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CLIMATE CHANGE ADAPTATION RESEARCH AMONG VINE GROWERS: EVIDENCE FROM MÁTRA WINE REGION

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Ph.D. dissertation

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- Farm types, challenges, directions of adaptation and their broader rural impact(NKFI 132975)

CHAPTER 1: INTRODUCTION

1.1. Opening remarks

In studies dealing with agricultural climate change adaptation issues, it is an often-cited statement that farming is a dynamic system that continuously responds to changing conditions. These changing conditions are mostly related to climate and natural resources and stimuli; however, there are other elements factoring in, such as market fluctuations, agricultural policies, access to technology, and extension (Anwar *et al.*, 2013). This wide range of changing conditions generates constant risks and pressures for farmers to manage and adapt to, making it a routine-like activity for those living from their land (Arbuckle, Morton and Hobbs, 2015). In that sense farmers are accustomed to dealing with climate variability and uncertainty, but as ranges of climate variability rise, so too could the need for farmers to become more adaptive (Crane, Roncoli and Hoogenboom, 2011). Farmers, on the other hand, is also considered as being particularly resistant to change, restricted by tradition, support policies, and social and behavioural variables (Wreford, Ignaciuk and Gruère, 2017). A rapidly growing body of work aims to understand the impacts of climate change on agriculture as well as farmers' perceptions of climate change and their likeliness to adopt adapting and mitigating practices (Sietsma *et al.*, 2021). These inquiries' fundamental premise is that all adaptation and mitigation action ultimately depends on people's willingness to act, either individually or collectively (Brown *et al.*, 2017).

This dissertation aims to investigate vine growers' climate change adaptation behaviour. Status of viticulture has been always an indicator of changing climate in the past as well as it will be in the present (Chuine *et al.*, 2004). This is explained by grape plants' sensitivity to year-to-year variability and the limited regions where grape vine growing is suitable (Schultz and Jones, 2010). Studies suggest major challenges induced by climate change that are very likely to have significant social, economic and ecological consequences for the wine sector (Mosedale *et al.*, 2016). What this research seeks to add to the otherwise intensively growing climate change adaptation discourse is an examination of vine growers' risk perception and risk management practices. Risks induced by climate change and risks from other sources will be systematically assessed as a network of interrelated concepts using a mixed-method research design with an emphasis given to mental modelling technique.

1.2. Research objectives

This research aims to enhance what is known about vine growers' climate-adaptive behaviour considering the multifaceted risk landscape in which they operate. This aim is fulfilled by adopting a *partially mixed sequential dominant research design*, in which a quantitative research segment (a large sample of survey data) will outline the overall picture of Hungarian farmers' perceptions of climate change and adaptation behaviour and then an individual-based mental modelling approach will be used to conduct a risk elicitation exercise embedded in qualitative interviews with vine growers.

However, research objectives can be further expanded upon by describing the motivations that influenced this research endeavor. Following Maxwell's instructions on research objectives, this section presents those personal, intellectual, and practical motivations that explain the choice of research problem for my PhD work (Maxwell, 2009). The source of *personal motivation* is my participation in a previous research project, which allowed me to author a case study on the Mátra wine region (Király, 2017, 2018). The case study aimed to illustrate the post-transitional development of the region with a focus on the typology of local vine growers and winemakers. The case study was based on extensive fieldwork that gave me the opportunity to interview local farmers and practitioners through which I gained deep insights into the factors that most determine the present of the wine region. Although that study did not address climate change issues, there were numerous comments on climate change related concerns and experiences during the interviews. It seemed logical that studying vine growers' climate change perception and adaptation would be an excellent follow-up research project. Thus, the personal motivation for writing this dissertation is based on previous personal experiences and research findings, in the hope that they will be a valuable source for the careful examination of the phenomena in this research.

Regarding the *practical motivation*, the intention is to strengthen the methodological toolkit for assessing the role of human behaviour in the adoption of climate change adaptation farming practices. These practices are understood here as an umbrella term that covers a wide range of practices aiming to improve the environmental and climate performance of agriculture (Dessart, Barreiro-Hurlé and Van Bavel, 2019). Due to the many academic attempts to investigate the factors that influence farmers' decision-making on sustainable practices, there has been a *behavioural turn* both in research and policy-making (Lange 2022; Bavel and Dessart 2018). The main driver of this turn is the growing scientific recognition that, beyond various economic, policy, social, technological, and cultural factors, behavioural factors can also largely influence the adoption of sustainable farming practices. This recognition has been fuelled by the growing body of research examining the significance of behavioural factors (Dessart, Barreiro-Hurlé, and Bavel 2019) and, more recently, by the gradual inclusion of behavioural insights in agri-environmental related policy-making, especially in the European Union's Common Agricultural Policy (CAP) reform (EC, 2017; OECD, 2017). From a methodological point of view, these types of studies tend to use quantitative methods like self-report assessments, economic experiments, or field observations (Colen *et al.*, 2016; Lange and Dewitte, 2019). In the dominance of quantitative methodology, qualitative approaches have been given less room to demonstrate their potential. Nevertheless, these approaches have great strengths to offer this methodological toolbox, such as the openness to novel insights, taking individuals' points of view, and a better understanding of social and cultural contexts (van Bavel and Dessart, 2018; Soubry, Sherren and Thornton, 2020). On this basis, the practical goal of this dissertation is to enrich and improve the existing methodological practice of studying the behavioural aspects influencing farmers' adaptation decisions to climate change. This will be done by applying a risk elicitation technique from mental modelling. Mental modelling approach has recently started gaining momentum in decision-making studies within agricultural and agri-environmental contexts (Winsen *et al.*, 2013).

Nalau and Verral (2021) provide the most recent large-scale overview of climate change adaptation related literature. Their bibliometric review shows how large this literature has become: they overviewed 11.506 publications between 1978 and 2020, that is supplied with an annual growth rate of 28,5%. The volume of information on adaptation has achieved a level that is hard, if not impossible, to manage, follow and reflect on (Sietsma *et al.*, 2021). Nevertheless, the opportunity for an early career researcher to continue to engage this extensive discourse presents a unique and intellectual challenge.

1.3. Structure of the dissertation

The reminder part of this introductory section provides an overview of the complex research design that underpins this research. The research design of this study has been inspired by Maxwell's research design structure (2009) and the concept of mixed methods research design (Schoonenboom and Johnson, 2017). In Maxwell's seminal work, five components are distinguished as elements of qualitative research design. These are goals, conceptual framework, research question, methods, and validity. In this interpretation, a good research design is a process that eventually leads to these components fitting together perfectly. This requires an interactive and iterative process in which the review of the connections between the individual components is an ongoing activity, both during the design and implementation phases. Figure 1 outlines the research design of this study in the form of a concept map.

Figure 1 Conceptual diagram of the research design

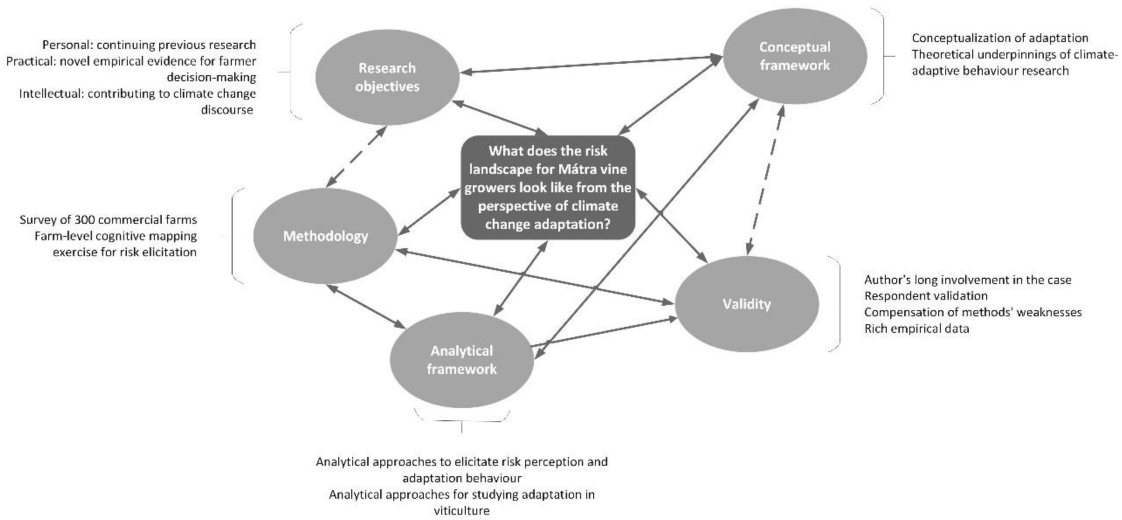


Figure was adapted from Maxwell, Joseph A. 2009. "Designing a Qualitative Study." In The SAGE Handbook of Applied Social Research Methods, edited by L. Bickman and D. J. Rog, 214–53. Los Angeles: SAGE.

Having clear ideas about the *research objectives* (including motives, desires, or purposes) that drive the research process is a key element in any research activity. Without them, the research can easily lose focus, and it can become harder to interpret the results. This research journey has been driven by personnel, practical, and intellectual goals, as described in Chapter 1. Chapter 2 presents adaptation research by outlining the most influential conceptual approaches for adaptation studies. Chapter 3 develops and presents a *conceptual framework* that is constructed to embed the research problem in the existing knowledge about climate-adaptive behaviour In the center of the design of the research, *research questions* have two central roles: they help to keep the focus on the research objectives and provide guidance for how to conduct it. The overarching research question of this research is,

”What does the risk landscape for Mátra vine growers look like from the perspective of climate change adaptation?”

From a *methodological* point of view, this research follows a *partially mixed sequential dominant* research design, which involves the use of both quantitative and qualitative methods for data collection and analyses. In Chapter 5, information is provided about a survey conducted with 300 commercial farmers and a cognitive mapping exercise incorporated into a qualitative interviewing process with Mátra vine growers. The results of both quantitative and qualitative research are shown and discussed in detail in Chapter 6. Last, but not least, Chapter 7 addresses the overarching research question by overviewing and synthetising the main research results.

CHAPTER 2: INTRODUCING THE CONTEXT OF CLIMATE CHANGE AND VITICULTURE

This chapter presents key climate change research findings in the context of agricultural production. The structure of this chapter follows a broad-to-narrow narrative. First, the global context is overviewed, followed by the discussion of climate change implications in Hungary, with a focus on the potential effects on viticulture and winemaking both from a global and domestic perspective.

2.1. Climate change impacts on agriculture from a global perspective

Before reviewing the likely implications of climate change in Hungary, I briefly examine the global context of the phenomenon. Climate change is having alarming impacts on agricultural and terrestrial food production in many parts of the world (FAO, 2016). These impacts have had more negative than beneficial consequences. Positive tendencies can be seen in several high-latitude areas, while climate extremes have caused multiple episodes of rapid food and cereal price increases in major producing regions, threatening food security in the face of accelerating food demand (Porter *et al.*, 2015; IPCC, 2019).

Studies on the relationship between agriculture and climate change have an element that has become conventional to include over the years: drawing attention to the twofold characteristic of their relationship. On the one hand, agriculture is highly vulnerable to variability and changes in climatic conditions. On the other hand, agriculture production is one of the largest sources of global anthropogenic greenhouse gas emissions (Vermeulen, Campbell and Ingram, 2012; Yohannes, 2015; Niles *et al.*, 2018). Agriculture is responsible for both direct and indirect emissions. Fertilized agricultural soils and animal manure produce direct and indirect emissions. While indirect emissions are caused by runoffs and fertilizer leaching, direct emissions are caused by land-use changes, the use of fossil fuels for mechanisation, and transportation. Deforestation and soil degradation are the most significant sources of indirect emissions created by agriculture (Yohannes, 2015; Niles *et al.*, 2018).

A large number of studies have addressed the complexity surrounding the link between agriculture, food production, and climate change. Crop yields can vary depending on extreme weather events and show a substantial link with temperature change, the duration of heat or cold waves, and variety in precipitation patterns (Yohannes, 2015). Livestock production and the livestock supply chain are affected by climate-related concerns over feed and water resources, and animal health issues (Godde *et al.*, 2021). Fisheries and aquaculture, both in-land, and marine, are no exception to the effects of climate change, mainly due to the increased vulnerability of fish population resulting from either overfishing or climate variability (Brander, 2007; Huang *et al.*, 2021). Biodiversity has an essential role in maintaining modern food systems, yet intensification and expansion of land-based food production is a major threat, that is worsened by the effects of climate change (Gitay *et al.*, 2002). Thinking of the end of the value chain, food consumption pattern overwhelmed by animal protein and food waste also present a greenhouse gas intensive issues yet to solve (Reisch *et al.*, 2021). It is also very well evidenced that climate change will strongly impact food security. Studies prove that all four dimensions of food security (food availability, access, stability of food supplies and food utilisation) will be affected; however, impacts will be varied across regions, and over time and dependent on socio-economic status (Schmidhuber and Tubiello, 2007).

