595875	1.771396204	-0.477361232	0.716466662	-23.35331872	21.66212697	-23.35331872	21.66212697
NBJTXS32 Loire Valley	-1.39688792	0.19744985	-7.074646639	0.089393871	-3.905726144	1.111950303	-3.905726144	1.111950303
NBJGELEE Loire Valley	-0.56086823	0.074164768	-7.562461918	0.083695988	-1.503220951	0.38148449	-1.503220951	0.38148449
NBJTMS24 Loire Valley	0.548790248	0.363109618	1.511362466	0.37211999	-4.064954905	5.162535402	-4.064954905	5.162535402
GLOT Loire Valley	0.000100994	5.98326E-05	1.687941872	0.340489881	-0.000659251	0.000861239	-0.000659251	0.000861239
NBJNEIG Loire Valley	0.485704299	0.102924698	4.719025732	0.132938332	-0.822077987	1.793486584	-0.822077987	1.793486584
NBJGREL Loire Valley	-1.464214125	0.336210164	-4.355056095	0.143688717	-5.736169308	2.807741057	-5.736169308	2.807741057
LATE_FROST Loire Valley	0.467081373	0.233619045	1.999329176	0.29525267	-2.501330046	3.435492792	-2.501330046	3.435492792

Examining the results of the T = +1 regression more closely, it appears that the only two independent variables that significantly explain the ROCE at a 95% confidence level are NBJTXS32 and NBJGELEE. According to the regression, an increase in the number of days with maximum temperatures greater than or equal to 32°C and the number of frost days both correlate negatively with the ROCE of the vineyards in the Loire region.

This observation aligns with intuition, as frost can heavily damage the vines, and extreme climate events such as significant heatwaves can be equally harmful to both production and the return to equity holders. Additionally, as the sale of the wine generally occurs at least one year after production, the T = +1 ROCE was impacted more than the other ROCE with different time periods.

As emphasized in the discussion of Burgundy's **interest coverage ratio**, it is crucial to consider this financial ratio as one of the most important, given its significance to lenders. In the case of the Loire region, the relationship between climate events and the interest coverage ratio is observed at T = +1, with a significance level of 0.090, indicating that this regression is statistically significant at a 90% confidence level (see Figure 13 below).

Figure 13: Regression of Loire's interest coverage against climate events for T = +1

Regression Statistics	
Multiple R	0.999141672
R Square	0.998284081
Adjusted R Square	0.984556725
Standard Error	0.839292957
Observations	10

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	8	409.8117642	51.22647053	72.72224485	0.090458924
Residual	1	0.704412668	0.704412668		
Total	9	410.5161769			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	327.4929957	35.84832706	9.135516843	0.069409889	-128.0031874	782.9891788	-128.0031874	782.9891788
NBJRR30 Loire Valley	25.93952356	2.553973656	10.15653529	0.062479426	-6.511788606	58.39083573	-6.511788606	58.39083573
NBJTXS32 Loire Valley	-3.295263749	0.284680364	-11.575311	0.054861857	-6.912470738	0.32194324	-6.912470738	0.32194324
NBJGELEE Loire Valley	-0.468797239	0.106929699	-4.38416309	0.142766515	-1.827467884	0.889873407	-1.827467884	0.889873407
NBJTMS24 Loire Valley	8.718362055	0.523526243	16.65315191	0.038182336	2.066330425	15.37039368	2.066330425	15.37039368
GLOT Loire Valley	-0.000821681	8.62658E-05	-9.524992265	0.066592823	-0.001917792	0.00027443	-0.001917792	0.00027443
NBJNEIG Loire Valley	-1.486527044	0.148395354	-10.01734219	0.063341912	-3.372068798	0.39901471	-3.372068798	0.39901471
NBJGREL Loire Valley	-0.650331736	0.484742996	-1.341601099	0.407778193	-6.809575485	5.508912013	-6.809575485	5.508912013
LATE_FROST Loire Valley	0.715901232	0.336828591	2.125417057	0.279964355	-3.563911803	4.995714267	-3.563911803	4.995714267

Examining the results of the T = +1 regression more closely, one can see that several independent variables significantly explain the interest coverage ratio at a 90% confidence level. These variables are NBJRR30, NBJTXS32, NBJTMS24, GLOT, and NBJNEIG. According to the regression, an increase in the number of days with total precipitation heights greater than or equal to 30.0 mm and a daily mean temperature greater than or equal to 24°C correlates positively with Loire's interest coverage ratio. Conversely, an increase in the number of days with maximum temperatures greater than or equal to 32°C, the monthly total of daily global radiation (in J/cm²), and the number of snowfall days correlates negatively with the interest coverage ratio of Loire's vineyards.

While this regression might be complex, some general trends can be noted. Indeed, sudden events occurring during the summer negatively impact the interest coverage ratio. For instance, high precipitation days often occur during winter or early spring, whereas extreme high temperatures (greater than or equal to 32°C) are more likely to occur during summer and cannot really be anticipated. On the other hand, days with a daily mean temperature greater than or equal to 24°C, which can be more easily anticipated and are less sudden, positively impact the ratio as they aid in the maturation of the wine and the production of sugar necessary for fermentation.

Loire's vineyard **collection period** only displayed a significant relationship for T = +2. The significance of this regression is 0.007, indicating that we can reject the null hypothesis at a 99% confidence level (see Figure 14 below).

Figure 14: Regression of Loire's collection period against climate events for T = +2

Regression Statistics	
Multiple R	0.999995154
R Square	0.999990309
Adjusted R Square	0.999912778
Standard Error	0.100984242
Observations	10

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	8	1052.253356	131.5316695	12898.02196	0.006809813
Residual	1	0.010197817	0.010197817		
Total	9	1052.263554			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	130.4913715	2.202197633	59.25506845	0.010742699	102.5097975	158.4729455	102.5097975	158.4729455
NBJRR30 Loire Valley	21.31125567	0.15552067	137.0316605	0.004645704	19.3351782	23.28733315	19.3351782	23.28733315
NBJTXS32 Loire Valley	4.263593876	0.036120202	118.039039	0.005393169	3.8046432	4.722544551	3.8046432	4.722544551
NBJGELEE Loire Valley	-0.33791017	0.012642157	-26.72883792	0.023806609	-0.498544007	-0.177276333	-0.498544007	-0.177276333
NBJTMS24 Loire Valley	-3.693455588	0.047111092	-78.39885388	0.008119829	-4.292058763	-3.094852412	-4.292058763	-3.094852412
GLOT Loire Valley	-7.75655E-05	4.44059E-06	-17.46737564	0.036406478	-0.000133989	-2.11424E-05	-0.000133989	-2.11424E-05
NBJNEIG Loire Valley	-0.349317515	0.01430083	-24.42638127	0.026048249	-0.531026784	-0.167608247	-0.531026784	-0.167608247
NBJGREL Loire Valley	-6.038061115	0.052102051	-115.8891261	0.005493216	-6.700080437	-5.376041792	-6.700080437	-5.376041792
LATE_FROST Loire Valley	2.734380214	0.035080067	77.94683658	0.008166911	2.288645706	3.180114722	2.288645706	3.180114722

Examining the results of the T = +2 regression more closely, it appears that several independent variables significantly explain the collection period at a 95% confidence level. These variables are NBJRR30, NBJTXS32, NBJGELEE, NBJTMS24, GLOT, NBJNEIG, and LATE_FROST, meaning that for this regression, all the variables were statistically significant enough to explain the observations. According to the regression, an increase in the number of days with total precipitation heights greater than or equal to 30.0 mm, maximum temperatures greater than or equal to 32°C, and late frost days (occurring in May and June) correlates positively with the collection period. Conversely, an increase in the number of frost days, days with daily mean temperatures greater than or equal to 24°C, monthly total of daily global radiation (in J/cm²), snowfall days, and hail days correlates negatively with the collection period.

These observations indicate that sudden and extreme events, such as heavy precipitation, very high temperatures, and late frosts, increase the collection period. This increase can be attributed to the damaging effects that these climate events have on production, which impacts net sales two years later, once the wine maturation is complete and the wine is ready for sale. As receivables tend to remain relatively stable from one year to another, the impact stems from fluctuations in net sales. In contrast, more predictable and moderate climatic conditions, such as frost days, moderate high temperatures, increased global radiation, snowfall, and hail, seem to reduce the collection period. These conditions likely promote more stable and favorable production cycles, ensuring consistent wine sales, which helps the timely collection of receivables. Consumers, in fact, appear to gain bargaining power when the harvest is not as expected (caused by sudden events) because the wine quality might be inferior to other vintages.

Regarding Loire's **cash and cash equivalents**, only the regression using data from T = +1 is statistically significant. The significance of this regression is 0.006, indicating a 0.6% probability of observing the data given the null hypothesis (see Figure 15 below), whereas the other regressions display significance levels above 0.1.

Figure 15: Regression of Loire's cash and cash equivalents against climate events for T = +1

Regression Statistics	
Multiple R	0.999995712
R Square	0.999991424
Adjusted R Square	0.999922816
Standard Error	1.969165213
Observations	10

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	8	452143.6186	56517.95233	14575.45459	0.006405993
Residual	1	3.877611636	3.877611636		
Total	9	452147.4962			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	4767.992451	84.10803163	56.68890781	0.011228894	3699.298581	5836.686321	3699.298581	5836.686321
NBJRR30 Loire Valley	222.5272064	5.992181914	37.13625681	0.017138668	146.3893162	298.6650966	146.3893162	298.6650966
NBJTXS32 Loire Valley	18.15256204	0.667922523	27.17764623	0.023413827	9.665801713	26.63932237	9.665801713	26.63932237
NBJGELEE Loire Valley	-13.76484303	0.250880508	-54.86613193	0.011601862	-16.95258212	-10.57710393	-16.95258212	-10.57710393
NBJTMS24 Loire Valley	46.67596575	1.2283073	38.00023476	0.016749183	31.06884172	62.28308978	31.06884172	62.28308978
GLOT Loire Valley	-0.008146971	0.000202398	-40.25213443	0.015812549	-0.010718687	-0.005575254	-0.010718687	-0.005575254
NBJNEIG Loire Valley	-23.45046001	0.348168023	-67.35385925	0.009451173	-27.87435419	-19.02656583	-27.87435419	-19.02656583
NBJGREL Loire Valley	-28.37271739	1.137313302	-24.94714283	0.02550509	-42.82365305	-13.92178172	-42.82365305	-13.92178172
LATE_FROST Loire Valley	67.97342222	0.790273692	86.012508	0.007401146	57.93204289	78.01480154	57.93204289	78.01480154

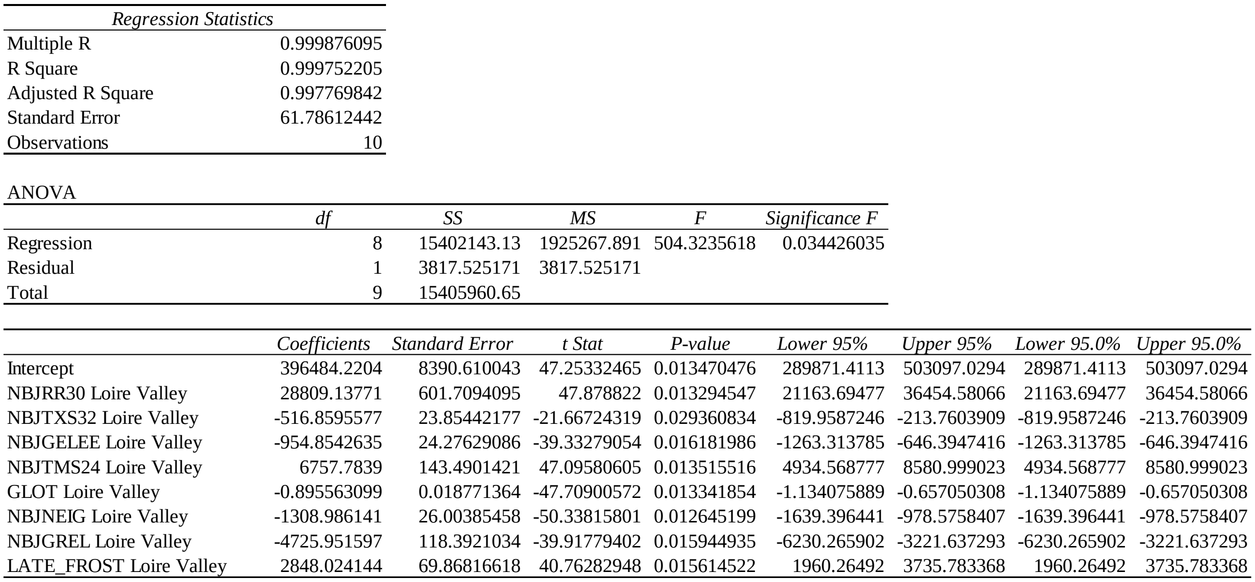
Examining the results of the T = +1 regression more closely, one can observe that several independent variables significantly explain the cash and cash equivalents at a 99% confidence level. These variables are NBJRR30, NBJTXS32, NBJGELEE, NBJTMS24, GLOT, NBJNEIG, and LATE_FROST, meaning that for this regression, all the variables were statistically significant enough to explain the observations. According to the regression, an increase in the number of days with total precipitation heights greater than or equal to 30.0 mm, maximum temperatures greater than or equal to 32°C, daily mean temperatures greater than or equal to 24°C, and late frost days (occurring in May and June) correlates positively with cash and cash equivalents. Conversely, an increase in the number of frost days, the monthly total of daily global radiation (in J/cm²), snowfall days, and hail days correlates negatively with cash and cash equivalents of Loire's vineyards.