2.2. Global climate change and its impacts on viticulture

There is a vast body of knowledge about how the vulnerability of viticulture is affected by climate change impacts (Jones and Webb, 2010; Ashenfelter and Storchmann, 2016; van Leeuwen and Darriet, 2016; Santos *et al.*, 2020; Bezner *et al.*, 2022). The idea of terroir is frequently at the core of this work. Terroir is an interactive ecosystem that determines a wine region's viticultural and winemaking characteristics (Van Leeuwen and Seguin, 2006). In other words:

> *"Vitivinicultural "terroir" is a concept which refers to an area in which collective knowledge of the interactions between the identifiable physical and biological environment and applied vitivinicultural practices develops, providing distinctive characteristics for the products originating from this area. "Terroir" includes specific soil, topography, climate, landscape characteristics and biodiversity features.* (OIV, 2010).

When certain physical and biological factors are altered by climate change, the local climatic and soil conditions that determine wine regions' terroir are inevitably altered as well. This inevitably results in changes in viticultural practices that can be referred to as "adaptation" (Naulleau *et al.*, 2021). Furthermore, three elements, temperature, water radiation, are typically highlighted by climate change studies on vine-growing ecosystems as being particularly vital to the development and growth of grape vines. Given that grapevine is a perennial plant, its biological cycles require warm and cold as well as moist and dry periods (Droulia and Charalampopoulos, 2022). Among these, thermal conditions are seen as the most significant ones because they clearly interact with plants' physiological development and berry composition (Gladstones, 2011). Moreover, temperature has a clear role in defining suitable locations, where grapevine cultivation is reasonably possible. Most of the major wine-growing regions are located within a belt defined by so called isotherms of mean climatic conditions. Isotherms of 22-24 C of maximum mean temperature and 12-13 C of minimum mean temperature mark those regions where grapevine cultivation is most likely feasible (Santos *et al.*, 2020). In the Northern Hemisphere, these fall between the 35^{th} and 50^{th} parallels, whereas in the Southern Hemisphere, they are located between the 30^{th} and 45^{th} parallels (van Leeuwen and Darriet, 2016). Related to this, another important research area is the potential latitudinal shift of grapevine cultivation. Such shifts would not be unprecedented, as there are historical evidence of such shifts due to changed climatic circumstances in the past millennia (Schultz and Jones, 2010). Recent suitability models project that suitable wine regions will shift upward in elevation, while cultivation will become unsuitable in the southern regions (Moriondo *et al.*, 2013). Accordingly, circumstances are projected to become unfavourable in many Mediterranean wine regions. Conversely, some areas in the northern hemisphere may open up to the production of quality wine grapes (Hannah *et al.*, 2013; Tóth and Végvári, 2016; Nesbitt *et al.*, 2022)

Precipitation plays another crucial role in grapevine development because the water status needed for balanced development varies depending on the phenological stages. A healthy soil moisture level is essential during plantation, just as it is during the budburst and shoot development stages. Nevertheless, from flowering through berry ripening and maturation, excessive precipitation may lead to detrimental effects (Santos *et al.*, 2020). Overall, drought negatively affects the yields of both black and white grape varieties, but in the case of black grape varieties, it is not necessarily associated with a deterioration in quality, and in many cases, moderate water shortages produce outstanding vintages. For white varieties, the greater the water stress, the lower the quality falls (Van Leeuwen *et al.*, 2019). Given that European vineyards are primarily rainfed, precipitation and its temporal distribution largely affect grape development (Droulia and Charalampopoulos, 2022).

The third vital element for grapevine development is solar radiation. In fact, high levels of solar radiation support the synthesis and accumulation of sugar, phenolic, and many aromatic compounds during maturation. Therefore, this factor often affects the organoleptic properties of the wine, including flavour and aroma attributes. Excessive UV radiation essentially leads to high alcoholic content and low acidity during maturation, can cause sunburn damage in both leaves and berries (Santos *et al.*, 2020).

It is also clear that these factors have significant impact on annual fluctuations in grapevine yield and quality. This notion clearly demonstrates how crucial it is to follow and monitor the evolving trends of these environmental factors since circumstances may arise in just a few vintages that force producers to adjust their management practices (Molitor and Keller, 2016).

2.3. Climate change in the Carpathian Basin

The Carpathian Basin's climate is changing in line with the overall trend of global warming. The fact that the national mean annual temperature increased by 0.99°C between the turn of the 20th century and the beginning of the 2000s is unequivocal proof of warming. Warming is indicated most profoundly by the fact that, as statistical climatology found: summer mean temperature has risen nearly 2°C between 1980 and the early 2000s. (Bartholy, Haszpra, *et al.*, 2011).

The increasing frequency of specific temperature extremes makes it possible to follow the warming in detail. The number of summer days (daily maximum temperature > 25°C) has clearly increased over the past century; between 1901 and 2009, there was an average increase of 8 days. In recent decades, the increase has followed a trend that has become more evident. Whereas, over the past century and in recent years, the number of frosty days (daily minimum 0 °C) has decreased steadily (minus 11 days between 1901 and 2009) (Bartholy, Haszpra, *et al.*, 2011).

The Carpathian Basin is a challenging region to model for precipitation. According to the meteorological data series, Hungary's annual precipitation is falling. Spring months lost nearly 10 % of precipitation between 1901 and 2009—nearly 20%. Drought is a recurring phenomenon in Hungarian agro-meteorology, as evidenced by the consistent occurrence of dry summers over the past century. However, the slight increase in precipitation during the winter is unlikely to help agriculture because rain, which is the dominant form of winter precipitation, does not penetrate the soil as deeply as snow does. Indications from the rise in average daily precipitation or daily intensity point to an increase in the frequency of brief, intense showers and thunderstorms, which has implications for agriculture (Bartholy, Haszpra, *et al.*, 2011).

Several research programs have already examined the meteorological, environmental, economic, and socioeconomic elements of the domestic implications of global climate change (Láng, Csete and Jolánkai, 2007; Czirfusz, Hoyk and Suvák, 2015; Biró *et al.*, 2017). From a meteorological point of view, four regional climate models serve as the foundation for climate dynamics research[1] in Hungary. These models agree that the average temperature increase in the 21st century will be continuous and trend-like in the Carpathian Basin. However, the models are no longer consistent about the extent of warming. Between 2021 and 2050, the mean annual increase is projected to be 1-2 degrees Celsius, and between 2071 and 2100, 3-4 degrees Celsius. By season and month, mean monthly temperatures in winter could be as low as above zero degrees, while in summer, mean temperatures in July and August will not fall below 20 degrees Celsius by the end of the century, and mean temperatures could even go above 30 degrees Celsius. Variability will continue to be a dominant feature of the Carpathian Basin climate, with summer and winter being the most variable seasons in the coming decades (Bartholy, Horányi, *et al.*, 2011).

There is more uncertainty and less confidence in the projections for precipitation. The uncertainty of the simulations is increased by the heterogeneous topography and by the fact that, in global climate models, the Carpathian Basin is typically placed in a transition zone between warmer Mediterranean and colder continental climate zones. Overall, precipitation is expected to decrease in spring and summer and increase in autumn and winter. The overall number of dry days, the average length of a dry period, and the maximum number of consecutive dry days are all expected to rise considerably in the

[1] These regional models are able to project climate change for a larger geographical unit (e.g., the Carpathian Basin) or country over a decadal horizon. Regional climate modelling in Hungary is based on the results of four regional climate models: ALADIN, RegCM, PRECIS, and REMO (Hoyk, 2015).

summer (Pongrácz, Bartholy and Kis, no date). More precisely, summer seasons will likely face 30 % of precipitation decrease leading to limited soil-moisture status (Kis, Pongrácz and Bartholy, 2017). Regarding rainy events, it was anticipated that the mean length of rainy spells, the number of wet days, and the number of precipitation days above 5 mm would all drop (Pongrácz, Bartholy and Kis, no date). Regarding the variability of precipitation, the models only agree that a decrease in summer precipitation should be expected; otherwise, the direction of change is uncertain for both seasons and months. Extreme precipitation is likely to decrease in summer and increase in winter; however, intensity is only projected to increase for winter by changes in heavy and very heavy precipitation days (Kis, Pongrácz and Bartholy, 2017). In terms of the total amount of rain that falls each year, the simulation results do not predict a significant change. This is because the less rain that falls in the summer will be compensated by more rain in the winter (Bartholy, Horányi, *et al.*, 2011).

In terms of extreme weather events, daily maximum and minimum temperatures will increase the most during the summer, but throughout the entire 21st century, it is projected that maximum temperatures will rise more than minimum temperatures in all seasons. The average increase in warm temperature extremes (summer, heat, hot and heatwave days) could reach 12 days in the near future and up to 37 days by the end of the century. The increase is expected to be more pronounced in the southeast of the country than in the north. This will impact the length of the growing season, which is expected to increase from an average of 24 days by 2050 to an average of 51 days by 2100. In the case of extreme precipitation events, an increase in the length of dry periods can be expected, and overall, a slight drying of the region's climate should be expected. The frequency of intense precipitation losses will increase slightly throughout the year, except in summer (Bartholy, Horányi, *et al.*, 2011).

2.4. Climate change impacts on the wine sector in Hungary

Several attempts have already been made to assess the impacts of climate change on Hungarian agriculture. In an integrated panel data model of yield response, Gaál, Quiroga, and Fernandez-Haddad (2014) assessed and compared agricultural production of Hungarian counties considering climatic and socioeconomic conditions with a special attention on water-related aspects. Their most remarkable results highlighted the crucial role of irrigation, particularly in the production of green peas, maize, and potatoes, as these crops might be subject to high yield volatility due to climate variability. Fogarasi et al. (2016) used the crop simulation model to estimate the impacts of climate change on yields in the Hungarian grain sector. This growth model resulted in that without adaptation, the predicted yields of winter wheat and maize will be on a slight declining trend in the upcoming decades as a result of climatic changes. The concepts of efficiency and productivity were brought into this dialogue by a study focusing on the impacts of changing climate factors on the technical efficiency of Hungarian arable farms (Vígh, Fertő and Fogarasi, 2018). They found significant linkage between warming, decreasing precipitation and plant production evidenced by phenology delays and yield reduction in case of most relevant crop species.

Although it is also true that the wine regions of Hungary are situated at the northern limit of wine grape growing potential, the Carpathian Basin's climate generally offers favourable conditions for grape a diverse cultivation. (Schultz and Jones, 2010). However, numerous studies have examined how domestic viticulture is likely to change in the upcoming decades due to climate change. Mesterházy et al. (2014), for instance, examined the potential effects of climate change on viticulture in Hungary. Diverse meso- and microclimates support the existence of a diverse grape and wine production in Hungary. In the 20th century, the climatic conditions favoured both early and medium-ripening grape varieties, while in some regions, late-ripening varieties have also been grown. Simulations indicate that by the middle of the 21st century, this spectrum will broaden, and the number of regions with favourable conditions for late and extremely late-ripening varieties will rise. By the end of the century, the extended growing season and stronger thermal effects may result in the rise of black grape varieties, including some Mediterranean varieties. As a result of warming, the number of frosty days causing potential crop damage will significantly decrease. Whereas in the reference period (1961–1990), less frost-tolerant varieties suffered frost damage every 2-3 years, by mid-century, severe frost damage is expected to occur every 4–10 years. It is very likely that Hungarian vine growers may no longer have to face the risk of frost at all by the end of the century. However, as frost becomes less frequent, growers must be prepared for significant heat-related damage. By the end of the century, the number of extremely hot days, when the daily maximum temperature rises above 35 degrees Celsius, might increase to 27 to 40 days, up from 8 to 16 days at mid-century. The extent of this impact is expected to be the most intense in the Danube region (Mesterházy, Mészáros and Pongrácz, 2014). In their follow-up study, these results have been reinforced. Based on regional climate model outputs and climatic indicators, they claim that growing seasons will start earlier and finish later for grapevine, resulting in significantly longer seasons in the current century. Their findings suggest that the likelihood of widespread settlement and cost-effective production of late-ripening and red grapevine cultivars with a greater heat demand will increase in Hungarian wine regions (Mesterházy *et al.*, 2018).

Studies at the wine region level are also available with varied results. For example, the moderately cool and dry Sopron wine region and the moderately cool and moderately humid Zala wine region can be considered winners of climate change. Continuous warming and drying will create climatic conditions that will be increasingly suitable for growing varieties that are more tolerant of heat and drought (Kovács, Puskás and Pozsgai, 2017; Kovács *et al.*, 2018). However, Szekszard wine region has been described as a climate-vulnerable growing area because of the sensitive local vine cultivars and the severe drought potential that winemakers are facing there in the future (Buzási, 2021). In their study on grapevine growing regions in Central Hungary, Szenteleki, Horváth, and Ladányi note that it is anticipated that precipitation will remain within an optimal range, but that longer dry periods may cause growth problems. However, based on regional climate models, increasingly frequent and more dangerous extreme weather events (such as the number of hot days and extended periods of drought) appear to be a greater risk that will inevitably raise the question of what changes are required in viticulture management to sustain and improve production (Szenteleki, Horváth and Ladányi, 2012).

In summary, according to the available model data, viticulture in Hungary remains within the optimal range for the most significant climatic drivers. The behaviour of vine growers must primarily adapt to rising temperatures, longer drought periods, and occasional extreme weather events. It is essential to emphasise that the introduction of new and the removal of unsustainable vine varieties from the terroirs of wine regions will not result in a drastic alteration of the image of any wine regions in Hungary. However, vine growers must be prepared for the potential alteration of wine characteristics and regional characteristics.

2.5. Research on climate change adaptation in agricultural context

Research on climate change adaptation covers an extremely broad range of topics. According to Nalau and Verral's multifaceted bibliometric review of the pertinent scientific literature within this field of studies, climate change adaptation in agriculture is the third largest thematic cluster based on the analysis of the most frequently used author keywords. This clearly indicates the weight of primary research evidence on food system studies in climate change adaptation discourse (Nalau and Verrall, 2021). Most of the research on adaptation in agriculture begins with assumption that some degree of food systems' adaptation to climate change will be necessary (Porter *et al.*, 2015). The broad spectrum of adaptation options is characterised by specificities of food systems.

Crop-based systems are the most commonly studied adaptation measures (Hansen *et al.*, 2019). These studies usually follow a quantitative approach to assessing existing agronomic options such as changes in planting schedules, cultivars, or irrigation. Although these models are frequently criticised for being characterised by varying levels of uncertainty over climate projections, their general conclusion is that warming above two degrees is the line beyond which a significant increase of adaptation costs will occur. Another significant outcome of these models is that the low resilience of food systems in desert and tropical regions makes them the least capable to cope with climate change. (Kummu *et al.*, 2021; Müller *et al.*, 2021). Looking at crop-based systems from global perspective, on-farm adaptation options with the highest confidence to contribute to successful adaptation are crop shifting, and changes in agronomy and water management. Other options, such as the uptake of biotechnology innovations or increasing agroecological diversity, are still strongly influenced by farmers' perceptions or the lack of institutional support (Bezner *et al.*, 2022).

Heat stress is one of the most severe factors that affect livestock-based systems. Heat stress has implications for animal health and land suitability for grassland-based livestock systems. Adaptation studies on livestock systems have explored a range of adaptation options, from changes in breeding and crossbreeding practices, through species switching, to shading and cooling solutions (Bezner *et al.*, 2022).

Forests provide various vital benefits, such as crucial ecosystem services like climate regulation and biological diversity, in addition to providing employment, energy, foods shelter, and health (FAO, 2014). Despite this, the greatest hazards for forest systems are frequently connected to human activities at the first place rather than climate change impacts. Human-driven land use change and pollution will lead to the reduction of built-in adaptation ability of natural forests. Numerous studies have shown that planting species that are warm-tolerant or disturbance-prone, purposeful thinning, or rotation period reduction all considerably improve a forests' ability to adapt. However, it is indisputable that these interventions may also lead to unwanted side-effects on key forest ecosystem services, such as carbon sequestration or biological diversity (Bezner *et al.*, 2022).

One of the biggest sources of animal protein in the world comes from fisheries and aquaculture, which are found in both marine and freshwater ecosystems. In the last decades, several issues have been raised regarding the status of these ecosystems: the rapid rise in consumption of fish and fish products leading to overfishing, water pollution, and the recognition of the impacts of climate change (FAO, 2020). Adaptation options in fisheries must address multiple issues. Solutions might include flexible permits, quota sharing, or new multilateral agreements targeting transboundary ecosystem management. Moreover, given the scale of social inequalities that are embedded in unsustainable fishing systems, they cannot be overlooked either when discussing climate-resilient fisheries (Bezner *et al.*, 2022).

2.6. Adaptation studies in viticulture

Viticulture refers to the "*cultivation or culture of grapes especially for wine making*"(Merriam-Webster.com Dictionary, 2022). Viticulture is one of the sectors that has long been the subject of adaptation measures in preparation for climate change. As a result, a number of summarising studies have been carried out on the potential impacts and possible adaptation practices (Bezner *et al.*, 2022, p. 739). While the impacts have already been outlined, this sub-section will overview what options characterize adaptation practices in the context vine growing and wine making.

The most obvious categorisation distinguishes between short-term and long-term practices. Short-term solutions include crop cultural practices (e.g., changes in canopy geometry or cluster zone leaf removal), protection against extreme sunburns (e.g., application of sunscreen materials upon leaves), irrigation (e.g., deficit, drip, or sprinkler irrigation), pest and disease control, and soil management (e.g., application of spontaneous or cultivated cover crops or organic or synthetic mulches). Long-term strategies include changes in training systems (e.g. changes in planting density, trunk height, pruning approach), changes in varietal spectrum (e.g. changes in cultivated varieties, clones or rootstocks), and vineyard relocation (Santos *et al.*, 2020).

Another approach, by Van Leeuwen et al. (Van Leeuwen *et al.*, 2019), distinguishes adaptation practices associated with thetwo most relevant climate change impacts: rising temperatures and increasing drought. Potential adaptations to higher temperatures include planting later ripening varieties, clones, and rootstocks; reducing leaf area, doing late pruning, or moving to higher altitudes. Due to the fact that vine is highly drought resistant, the majority of vineyards in Europe are currently dry-farmed and will remain so; however, the number of irrigated vineyards is rising. Irrigation in vineyards not only has a dubious financial return on investment, but it would also undoubtedly seriously affect the soil salinity and local surface and groundwater resources. Beside potential irrigation, there are other practices that may mitigate the effect of increased drought. These are the application of drought resistant varieties, clones, and rootstocks, changes in training systems (e.g. increasing or decreasing vine spacing), increasing soil water capacity (Van Leeuwen *et al.*, 2019).

Another categorisation was applied by Neethling et al. (2017) in an assessment of local climate vulnerability in French wine producing regions. Adaptive responses were most frequent during harvest and winemaking periods. They grouped adaptive responses into four categories: tactical responses (reactive and anticipatory) and strategic responses (reactive and anticipatory) depending on which development stages the plant is in. Generally speaking, tactical responses are triggered by short-term climate variability, while strategic responses are made to address long-term climate changes. More precisely, the tactical and reactive responses included harvesting at night by machine, requesting crop insurance, or turning on heaters or wind machines. The tactical and anticipatory responses included allowing natural vegetation to grow as cover crops, using shallow soil tillage, or delaying winter pruning. The strategic reactive practices included changing in pruning mode, changing perennial cover crop species, or increasing the trellis system height. Strategic anticipatory practices are changing the growing site or vine species (Neethling, Petitjean and Quénol, 2017). Categorizing each activity is a useful descriptive technique, but research evidence suggests that there is always a combination of adaptation, so the single stimuli and single respond strategy is rare among vine growers (Naulleau *et al.*, 2021).

The most significant evidence regarding how farming, including viticulture, is impacted by climate change has been outlined in this chapter. In particular, the chapter has focused on the research evidence on viticulture that is known from global and domestic contexts. The next chapter looks at how the concept of adaptation research has evolved over time and provides the conceptual background for this research.

CHAPTER 3: CONCEPTUAL FRAMEWORK

This chapter presents the conceptual background of this research. Following a broad introduction to adaptation research, the chapter provides an overview of key terms used in this field of inquiry. That is followed by an outline of the journey that adaptation research has taken to enter the mainstream of scientific discourse. Last, but not least, the chapter looks at the theoretical cornerstones of climate-adaptive behaviour research.

3.1. Adaptation research - adaptation science

Despite the extraordinary scientific interest in adaptation research and the clearly articulated needs for adaptation actions in public policy making, there are still several ambiguous aspects around the concept of adaptation (Klepp and Chavez-Rodriguez, 2018). Some argue that adaptation should be considered a stand-alone science within climate science (Smit *et al.*, 1999; Moss *et al.*, 2013; Swart, Biesbroek and Lourenco, 2014; Nalau and Verrall, 2021; Sobel, 2021). Moss et al. (2013) argue that even if adaptation is just a formulating science, that has both basic and applied science implications at the same time, there is a clear role to fill with its scope: "*understanding decision processes and information requirements, identifying vulnerabilities, improving foresight about climate risks and other stressors, and understand barriers and options for adaptation*". Swart et al. (2014) go further and dismantle adaptation science into science of and science for adaptation. From their perspective, science for adaption stands for a currently trending research programmes focusing mostly on practice-oriented studies aiming to serve adaptation decision-making. However, they argue that this approach does not lead to the development of fundamental theories and frameworks that indicate the need for better understanding adaptation. Therefore, they argue for a science of adaptation that is defined "*as a combination of disciplinary research theories and methods, grounded in the classical science traditions, to theorize and test the fundamental assumptions, processes, and principles of adaptation to a changing climate so as to* *provide an evidence base for the science for adaptation*" (Swart, Biesbroek and Lourenco, 2014, p. 5). They conclude that this theoretical work has not yet been done.

The lack of fundamental theories has also been pointed out by other authors. Dupuis and Biesborek (2013) describe it as the problem of the dependent variable. They argue that the fact that adaptation studies generally suffer from a lack of definition, scope, and boundaries of the phenomenon under study leads to challenges undermining conceptualisation and measurement, especially in comparative studies. That is perhaps the reason why evaluating and measuring adaptation to climate change is a challenge both conceptually and analytically. While mitigation efforts have a solid set of measurement indicators based mostly on natural sciences, adaptation is hard to monitor and measure because of the conceptual diversity that embraces adaptation, and other related concepts, such as vulnerability, and resilience studies. There are factors (e.g. poverty, class, gender, ethnicity, age, (dis)ability and citizenship status) whose impacts on adaptation capacity have been evidenced and demonstrated, but due to the lack of a universally applicable measurement system, such a comparable and coherent framework that tracks greenhouse gas emissions is not yet in place (Vardy *et al.*, 2017).

Despite that, the scientific community appears to hold a strong consensus that the 2015 Paris Agreement offers the potential to elevate adaptation as an even more essential component of global climate policy (Ford *et al.*, 2015; Lesnikowski *et al.*, 2017). As the Agreement requires a global stocktake every five years, monitoring and evaluating, adaptation studies are likely to gain further foothold in climate change research. This may include adaptation plans, policies, programmes, and actions, as there is a need to provide guidance on how to communicate adaptation information to the international community (Ara Begum *et al.*, 2022). However, available empirical databases of adaptation actions are currently rare and fragmented due to the locally diverse characteristics of adaptation. There has been too much focus on factors contributing to adaptive capacity, instead of collecting evidence that capacities have been translated into real adaptation actions (Tompkins *et al.*, 2018). Standardised documentation of actions would help assess the outcomes of these actions. However, there is also little agreement on what constitutes effective adaptation actions (Owen, 2020).

3.2. Definitions, terms, and typologies used in adaptation research

A huge part of the growing literature on climate change adaptation has made numerous efforts to delineate the concept for taxonomic purposes. These conceptual groundworks produced several classifications, typologies, and categorisations that supported framing the research area by defining and explaining the most important dimensions of adaptation.

Smit and his colleagues' work has been a reference point for academics working in this field (Smit *et al.*, 1999, 2000; Smit and Skinner, 2002). They proposed a systematic analytical framework that provides an "*evergreen*" guidance on how to define key elements of adaptation. This framework identifies the stimuli that trigger adaptation (*Adaptation to what?*), the agent of adaptation (who or what adapts?) and there is also a need for evaluation (*how does adaptation occur?*).

The most frequent differentiating attributes that help describe adaptation are purposefulness, timing, temporal and spatial scope, function/effects, form, and performance. As regards the purposiveness of adaptation, Smit et al. (1999, 2000) distinguish between spontaneous, autonomous, and planned adaptations or their combinations. Regarding timing, adaptation responses can be anticipatory (proactive), concurrent, or responsive (reactive). The duration of adaptation depends on the magnitude of adjustments. Tactical responses react to stimuli in the present, while strategic responses think further into the future and lead to structural changes. Adaptation can also occur at various scales (plant, plot, field, farm, region, and nation) as a result of various agents (farmers, industries, public agencies, governments). Adaptation responses can take many forms that determine characteristics of adaptation (administrative, financial, institutional, legal, managerial, organisational, political, practical, structural, and technological) (Smit *et al.*, 1999, 2000).