This regression is similar to the previous one that regressed the collection period to climate events at T = +2. Only NBJTMS24 behaved differently and is now positively correlated with cash and cash equivalents. Furthermore, it is important to note that the regression is for the T = +1 period, indicating that cash collection occurs the year after production.

As sudden and extreme events are positively correlated with the company's financial health, one should be careful in interpreting these results. One might be tempted to say that hail and extreme climate events tend to increase the financial health of vineyards. However, as was the case for Burgundy, caution is needed as this observation does not necessarily imply that the company is in a better financial position when such events are experienced but rather that the company has more cash the following year. This phenomenon could be explained by winemakers taking on additional debt, liquidating stocks or reducing investments the year after to cover losses incurred from hail-damaged production and potentially overcome another future unforeseen climate event.

Loire's vineyard **working capital** only displayed a significant relationship for T = 0. The significance of this regression is 0.034, indicating that we can reject the null hypothesis at a 95% confidence level (see Figure 16 below).

Figure 16: Regression of Loire's working capital against climate events for T = 0



Regression Statistics	
Multiple R	0.999876095
R Square	0.999752205
Adjusted R Square	0.997769842
Standard Error	61.78612442
Observations	10

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	8	15402143.13	1925267.891	504.3235618	0.034426035
Residual	1	3817.525171	3817.525171		
Total	9	15405960.65			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	396484.2204	8390.610043	47.25332465	0.013470476	289871.4113	503097.0294	289871.4113	503097.0294
NBJRR30 Loire Valley	28809.13771	601.7094095	47.878822	0.013294547	21163.69477	36454.58066	21163.69477	36454.58066
NBJTXS32 Loire Valley	-516.8595577	23.85442177	-21.66724319	0.029360834	-819.9587246	-213.7603909	-819.9587246	-213.7603909
NBJGELEE Loire Valley	-954.8542635	24.27629086	-39.33279054	0.016181986	-1263.313785	-646.3947416	-1263.313785	-646.3947416
NBJTMS24 Loire Valley	6757.7839	143.4901421	47.09580605	0.013515516	4934.568777	8580.999023	4934.568777	8580.999023
GLOT Loire Valley	-0.895563099	0.018771364	-47.70900572	0.013341854	-1.134075889	-0.657050308	-1.134075889	-0.657050308
NBJNEIG Loire Valley	-1308.986141	26.00385458	-50.33815801	0.012645199	-1639.396441	-978.5758407	-1639.396441	-978.5758407
NBJGREL Loire Valley	-4725.951597	118.3921034	-39.91779402	0.015944935	-6230.265902	-3221.637293	-6230.265902	-3221.637293
LATE_FROST Loire Valley	2848.024144	69.86816618	40.76282948	0.015614522	1960.26492	3735.783368	1960.26492	3735.783368

Examining the results of the T = 0 regression more closely, it seems that several independent variables significantly explain the working capital at a 95% confidence level. These variables are NBJRR30, NBJTXS32, NBJGELEE, NBJTMS24, GLOT, NBJNEIG, NBJGREL and LATE_FROST. According to the regression, an increase in days with total precipitation heights greater than or equal to 30.0 mm, daily mean temperatures greater than or equal to 24°C, and late frost days (occurring in May and June) correlates positively with working capital. Conversely, an increase in the number of days with maximum temperatures greater than or equal to 32°C, frost days, monthly total of daily global radiation (in J/cm²), snowfall days, and hail days correlates negatively with working capital of Loire's vineyards.

These observations may be linked to producers' perception that non-recurring events pose more risk to their activity, encouraging them to increase their working capital, which is considered a sign of good company health. In contrast, recurring events like high temperatures and frost might be seen as less significant because they occur frequently and therefore cannot really influence their financial position in the long run. Consequently, producers might focus more on improving the working capital period when sudden events happen to maintain the impression of a strong financial posture.

Moreover, there is one notable difference with the cash and cash equivalents regression previously analyzed. This regression was conducted for the T = 0 period, indicating that climate events have an "instant" impact on the working capital of winemakers. In contrast, the effect on cash was only statistically significant at T = +1. This observation suggests that it might be more challenging for winemakers to generate immediate cash, leading them to rely on rescheduling short-term debt repayments.

Regarding Loire's **operating revenue** relationship with climate events, only the T = +1 regression was shown to be statistically significant. Although the regression's significance is not low enough to be considered at a 95% confidence level, it can be considered at a 90% confidence level with a significance of 0.06 (see Figure 17 below).

Figure 17: Regression of Loire's operating revenue against climate events for T = +1

Regression Statistics	
Multiple R	0.999602099
R Square	0.999204356
Adjusted R Square	0.9928392
Standard Error	353.3198461
Observations	10

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	8	156773030.9	19596628.87	156.9803534	0.061654114
Residual	1	124834.9137	124834.9137		
Total	9	156897865.8			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	-17764.33883	15091.18514	-1.17713345	0.448317905	-209516.0269	173987.3492	-209516.0269	173987.3492
NBJRR30 Loire Valley	-965.1168847	1075.154475	-0.897654157	0.534301468	-14626.24977	12696.016	-14626.24977	12696.016
NBJTXS32 Loire Valley	-324.6593246	119.8428052	-2.7090431	0.225120218	-1847.406544	1198.087895	-1847.406544	1198.087895
NBJGELEE Loire Valley	329.3589401	45.014538	7.316723767	0.086473087	-242.6049959	901.322876	-242.6049959	901.322876
NBJTMS24 Loire Valley	694.2792856	220.3905204	3.150222996	0.195682313	-2106.047789	3494.60636	-2106.047789	3494.60636
GLOT Loire Valley	0.000871878	0.036315591	0.024008357	0.984718741	-0.460561451	0.462305207	-0.460561451	0.462305207
NBJNEIG Loire Valley	-248.8655172	62.47046792	-3.98373064	0.15656986	-1042.628072	544.8970381	-1042.628072	544.8970381
NBJGREL Loire Valley	2437.045012	204.0638125	11.94256337	0.053182731	-155.8315686	5029.921593	-155.8315686	5029.921593
LATE_FROST Loire Valley	-735.666031	141.7958114	-5.18820707	0.121218634	-2537.352641	1066.020579	-2537.352641	1066.020579

Examining the results of the T = +1 regression more closely, it appears that only one independent variable significantly explains the operating revenue at a 95% confidence level. The variable is NBJGREL. According to the regression, an increase in the number of days with hail correlates positively with operating revenue.

Although this observation might seem counterintuitive, it could be that winemakers try to liquidate their stocks more aggressively the year after intense hail periods due to fear that such climate events might reoccur and affect future production. Loire winemakers might want to demonstrate financial position resilience in facing those events. Additionally, it is essential to note that the revenue of winemakers is usually not based solely on the production of a single year. The revenue for a given year is a combination of several vintages, making it challenging to directly trace the impact of climate events on vineyards' revenue.

Finally, none of the regressions indicate any statistically significant relationship between climate events and either the **current ratio**, the **profit ratio**, the **ROE**, the **solvency ratio**, the **EBITDA margin**, the **EBIT margin**, or the **stock turnover** of Loire's vineyards.

4.1.3.3 Comparison Between the Burgundy and Loire Regions

This subpart aims to facilitate the comparison of the results of the regressions made for the Burgundy and Loire regions.

Table 1: Regression significance of financial indicators against climate events in Burgundy

Key Financial Indicator	**T = 0**	**T = +1**	**T = +2**	**T = +3**
Current Ratio	o	o	o	x
Profit Margin	X	o	o	o
ROE	o	o	o	x
ROCE	o	o	o	x
Solvency Ratio	o	o	o	o
EBITDA	o	o	o	o
EBIT	o	o	o	o
Interest Coverage	o	o	x	o
Stock Turnover	o	o	o	o
Collection Period	o	o	o	o
Cash and Cash Equivalents	o	X	o	o
Working Capital	x	o	o	o
Operating Revenue	o	o	o	o

Note: "o": regression was not significant [>0.1]; "x": regression was significant [≤0.05]; "X": regression was partially significant [≤0.1]

Table 2: Regression significance of financial indicators against climate events in Loire

Key Financial Indicator	**T = 0**	**T = +1**	**T = +2**	**T = +3**
Current Ratio	o	o	o	o
Profit Margin	o	o	o	o
ROE	o	o	o	o
ROCE	o	X	o	o
Solvency Ratio	o	o	o	o
EBITDA	o	o	o	o
EBIT	o	o	o	o
Interest Coverage	o	X	o	o
Stock Turnover	o	o	o	o
Collection Period	o	o	x	o
Cash and Cash Equivalents	o	x	o	o
Working Capital	x	o	o	o
Operating Revenue	o	X	o	o

Note: "o": regression was not significant [>0.1]; "x": regression was significant [≤0.05]; "X": regression was partially significant [≤0.1])

Based on the two tables above, it quickly becomes apparent that there are some commonalities between the two regions regarding the significance of climate events on specific financial indicators. Although the data observed for both regions is not identical, and differences exist in relevance and timing, some findings are worth further analyzing. Notably, this is the case for ROE/ROCE (Burgundy: T = +3; Loire: T = +1), the interest coverage ratio (Burgundy: T = +2; Loire: T = +1), cash and cash equivalents (Burgundy: T = +1; Loire: T = +1) and working capital (Burgundy: T = 0; Loire: T = 0). The table below, which summarizes the relationship sign for each climate event, allows to better understand the levers impacting these financial ratios the most.

Table 3: Summary of selected regressions of climate events on financial indicators for Burgundy and Loire regions

	NBJRR30	NBJ TXS32	NBJ GELEE	NBJ TMS24	GLOT	NBJ NEIG	NBJ GREL	LATE FROST
ROE (Burgundy; T = +3)	+	o	+	o	+	-	+	o
ROCE (Loire; T = +1)	o	-	-	o	o	o	o	o
Interest Coverage (Burgundy; T = +2)	+	-	+	+	+	-	+	o
Interest Coverage (Loire; T = +1)	+	-	o	+	-	-	o	o
Cash and Cash Equivalents (Burgundy; T = +1)	+	-	+	+	+	-	+	o
Cash and Cash Equivalents (Loire; T = +1)	+	+	-	+	-	-	-	+
Working Capital (Burgundy; T = 0)	+	-	+	o	+	-	+	-
Working Capital (Loire; T = 0)	+	-	-	+	-	-	-	+

Note: "o": p-value of the climate event was not significant [>0.05], or the associated coefficient was equal to 0; "+": p-value of the climate event was significant [≤0.05], and associated coefficient was strictly positive; "-": p-value of the climate event was significant [≤0.05], and the associated coefficient was strictly negative

4.1.3.4 Climatic Events with Statistical Significance in Both Regions

In this final section of the financial analysis, the study focuses on assessing the financial impacts of each climate event for which regressions on at least one financial indicator were proven to be statistically significant in both regions. A more detailed table summarizing all the significant regressions is provided in Appendices 12 and 13.