Smit and Skinner (2002) later adopted this analytical framework for agriculture, using examples from Canada. They came up with a typology that describes adaptation options in agriculture: technology developments (e.g. installation of an early warning system), government programmes (e.g. crop insurance program), farm production practices (e.g. implementation of irrigation practices) and financial management (e.g. income diversification). These options are also feasible in combinations, as the categories are not mutually exclusive (Smit and Skinner, 2002).

There are other influential approaches or efforts at classification that utilize empirical data. By reviewing adaptation actions, Berrang-Ford et al. (2011) describe adaptation profiles between low- and high-income countries. They say that low-income countries take reactive adaptation steps in the short-term, involving mostly individual actors. High-income countries take proactive adaptation actions with long-term planning and preparation. They argue that this is a clear sign of unequal adaptive capacity (Berrang-Ford, Ford and Paterson, 2011).

Biagini et al. (2014) attempted to relate already existing theoretical typologies of adaptation and on-the-ground adaptation practices. Numerous actions were reviewed and assessed for a certain selection of adaptation projects, and then these actions were grouped into groups, identifying ten types of adaptation actions. These actions are capacity building, management and planning, practice and behaviour, policy, information, physical infrastructure, warning or observing systems, green infrastructure, financing, technology. The most grounded categories are capacity building, management and planning, and the practice or behaviour categories. This can be explained by the fact that these actions are all prerequisites for adaptation projects (Biagini *et al.*, 2014).

There are three other key concepts that often appear in the literature: vulnerability, adaptive capacity, and resilience. Although vulnerability is a well-established concept in climate change science, there is a sense of a lack of clarity over its precise meaning. While there is still little agreement on its precise meaning, conceptual approaches share that vulnerability means susceptibility to harm and is comprised of exposure, sensitivity, and adaptive capacity (Ford *et al.*, 2018). There is one important point of distinction that is worth mentioning regarding the concept. *Outcome vulnerability* looks at things that are directly caused by climate change, while *contextual or starting point vulnerability* looks at vulnerability as a current state that is rooted in socioeconomic contexts and affects the ability to deal with pressures or changes from external world (IPCC, 2014a).

Research on adaptive capacity as a key element of vulnerability research came to the fore in 2001 after the third Assessment Report of The Intergovernmental Panel on Climate Change (IPCC). Similarly, to vulnerability, adaptive capacity is also burdened with conceptual problems. In his systemic review, Siders (2019) identified five different definitions of adaptive capacity in the literature that clearly highlight the lack of consensus in this field. The most frequently used definition was developed by the IPCC in 2007: "*adaptive capacity is the ability or potential of a system to respond successfully* *to climate variability and change, and includes adjustments in both behaviour and in resources and technologies*" (Adger *et al.*, 2007, p. 727).

Resilience is another key concept in adaptation studies. In their seminal work, Folke et al. (2010) use the following definition of resilience in the context social-ecological systems: "*the capacity of a system to absorb disturbance and reorganize while undergoing change so as to still retain essentially the same function, structure and feedbacks, and therefore identity, that is, the capacity to change in order to maintain the same identity*" (Folke *et al.*, 2010, p. 3). It means that the resilience of a system marks out a critical threshold within which stability can be ensured or continual change essentially leads to either adjustment or transformative changes. These three concepts can be seen as the fundamental goals of adaptation. Increasing capacity leads to the ability to better respond to stress. Increasing resilience enables systems to continue functioning when faced with stress. And eventually, increasing capacity and increasing resilience will reduce vulnerability (Owen, 2020).

Climate change research has been also long addressing the differences and similarities between adaptation and mitigation. Although both concepts can be understood as responses to climate change, they cover substantially different activities. One important difference is the scale at which the response can be implemented. Mitigation is a global problem with a top-down perspective. Thus, it requires a globally coordinated set of efforts, intentions, and actions underpinned by an effective measurement and monitoring methodology based on a broad scientific consensus. Nation state commitments to any form of decarbonisation are being enforced through international agreements and a variety of regulatory, fiscal, and support policy instruments. In contrast, adaptation actions present local concerns for national or local decision-makers and are usually implemented in micro-environments using locally available capacities. In other words, mitigation efforts are driven by global concerns, while adaptation is driven by the self-interest of those who have been affected by climate change impacts (Pielke *et al.*, 2007; Berrang-Ford, Ford and Paterson, 2011; Brown *et al.*, 2017).

The distinction seems also clear from a research point of view. The IPCC has two distinct working groups to deal with mitigation and adaptation, and they produce separate reports. There are distinct funding mechanisms, and there are research communities picking up and working with only one of these concepts (Kongsager, 2018). Research on mitigation follows a top-down approach with a strong interest in technological and economic issues, using aggregate modelling for studying trade-offs in mitigation actions. Adaptation research follows a place-based approach, studying the adaptation of private individuals, communities, or sectors (Klein et al. 2007). Kongsager (2018) narrows this conceptual gap between adaptation and mitigation by arguing that the general objective is shared: dealing with climate change. He observes that spatial, temporal, and sectoral issues have indeed helped maintain the sharp distinction, but the number of commonalities has started to increase recently due to the fact that successful adaptation actions outnumber mitigation actions. Kongsager gives the example of agriculture and forestry as sectors where interlinkages have been observed: "a*griculture and forestry are inextricably linked to both adaptation and mitigation in climate change, as they are highly affected by climate change and, at the same time, contribute significantly to the world's greenhouse gas emissions*" (Kongsager, 2018, p. 10). Although research concerned with these linking strategies is now a recognised field of inquiry within climate change science, there is a need for more ground-based empirical evidence that can support our understanding of what synergies and trade-offs may exist between adaptation and mitigation.

3.3. Conceptualisation of adaptation

The concept of adaptation had to make a great comeback to the mainstream scientific discourse because, in the early 1990s, the idea of adaptation was seen as a dead-end or an excuse for the large greenhouse gas emitters to maintain the status quo rather than getting involved in mitigation efforts (Pielke *et al.*, 2007; Vardy *et al.*, 2017). Pielke (2007) finds three reasons why adaptation cannot be undervalued anymore in the fight against climate change. Firstly, decarbonisation is the driving force in mitigation policy, but the timescale for both implementation and realisation of effects is so long that it makes adaptation inevitable in the short term. Secondly, while mitigation takes very slow steps, vulnerability is increasing in the most fragile populations and the most exposed sectors. In strong relation to the latter one, there are increasing voices from scholars calling for actions to strengthen the resilience of the most vulnerable populations, which is actually a call for adaptation. Bassett and Fogelman (2013) also came to the same conclusion when they looked at why the idea of adaptation has become popular again in the last few decades. On the one hand, the global community recognised by the second, but more like by the third IPCC Assessment Report, that some climate change had already happened, and would happen, so people had to start making adjustments in their lives. The second reason is rooted in the failure of global climate change mitigation efforts. The reluctance of the largest emitters to adopt ambitious emission reductions has made adaptation a scholar as well as a policy priority.

This has led to a huge growth both in the volume of and in the disciplines involved in the literature on climate change adaptation. This huge amount of literature is regularly and systematically reviewed by the IPCC, producing a unique, authoritative, and comprehensive assessment of scientific findings to offer policy recommendations in relation to mitigation and adaptation (IPCC, 2021). Since its inception in 1988, this UN body has produced six Assessment Reports (ARs) and many special and methodology reports, providing unique knowledge support for the United Nations Framework Convention on Climate Change. Publications encompassing the literature to be reviewed for the IPCC's fifth assessment report doubled between 2005 and 2010 compared to the number of studies reviewed in the fourth Assessment Report. Accordingly, there has been a clear progress on adaptation that is based on accumulated adaptation experience and increasing scientific inquiry across regions and sectors. However, these experiences rather relate to impacts, vulnerability, and planning, while limited focus has been given to the assessment of implementation and impacts of adaptation (IPCC, 2014b).

This incredible increase in the literature clearly demonstrates that the concept of adaptation has taken a full-time position on the climate change agenda. The journey to this position can be followed all the way through by looking at the various definitions of adaptation in the IPCC assessment reports. The first two IPCC reports did not pay too much detailed attention to adaptation. The first report was only about research and policies to reduce the effects of climate change and did not address adaptation. Even though the second report, which came out in 1996, talked about adaptation, it mostly focused on technical solutions for adaptation (Bassett and Fogelman, 2013).

Since the third Assessment Report, the focus has shifted towards developing and researching the concepts of adaptive capacity, resilience, and vulnerability. Reflecting on that, Dupuis and Biesborek (2013) distinguish two authoritative discourses in the interpretation of climate change adaptation. The discourse titled "*Climate Change Adaptation*" understands adaptation as a process of changes undertaken to address effects induced by anthropogenic climate change effects. In that understanding, vulnerability is caused mainly by climate change impacts. The other discourse, titled "*Vulnerability Centered Adaptation perspective*" takes into account that, in addition to climatic influences, a number of other factors, such as social, political, economic, and other environmental factors, determine vulnerability. In Basset and Fogelman's interpretation, this opposition is based on the natural hazard school and its political economic critique (Bassett and Fogelman, 2013). The natural hazard school focuses on the unfavourable consequences of natural and social system interactions, the effects of which are aimed at being mitigated through incidental or intentional adaptation actions. This approach stresses the enhancement of adaptive capacity by highlighting biophysical risks and technical solutions to minimise losses and preserve the characteristics of the existing system. In that framework, adaptive choices are often seen and explained as rational decisions. However, political economists emphasise the causal relationships between political economic processes and vulnerability when highlighting the multiple sources of vulnerability. They argue that the adaptive choices of people exposed to risks are often driven by constraints rather than the results of cost-benefit analysis (Bassett and Fogelman, 2013).

Both the "*Vulnerability Centered Adoption perspective*" or the political economic critique of natural hazard schools claim that there are many other factors (environmental, social, economic, etc.) that can increase vulnerability and provoke adaptation action to reduce vulnerability. This viewpoint frequently includes concerns about resources, poverty, insecurity, equity, justice, and fairness. The emergence of vulnerability represented a significant shift in perspective, as previous assessment reports viewed adaptation as a reactive intervention to the effects of climate change, particularly at the local level (Moore, 2010; Bassett and Fogelman, 2013).

In the third IPCC report, authors gave a broader definition of adaptation, which led to studying adaptation as a combination of adjustment and transformation:

> "*Adaptation refers to adjustments in ecological, social, or economic systems in response to actual or expected climatic stimuli and their effects or impacts. It refers to changes in processes, practices, and structures to moderate potential damages or to benefit from opportunities associated with climate change.*'' (Smit and Pilifosova, 2001, p. 889)

This shift in thinking also started to change the perspective on how adaptation was considered in the global policy agenda. Thanks to Smit et al. (1999), a theoretical framework was proposed that helped adaptation take on an abstract and decontextualised understanding, allowing it to take its role alongside mitigation in global policy making stage. However, climate stimuli were still disproportionately overemphasised, owing to political conflicts or economic inequalities that further reinforced the tendency to highlight technocratic approaches to adaptation challenges (Bassett and Fogelman, 2013).

In the fourth report, there is a coherent review of social and economic factors that may lead to adaptive inequalities. It continues to further improve the understanding of multiple stresses and various processes that may pose barriers to successful adaptation. However, the definition of adaptation did not move on from the core view of the role of adaptation:

> "*Adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities. Various types of adaptation can be distinguished, including anticipatory, autonomous and planned adaptation*" (IPCC, 2007, p. 869).

Bassett and Fogelman (2013) claim that the definition limits the scope of adaptation by calling it only adjustments instead of transformation. Critical voices in climate change science stated that adaptation studies should first focus on social and political conditions because they are the primary roots of vulnerability, not environmental hazards, and climate change-induced impacts.

The fifth report in 2014 produced a strong shift from that perspective by claiming that "*differences in vulnerability and exposure arise from nonclimatic factors and from multidimensional inequalities often produced by uneven development processes"* (IPCC, 2014b, p. 6). In that sense, adaptations can be either incremental, "*where the central aim is to maintain the essence and integrity of a system or process at a given scale*" or transformative "*that changes the fundamental attributes of a system in response to climate and its effects*" (IPCC, 2014a, p. 1758). Recently, scientific attention has been given mostly to incremental adaptation practices that is based on the fact that adaptation happens mostly autonomously at the level of individual farmers (Vermeulen et al. 2013). However, there is evidence showing that there might be a rate of change or a level of risk that poses such challenge when previous experience or knowledge might become insufficient. In situations like this, scientific consensus claims that adaptations will need to be transformational (Vermeulen et al. 2018; Panda 2018; Wreford, Ignaciuk, and Gruère 2017). Such changes, however, are challenging to bring about because of constraint-full environments. Transformational adaptations may *"include both the inability of natural systems to adapt to the rate and magnitude of climate change, as well* *as technological, financial, cognitive and behavioural, and social and cultural constraints"* (Adger *et al.*, 2007, p. 719). This classification was further developed by Basset and Fogelman (2013) based on a content analysis of climate change literature. Accordingly, three categories were defined: adjustment, reformist, and transformative adaptations. *Adjustment adaptation* frames climate change impacts as the primary source of vulnerability without efforts to understand other causes possibly factoring in. Accordingly, the main aim of this type of adaptation is to make the necessary adjustments to maintain the equilibrium state. On the contrary, the objective of *transformative adaptation* is to comprehend the multiscale political-economic, social, and environmental factors that lead to vulnerability and to recommend radical changes to overcome structural barriers. *Reformist adaptation* is positioned somewhere halfway between adjustment and transformative adaptation. The main characteristic of this type of adaptation is that it recognises vulnerability as a multiple-sourced condition but seeks solutions to reduce it within the boundaries of the given system (Bassett and Fogelman, 2013).

The point of departure in the recently published sixth IPCC Assessment Report is that synergies, trade-offs and efficiency increase are possible between adaptation and mitigation actions, especially if these joint works between these two key concepts take into account Sustainable Development Goals as well (Ara Begum *et al.*, 2022). In conclusion to this section, we can quote Klepp and Chavez-Rodriguez's (2018, p. 22) statement: "*In synthesis, it seems to us that climate change adaptation can be seen as a magnifier – a contemporary phenomenon that, also in the form of a biopolitical tool, is connected closely to the most powerful narratives of our time*."

3.4. Theoretical underpinnings of climate-adaptive behaviour

The previous chapters have reviewed those climate change impacts that are most likely to affect viticulture and winemaking, both globally and domestically. It has also been described what the most common adaptation practices are that grape growers have been using to try to adjust their farming systems in order to mitigate or exploit climate change impacts. This sub-chapter provides an overview of the theoretical foundations of behaviour-centered adaptation research.

Although some argue that adaptation research is an under-theorised field of inquiry (See Chapter 3), there have been many analytical approaches developed and applied to illuminate barriers that may hinder or block adaptations and those opportunities that may create enabling conditions for adaptation (Davidson, 2016; Klepp and Chavez-Rodriguez, 2018). Either barriers, limits or opportunities, these include factors and processes that fundamentally determine the conditions for adaptation actions (Klein et al. 2014). In that perspective, there has been a growing recognition that adaptation studies need to focus on the human dimension of climate change. According to Goldman et al. (2018, p. 3) "*Human dimensions of climate change" broadly refers to human capacities, exposure, and response to climate change*". This insight stems from the fact that although climate change literature has been booming, it has long ignored the differences in individuals' thinking about, perceiving, and reacting to climate change risks. In other words, as Gifford, Kormos and McIntyre (2011, p. 2) state: "*Human behavior is changing the climate, and humans are, in turn, impacted by climate change".*

For quite a long time, however, when it comes to the behaviour of individuals, the dominant and influential view has been that individuals follow rationally expected, optimalisation-led and profit-maximising behaviour, also known as Homo economicus or homo agricola economicus in agricultural context (Levine, Chan and Satterfield, 2015; Dessart, Barreiro-Hurlé and Van Bavel, 2019). This assumes a situation in which individuals have stable references and have all the information needed to make a rational and profit maximizing decisions (Levine, Chan and Satterfield, 2015).

This theoretical assumption has influenced climate change scenario research. While simulated climate change scenarios can be helpful for identifying potential stress points and vulnerabilities in biophysical agro-ecological systems, these rationally calibrated assessments frequently ignore the fact that farmers are proactive agents who respond to climate variability, both in the short and long term. Even though it is hard to measure, this factor must be a key part of understanding the relationship between changes in the climate and the results of farming (Crane, Roncoli and Hoogenboom, 2011). Farmers are frequently misrepresented in these integrated assessment models because it is assumed that they act in accordance with rational decision theory. This implies that crucial elements like potential climate change effects, low-carbon innovation, knowledge, or disruptive changes in personal or professional life are either grossly understated or not taken into account at all (Stern, 2016). Similar arguments are made by Brown et al. (2017), who argue that even the most complex conceptualisations cannot fully replace real-world circumstances. As a result, an agent-based, multi-agent, microsimulation model approaches will unlikely be able to depict human behaviour completely and comprehensively.

The canonical theory of rational theory has been exposed to a large amount of empirical evidence, and although it still has considerable influence, many other psychologically more realistic interpretations of economic behaviour are available today (Ajzen, 1991; Kahneman and Tversky, 2013; Thaler, 2018). These theoretical cornerstones offer alternatives to the theory of rational behaviour (Starmer, 2011). Thanks to these influential empirical and theoretical works, it is widely known that "*people are primarily driven not by a clear-headed, time-and-energy intensive optimization of abstract utiles, but rather by rapid, less cerebrally-taxing, emotionally- and viscerally- felt responses to a narrow band of environmental complexity*" (Levine, Chan and Satterfield, 2015, p. 23). They also claim that framing and context, schemas and heuristics have been found to be relevant driving elements in people's decision making, especially if these are risk-related decisions.

In agricultural context, this behavioural approach builds on the difference between *performative* and *planning* aspects of agricultural activity. Although agriculture demands extensive planning—including organising labour, equipment, seeds, inputs, and capital—there are numerous opportunities and frequently a need for improvisation and know-how in carrying out ad-hoc actions and deviating from plans (Crane, Roncoli and Hoogenboom, 2011). Performative aspect of agriculture acknowledges and considers the fact that farmers are not just individuals who carry out specific, pre-planned technical tasks on their farms. Farmers carry out their roles as group and social network members. Consequently, the social spaces and processes in which technical agricultural practices are embedded influence the way in which they perform (Crane, Roncoli and Hoogenboom, 2011). In addition the impacts of extreme weather events on decisions is another typical example where behavioural aspects can help to understand farmers' decision-making.

Among the many areas of application, climate change research has been late in finding and applying these behavioural approaches that offer more than explaining farmers' adaptation decisions through expected utility theory. This scholarship first attempted to link perception of change and risk behaviour, then incorporated evidence on individuals' perceptions of self-efficacy and belief (Grothmann and Patt, 2005; Burch and Robinson, 2007; Clayton *et al.*, 2015). Despite this, adaptation case studies still do not make full use of behavioural theories, probably due to the context-specific embeddedness of the studies and the mechanisms of multivariable effects. The result of this is that farmers often continue to be portrayed as actors following the guidance of rationality in adaptation research (Bassett and Fogelman, 2013). Findlater et al. (2019) reflect further on this when they argue that the assumption of an economically rational theory in decision making may lead to analytical challenges in understanding of farmers' climate adaptive behaviour due to the complex, uncertain, and long-term risks posed by climate change. This is particularly true if we consider that climate change risks are not the only risks farmers face in their activities: farmers manage their activities within "*landscapes of multicausal risks*" (Findlater, Satterfield and Kandlikar, 2019, p. 2).

Risks in agriculture are numerous and diverse and can arise from various sources, such as uncertainties, hazards, and unforeseen events (OECD, 2009). Hardaker et al. (2004) identified five types of risks in agricultural production. These are production risk, market risk, institutional risk, financial risk, and personal risk. The unpredictability of the weather and the unpredictability of the performance of crops or livestock constitute *production risks*. Market risk stems from changes in sale prices, input prices, or exchange rates. *Institutional risks* are generated by government related decisions such as income-tax provisions, regulations, trade agreements, or development programmes. *Personal risks* are related to major life events that might influence the profitability and sustainability of the farm business. Business or financial risks describe the uncertainty that that influence profitability of the activity (Hardaker *et al.*, 2004). Regarding climate change associated risks, they all belong to production risks based on the classification of Hardaker et al. (2004)'s classification (Komarek, De Pinto and Smith, 2020). Research on risk-management strategies distinguishes two types of strategies: on-farm strategies and strategies to share risk with others. The former includes decision to aim to collect information, avoid or reduce exposure, apply less risky technology, increase diversification, and enhance flexibility. The latter constitutes farm financing through credits, insurance, share contracts, price pooling, forward contracting, and trading in commodity derivatives (Hardaker *et al.*, 2004, pp. 222–240).

Farmers' decisions are inevitably influenced by the perception of these risks. In agricultural economics, the conventional and dominant view on risks, including climate change induced risks, premise rational risk attitude and behaviour. This universally adopted view places maximisation of profit and utility in a central position in farmers' decision-making process. This assumption describes risks as quantifiable concepts, measured by quantitative techniques (Hardaker *et al.*, 2004). Several empirical findings, however, have challenged this understanding, demonstrating that human risk behaviour is performed, particularly when faced with uncertainty in a complex landscape of risks (Hardaker and Lien, 2010). Continuing this line of thinking, the combination of two disciplines has given a new stimulus to adaptation research. On the one hand, agricultural adoption research concentrates on factors that correlate with farmers' technology uptake. On the other hand, behavioural economics aims to explain, model, and theorise human behaviour that is somehow deviates from standard economic theories (Streletskaya *et al.*, 2020). Behavioural economics has many elements that relate to climate change studies. Among these, the most relevant point is that the process of decision making in the face of risk or under uncertainty is heavily influenced by values, cognitive biases, mental shortcuts, emotions, social experiences, social relationships, norms, peer validation, learning, and other contextual factors (OECD, 2012; Clayton *et al.*, 2015; Brown *et al.*, 2017; Sok *et al.*, 2021).

This list demonstrates the diversity of a wide range of aspects, factors, and circumstances that the behaviour-centred climate change adaptation studies need to take into account if they intend to overcome the assumptions of rationally expected, optimalisation-led and profit-maximising behaviour. The following chapter provides an overview of the most frequently cited analytical approaches used to understand the complexity of decision-making

CHAPTER 4: ANALYTICAL FRAMEWORK

There are several individual-based approaches that have the capacity to explore and understand the complexity of factors that affect individuals' decision making and have been tested in an agricultural context. This will be followed by an overview of methods frequently used for vulnerability-centered adaptation research in the viticulture and wine sector

4.1. Review of analytical approaches relevant for climate change adaptation in agriculture

There are several individual-based approaches that have the capacity to provide insights into the factors listed in the previous chapter. These approaches stand on a common ground, claiming that risk perception has a fundamental role in adaptation decision making. This has led to inquiries focusing on how people understand, perceive, communicate, and respond to climate change risks (Granderson, 2014). In addition, Mortreux and Barnett (2017) also point out that the often-recognised gap between adaptive capacity and actual adaptation action can adequately be bridged by psycho-social or biophysical triggers. In the recent past, these approaches have been dominating climate change adaptation studies both conceptually and methodologically. However, this high level of interest has not led to comprehensive theory development (Bassett and Fogelman, 2013; Clayton *et al.*, 2015; Davidson, 2016).

The rest of this section reviews these analytical approaches that have been dominant in individual-based studies on perceptual and socio-cognitive processes of decision making. These approaches stand on different theoretical assumptions and highlight various drivers for agricultural adaptation. These models usually aim to explain pro-environmental behaviour because adoption of climate-friendly measures is often seen by farmers as additional element to environmental measures (Gifford, Kormos and McIntyre, 2011; Wreford, Ignaciuk and Gruère, 2017). Therefore, studying pro-environmental behaviour is seen as being in line with the theoretical and analytical approaches applied in climate change adaptation research. The list of reviewed theories and methods is as follow:

- Ajzen’s theory of planned behaviour
- Stern’s value-belief-norm theory
- Grothmann and Patt’s Model of Private Proactive Adaptation to Climate Change
- Elicitation risk perception by mental modelling exercises

According to Ajzen’s (2020) estimation, there have been more than 2000 empirical studies that relied on the theory of planned behaviour (TPB) (Ajzen, 1991). In that sense, the theory of planned behaviour assumes behavioural intention is determined by individuals’ attitudes toward behaviour (*the person’s belief in relation to the likely outcomes of the behaviour*), individuals’ subjective norms (*the person’s belief about social pressure or norms*) and individuals’ perceived behavioural control (*the person’s accessible control beliefs*). The most frequently used procedure to measure these beliefs is based on standardised questionnaire-based data collection, and multivariate-analysis. (Ajzen, 1991, 2020) Although Ajzen’s approach has been dominant in behaviour research across many disciplines, it has been criticised for its exclusive focus on rational reasoning and lack of inclusion of variables such as personality traits or emotions (Sniehotta, Presseau and Araújo-Soares, 2014).