The climate event named **NBJRR30 (number of days with total precipitation heights superior to or equal to 30.0 mm)** shows a generally positive impact on multiple financial indicators across both regions. It positively influences ROE for Burgundy at T = +3, interest coverage for both regions, cash and cash equivalents, and working capital (an increased working capital is considered beneficial for the company). Only the ROCE for Loire at T = +1 showed a p-value that was not statistically significant enough to draw any conclusions. Those observations suggest that large amounts of rainfall in one day are not detrimental and benefit vineyards' financial health.

Looking at the event entitled **NBJTXS32 (number of days with maximum temperature superior to or equal to 32°C)**, it appears that maximum temperatures above 32°C negatively impact financial indicators such as ROCE, interest coverage, and working capital. Only the cash and cash equivalents at T = +1 for the Loire region showed a positive impact of this climate event on the balance sheet. These observations align with the fact that high temperatures can stress the vines, reducing yields and negatively affecting financial performance, as sudden extreme temperatures affect winemakers’ ability to cover interest payments and maintain working capital.

The event called **NBJGELEE (number of days with frost)** shows mixed results, with both positive and negative impacts on financial indicators. Indeed, this climate event positively impacted all four indicators displayed in the table for the Burgundy region. In contrast, negative impacts on ROCE, cash and cash equivalents, and working capital for the Loire region were also shown. It should be noted that the p-value of Loire's interest coverage at T = +1 was not low enough to be considered statistically significant to draw any conclusions. This difference could stem from the fact that Burgundy grape varieties (mostly Pinot Noir and Chardonnay) are more adapted to cold continental climates, and frost can reduce the population of pests and diseases that thrive in milder conditions. On the other hand, Loire's Chenin Blanc and Cabernet Franc are more sensitive to cold weather because they are accustomed to a more maritime climate (Mowery, 2018).

The climatic event named **NBJTMS24 (number of days with daily mean temperature superior to or equal to 24°C)** demonstrates predominantly positive impacts on the financial indicators, with no negative impacts observed. However, it was statistically insignificant for ROE/ROCE in both regions (T = +3 for Burgundy and T = +1 for Loire) and for working capital at T = 0 for Burgundy, indicating that caution should be exercised when interpreting these results. Nonetheless, moderately high temperatures support vine growth and grape ripening, making it plausible that mildly warm temperatures positively correlate with financial indicators.

Considering the climatic phenomenon entitled **GLOT (monthly total of daily global radiation in J/cm²)**, it appears that global radiation has a mixed impact on financial ratios, as the two regions respond differently. All four indicators of Burgundy reacted positively to this climatic event, while the interest coverage ratio, cash and cash equivalents, and working capital of Loire reacted negatively. The p-value for Loire's ROCE in response to this climate event was greater than 0.05, indicating a statistically insignificant relationship. These differing observations can be explained by the climatic differences between the two regions. Indeed, the Burgundy region has a cold continental climate with cooler growing seasons, and increased radiation can help raise temperatures slightly, thereby improving grape ripening.

Additionally, higher radiation can mitigate the risk of late spring frosts, a significant threat in Burgundy (Mowery, 2018). Conversely, the Loire Valley is less prone to late frosts due to its more maritime climate, lacking this positive effect. Instead, increased radiation exacerbates extreme warmth during summer, hindering grape development through heatwave shock.

The indicator called **NBJNEIG (number of days with snowfall)** points out that snowfall days negatively impact financial indicators for all statistically significant p-values. Only Loire's ROCE at T = +1 was not statistically significant. Indeed, snowfall can cause physical damage due to its weight on the vines, as Wine Scribes (2023) highlighted: "Snow accumulation can also be problematic for vineyard grape vines. When snow accumulates on the vines, it can add weight and cause the branches to bend or break. In addition, as the snow melts and refreezes, it can damage the vine's bark and cause cracks and other forms of damage."

Focusing on the **NBJGREL (number of days with hail)** event, it turns out that hail days exhibit mixed impacts, with a negative influence on cash and cash equivalents and working capital for the Loire region but a positive correlation with all four financial indicators for the Burgundy region.

Additionally, Loire's T = +1 ROCE and T = +1 interest coverage were not significant at a 95% confidence level. This mixed impact observation is counterintuitive, as hail is often considered one of the most damaging climate events among winemakers, and the observed impacts differ between the two regions. One possible explanation is that Burgundy's winemakers may use strategic stock liquidation to compensate for future losses and reassure equity holders. In contrast, Loire winemakers may prefer to absorb the loss immediately or lack the capacity to mitigate the impact through stock liquidation.

Finally, the **LATE_FROST (number of days with late frost occurring in May and June)** indicator outlines that late frosty days during May or June are often considered the most harmful climate event for vineyards. This study showed a negative impact on T = 0 working capital for the Burgundy region and a positive impact on T = +1 cash and cash equivalents and T = 0 working capital for the Loire region. This climate event did not impact the other five financial indicators at a 95% confidence level. Furthermore, according to the data, these events occured on average 1.6 times per year in Burgundy and 2.5 times per year in the Loire region from 2010 to 2022. As the Loire Valley is more frequently affected by this climate event, Burgundy winemakers might anticipate them less, making them less likely to implement safety measures. On the other hand, Loire vineyards might liquidate more stock when late frost occurs to compensate for the incurred loss, while Burgundy winemakers might be more inclined to believe that these events will not recur, hence not taking financial measures.

4.1.3.5 Additional Considerations

In light of the tables above, the study highlights the different time lags between some climate events and their financial impacts. For instance, Burgundy's ROCE is impacted at T = +3, whereas Loire's ROCE is affected at T = +1, implying that differences exist not only in the amplitude but also in the timing of the impact on winemakers' financial statements in the two regions. These differences could stem from various factors, although it is very likely that they are influenced by different ageing lengths. Grape varieties in Burgundy are more prone to ageing, resulting in the sale of wine from this region occurring later than that from regions like the Loire Valley, where the grape varieties are not as renowned for their aging capacity (Joanne, 2024; Joy, 2007).

Lastly, some financial indicators were only proven to be statistically significant with climate events for one of the two regions studied, such as the current ratio at T = +3 and the profit margin at T = 0 for the Burgundy region and the collection period at T = +2 for the Loire Valley. Those observations do not necessarily mean that climate events do not impact those financial indicators, but simply that the data presented did not show any significant correlation. Indeed, implying that climate hazards would not impact the profit/production for a given year in the Loire region would be abusive and, most likely, wrong.

4.2 Questionnaire Analysis

This part will now look into the answers to the questionnaire that was distributed to winemakers across the Burgundy and Loire regions, in order to get a sense of practitioners’ perspective regarding climate change, its financial impacts, and how to deal with it. As a reminder, the questionnaire asked respondents about the specific challenges caused by climate change that they are facing, the impact of climate change on six key financial metrics, the solutions implemented as a response, and the costliness and effectiveness of these solutions.

4.2.1 Effects of Climate Change on Winemakers’ Activities

The first question focused on the main non-financial consequences of climate change, asking winemakers to select the climate change effects that have impacted their activities and giving them the possibility to add any additional impactful elements. The results can be observed in Figure 18 below.

Figure 18: Climate change effects on winemakers’ activities

Climate change effects	**Global**		**Burgundy**		**Loire Valley**	
	Count	% of respondents	Count	% of respondents	Count	% of respondents
Too high temperatures	41	60,3%	24	64,9%	17	54,8%
Water deficits and/or precipitation disruptions	40	58,8%	25	67,6%	15	48,4%
Increased frequency of extreme climatic events	61	89,7%	34	91,9%	27	87,1%
Impact on grape composition and quality	33	48,5%	23	62,2%	10	32,3%
Impact on wine characteristics and quality	33	48,5%	21	56,8%	12	38,7%
Affected periodicity	55	80,9%	30	81,1%	25	80,6%
Increase in the number of diseases	21	30,9%	10	27,0%	11	35,5%
Improvement in maturity	1	1,5%	1	2,7%	0	0,0%
Too mild winter	1	1,5%	0	0,0%	1	3,2%
Very volatile and unreliable weather in terms of temperatures and rain	1	1,5%	0	0,0%	1	3,2%

First, it is interesting to note that every effect given as a selection option – the entries “improvement in maturity”, “too mild winter”, and “very volatile and unreliable weather in terms of temperatures and rain” were added individually in the “other” section – was selected by at least 30% of the respondents, indicating that each given phenomenon is considered an important element by Burgundy and Loire winemakers. In particular, the two effects that gathered the most votes are "increased frequency of extreme climatic events" and "affected periodicity", with about respectively 90% and 80% of the respondents selecting these two options. This finding implies that 1) the extreme events fostered by climate change, such as droughts, spring frosts, hailstorms, or heatwaves, have had a strong detrimental impact on winemakers' activities and 2) climate change and, more precisely, global warming are triggering a clear advancement in grapevine phenological stages and thus in harvest periods.

The option "too high temperatures" comes in third position, selected by 60.3% of the respondents, which shows that a clear majority of winemakers in the combined regions perceive that their activities have been impacted by climate change through too high temperatures. Interestingly, this result, which is much lower than the 80.9% achieved by "affected periodicity", also suggests that some winemakers may not recognize that the main reason for this advanced periodicity is precisely higher temperatures. Or perhaps the discrepancy between the two numbers is merely due to the formulation "too high" instead of "higher", which may have deterred the winemakers who believe that temperatures are higher but not necessarily too much so from selecting this option.

"Water deficits and/or precipitation disruptions" come closely after, with a selection rate of nearly 60%, which demonstrates the crucial character of water-related issues stemming from climate change for winegrowing activities. Then, at a perfect tie just below the 50% line, come the impacts on grape composition and quality as well as on wine characteristics and quality. This could mean either that more than half of the winemakers surveyed actually manage to keep their grapes and wines relatively unscathed despite climate change or that they attribute any changes in grape physiology and wine characteristics to causes other than climate change. Finally, "increase in number of diseases" comes last, with a selection rate of slightly more than 30%, indicating that though an increase in diseases is not the most pressing issue, it is still among the main consequences of climate change for vintners.

The three entries added manually are also worth noting, with respondents highlighting 1) too mild winters, an element closely related to the notion of higher temperatures, 2) the high variability in weather and more precisely temperatures and precipitation, which is closely linked to the notions of precipitation disruptions as well as increased frequency of extreme weather episodes, and 3) an improvement in maturity. This last element, proposed by a Burgundy winemaker, interestingly denotes that climate change may also have positive effects on grapes' physiological aspects, even for vintners operating in traditional winemaking regions.

Looking at Burgundy and Loire separately, the results remain roughly similar, however with some noticeable differences. Extreme climatic events and impacted periodicity still come first and second, far in front of the other options, and increased diseases were also selected by about 30% of the respondents, though this issue appears to be more concerning in Loire than in Burgundy (35.5% vs 27%). Nevertheless, two initial differences can be observed when looking at the temperature and water- and precipitation-related entries. Indeed, while these two options were selected by a clear majority of Burgundy vintners (respectively 64.9% and 67.6%), barely more than half of Loire winemakers (54.8%) believe that their activities have been affected by climate change through too high temperatures and less than half (48.4%) through water deficits and precipitation disruptions. Furthermore, two other noticeable differences arise when looking at the effects of climate change on grape physiology and wines themselves, these two entries achieving relatively high and above-average numbers in Burgundy (respectively 62.2% and 56.8%) but clearly below-average rates in Loire (respectively 32.3% and 38.7%). Thus, either Loire vintners have been much better than their Burgundy counterparts at protecting their grapes and wines from climate change, or the latter has proven less detrimental to grape physiology and wines in Loire than in Burgundy.

4.2.2 Financial Consequences

4.2.2.1 Productivity

Regarding productivity (see Figure 19 below), the results across both regions indicate that climate change has caused a decrease in yield. Indeed, 80.9% of respondents reported a reduction in productivity following the effects of climate change, the majority recording decreases of 10-20% (selected by 33.8% of respondents) and 20-30% (selected by 32.4% of respondents). Roughly 6% of respondents experienced even higher losses, selecting the 30-40% range, while the productivity of about 9% of the winemakers surveyed decreased by only 0-10%. Nobody recorded productivity losses of more than 40%. The results for each region separately are roughly similar, with productivity losses recorded by respectively 83.8% and 77.4% of respondents in Burgundy and Loire, the ranges 10-20% and 20-30% selected by the majority of respondents, and the options 0-10% and 30-40% picked by some.

Figure 19: Impact of climate change on productivity

Productivity decrease	**Global**		**Burgundy**		**Loire Valley**	
	Count	% of respondents	Count	% of respondents	Count	% of respondents
No decrease	13	19,1%	6	16,2%	7	22,6%
0-10%	6	8,8%	3	8,1%	3	9,7%
10-20%	23	33,8%	15	40,5%	8	25,8%
20-30%	22	32,4%	12	32,4%	10	32,3%
30-40%	4	5,9%	1	2,7%	3	9,7%
40-50%	0	0,0%	0	0,0%	0	0,0%
>50%	0	0,0%	0	0,0%	0	0,0%

4.2.2.2 Revenues

When it comes to revenues (see Figure 20 below), the results seem less alarming, with exactly 50% of respondents revealing that their revenues have not decreased because of climate change. For the other half, the selections are evenly distributed across the ranges 0-10%, 10-20%, and 20-30%, with one winemaker – from Burgundy– experiencing a revenue decrease of 30-40%. Again, no response went above the 30-40% range. Looking at the two regions individually, it appears that revenues of Loire vintners have been more severely impacted than revenues in Burgundy. Indeed, while 59.5% of Burgundy respondents have not observed any climate-change-induced decrease in revenue, this is the case for only 38.7% of Loire winemakers. In both regions though, there is still a striking roughly 16% of respondents that have witnessed a 20-30% revenue loss.

Figure 20: Impact of climate change on revenues

Revenue decrease	**Global**		**Burgundy**		**Loire Valley**	
	Count	% of respondents	Count	% of respondents	Count	% of respondents
No decrease	34	50,0%	22	59,5%	12	38,7%
0-10%	11	16,2%	6	16,2%	5	16,1%
10-20%	11	16,2%	2	5,4%	9	29,0%
20-30%	11	16,2%	6	16,2%	5	16,1%
30-40%	1	1,5%	1	2,7%	0	0,0%
40-50%	0	0,0%	0	0,0%	0	0,0%
>50%	0	0,0%	0	0,0%	0	0,0%

4.2.2.3 Profits

Winemakers’ profits (see Figure 21 below) have been more severely impacted by climate change, with about 60% of respondents having experienced a decrease in profits due to climate change effects and a quarter reporting a decrease of 10-20%. Respectively 16.2% and 14.7% of the vintners surveyed unveiled a profit decrease of 0-10% and 20-30%, while the ranges 30-40% and

40-50% were selected by one winemaker each, one from each region. No profit decrease of more than 50% was reported. The situations of the two regions observed appear quite similar, with close to 60% of winemakers witnessing a profit decrease – 56.8% for Burgundy and 61.3% for Loire –, the vast majority of whom – all except one in both cases – reported a reduction that did not exceed 30%. While the Burgundy results display a roughly even distribution between the ranges 0-10%, 10-20%, and 20-30%, a clear majority of the Loire winemakers having incurred a profit decrease are located in the 10-20% range.

Figure 21: Impact of climate change on profits

Profit decrease	**Global**		**Burgundy**		**Loire Valley**	
	Count	% of respondents	Count	% of respondents	Count	% of respondents
No decrease	28	41,2%	16	43,2%	12	38,7%
0-10%	11	16,2%	7	18,9%	4	12,9%
10-20%	17	25,0%	6	16,2%	11	35,5%
20-30%	10	14,7%	7	18,9%	3	9,7%
30-40%	1	1,5%	1	2,7%	0	0,0%
40-50%	1	1,5%	0	0,0%	1	3,2%
>50%	0	0,0%	0	0,0%	0	0,0%

4.2.2.4 Number of Sales

Focusing on respondents' answers regarding their sales numbers (see Figure 22 below) reveals that this metric has withstood the challenges brought by climate change relatively well, at least compared to the other financial indicators studied. Indeed, 60.3% of respondents disclosed that their sales had not decreased, despite climate change and related environmental phenomena. About 30% of respondents did, however, report a sales decrease of 10-20% or 20-30%, two Loire vintners also selecting the 30-40% range, which was the highest selection made. Taking a closer look at each region on its own gives a similar outlook, with again close to 60% of respondents explaining that they have not experienced a sales reduction. The main discrepancy relies in the answer distribution among the respondents who reported sales losses, with a clear majority located in the 20-30% range for Burgundy, the highest range selected, followed by the 10-20% one, while Loire vineyards are mostly split between the 10-20% and 0-10% ranges, with two winemakers incurring a sales loss of 30-40%.

Figure 22: Impact of climate change on the number of sales

Sales decrease	**Global**		**Burgundy**		**Loire Valley**	
	Count	% of respondents	Count	% of respondents	Count	% of respondents
No decrease	41	60,3%	23	62,2%	18	58,1%
0-10%	5	7,4%	1	2,7%	4	12,9%
10-20%	10	14,7%	5	13,5%	5	16,1%
20-30%	10	14,7%	8	21,6%	2	6,5%
30-40%	2	2,9%	0	0,0%	2	6,5%
40-50%	0	0,0%	0	0,0%	0	0,0%
>50%	0	0,0%	0	0,0%	0	0,0%

4.2.2.5 Production Costs

Production costs (see Figure 23 below) seem to be the most heavily impacted financial indicator for Burgundy and Loire vineyards. Indeed, only 13.2% did not notice a cost increase caused by climate change effects, while more than half (51.5%) reported an increase in production costs of 10-25%. In second place comes the 25-50% range, with a selection rate of 17.6%, closely followed by a modest 0-10% increase in production costs. Moreover, three respondents – all from Burgundy – even reported a cost increase of 50-75%, which was the highest range selected. The outcome for each region taken individually is very similar to the overall one, with only about 13% of winemakers not noticing any rise in costs, roughly 50% experiencing a cost increase of 10-25%, and the 25-50% and 0-10% ranges coming respectively in second and third position. Finally, though no Loire vineyard suffered a cost increase of more than 50%, nearly a quarter of them are located in the 25-50% range.

Figure 23: Impact of climate change on production costs

Cost increase	**Global**		**Burgundy**		**Loire Valley**	
	Count	% of respondents	Count	% of respondents	Count	% of respondents
No increase	9	13,2%	5	13,5%	4	12,9%
0-10%	9	13,2%	4	10,8%	5	16,1%
10-25%	35	51,5%	20	54,1%	15	48,4%
25-50%	12	17,6%	5	13,5%	7	22,6%
50-75%	3	4,4%	3	8,1%	0	0,0%
75-100%	0	0,0%	0	0,0%	0	0,0%
>100%	0	0,0%	0	0,0%	0	0,0%

4.2.2.6 Bottle Prices

Finally, further interesting results emerge when looking at the impact of climate change on wine bottle prices (see Figure 24 below). First, nearly all respondents noted an increase in bottle prices, with only 3% noting a reduction and 8.8% reporting no fluctuation whatsoever. The vast majority of respondents (80.9%) disclosed a price increase of either 0-10% or 10-25%. The remaining 7.4% even went above the 25%-increase mark. The results are very similar for Burgundy and Loire taken separately, with respectively 86.4% and 90.3% of respondents reporting a price increase, the vast majority of whom are distributed across the 0-10% and 10-25% ranges, with a clear preponderance in Loire for the former (54.8%). In view of the observed decrease in productivity, revenues, and profits, coupled with an increase in production costs, witnessing such widespread price increases is no surprise.

Figure 24: Impact of climate change on wine bottle prices

Price impact	**Global**		**Burgundy**		**Loire Valley**	
	Count	% of respondents	Count	% of respondents	Count	% of respondents
Decrease of >25%	0	0,0%	0	0,0%	0	0,0%
Decrease of 10-25%	1	1,5%	0	0,0%	1	3,2%
Decrease of 0-10%	1	1,5%	1	2,7%	0	0,0%
No fluctuation	6	8,8%	4	10,8%	2	6,5%
Increase of 0-10%	30	44,1%	13	35,1%	17	54,8%
Increase of 10-25%	25	36,8%	15	40,5%	10	32,3%
Increase of >25%	5	7,4%	4	10,8%	1	3,2%

4.2.3 Solutions Put in Place

4.2.3.1 Implementation Rates in General, by Vineyard Size, and by Revenue

The analysis of survey responses (see Figure 25 below) reveals that 79.4% of all respondents have implemented at least one strategy or viticultural technique to tackle the detrimental effects of climate change. Climate change impacts thus seem to be taken very seriously by winemakers, the vast majority of whom take active measures to respond to these challenges. Burgundy vintners have proven particularly inclined to adopt new strategies, with only 10.8% selecting the option “I have not implemented any technique or strategy linked to climate change”, while this percentage increases to 32.3% when looking at Loire vineyards.

Figure 25: Respondents having implemented at least one strategy to tackle climate change

Region	**Count**	**% per region**
Burgundy	33	89,2%
Loire Valley	21	67,7%
Total	54	79,4%

Interestingly, classifying vineyards by size or revenue unveils that these two characteristics do not play a role in determining whether or not winemakers are able to implement new techniques to deal with the challenges brought by climate change. Indeed, as displayed in Figures 26 and 27 below, very high percentages of vintners adopting at least one strategy are achieved for both low and high size and revenue ranges. For instance, 100% of the vineyards of 10-15 hectares surveyed reported having implemented a response strategy, just as much as the vineyards of 40-50 hectares. A similar comparison can be made between vineyards of 5-10 and 50-100 hectares. And even if the 50% adoption rate for vineyards of 0-5 hectares can seem rather low, this is no different from the rate achieved by vineyards of 30-40 hectares. When looking at revenue, similar outcomes can be highlighted. Indeed, vineyards with revenues of €100-250k achieve the highest adoption rate, while the lowest rate is displayed by vineyards with €5m+ in revenue. Furthermore, having revenues of €500k-1m rather than €2-5m does not seem to influence vintners' ability to implement new techniques to respond to climate change, as both achieve very similar rates (89.5% vs 88.9%). Two regressions were run to check the relationship between 1) vineyard size and strategy adoption rate and 2) revenue and adoption rate (see Appendices 14 and 15), and indeed, no relation whatsoever was found.

Figure 26: Strategy implementation by vineyard size

Size range (in ha)	Count with implementation	Count in that range	% with implementation
0-5	2	4	50,0%
5-10	6	7	85,7%
10-15	10	10	100,0%
15-20	15	16	93,8%
20-30	8	11	72,7%
30-40	5	10	50,0%
40-50	2	2	100,0%
50-100	6	7	85,7%
100+	0	1	0,0%

Figure 27: Strategy implementation by vineyard revenue

Revenue range (in €m)	Count with implementation	Count in that range	% with implementation
0-0,1	0	0	0,0%
0,1-0,25	5	5	100,0%
0,25-0,5	10	14	71,4%
0,5-1	17	19	89,5%
1-2	8	12	66,7%
2-5	8	9	88,9%
5+	2	4	50,0%

4.2.3.2 Implementation Rates of Each Strategy

Figure 28 below shows the specific strategies and methods that were adopted by at least one vineyard, meaning that all techniques proposed to vintners in the questionnaire that are not present in the table were not used at all by the interviewed winemakers.