Another theoretical framework that has a pivotal impact on climate change adaptation studies is the value-belief-norm (VBN) theory of environmentalism, proposed by Stern (2000). In his seminal work, Stern offers a conceptual framework to identify and understand causal variables influencing individuals’ pro-environmental behaviour. The approach sets up a causal chain with five interacting variables. Stern’s approach states that individuals’ general predispositions to pro-environmental action are dependent on personal moral norms. These norms become activated when there is a belief that certain environmental conditions or changes might endanger something that the individual values. Individuals’ personal values (e.g. biospheric, altruist, egoistic) and ecological worldview influence the beliefs about endangering consequences of environmental changes of interest and the perception of their self-ability to do something in favour of reducing environmental threats. Having these beliefs may lead to actions aiming to reduce the potential threats. At the end of the causal chain, personal norms are activated, and a sense of obligation leads to taking pro-environmental actions (Stern, 2000).

Both of the two authors’ approaches have been applied in studies with a focus on the correlative relationship between climate change and agricultural adaptation and insights into the determinants of actions (Arbuckle, Morton and Hobbs, 2015; Sanderson and

Curtis, 2016). The main difference between the two models is that theory of planned behaviour offers a self-focused approach to explaining universal behaviour without assessing moral norms, while VBN looks at the psychological causal processes with a focus on self-interest, altruism, and moral norms by incorporating personal values into the concept (Kaiser, Hübner and Bogner, 2005; Zhang *et al.*, 2020) Stern's model acknowledges the complexity of the relationship between values and environmental behaviour, but similarly to Ajzen's approach, it does not reflect how habits, emotions, and experience when explaining what affects behaviour.

This line of thought was further developed by Grothmann and Patt (2005). They proposed a model that not only addresses two key cognitive processes: climate change risk appraisal and adaptation appraisal. However, they also included socio-environmental context factors. The Model of Private Proactive Adaptation to Climate Change (MPPACC) has gained widespread popularity among researchers working on adaptation studies, because it offers a flexible framework to understand why people adopt adaptive behaviour. The model also offers a conceptual solution to tackle the most important bottlenecks in adaptation. These bottlenecks are climate change risk appraisal and perceived adaptive capacity. Risk appraisal is the result of the perceived probability and severity of any climate change-associated threat. An appraisal refers to the process that leads to comparing what is wanted to happen (nominal value) to what is expected to happen (actual value) in a natural-hazard context. The larger the difference, the more motivation will be there for adaptation. Perceived adaptive capacity is another cognitive factor that decides whether risk perception leads to adaptation intention and then adaptation action.

It is made up of three elements: perceived adaptation efficacy, perceived self-efficacy, and perceived adaptation costs. Perceived adaptation efficacy refers to beliefs in adaptation actions ("*Will it work or not?*"). Perceived self-efficacy refers to how the individual perceives their own ability to perform adaptive actions (*"Am I able to do that?"*), perceived adaptation costs can be any cost (money, time, etc.) that is required to perform adaptation actions. The model identifies two general outcomes: adaptation and avoidant maladaptation. The second group is made up of attitudes, such as fatalism, denial, and wishful thinking (Grothmann and Patt, 2005).

Cognitive biases and heuristics are in negative correlation with risk perception appraisal and adaptation appraisal. These variables refer to over-, under-, or misestimation of risk and capacity (e.g. optimistic bias, availability heuristics) that directly lead to wrong adaptation or avoidant maladaptation. Social discourse on climate change risks and adaptation refers to anything heard on these topics from the broad societal, institutional, and cultural contexts individuals live and work in. Adaptation incentives (e.g. tax reductions, regulations, etc.) can positively influence adaptation intentions. The model also assumes that there must be a minimum level of fear or anxiety that prompts people to think about risks or benefits when facing uncertainty. After that, the dynamics of the model are based on positive and negative correlations. Risk appraisal and perceived adaptive capacity are positively correlated with adaptation intention. On the contrary, avoidance is negatively correlated to perceived adaptive capacity and positively correlated to risk appraisal. This means that avoidance is a realistic outcome if risks are known but adaptation options are not (Grothmann and Patt, 2005).

Another novel analytical approach is based on mental modelling for elucidating, eliciting, and presenting in a form of network the landscape of risks. This technique reflects individuals' internal mental models, which include conceptual representations used to understand, interact with, and filter stimuli from the external world (Jones et al. 2011). Mental models are simplified representations of the external world that are particularly useful in complex or uncertain decision-making context (Gray, Zanre and Gray, 2014). The techniques used to capture, analyse, and visualise individuals' mental models are called elicitation techniques (Harper and Dorton, 2019). Recently, there have been several attempts to adopt these elicitation techniques in agriculture to understand risk assessment and management (Jones et al. 2011; Winsen et al. 2013; Akimowicz, Cummings, and Landman 2016; Wood et al. 2012).

In the context of climate change risk perception, one of the most recently tested analytical approaches was introduced by Findlater et al. (2019). The authors' aim was to understand and model farmers' naturalistic (or, in other words, messy) climate-adaptive behaviour by analysing their multifaceted in situ risk perceptions and responses. Their research reaffirmed that climate related risks are rarely the sole drivers in farmers' risk-based decisions, but there are many other risks (economic, political, labour, crop, technological, societal, etc.) at play in parallel. Farmers, according to Findlater et al. (2019) respond to negative weather and climate stresses through a series of loosely coordinated and simultaneous responses with their own frame of reference that is influenced by various endogenous and exogenous factors, including information, knowledge, emotions, and so on. The authors claim that farmers cannot optimise under such circumstances; therefore, they employ two nonoptimizing strategies. *Cognitive thresholds* are such trade-offs made imprecisely and roughly with the aim to achieving a "*good enough*" (or "*less is more*") outcome in a decision-making situation. These rough thresholds are used instead of precisely calculated costs and benefits. They claim that thresholds are "*primarily stored in memory and shaped by social and experiential learning, updated iteratively with the accumulation of experience, the evolution of norms, and the cautious adoption of expert advice*" (Findlater, Satterfield and Kandlikar, 2019, p. 12). The other strategy is called "h*azy hedging*. It is the employment of simultaneous risk management measures that are not always coordinated and may undercut some of the advantages of the others. These concurrent strategies are produced by parallel decision-making procedures across several risk domains. Hazy hedging reflects farmers' varying risk averse attitudes, as it describes farmers' decision-making process from the perspective of competing or complementing responses (Findlater, Satterfield and Kandlikar, 2019).

4.2. Analytical approaches for studying adaptation in viticulture

There have been various analytical approaches identified for studying adaptation procedures in viticulture. The widely recognized study by Holland and Smit (2010) offers the most evident categorisation of these approaches. They distinguished four streams of studies. Figure 2 provides an overview of these four research areas. The first three areas are based on biophysical approaches. (1) Studies looking at the implications of climate variability and warming on wine quality attempt to address changes in phenology and grape composition (Mira de Orduña, 2010; van Leeuwen and Darriet, 2016). (2) The second stream of research constitutes growth modelling that assesses the links between grapevine phenology, yields and climate change impacts. These research efforts are based on grape plants' physiological processes and aim to measure climate impacts on yields by linking historical climate patterns with projected climate changes (Holland and Smit, 2010; Mosedale *et al.*, 2016). (3) The third type of research examines vineyard suitability under future climate conditions. This approach takes bioclimatic indices and existing climate models to geographically map out future distributions of viticulture. This sort of assessment has a key role in understanding potential changes in the suitability of wine regions. These three research areas produce essential knowledge for maintaining the continuous optimisation of viticultural and oenological processes in specific wine regions and industries. (4) The fourth research direction identified by Holland and Smit (2010) seeks to determine how this occurs in practice, or in other words, how vine farming and wine industry adapts to climate change impacts. This line of research is based on the widely accepted view that adaptation can mitigate the effects of climate change. The capacity for adaptation must therefore be explored, assessed, and understood in order to reduce vine growing systems' vulnerability to climate change. However, Holland and Smit (2010) point out that these vulnerability studies frequently involve scenario-based impact analyses that do not place enough emphasis on the fact that these growing systems are being operated by people living and working in various socio-economic contexts. Mosedela et al. (2016) reach a similar conclusion, pointing out that although there has been a growing interest in the inclusion of socioeconomic variables, the majority of adaptation research continues to take one of the aforementioned biophysical approach. In this regard, the authors call for more primary research evidence on the wider risk context and factors that affect adaptive decision making (Mosedale *et al.*, 2016). This remark is supported by the review from Sacchelli et al. (2016): they indicate that although interest in adaptation methods has increased in recent years, this interest has primarily led to numerous research efforts concerned with the negative effects of climatic fluctuation and water scarcity, but with limited attention given to risk perception and risk assessment of those working in the wine sector.

Figure 2 Research foci in the field of viticulture and the wine industry in the context of climate change

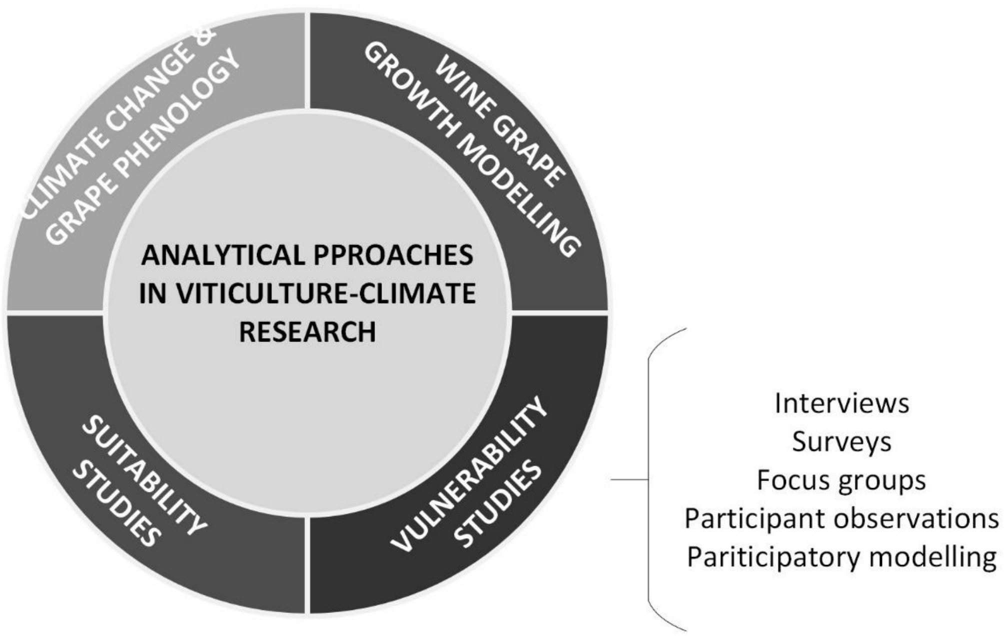


Figure was adapted from Holland, Tara, and Barry Smit. 2010. "Climate Change and the Wine Industry: Current Research Themes and New Directions." Journal of Wine Research 21 (2): 125–36.

These claims show the need for research on adaptation behaviour that collects evidence from practitioners not just about what climate change impacts they perceive and what adaptation practices they take but also tries to capture that multiple exposures and non-climatic risks that affect adaptation decisions (Belliveau, Smit and Bradshaw, 2006). These climatic and non-climatic risks, together with circumstances defined by individual farmers, locations, and farming systems, form that dynamically changing environment that is supposed to be the subject of climate change vulnerability studies (Turner *et al.*, 2003; Adger, 2006).

Lereboullet et al, (2013) expanded on this by highlighting the importance of a socio-ecological perspective in adaptation research on vine grape production. The socio-ecological approach offers a conceptual framework to address the complexity of biophysical and socio-economic factors, including human agency as well, that define agricultural systems and the way how they adapt to climate change impacts. In order to explore, understand and present these factors as interconnected ideas that affect farmers' decision-making, adaptation studies are encouraged to take this holistic perspective (Eakin and Patt, 2011). The holistic approach allows researchers to encompass all elements that have a function on maintaining agricultural systems. From a conceptual point of view, this socio-ecological approach with a strong emphasis on climatic, biophysical, and socio-economic factors and interactions also leads to the realisation of that complex landscape of risks that might fuel uncertainty in farmers' decision making (Winsen *et al.*, 2013; Findlater, Satterfield and Kandlikar, 2019). This is especially important in viticultural and oenological research, as the concept of terroir already implies an understanding of the complex interactions between physical, biological, and human factors that give a wine region its distinctive character (Van Leeuwen and Seguin, 2006).