Figure 28: Strategies implemented by vintners as a response to climate change

Solutions to climate change	Global		Burgundy		Loire Valley	
	Count	% among implemented	Count	% among implemented	Count	% among implemented
Cooling equipment	41	75,9%	24	72,7%	17	81,0%
Nighttime harvesting	18	33,3%	8	24,2%	10	47,6%
Reinspection of cellar hygiene	11	20,4%	6	18,2%	5	23,8%
Improvement of soil composition	21	38,9%	17	51,5%	4	19,0%
Growing of better-suited varieties for warmer conditions	10	18,5%	6	18,2%	4	19,0%
Vineyard placement management (altitude, orientation, slope, etc.)	10	18,5%	7	21,2%	3	14,3%
Shading techniques	3	5,6%	3	9,1%	0	0,0%
Use of the insurance market	22	40,7%	19	57,6%	3	14,3%
Water reuse, treatment, and/or recycling	14	25,9%	10	30,3%	4	19,0%
Strategies aiming at delaying grape maturation	11	20,4%	7	21,2%	4	19,0%
New blending techniques	1	1,9%	1	3,0%	0	0,0%

The strategy that proved the most popular among respondents was the use of cooling equipment, selected by more than three quarters of the winemakers who implemented at least one strategy. The use of the insurance market came second, with an adoption rate of 40.7%, followed closely by "improvement of soil composition" (38.9%) and "nighttime harvesting" (33.3%). The remaining methods also achieved good adoption rates, between 18.5% and 25.9%. Only shading techniques and new blending methods stand out through very low adoption rates, with only respectively 5.6% and 1.9%. The former result could imply that Burgundy and Loire winemakers are not particularly worried about the risk of sunburn, heatwaves, and rising temperatures. However, as mentioned earlier, "too high temperatures" was the third most selected climate change effect impacting winemaker's activities, picked by 60.3% of respondents. Therefore, it may rather be that shading techniques are either too complicated or too expensive to implement and that vintners thus focus on other strategies in priority. A similar – though more nuanced – remark can be made with regards to “strategies aiming at delaying grape maturation”. Indeed, even though “affected periodicity” was selected by 80.9% of respondents as a climate change effect impacting their activities, only 16.2% of the total number of respondents actually implemented a strategy aiming at delaying grape maturation. Finally, it should be noted that many other viticultural methods were added directly by respondents (see Figure 29 below), which demonstrates again the perceived importance of climate change for winemakers in the observed regions. In particular, anti-frost methods were spontaneously mentioned three times, which demonstrates winemakers’ willingness to deal with the risks created by late frosts for their vineyards.

When considering each region individually, one can observe that both Burgundy and Loire vintners put cooling equipment clearly on top, with respectively 72.7% and 81.0% of winemakers having implemented new methods to cope with climate change using that strategy. Moreover, both regions put shading techniques and new blending methods last, with adoption rates of respectively 9.1% and 0% for the former and 1.9% and 0% for the latter. However, in between, results vary quite a bit. Indeed, in Burgundy, “use of the insurance market” and “improvement of soil composition” are respectively second and third, with adoption rates above 50%, and all remaining techniques achieve rates between 18.2% and 30.3%. But when focusing on Loire winemakers, the second most used viticultural technique is nighttime harvesting, which comes only in fifth position in Burgundy. All remaining methods are then comprised between 14.3% and 23.8%, with the soil composition improvement method achieving only 19% and the insurance market one doing even worse, with only 14.3%.

Figure 29: Other strategies implemented by vintners to deal with climate change

Other solutions	**Count**
Wine stock	1
Anti-frost techniques (towers, candles, spray)	3
Tree plantation	1
Earlier harvesting	1
Delayed pruning	2
Grassing management	1
Less extraction during vinifixations	1
Use of acidifying and/or less ethanol-producing yeasts	1
Agroforestry	1
Higher trimming and adapted soil cultivation	1
Pergola plantation	1
Wind turbines on several plots	1

4.2.3.3 Strategies' Costliness

Analyzing winemakers' answers regarding the costliness of the strategies adopted (see Figure 30 below) reveals that the latter are overall rather costly, 55.1% of the cost ratings given – this percentage changes to 53.9% when looking at Burgundy and 56.7% for Loire – being either "costly" or "very costly". However, this also means that a quite interesting proportion of ratings given (44.9%) were either "slightly costly" or "not costly", which is a promising sign for Burgundy and Loire vintners.

Figure 30: Overall costliness ratings

Costliness	**Global**		**Burgundy**		**Loire Valley**	
	Count	% of answers	Count	% of answers	Count	% of answers
Not costly	32	17,1%	9	8,0%	23	31,1%
Slightly costly	52	27,8%	43	38,1%	9	12,2%
Costly	67	35,8%	37	32,7%	30	40,5%
Very costly	36	19,3%	24	21,2%	12	16,2%

Looking more closely at these results (see Figure 31 below), it appears that the least costly solutions are nighttime harvesting, with 41.2% of "not costly" and 47.1% of "slightly costly" votes, strategies for delaying grape maturation, with 40% for both "not costly" and "slightly costly" and no "very costly" vote, reinspection of cellar hygiene, with a combined 72.7% for the two less costly ratings, and shading techniques, with two thirds of "slightly costly" votes and zero "very costly" rating. On the other hand, the costliest alternatives are using the insurance market, with exclusively "costly" and "very costly" ratings, as well as cooling equipment, with 94.4% of votes attributed to the "costly" and "very costly" options and no respondent selecting the "not costly" option. The four remaining choices achieved rather balanced results between the two more costly and the two less costly ratings.

Figure 31: Costliness ratings by strategy

Solutions	% not costly	% slightly costly	% costly	% very costly
Cooling equipment	0,0%	5,6%	58,3%	36,1%
Nighttime harvesting	41,2%	47,1%	5,9%	5,9%
Reinspection of cellar hygiene	9,1%	63,6%	18,2%	9,1%
Improvement of soil composition	5,0%	35,0%	50,0%	10,0%
Growing of better-suited varieties for warmer conditions	28,6%	14,3%	28,6%	28,6%
Vineyard placement management (altitude, orientation, slope, etc.)	11,1%	33,3%	55,6%	0,0%
Shading techniques	0,0%	66,7%	33,3%	0,0%
Use of the insurance market	0,0%	0,0%	50,0%	50,0%
Water reuse, treatment, and/or recycling	7,7%	46,2%	46,2%	0,0%
Strategies aiming at delaying grape maturation	40,0%	40,0%	20,0%	0,0%

4.2.3.4 Strategies' Effectiveness and Profitability

In addition to the costs, it is also interesting to investigate the effectiveness and profitability of the strategies in which winemakers have invested (see Figure 32 below). When asked whether the costs associated with the adoption of the new climate-change-focused methods selected earlier were compensated for by gains in other indicators such as productivity or revenues, 42.4% answered “not at all”, 43.6% “partially”, and 13.9% “entirely”. Looking at Burgundy and Loire individually, one can observe that winemakers in the former region reported slightly better results than the ones in the latter, but overall, the survey unveils that only a small proportion of vineyards has managed to fully recover their investments while a large one has recovered nothing at all. This may be a concerning finding, as it could suggest 1) that most winemakers are facing important difficulties either when choosing the methods to adopt or when proceeding with their implementation or 2) that some of the solutions chosen as a response to climate change are simply too costly to be profitable. It may also be simply an indication that such investments were made rather recently and take time to recover.

Figure 32: Overall effectiveness/profitability ratings

Costs compensated by other gains	% Global	% Burgundy	% Loire Valley
Not at all	42,4%	39,3%	49,1%
Partially	43,6%	45,5%	39,6%
Entirely	13,9%	15,2%	11,3%

Figure 33, available down below, shows that the most challenging techniques in terms of profitability are the use of insurance markets and water reuse strategies with respectively 52.9% and 53.8% of winemakers disclosing no cost recovery whatsoever and a very small proportion reporting a complete recovery (respectively 11.8% and 7.7%). Nighttime harvesting and reinspection of cellar hygiene seem to create some difficulties as well, with a 50% no-recovery rate for each, which is surprising given that both strategies were previously identified as some of the least costly viticultural methods. On the other hand, the least challenging methods – i.e., methods with a low no-recovery rate and decent complete recovery results – are shading techniques, with respectively 0% and 33.3%, and strategies for delaying grape maturation, with 20% for both "not at all" and "entirely". The strategy focusing on growing other grape varieties seems interesting as well, with only 20% reporting no recovery at all.

Figure 33: Effectiveness/profitability ratings by strategy

Solutions	**% not at all**	**% partially**	**% entirely**
Cooling equipment	37,1%	48,6%	14,3%
Nighttime harvesting	50,0%	35,7%	14,3%
Reinspection of cellar hygiene	50,0%	25,0%	25,0%
Improvement of soil composition	30,0%	60,0%	10,0%
Growing of better-suited varieties for warmer conditions	20,0%	80,0%	0,0%
Vineyard placement management (altitude, orientation, slope, etc.)	44,4%	33,3%	22,2%
Shading techniques	0,0%	66,7%	33,3%
Use of the insurance market	52,9%	35,3%	11,8%
Water reuse, treatment, and/or recycling	53,8%	38,5%	7,7%
Strategies aiming at delaying grape maturation	20,0%	60,0%	20,0%

4.2.3.5 Concluding Remarks

Considering these results together, it interestingly appears that though the four mostly used strategies are cooling equipment, insurance markets, soil composition enhancement, and nighttime harvesting, only the last one was considered by respondents as generating low additional costs while the two first ones turned out to be the two most expensive alternatives. Furthermore, all four strategies reached rather high no-cost-recovery rates (from 30% to 52.9%) coupled with low full-recovery percentages (from 10% to 14.3%). These elements suggest that the strategies most favored by Burgundy and Loire winemakers may in fact not be the most viable ones.

5 Discussion

5.1 Climate Change Effects on Winemaking Activities

Overall, the results obtained through the questionnaire seem to corroborate the findings from existing research on the main challenges caused by climate change for winemakers. Indeed, every climate change effect given in the questionnaire, all of which were derived from the existing literature, was picked by 30% of the respondents or more, which confirms the already identified importance of these various elements, at least among Burgundy and Loire vintners. Respondents particularly emphasized an increased frequency of extreme weather occurrences and an affected periodicity, two of the most essential elements identified by researchers on the topic. High temperatures, as well as water deficits and precipitation disruptions were also given significant importance by the winemakers surveyed – though this importance was more evident among Burgundy than Loire vintners –, thus also substantiating existing literature insights.

However, the analysis of the survey results also uncovered a couple of discrepancies between existing research and Burgundy and Loire vintners' statements. First, though still close to a third of respondents (30.9%) did select that option, winemakers did not put a lot of emphasis on potential increases in the number of diseases, at least compared to the other proposed climate change effects, all of which achieved selection rates of at least 48.5%. Second, it is somewhat surprising to observe that less than half of the respondents included "impact on grape composition and quality" and "impact on wine quality and characteristics" in their selection of climate-change-related effects on their activities, as these two elements are clearly described by existing research as key consequences of climate change for winemakers, with a wide variety of identified physiological impacts. This outcome is mainly due to the answers of Loire winemakers, among whom only about a third reported an impact of climate change on grape and wine characteristics. As mentioned earlier, it could be that vintners in the Loire Valley are particularly skilled at shielding their vineyards from climate-change-induced phenomena or that they do not consider climate change to be the cause of any observed changes in the composition and quality of grapes and wines. It is also possible that combining changes in composition/characteristics with changes in quality deterred some winemakers from selecting these two options if they observed a switch in grape physiology or wine attributes but managed to keep the same quality standards. Anyhow, this is an interesting finding that needs further investigation.

5.2 Effects of Climate Change on Vineyards' Financials

The financial analysis of vineyards in Burgundy and the Loire Valley over the 2013-2022 period reveals the importance of climate for vineyards, as much on the absolute values as on the volatilities.

Regarding production, both regions observed an increase in their volatilities, which almost doubled. Differences, however, arise in the volatility of their revenues. While Burgundy winemakers managed to reduce revenue volatility, the Loire Valley experienced a significant increase in this metric. Both regions tried to stabilize their revenues with price increases – amid the price volatility increase for both regions – but only Burgundy managed to do so.

On the cost side, Burgundy experienced a revenue increase of the same magnitude as the material and employee costs. At the same time, other operating expenses decreased, and the region increased its EBITDA significantly. Although it might be hard for a company to efficiently manage operating costs when revenues increase, the region was able to efficiently respond to this increase through effective cost management, leading to an increase in profit before tax of approximately 46%. The Loire Valley experienced a similar situation, with material costs efficiently managed despite a larger impact on revenues. However, a surge in other operating expenses, depreciation, and amortization led to a profit increase that was smaller than in Burgundy, of around 23%, reducing the percentage of profit per revenue for this region.

Furthermore, similar to absolute values, cost volatilities displayed a greater struggle in the Loire region to adapt to recent years' complicated business environment. Indeed, the volatilities of the Loire Valley considerably increased, while the contrary can be observed when focusing on Burgundy, highlighting again the former region's very efficient cost management.

Although this financial analysis cannot provide sufficient evidence to claim that climate change impacts vineyards' financials, it does show an increase in the difficulty of navigating the business environment in recent years, which is why it was decided to study the relationships between climate events and Burgundy and Loire vineyards' financials.

One important finding is that Burgundy's production is, with a very high probability, heavily impacted by climate events. This finding underscores that if climate evolves, which is the case with climate change, as proven by a wide range of sources and in this paper's literature review, the production output will be impacted.

As per the impacts on financials, the relationship is less direct, with more intermediate variables. Still, some financial metrics were significantly impacted for both the Burgundy and Loire regions, indicating that a relationship does exist. Indeed, vineyards' working capital, interest coverage, and cash and cash equivalents were all impacted by climate events. For instance, the number of days with total precipitation heights superior to or equal to 30.0 mm and the number of days with daily mean temperature superior to or equal to 24°C both positively impacted all three financial metrics. Similarly, the number of days with snowfall showed a negative relationship with the three variables, underlying the impacts of climate events on vineyards' financial metrics. Some other climatic events were also shown to have an effect, though the impact is not as straightforward since the metrics were not always significant or showed relationships with diverging impacts, as will be discussed later. Nevertheless, overall, this implies that if the climate actually changes, there will be an impact on the financial statements of winemakers.

So far, the study depicted a similar general picture for both regions. However, it also displayed slight differences in the results that should be discussed. On the one hand, the timing of the impacts was slightly different, and, on the other hand, the coefficients associated with some impacts were inversed.

Focusing first on the timing, it appears that although the latter was similar for most metrics (i.e., interest coverage, cash and cash equivalents, and working capital), some indicators were not impacted with the same time lag across the two regions. For instance, some climate events impacted the ROCE and ROE (considered closely related ratios in this study) with different time lags. For the Burgundy region, the ROCE and ROE were both impacted at T = +3, implying that the winemakers could only notice the impact on those two metrics three years after the year of production. On the contrary, the Loire region experienced an impact of climate events on ROCE just one year after the year of production. This study suggested a difference in the sale schedule of wine bottles due to aging and maturation schemes discrepancies between the two regions as the most likely explanation to this observation.

Secondly, the coefficient signs differed between the two regions for a given climate event and finance indicator. For instance, the number of days with frost and a greater monthly total of daily global radiation in J/cm² appear beneficial for indicators in the Burgundy region, while they seem to negatively impact the financials of Loire winemakers. A rational explanation for the first difference could be the variation in climate types between regions. Indeed, Burgundy experiences a more continental climate, whereas the Loire region typically has an oceanic climate. Consequently, Burgundy's winemakers have cultivated grape varieties (i.e., Pinot Noir and Chardonnay) that are more resistant to winter frost and benefit from increased radiation that offset the effects of frost, while Loire winemakers operate in a warmer winter climate, with grape varieties that are not as resistant to frost episodes, resulting in damage when freezing occurs. Furthermore, during the summer, the Loire region does not benefit as much from increased radiation as Burgundy does, because the grapes have already grown, and extensive exposure may instead harm the fruit.

Thirdly, the study presented surprising results that were not entirely in line with previous research concerning hailstorms. Previous studies indicated that hail was typically harmful to wine production and, consequently, to financial performance. However, this research presented regressions which indicated that hailstorms, though detrimental to Loire vineyards, proved beneficial to Burgundy. For instance, interest coverage, cash and cash equivalents, and working capital were positively impacted by an increase in the number of hail days in Burgundy. Nevertheless, this observation does not necessarily suggest that hailstorms benefit the entire value chain in that region. Indeed, it could rather imply that Burgundy winemakers take proactive measures to manage their liquidity ratios and demonstrate financial resilience when these climate events occur.

Similarly, Loire Valley winemakers have increased cash and cash equivalents and working capital when late frost happens, which is contrary to what would usually be expected and what Burgundy winemakers have been doing. According to the data, the Loire Valley experienced 50% more late frost episodes than the Burgundy region, indicating a possible explanation: as Loire vineyards are more frequently exposed to these events, winemakers in the region may try to demonstrate greater resilience and be more inclined to find solutions to mitigate the impacts of late frost.

Lastly, this study uncovered that one of the main reasons why climate events have impacted Burgundy and Loire differently is because each region has adapted in differing ways to specific conditions. However, it could become impossible to maintain financial resilience if harmful events occur too frequently, as short-term solutions, such as liquidity measures, may no longer be sufficient. Hence, more sustainable and vineyard-specific solutions may need to be implemented in the coming years if the effects of climate change continue to intensify.

Finally, some differences can be observed when comparing the financial statement data retrieved from the Orbis database and the results obtained from the poll. Firstly, while Burgundy and Loire winemakers surveyed through the questionnaire reported that their revenue had decreased, the financial data analysis showed that their revenues actually increased, even when adjusted for inflation. A similar observation can be made for profit, where winemakers believed that climate change (or the changing environment) had decreased their profits, whereas the data showed an increase in both regions. Only the profit as a percentage of revenue declined for the Loire region. The difference could stem from Orbis's data, which might be slightly different from the anonymous information that the poll retrieved. It could also stem from an exaggeration of beliefs on the impact of climate change on vineyards, as recent years have proven particularly harsh for the wine industry. Looking at the production output for 2021 or 2023, for which the data is not yet available, would give a good idea of the climate pressure that vineyards are currently facing.

On the other hand, the winemakers surveyed in both regions noticed an increase in their operating costs, a decrease in their productivity, and an increase in the price of the bottles sold. Those observations align with the financial analysis made, although the magnitude of those impacts differs a little. Again, more data (survey respondents and financial data) is required to draw any analysis of this comparison.

5.3 Review and Analysis of the Solutions Implemented So Far

The existing literature is full of potential solutions that vineyards can implement to try and respond to the challenges created by climate change, and the questionnaire that was distributed to Burgundy and Loire winemakers allowed to better understand which strategies, if any, have been adopted by these practitioners, at what cost, and with how much success.

The analysis notably revealed that nearly 80% of the winemakers surveyed have implemented at least one viticultural method in response to climate change, which indicates that the issue is well recognized and actively dealt with by most vintners in the two observed regions. It also showed that while some strategies have been rather widely adopted, such as cooling equipment – in both

Burgundy and Loire –, insurance markets – mainly in Burgundy–, soil composition improvements – mainly in Burgundy–, or nighttime harvesting – mainly in Loire –, other methods highlighted by existing research received little to no recognition. For instance, the entries "increased irrigation", "more efficient irrigation", and sugar-reducing techniques" were not selected at all, even though existing research finds that the increase in grapes' sugar content and water shortages are among the most essential consequences of climate change and that irrigation practices and sugar-reducing methods are very useful tools to cope with those issues. And, while the absence of selection rather makes sense for sugar-reducing techniques in view of respondents' previous answers – as mentioned earlier, less than half selected impacts on grape composition as one of the consequences of climate change impacting their activities – it is quite surprising to see no mention of irrigation adaptation strategies given that almost 60% of respondents selected "water deficits and/or precipitation disruptions" when picking the challenges generated by climate change. Furthermore, four other important coping strategies according to the current literature achieved rather low adoption rates among the winemakers surveyed. Indeed, shading techniques, methods focusing on delaying grape maturation, the growing of new varieties, and vineyard placement adaptation strategies reached adoption rates – among vintners having implemented at least one strategy – of 5.6% to 20.4% only, despite existing research putting a lot of emphasis on such techniques. As mentioned earlier, it is particularly surprising to see such low rates for grape maturation delaying methods and shading techniques, since large proportions of respondents selected "affected periodicity" and "too high temperatures" as part of the effects of climate change affecting their businesses.

The questionnaire also revealed that the four mostly used response methods may not necessarily be the best strategic alternatives from a cost and profitability perspective. Indeed, insurance markets were identified as the most expensive and the second least profitable option, while cooling equipment proved to be the second most expensive alternative, also not appearing very profitable, and soil composition improvements turned out to be neither very cheap nor particularly profitable. Only nighttime harvests displayed a slightly better outlook, being the least costly alternative despite a surprisingly low profitability, which indicates that this technique may not be particularly effective. Therefore, perhaps Burgundy and Loire vintners should at least partially shift their focus towards other strategies, such as methods aiming at delaying grape maturation as well as shading techniques. Indeed, not only are both strategies among the cheapest and most profitable and effective strategies, as highlighted by winemakers’ answers to the questionnaire, but they are also widely recognized as key coping strategies in the existing literature. Furthermore, given the high proportion of winemakers who selected water shortages and precipitation disruptions among the climate change effects impacting their activities, Burgundy and Loire vintners should at least consider the use of modern irrigation practices as part of their responses to climate change. However, more research would be needed in order to identify the specific reasons behind the cost and profitability results of this survey as well as to better understand vineyards’ specific situations, before being able to provide a definitive recommendation to Burgundy and Loire winemakers on how to effectively and efficiently adapt to climate change.

Conclusion

To conclude, this study generally corroborates previous studies on climate change impacts on vineyards, such as higher temperatures, water shortages, extreme event occurrences, and periodicity of grape phenology and harvests. Although the majority of the poll respondents did not confirm a potential impact on the quality and composition of grapes and wines and on an increase of diseases, a significant number of respondents still confirmed those potentially harmful aspects of climate change.

Likewise, this research has established a broad overview of vineyards’ financial conditions in the two regions, noting an increase in volatility and a slight deterioration in the financial health of winemakers, especially in the Loire Valley region, where profits (compared to revenues) eroded. This paper also found that Burgundy vineyards have displayed greater financial resilience in adapting to changing environments with higher production output volatilities thanks to better pricing management.

Moreover, this study contributes to the existing literature by focusing extensively on the financial impacts of climate change. Indeed, relationships between some climate events and some financial metrics were proven to be statistically significant, indicating that some financials are impacted by climate change, since those events were shown to be more frequent or more intense as climate change intensifies. Furthermore, it appeared that the impacts of given climate events sometimes depended on the region, as the climate profiles of Burgundy and the Loire Valley are different.

Additionally, this thesis revealed that most Burgundy and Loire winemakers are actively dealing with the challenges imposed by climate change. It also pointed out that while some of the solutions identified by existing research have been widely implemented by vintners, other viticultural methods demonstrate little to no adoption. The analysis also suggested that, from a cost and profitability perspective, the adaptation strategies chosen by most Burgundy and Loire vineyards may not be the most advisable ones. It therefore recommended a potential shift to cheaper and more profitable methods, such as grape maturation delaying techniques and shading strategies.

Lastly, it is essential to note that this paper uses data sets that are not extensive. The valid data gathered from the Orbis database had to be heavily filtered to keep the vineyards with sufficient information, reducing the number of vineyards used for the analysis. Hence, out of the 339 vineyards collected, only 60 were kept to analyze both Burgundy and the Loire Valley. Similarly, the period studied was very short (i.e., slightly over ten years) and should be extended to confirm the results found in this paper. Likewise, the poll displays only 69 responses for the two regions, which can be considered insufficient to draw highly significant conclusions. This small survey sample, as well as some questions that may not have been well understood by a few respondents given their formulation, also add to the potential imprecision and discrepancies in the answers provided by the winemakers. Some additional research should therefore be conducted in order to confirm the findings and ensure the reliability and validity of the conclusions drawn from this study.

Appendices

Appendix 1: Questionnaire – English translation

Climate change impacts on your winemaking activity over the past 10 years

The purpose of this questionnaire is to understand your situation, the financial impacts of climate change on your activity over the past 10 years, as well as the measures which you have adopted as a response.

Question 1: In which region do you operate?

- ○ Bourgogne
- ○ Loire
- ○ Other: ...

Question 2: What is the size (in hectares) of your domain?

Question 3: Which varieties do you mainly cultivate?

Question 4: What is your annual revenue (in euros)?

Question 5: So far, which effects has climate change had on your activity?

- ○ Too high temperatures
- ○ Water deficits and/or precipitation disruptions
- ○ Increased frequency of extreme climatic events (droughts, storms, frost, etc.)
- ○ Impact on grape composition and quality
- ○ Impact on wine characteristics and quality
- ○ Affected periodicity (advancement of phenology, of maturation, of harvest, etc.)
- ○ Increase in the number of diseases
- ○ Climate change has not impacted my activity.
- ○ Other: ...