Regarding the analytical approaches applied in vulnerability centered adaptation studies in viticulture and wine sectors, the literature provides examples of the application of a wide range of methods (See Figure 2!). Interviews and questionnaires are the two methods most frequently used. Interviewing is an efficient, resourceful, and flexible method to collect information from a wide range of local actors to explore the various aspects of adaptation in a given context (Lereboullet, Beltrando and Bardsley, 2013; Holland and Smit, 2014; Neethling, Petitjean and Quénol, 2017). Flexibility may be the most valuable aspect of interviews, particularly semi- or unstructured interviews, as these allow researchers to address the complexity that may surround respondents' beliefs about climate change impacts (Kuehne, 2014).

Interviews can take place in a drive-and-talk or walk-and-talk format (Bardsley, Palazzo and Pütz, 2018). This is not just a exciting renewal of the conventional interview format, but an innovative method for assessing people's environmental attitudes and knowledge in their own settings (Evans and Jones, 2011). There are numerous other techniques, such as focus groups, participatory modelling and participant observations; however, the most common approach is to combine these techniques within a mixed research design (Belliveau, Smit and Bradshaw, 2006; Sacchelli *et al.*, 2017).

Statistical surveying is the other most commonly used method to gather stakeholders' views on climate change adaptation. The reason is probably that surveys and data gathered through questionnaires allow one to statistically link participants' perceptions of climate change with their past behaviour and future adaptation plans (Goulet and Morlat, 2011; Pickering *et al.*, 2015; Jobin-Poirier, Pickering and Plummer, 2019). Nevertheless, the method has been criticised in relation to the use of respondents' responses regarding future adaptation plans, as they rely on declarations and not observations, so it cannot be guaranteed whether adaptation plans will be implemented or not (Graveline and Grémont, 2021). However, this shortcoming is frequently outweighed by the method's benefits, such as the easy and quick way to reach a high number of research participants in a cost-effective framework (Duarte Alonso and O'Neill, 2011).

CHAPTER 5: RESEARCH METHODOLOGY

This chapter presents the *partially mixed sequential dominant research design* that defines the approach to data collecting and data analysing techniques for this research. The chapter is structured as follows. The research questions are presented first, followed by an explanation of the mixed research design and an outline of the qualitative and quantitative research segments, including the description of the data, participants, and analytical methods. The chapter ends with a summary of the factors that determine the validity of this research.

5.1. Research questions

Despite relying on Maxwell’s (2009) qualitative research design, this study also uses quantitative data and data analysis methods. As a result, this research follows a mixed research design that has implications for how the research questions are formulated. There are several ways to incorporate research questions into a mixed research design. A mixed-method research question, also known as a hybrid research question, specifically addresses the mix of the quantitative and qualitative components of the research. Alternately, we can create distinct questions for the quantitative and qualitative components. In this case, the purpose of the research determines how much emphasis is given to these components (Creswell, 2009). This research follows a *partially mixed sequential dominant status design.* In that type of research design, research phases follow each other sequentially, with greater emphasis given to either quantitative or qualitative methods. Given that this paper places a strong emphasis on qualitative research segment, I developed the research questions in accordance with the qualitative approach. In Maxwell's interpretation (2009), research questions serve two functions: they help keep the research on track and offer guidance for implementation. The formulation of research questions in qualitative research is the product of an interactive and inductive process of clarifying research objectives and a conceptual framework. This research is the culmination of a multiyear process that involved multiple seminar papers, conference presentations, journal (Király, 2017, 2018; Király, Giuseppina and Tóth, 2022) and book publications (Király, 2016), and project commitments (Biró *et al.*, 2017), all of which contributed to the formulation of the overarching research question and its sub questions.

This research aims to investigate vine growers' climate adaptive-behaviour, while eliciting farm-level risks and management decisions. This aim will be fulfilled by applying a *partially mixed sequential research design* with an emphasis on a mental modelling technique. Accordingly, the overarching research question is:

What does the risk landscape for Mátra vine growers look like from the perspective of climate change adaptation?

The main research question will be unfolded by three quantitative and three qualitative sub-questions. Quantitative questions are presented with research hypotheses.

Quantitative sub-research questions (SRQ):

SRQ1: Are there any differences between grape growing farmers and other farmers in how they perceive climate change?

Research hypothesis: vine farming is more vulnerable to the impacts of climate change; therefore, vine growers have stronger perception of climate change impacts than farmers working in other sectors.

SRQ2: Are there any differences between vine growers and farmers working in other sectors in how they adapt to climate change?

Research hypothesis: Vineyard farming is ahead of other sectors in the adaptation process due to the high vulnerability of the sector; therefore, vineyard farming is ahead of other sectors in the adaptation process.

SRQ3: Is there a statistically significant relationship between respondents' climate change perception and sensitivity and their adaptation behaviour?

Research hypothesis: Farmers who perceive more of the impacts of climate change and farmers who are more sensitive to climate change impacts are more likely to engage in adaptation actions

Qualitative sub-research questions:

SRQ4: What are the main characteristics of the multi-faceted landscape of risks in which vine growers operate?

SRQ5: What is interaction between risks associated with climate change and other non-climatic risks?

SRQ6: What characteristics define vine growers' adaptation behaviour in relation to the identified risk landscape?

5.2. Partially mixed sequential research design

This section outlines the rationale for the choice of mixed methodology. Although this study follows a qualitative research design, it also involves quantitative data and data analysis techniques, making it a mixed-method study. Mixed methods research design combines the collection, analysis, and interpretation of quantitative and qualitative data either in a single study or in a series of studies that examine the same issue (Creswell and Creswell, 2005). Leech and Onwuegbuzie (2009) developed a typology of mixed method research designs by crossing three decisive dimensions. In that sense, mixed research design can be partially or fully mixed, concurrent or sequential, and equal of or dominant status. Following this typology, this research is structured according to a *partially mixed sequential dominant status design.* In that type of research design, there are two or more research phases that follow each other sequentially, with greater emphasis given to either quantitative or qualitative methods. Creswell's (Creswell, 1994) argument, that mixed-methods research designs can also differ depending on how the methods are nested, can further help to define the research design of this research. In that sense, nesting means that the embedded method may seek answers to a different research question than the dominant method.

Creswell's embedded model (1994) is used to connect the two methods. In that sense, the quantitative segment plays a complementary role in the design, as it is used to outline an overall picture of Hungarian farmers' perceptions of climate change and adaptation behaviour based on a large sample of survey data. Following that, an individual-based approach will be used to conduct a risk elicitation exercise embedded in qualitative interviews with vine growers using a mental modelling approach. The findings from that method will play a significant role in answering the overarching research question. The results of each method, however, will be jointly interpreted in the final chapter.

The rationale for choosing a mixed method research design is fourfold. Firstly, several recent studies on similar topics prove that this type of research design is a well-established practice in adaptation research. For instance, Schattman et al. (2018) conducted research on farmers' and advisors' climate change and risk perceptions through a two-part longitudinal survey and semi-structured interviews. In the study by Niles et al. (2016) on intended and actual adoption of climate change practices, semi structured interviews with farmers were used a priori to contribute to the development of a questionnaire. Costellano and Moroney (Castellano and Moroney, 2018) applied a series of qualitative and quantitative techniques (including semi-structured interviews, unstructured interviews, participant observation, and surveys) to develop a model that explains how farmers' climate change beliefs influence their adaptation strategies. Similarly to climate change adaptation behaviour, conservation or pro-environmental behaviour can also be effectively studied by mixed methods if the research design mutually exploits the benefits of different methods (Floress *et al.*, 2018). Mixed method research has been emerging in agricultural economics as well. In the study of Belliveau et al. (2006)a bottom-up vulnerability approach was adopted. They aimed to understand the nature of vulnerability based on the experience of producer stakeholders in the Canadian wine growing region. In the first stage, semi-structured interviews and focus group meetings were conducted, for an in-depth understanding of the complex behaviours and motivations behind farmer decision-making. The second stage was about vulnerability projection based on data from climate change scenarios (Belliveau, Smit and Bradshaw, 2006). Akimowicz et al. (2018) compared econometrics and mental mapping as techniques used in two separate research studies that addressed farm investments. They highlighted that the flexibility and openness offered by mixed research methods help address farmers' ever-changing ecological, social, and political environments. The use of mixed method research designs considerably broadens the scope within which the researcher can better understand the research problem. This broadened scope is not just pivotal when the aim of the research is to examine the complexity and diversity of farmers' behaviour but also facilitates deeper understanding and interpretation of results (Feola *et al.*, 2015).

In that regard, it appeared that the most logical course of action was to move forward with a research design that relies on the generalisation that can be drawn from quantitative survey data while applying qualitative techniques to enhance and expand the depth of this study with a greater emphasis on context-bound research evidence. Moving from a broad to a narrower perspective in a mixed research design is a well-established logical structure (Creswell and Creswell, 2005). In that sense, this paper uses a cross-sectional sample of Hungarian farmers to offer broad and general insights into their attitudes and perceptions toward climate change and adaptation. Later, to focus this research and deepen our understanding of vine growers' adaptive behaviour, the research design was oriented toward qualitative techniques, such as interviews and mental model exercises. In that sense, the justification used by this paper for conducting mixed method research serves the "expansion". According to Green, Caracelli and Graham's often-cited typology, when expansion is the purpose, papers seek to "*expand the breadth and range of research by using different methods for different inquiry components*" (Greene, Caracelli and Graham, 1989, p. 259). In that regard, this study wants to explore the risk landscape for Mátra vine growers through individual cases embedded in the larger context of Hungarian agriculture.

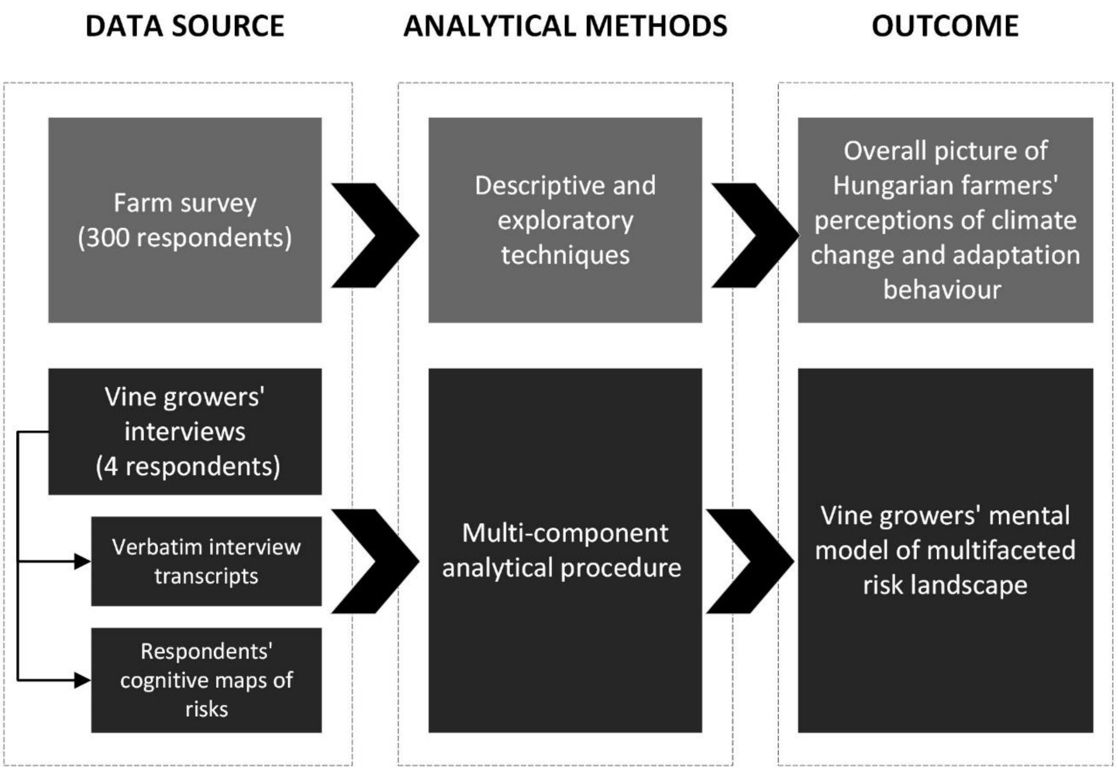
In addition, there should be some context-driven justification for choosing mixed method research in this paper. Some argue that we can picture purely quantitative and purely qualitative research as two ends of a continuum in which researchers can locate themselves and their works without taking an exclusionary stand on one or the other (Akimowicz et al. 2018). On such a continuum, the author of this paper positions himself and his work toward the qualitative endpoint by considering his prior research experience and expertise.

The circumstances in which the data for this study were gathered is also a crucial aspect and another justification for applying a mixed research design. Survey data was collected in the second half of 2017. Since then, this dataset was used in numerous publications (Király, Giuseppina, and Tóth 2022; Tóth and Király 2018) and it has always been intended to include this dataset in the work for this dissertation, given that the author had played a leading role in the development of the survey. Following that, the next step in the development of the research design for this research was to come up with a solution to integrate quantitative survey data and analysis, while still allowing the author to work in his comfort zone with qualitative techniques.