Question 6: Following the effects of climate change, has your productivity decreased by:

- ○ 0-10%?
- ○ 10-20%?
- ○ 20-30%?
- ○ 30-40%?
- ○ 40-50%?
- ○ > 50%?
- ○ My productivity has not decreased.

Question 7: Have your revenues decreased by:

- ○ 0-10%?
- ○ 10-20%?
- ○ 20-30%?
- ○ 30-40%?
- ○ 40-50%?
- ○ > 50%?
- ○ My revenues have not decreased.

Question 8: Have your profits decreased by:

- ○ 0-10%?
- ○ 10-20%?
- ○ 20-30%?
- ○ 30-40%?
- ○ 40-50%?
- ○ > 50%?
- ○ My profits have not decreased.

Question 9: Have your sales decreased by:

- ○ 0-10%?
- ○ 10-20%?
- ○ 20-30%?
- ○ 30-40%?
- ○ 40-50%?
- ○ > 50%?
- ○ My sales have not decreased.

Question 10: Have your production costs increased by:

- ○ 0-10%?
- ○ 10-25%?
- ○ 25-50%?
- ○ 50-75%?
- ○ 75-100%?
- ○ > 100%?
- ○ My production costs have not increased.

Question 11: Has the price of your bottles:

- ○ Decreased by 0-10%?
- ○ Decreased by 10-25%?
- ○ Decreased by more than 25%?
- ○ Increased by 0-10%?
- ○ Increased by 10-25%?
- ○ Increased by more than 25%?
- ○ The price of my bottles has not fluctuated.

<u>Question 12:</u> Which techniques and strategies have you implemented in order to respond to the challenges of climate change?

- Nighttime harvesting
- Cooling equipment
- Increased irrigation
- Reinspection of cellar hygiene
- Shading techniques (crop covers, shading nets, canopy management, etc.)
- Vineyard placement management (altitude, latitude, orientation, slope, etc.)
- Relocation
- Growing of better-suited varieties for warmer conditions
- Water reuse, treatment, and/or recycling
- More efficient irrigation system
- Improvement of soil composition
- Sugar-reducing techniques (filtration techniques, reverse osmosis, etc.)
- Genetic grape modification
- New blending techniques
- Strategies aiming at delaying grape maturation
- Use of the insurance market
- I have not implemented techniques or strategies linked to climate change.
- Other: ...

<u>Question 13:</u> How would you qualify the cost of the techniques/strategies implemented?

- Very costly
- Costly
- Slightly costly
- Not costly

<u>Question 14:</u> Please give an estimation of the cost of each technique/strategy: ...

<u>Question 15:</u> Have the different costs associated with the adoption of these techniques and strategies been compensated for by gains in other sectors (better productivity, revenue increase, etc.)?

- Not at all
- Partially
- Entirely

<u>Question 16:</u> Please write here any other information or comment which you would like to share: ...

Appendix 2: Harmonized Income Statement Comparison

Income Statement (average of vineyards in th of USD)	**Burgundy**			**Loire**			**Global**		
	2013-2017	2018-2022	*%change*	2013-2017	2018-2022	*%change*	2013-2017	2018-2022	*%change*
Revenue	22'599	27'450	*21.5%*	18'075	25'076	*38.7%*	20'522	26'506	*29.2%*
Material costs	(17'415)	(21'344)	*22.6%*	(13'949)	(19'400)	*39.1%*	(15'824)	(20'569)	*30.0%*
Costs of employees	(2'526)	(3'011)	*19.2%*	(2'098)	(2'668)	*27.2%*	(2'323)	(2'875)	*23.8%*
Other operating items	(1'137)	(1'047)	*-7.9%*	(531)	(1'013)	*90.8%*	(862)	(1'033)	*19.9%*
EBITDA	1'521	2'049	*34.7%*	1'497	1'996	*33.3%*	1'513	2'028	*34.0%*
as % of Revenue	*6.7%*	*7.5%*	*10.9%*	*8.3%*	*8.0%*	*-3.9%*	*7.4%*	*7.7%*	*3.8%*
Depreciation & Amortization	(673)	(839)	*24.7%*	(495)	(819)	*65.3%*	(589)	(831)	*41.0%*
Operating profit (loss) [EBIT]	848	1'210	*42.7%*	1'002	1'177	*17.5%*	924	1'197	*29.6%*
as % of Revenue	*3.8%*	*4.4%*	*17.5%*	*5.5%*	*4.7%*	*-15.3%*	*4.5%*	*4.5%*	*0.3%*
Financial revenue	59	54	*-7.5%*	65	148	*126.4%*	62	91	*48.5%*
Financial expenses	(135)	(137)	*1.1%*	(204)	(266)	*30.1%*	(167)	(187)	*12.3%*
Financial profit (loss)	(77)	(82)	*7.7%*	(139)	(118)	*-15.1%*	(105)	(96)	*-8.9%*
Profit (loss) before tax [PBT]	772	1'128	*46.2%*	863	1'059	*22.7%*	818	1'101	*34.6%*
as % of Revenue	*3.4%*	*4.1%*		*4.8%*	*4.2%*		*4.0%*	*4.2%*	
Income tax expenses (benefit)	(185)	(299)	*61.7%*	(191)	(227)	*18.7%*	(187)	(270)	*44.7%*
Profit (loss) after tax [PAT]	587	829	*41.3%*	672	832	*23.9%*	631	831	*31.5%*
Production Output	2'222	2'255	1.5%	2'509	2'549	1.6%	2'366	2'402	1.5%
Theoritical Selling price	10.2	12.2	19.7%	7.2	9.8	36.5%	8.7	11.0	27.2%

Appendix 3: Regression of Burgundy's production output against climate events for T = +1

Regression Statistics	
Multiple R	0.903938041
R Square	0.817103981
Adjusted R Square	-0.646064169
Standard Error	491.3426165
Observations	10

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	8	1078554.122	134819.2652	0.558448447	0.782370683
Residual	1	241417.5668	241417.5668		
Total	9	1319971.689			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	5714.576025	66090.99919	0.086465269	0.945091066	-834051.1909	845480.343	-834051.1909	845480.343
NBJRR30 Burgundy	-134.5366861	2251.118479	-0.059764374	0.96199802	-28737.70897	28468.6356	-28737.70897	28468.6356
NBJTXS32 Burgundy	29.90522979	437.3599274	0.068376703	0.956537689	-5527.279551	5587.09001	-5527.279551	5587.09001
NBJGELEE Burgundy	-32.186195	134.3404058	-0.239586853	0.850296124	-1739.142895	1674.770505	-1739.142895	1674.770505
NBJTMS24 Burgundy	-19.13494401	398.7603036	-0.04798608	0.969474528	-5085.865002	5047.595114	-5085.865002	5047.595114
GLOT Burgundy	-0.004770651	0.112296079	-0.042482788	0.97297087	-1.431627626	1.422086325	-1.431627626	1.422086325
NBJNEIG Burgundy	19.78882798	69.0927343	0.286409681	0.822419719	-858.1175999	897.6952558	-858.1175999	897.6952558
NBJGREL Burgundy	7.354027797	537.0364624	0.013693722	0.991282851	-6816.341214	6831.04927	-6816.341214	6831.04927
LATE_FROST Burgundy	-97.07989975	115.7843625	-0.838454327	0.555796707	-1568.259715	1374.099915	-1568.259715	1374.099915

Appendix 4: Regression of Burgundy's production output against climate events for T = +2

Regression Statistics	
Multiple R	0.845669292
R Square	0.715156552
Adjusted R Square	-1.563591033
Standard Error	543.9599885
Observations	10

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	8	742897.3333	92862.16666	0.313837547	0.887914636
Residual	1	295892.4691	295892.4691		
Total	9	1038789.802			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	31378.19457	76315.57186	0.411163722	0.751659035	-938303.086	1001059.475	-938303.086	1001059.475
NBJRR30 Burgundy	-1061.172359	2503.015644	-0.423957542	0.744723528	-32865.00159	30742.65688	-32865.00159	30742.65688
NBJTXS32 Burgundy	226.1362076	475.4926148	0.475583007	0.717389261	-5815.570307	6267.842722	-5815.570307	6267.842722
NBJGELEE Burgundy	-86.40382148	166.4679391	-0.519041816	0.695208888	-2201.579538	2028.771895	-2201.579538	2028.771895
NBJTMS24 Burgundy	-194.1212352	385.7950235	-0.503171952	0.703219353	-5096.111791	4707.86932	-5096.111791	4707.86932
GLOT Burgundy	-0.04755559	0.133358718	-0.356599031	0.781931276	-1.74203877	1.64692759	-1.74203877	1.64692759
NBJNEIG Burgundy	50.27838359	86.93612965	0.578337036	0.666195721	-1054.349879	1154.906646	-1054.349879	1154.906646
NBJGREL Burgundy	-206.5586639	511.6584657	-0.403704185	0.755731823	-6707.795885	6294.678557	-6707.795885	6294.678557
LATE_FROST Burgundy	-81.55819601	125.0298449	-0.652309823	0.6320355	-1670.213003	1507.096611	-1670.213003	1507.096611

Appendix 5: Regression of Burgundy's production output against climate events for T = +3

Regression Statistics	
Multiple R	0.882064861
R Square	0.77803842
Adjusted R Square	-0.997654223
Standard Error	478.72731
Observations	10

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	8	803340.4618	100417.5577	0.438160524	0.830695036
Residual	1	229179.8374	229179.8374		
Total	9	1032520.299			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	-83715.09289	192292.838	-0.435352111	0.738599973	-2527027.262	2359597.076	-2527027.262	2359597.076
NBJRR30 Burgundy	2623.918257	6106.994077	0.429657901	0.741653771	-74972.7988	80220.63532	-74972.7988	80220.63532
NBJTXS32 Burgundy	-188.0459377	689.7285921	-0.272637585	0.830551826	-8951.878641	8575.786766	-8951.878641	8575.786766
NBJGELEE Burgundy	163.9522647	416.0321069	0.394085605	0.761014602	-5122.236863	5450.141392	-5122.236863	5450.141392
NBJTMS24 Burgundy	5.999406259	360.4993633	0.016641933	0.989406394	-4574.579311	4586.578124	-4574.579311	4586.578124
GLOT Burgundy	0.153930392	0.337087687	0.456647924	0.727292099	-4.129174772	4.437035557	-4.129174772	4.437035557
NBJNEIG Burgundy	-78.95297989	204.6248362	-0.385842605	0.765569564	-2678.958042	2521.052082	-2678.958042	2521.052082
NBJGREL Burgundy	549.9016235	1253.384421	0.438733412	0.736792592	-15375.85744	16475.66069	-15375.85744	16475.66069
LATE_FROST Burgundy	-267.1475419	327.2709616	-0.81628856	0.564173683	-4425.519384	3891.2243	-4425.519384	3891.2243

Appendix 6: Regression of Loire's production output against climate events for T = +1

Regression Statistics	
Multiple R	0.997896146
R Square	0.995796717
Adjusted R Square	0.962170457
Standard Error	91.66062224
Observations	10

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	8	1990433.643	248804.2054	29.61366195	0.141226978
Residual	1	8401.66967	8401.66967		
Total	9	1998835.313			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	12041.90187	3915.057235	3.075792037	0.200115052	-37703.61691	61787.42065	-37703.61691	61787.42065
NBJRR30 Loire Valley	1233.200371	278.92384	4.421279912	0.141607285	-2310.863046	4777.263788	-2310.863046	4777.263788
NBJTXS32 Loire Valley	-14.23486494	31.09043044	-0.457853582	0.72665728	-409.2762394	380.8065095	-409.2762394	380.8065095
NBJGELEE Loire Valley	-73.86793106	11.67797566	-6.325405465	0.099818767	-222.2506807	74.51481858	-222.2506807	74.51481858
NBJTMS24 Loire Valley	271.7033676	57.17519823	4.752119381	0.132038963	-454.7764069	998.1831421	-454.7764069	998.1831421
GLOT Loire Valley	-0.02288324	0.009421236	-2.428899979	0.248637848	-0.142591392	0.096824913	-0.142591392	0.096824913
NBJNEIG Loire Valley	6.310955207	16.20651097	0.389408628	0.763595912	-199.6122912	212.2342016	-199.6122912	212.2342016
NBJGREL Loire Valley	-177.2445247	52.93961332	-3.348050989	0.184776647	-849.9060902	495.4170408	-849.9060902	495.4170408
LATE_FROST Loire Valley	52.99650467	36.78562765	1.440685074	0.386278498	-414.4092116	520.4022209	-414.4092116	520.4022209

Appendix 7: Regression of Loire's production output against climate events for T = +2

Regression Statistics	
Multiple R	0.96777923
R Square	0.936596638
Adjusted R Square	0.429369744
Standard Error	331.3119335
Observations	10

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	8	1621490.718	202686.3398	1.846504295	0.517198132
Residual	1	109767.5973	109767.5973		
Total	9	1731258.316			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	-5011.599644	7225.031752	-0.693643961	0.613923584	-96814.33231	86791.13302	-96814.33231	86791.13302
NBJRR30 Loire Valley	-505.4297104	510.2365762	-0.990579143	0.503012922	-6988.600111	5977.74069	-6988.600111	5977.74069
NBJTXS32 Loire Valley	-4.236191982	118.5041701	-0.035747198	0.977252313	-1509.97444	1501.502056	-1509.97444	1501.502056
NBJGELEE Loire Valley	-65.68675139	41.47674377	-1.583700778	0.358551578	-592.6987495	461.3252467	-592.6987495	461.3252467
NBJTMS24 Loire Valley	-16.59869672	154.5633906	-0.107390868	0.931893868	-1980.512782	1947.315388	-1980.512782	1947.315388
GLOT Loire Valley	0.023157176	0.014568826	1.589501885	0.357501597	-0.161957306	0.208271657	-0.161957306	0.208271657
NBJNEIG Loire Valley	109.4740225	46.91856266	2.333277412	0.257767641	-486.6828407	705.6308856	-486.6828407	705.6308856
NBJGREL Loire Valley	-52.36790615	170.9378689	-0.306356377	0.810746895	-2224.339465	2119.603653	-2224.339465	2119.603653
LATE_FROST Loire Valley	-56.23917163	115.0916661	-0.488646776	0.710641131	-1518.617444	1406.139101	-1518.617444	1406.139101

Appendix 8: Regression of Loire's production output against climate events for T = +3

Regression Statistics	
Multiple R	0.990980089
R Square	0.982041537
Adjusted R Square	0.838373829
Standard Error	187.6984364
Observations	10

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	8	1926557.576	240819.6971	6.835506427	0.287937153
Residual	1	35230.70304	35230.70304		
Total	9	1961788.28			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	-5497.424287	3549.390025	-1.548836349	0.364979414	-50596.70063	39601.85206	-50596.70063	39601.85206
NBJRR30 Loire Valley	-211.2952041	152.5837886	-1.384781477	0.3981599	-2150.056062	1727.465654	-2150.056062	1727.465654
NBJTXS32 Loire Valley	-73.79430904	75.29587765	-0.980057758	0.506411528	-1030.519146	882.9305281	-1030.519146	882.9305281
NBJGELEE Loire Valley	-103.5033081	28.08305477	-3.685614296	0.168670225	-460.3323516	253.3257354	-460.3323516	253.3257354
NBJTMS24 Loire Valley	86.77254405	79.78791627	1.08753992	0.473319307	-927.0290556	1100.574144	-927.0290556	1100.574144
GLOT Loire Valley	0.027256037	0.008247435	3.304789696	0.18705943	-0.077537556	0.13204963	-0.077537556	0.13204963
NBJNEIG Loire Valley	142.8086953	35.09545053	4.06915122	0.153410144	-303.1212844	588.7386751	-303.1212844	588.7386751
NBJGREL Loire Valley	-213.7171312	97.76111016	-2.186116042	0.273120946	-1455.889812	1028.45555	-1455.889812	1028.45555
LATE_FROST Loire Valley	86.59307313	89.08677683	0.97200815	0.509035951	-1045.361753	1218.547899	-1045.361753	1218.547899

Appendix 9: Regression of Burgundy's Current Ratio against climate events for T = 0

Regression Statistics	
Multiple R	0.737452146
R Square	0.543835668
Adjusted R Square	-3.105478991
Standard Error	2.040028735
Observations	10

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	8	4.961567823	0.620195978	0.149024055	0.967908336
Residual	1	4.161717239	4.161717239		
Total	9	9.123285061			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	-45.22901463	232.1253888	-0.19484734	0.877491306	-2994.661729	2904.2037	-2994.661729	2904.2037
NBJRR30 Burgundy	1.427122218	8.00286748	0.178326359	0.88765485	-100.2589505	103.1131949	-100.2589505	103.1131949
NBJTXS32 Burgundy	-0.186849355	1.302621258	-0.143441045	0.90930127	-16.73822176	16.36452305	-16.73822176	16.36452305
NBJGELEE Burgundy	0.100563069	0.478160545	0.210312352	0.868034238	-5.975042716	6.176168854	-5.975042716	6.176168854
NBJTMS24 Burgundy	-0.038068674	1.261867042	-0.03016853	0.980799941	-16.07160966	15.99547231	-16.07160966	15.99547231
GLOT Burgundy	8.84098E-05	0.000400577	0.220706176	0.861711046	-0.005001404	0.005178223	-0.005001404	0.005178223
NBJNEIG Burgundy	-0.018256514	0.249292844	-0.073233207	0.953461371	-3.185822425	3.149309397	-3.185822425	3.149309397
NBJGREL Burgundy	0.267347151	1.606926182	0.166371769	0.895045759	-20.15058591	20.68528021	-20.15058591	20.68528021
LATE_FROST Burgundy	-0.15290558	0.472399191	-0.323678751	0.800714831	-6.155306423	5.849495262	-6.155306423	5.849495262

Appendix 10: Regression of Burgundy's Current Ratio against climate events for T = +1

Regression Statistics	
Multiple R	0.71567001
R Square	0.512183563
Adjusted R Square	-3.390347937
Standard Error	2.109618073
Observations	10

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	8	4.672796645	0.584099581	0.131243928	0.975337651
Residual	1	4.450488416	4.450488416		
Total	9	9.123285061			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	-134.389398	283.7668904	-0.473590833	0.718424377	-3739.989604	3471.210808	-3739.989604	3471.210808
NBJRR30 Burgundy	4.16824334	9.665353809	0.431256157	0.74079535	-118.641721	126.9782077	-118.641721	126.9782077
NBJTXS32 Burgundy	-0.74961285	1.877839162	-0.39918906	0.758207293	-24.60982171	23.11059601	-24.60982171	23.11059601
NBJGELEE Burgundy	0.28027188	0.576801072	0.48590735	0.712050472	-7.048680634	7.609224394	-7.048680634	7.609224394
NBJTMS24 Burgundy	0.563660062	1.712108649	0.329219797	0.797527019	-21.19074296	22.31806309	-21.19074296	22.31806309
GLOT Burgundy	0.000233859	0.000482152	0.485032145	0.712501375	-0.005892463	0.006360182	-0.005892463	0.006360182
NBJNEIG Burgundy	-0.14342328	0.296655076	-0.483468149	0.713307914	-3.912783407	3.625936846	-3.912783407	3.625936846
NBJGREL Burgundy	1.208708016	2.305808186	0.524201459	0.692626735	-28.08936288	30.50677891	-28.08936288	30.50677891
LATE_FROST Burgundy	-0.396635811	0.497129244	-0.797852501	0.571281071	-6.713261771	5.919990149	-6.713261771	5.919990149

Appendix 11: Regression of Burgundy's Current Ratio against climate events for T = +2

Regression Statistics	
Multiple R	0.954648162
R Square	0.911353114
Adjusted R Square	0.202178024
Standard Error	0.89930574
Observations	10

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	8	8.314534248	1.039316781	1.285089009	0.596568574
Residual	1	0.808750813	0.808750813		
Total	9	9.123285061			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	63.60931158	126.1692647	0.504158534	0.702718365	-1539.523197	1666.74182	-1539.523197	1666.74182
NBJRR30 Burgundy	-1.703314985	4.138128507	-0.411614812	0.751413429	-54.28322302	50.87659304	-54.28322302	50.87659304
NBJTXS32 Burgundy	0.297338094	0.786111565	0.378239053	0.769793605	-9.691156391	10.28583258	-9.691156391	10.28583258
NBJGELEE Burgundy	-0.083514874	0.27521431	-0.303453968	0.812437458	-3.580444248	3.413414499	-3.580444248	3.413414499
NBJTMS24 Burgundy	-0.199802216	0.637818381	-0.313258793	0.806737514	-8.304053143	7.904448712	-8.304053143	7.904448712
GLOT Burgundy	-0.000107909	0.000220476	-0.48943623	0.710235549	-0.002909325	0.002693507	-0.002909325	0.002693507
NBJNEIG Burgundy	0.017761937	0.143727778	0.123580402	0.921723147	-1.808472634	1.843996508	-1.808472634	1.843996508
NBJGREL Burgundy	-0.496873156	0.845903016	-0.587387853	0.661894903	-11.24509007	10.25134375	-11.24509007	10.25134375
LATE_FROST Burgundy	0.568705566	0.206706485	2.75127104	0.221940054	-2.057749351	3.195160482	-2.057749351	3.195160482

Appendix 12: All Statistically Significant Regressions of Financial Indicators with Climate Events (1/2)

	NBJRR30	NBJ TXS32	NBJ GELEE	NBJ TMS24	GLOT	NBJ NEIG	NBJ GREL	LATE FROST
Production (Burgundy)	-	+	-	-	-	+	-	-
Current Ratio (Burgundy; T = +3)	+	o	+	o	+	-	+	-
Profit Margin (Burgundy; T = 0)	-	+	-	o	-	+	-	o
ROE (Burgundy; T = +3)	+	o	+	o	+	-	+	o
ROCE (Burgundy; T = +3)	o	o	o	o	o	o	o	o
Interest Coverage (Burgundy; T = +2)	+	-	+	+	+	-	+	o
Cash and Cash Equivalents (Burgundy; T = +1)	+	-	+	+	+	-	+	o
Working Capital (Burgundy; T = 0)	+	-	+	o	+	-	+	-
ROCE (Loire; T = +1)	o	-	-	o	o	o	o	o

Appendix 13: All Statistically Significant Regressions of Financial Indicators with Climate Events (2/2)

	NBJRR30	NBJ TXS32	NBJ GELEE	NBJ TMS24	GLOT	NBJ NEIG	NBJ GREL	LATE FROST
Interest Coverage (Loire; T = +1)	+	-	o	+	-	-	o	o
Collection Period (Loire; T = +2)	+	+	-	-	-	-	-	o
Cash and Cash Equivalents (Loire; T = +1)	+	+	-	+	-	-	-	+
Working Capital (Loire; T = 0)	+	-	-	+	-	-	-	+
Operating Revenue (Loire; T = +1)	o	o	o	o	o	o	+	o

Appendix 14: Regression of strategy adoption rates against vineyard size

Regression Statistics	
Multiple R	0,011785711
R Square	0,000138903
Adjusted R Square	-0,020266426
Standard Error	1,555066391
Observations	51

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	0,016461366	0,016461366	0,006807192	0,934580698
Residual	49	118,4933426	2,418231481		
Total	50	118,5098039			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	3,104395014	0,230977576	13,44024413	4,66223E-18	2,640228197	3,568561832	2,640228197	3,568561832
Size	-0,000154723	0,001875306	-0,082505709	0,934580698	-0,003923293	0,003613846	-0,003923293	0,003613846

Appendix 15: Regression of strategy adoption rates against vineyard revenue

Regression Statistics	
Multiple R	0,144542568
R Square	0,020892554
Adjusted R Square	0,000910769
Standard Error	1,538842869
Observations	51

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	2,475972471	2,475972471	1,045579979	0,311549223
Residual	49	116,0338315	2,368037377		
Total	50	118,5098039			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	2,895008444	0,293013021	9,880135807	2,99957E-13	2,306176732	3,483840156	2,306176732	3,483840156
Revenue	1,59049E-07	1,55544E-07	1,022536053	0,311549223	-1,53528E-07	4,71626E-07	-1,53528E-07	4,71626E-07

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