4.3. Analytical framework of this research

This sub-chapter has already outlined the most influential analytical approaches within climate-adaptive behaviour research. It has also been presented that this research is heavily built on the mental modelling approach. The study assesses the risk perception and risk management characteristics of grape growers in the context of climate change adaptation using the analytic approach of mental modelling. The review carried out to provide an analytical foundation for this research revealed that risk elicitation based on mental modelling approach has not yet been applied in the context of viticulture and oenology. Therefore, the application of this risk elicitation method is novel in both domestic and international viticulture and oenology climate change research. The analytical framework of this research is presented in detail in the next sections, and illustrated in Figure 3.

Figure 3 Analytical framework of the research



5.3. Methods and data

This section presents the methods, data and data analysing techniques of this research. As described above, this study follows a mixed method research, which involves the use of two methods:

1) a thematic cross-sectional farmer survey based on a sample of the Hungarian Farm Accountancy Data Network; and
2) a mental mapping exercise embedded in qualitative interviews with vine growers from the Mátra wine region.

The following two sub-sections outline and describe these two methods.

5.3.1. Farmer survey

The survey was based on the Hungarian Farm Accountancy Data Network (FADN). The Hungarian FADN is based on a sample of over 106 thousand commercial farms (including individual and commercial farms) with an economic size over the threshold value of 4000 EUR of Standard Output. It provides a unique opportunity to obtain continuous farm-level data on commercial farms in the form of a representative sample of 2100 farm holdings. This research is based on a subsample of this sample. This subsample included 300 farms whose selection followed a convenience sampling procedure. Convenience sampling procedure was followed because FADN staff members administered the survey as part of their regular activities, which was necessarily influenced by accessibility, geographical proximity, and the availability of potential respondents (Etikan, 2016). For operational and budgetary purposes, the number of responses was limited to 300. The survey was conducted in the second half of 2017.

Data gathering was conducted in a face-to-face set-up, meaning that survey administrators asked the questions and registered responses in person on a paper-based survey (Donohoe and Karadakis, 2014). Paper-based responses were later recorded on an online interface, which resulted in a standardised and structured database of responses. Survey administrators were staff members of domestic FADN partners whose responsibility was to collect data from farms selected to take part in regular and thematic FADN surveys. A copy of questionnaire is included in Appendix 1.

The design of the questionnaire followed the conceptual framework proposed by Woods et al. (2017). That framework aimed to assess the likelihood of adaptation by addressing farmers' climate change beliefs, climate change concerns, and perceived barriers to climate adaptation. In this adoption, however, the survey design differed in some respects from Woods' framework:

Climate change beliefs: climate change adaptation research has demonstrated that belief in climate change shapes adaptive behaviour.

Climate change perception: based on the decision theory literature on climate change, the most important factor influencing adaptation, beyond belief, is what farmers perceive from impacts associated with climate change.

Farmers' adaptation practices: by the very nature of their activity, farmers are under constant pressure to adapt. A key objective of the survey was to find out what responses they have made or plan to make to increase the climate resilience of their activities.

Adaptation barriers: there are numerous reasons why a farmer may be unable to implement adaptation practices they deem necessary. The survey inquired about barriers associated with economic capital, knowledge and skills, tendering prospects, the regulatory environment, technology, labour, and lack of cooperation.

Socio-economic and farm variables: the FADN background allowed to link survey responses with FADN data, which resulted in a unique joint-pool of variables on respondents' socio-demographic and farm characteristics.

Variables used in the analysis

The research used a selection of variables instead of the full list of variables (Table 1). This sub-section briefly outlines what types of variables were derived from the farmer survey. Dependent variables included adaptation variables. These adaptation variables included past adaptive actions and future intentional actions. These were all nominal variables. Independent variables included variables asking farmers about weather variability, warming, precipitation, profitability, and yield quality. Perceived climate change impacts were measured by asking farmers about impacts associated with climate change. These perception variables were measured on a five-point Likert scale. The climate change belief variable was an ordinal variable that ranged through four categories, from denial to acceptance.

The survey data was analysed using descriptive and exploratory techniques. These included descriptive statistics and conventional statistical tests. The latter includes non-parametric comparison and correlation tests.

Table 1 List of variables used in the quantitative segment of the research

Variables	**Attributes**
Farm type	Arable crops Fruits Grapes Vegetables Grazing livestock Confined livestock
Farm size	4 000 Euro - 25 000 Euro 25 000 Euro - 50 000 Euro 50 000 Euro - 100 000 Euro 100 000 Euro - 250 000 Euro 250 000 Euro =<
Climate change belief	I disagree with the theory of climate change, I don't think the climate is changing Climate change is caused by natural forces, human activity does not contribute to it Both human activity and natural cycles contribute to climate change Climate change is caused by human activities (e.g. burning fossil fuels)
Climate change perception and sensitivity	
Over the past 10 years, the weather has clearly become more variable Average temperatures have clearly risen over the past 10 years Annual rainfall has clearly decreased over the last 10 years The changing climate has reduced the profitability of my farm Because of the changing climate, the quality of my crops has deteriorated Due to changing climatic conditions, yields on my farm have decreased Changing climate has influenced my investment decisions over the past 10 years	Strongly disagree - 2- 3- 4- Strongly agree

(continued on next page)

Climate change impacts	
Persistent drought - Impacts of a changing climate	Not typical - 2 - 3 - 4 - Typical
Soil degradation by water- Impacts of a changing climate	
Soil degradation by wind- Impacts of a changing climate	
Waterlogging- Impacts of a changing climate	
Floods- Impacts of a changing climate	
Hail- Impacts of a changing climate	
Emergence of invasive plant species- Impacts of a changing climate	
Emergence of new pests- Impacts of a changing climate	
Emergence of new pathogens and diseases- Impacts of a changing climate	
Extremely warm- Impacts of a changing climate	
Spring frost- Impacts of a changing climate	
Adaptation practices	
Changing the sowing structure	Already applied - Planning to apply in the next 5-10 years - Not planning
Change in the timing of tillage tasks	
Application of deep ploughing	
Application of soil leaching	
Application of mulching	
Use of soil without rotation	
Change of production location	
Irrigation development	
New fertilisation practices	
Weather adapted crop protection	
Use of new varieties (plant and/or animal)	
Groundwater protection operations	
Prevent soil erosion operations	
Ice and frost protection improvements	
Ventilation or cooling improvements	
Weather adapted feeding	
Use of agrometeorological data, forecasts	
Priority insurance for weather damage	
Financial provisioning	

5.3.2. Mental modelling exercise embedded in qualitative interviews with vine growers from the Mátra wine region

The qualitative methodology of this research largely relies on a risk elicitation exercise embedded in a qualitative interview protocol conducted with vine growers. The protocol provided two types of data: respondents' cognitive maps of risks and interview transcripts. This section takes a deeper look into these types of data and the techniques applied for analysing them.

Mental modelling

The primary purpose of the interviews was to carry out a mental modelling exercise with the respondents. According to cognitive science and psychology, people develop and use internal representations of external reality, called mental models. These dynamic cognitive structures support individuals' reasoning, the construction of cause-and-effect dynamics, and learning and knowledge creation. In other words, people use their mental models to understand and interact with the external world (Jones et al. 2011). According to Wood (Wood *et al.*, 2009), deeply embedded risks and value beliefs can also be better understood and addressed using mental modelling exercise. This can increase stakeholder involvement in strategic planning. The challenge is that these models are internally constructed, making them difficult to inspect or measure. Various methods involving various domains have been proposed and applied to elicit, elucidate, and present individuals' internal representations of external reality (Harper and Dorton, 2019). The most crucial thing to understand about these methods is that they can never make an exact reproduction of the mental models (See Figure 4!). This is because, on the one hand, these models are already simplified representations of reality due to individuals' cognitive limitations. On the other hand, these models are so-called working models as they are in constant formulation in response to stimuli and experiences from the external world (Jones et al. 2011).

Figure 4 Simplified demonstrations of differences between reality, mental models and representation of mental models inspired by Winsen et al. (2013)

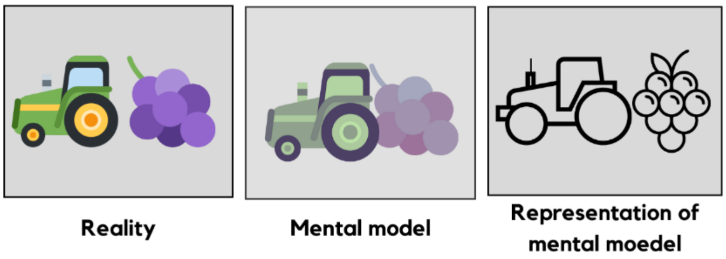


Figure was adapted from and inspired by Winsen, Frankwin van, Yann de Mey, Ludwig Lauwers, Steven Van Passel, Mark Vancauteren, and Erwin Wauters. 2013. "Cognitive Mapping: A Method to Elucidate and Present Farmers' Risk Perception." Agricultural Systems 122: 42–52.

Mental modelling has been gradually integrated into the decision-making and risk assessment methodological toolbox. Kolkman et al. (2005) used mental model mapping to visualise the application of knowledge, analyse challenges in the problem-solving process, and facilitate information transfer and communication. Winsen et al. (2013) highlight in their risk-based study that cognitive maps are not just a good communication tool; but they are also able to capture the complexity and context of perceived risks. Elsawah et al. (2013) applied cognitive mapping as to elicit, visualise and analyse how stakeholders perceive complex issues in natural resource management. Prager and Curfs (2016) applied mental models to illustrate the diverse specifics of soil degradation, highlighting the potential of this approach in exploring the underlying perceptions and beliefs of stakeholders. Hulst et al. (2020) utilized mental model approach to capture knowledge system of ecological scientists and farmers about agroecology. In the context of farmers' climate change adaptation, this strategy appears to be a particularly novel development in the literature. The mental model approach that Findlater et al. (2019) or Winsen (2013) applied seeks to enhance what is known about farmers' climate-adaptive behaviour considering their multifaceted nature of risk-based environment.

Mental models can be captured via either direct or indirect elicitation, depending on whether the researcher can interact with the research subjects or not. This study applied the combination of two frequently used direct methods known as *card sorting and cognitive mapping* (Harper and Dorton, 2019). In card sorting technique, cards are used to represent concepts about the domain of interest and to serve to establish a mutual understanding of research problems (Eden, 2004). Cards are generated either by the participant or the researcher and help the interviewer ask further questions for clarifications. Cognitive maps take this technique further because they collect individuals' cognitions about a specific topic and incorporate them into a diagram of concepts and their relations. This is seen as a visual representation of mental models. In that sense, "a *cognitive map can be thought of as a concept map that reflects mental processing, which is comprised of collected information and a series of cognitive abstractions by which individuals filter, code, store, refine and recall information about physical phenomena and experiences*" (Gray, Zanre and Gray, 2014, p. 30).

In this study, cognitive mapping and card sorting will be combined into an in-depth interview protocol based on inspirations gained from Findlater, Satterfield and Kandlikar (2019), Akimowicz, Cummings, and Landman (2016) Winsen et al. (2013). The process comprises the following protocol. As a first step, participants are asked to start talking about the risks they face in their day-to-day management. Each risk is documented on a card (e.g. on standard sticky notes) and placed on a white board. This exercise is practically a one-man brainstorming session facilitated by the interviewer. In the last step, participants are asked to group all the "risk-card" into two groups: manageable and unmanageable risks. In that sense, a cognitive map is created around two fundamental concepts: manageable and unmanageable risks. This exercise not only forms the basis for creating the cognitive map but also allows participants to elicit their own mental models of risks, highlighting relationships, causations, management, and adaptation responses. As a final step, a talk through' exercise comes next leading to the collaborative creation of a map by positioning and linking each card as the participant would like.

However, based on the limited applications of mental modelling, this approach clearly appears to enhance understanding of the complexity of decision-making in various contexts in comparison to conventional data collection techniques. From participants' perspectives, there are many advantages to co-creating mapping exercise compared to conventional risk elicitation methods. It is flexible and easy-to-adopt in farmer interview situations: farmers can easily understand and respond to the exercise thanks to its simple and intuitive nature (Winsen *et al.,* 2013). Mental mapping is a participatory research approach where both the researcher and participants are involved in the mapping exercise. This co-creating setting of the technique allows participants to constantly reflect upon and engage with their mental maps, ensuring that the final product reflects their views as much as possible (van Hulst *et al.*, 2020). From an analytical point of view, it is argued that the maps help structure the analysis process from the very first stage of data processing. The concepts captured throughout the mapping exercise can be transformed into a preliminary set of codes at the beginning of the thematic analysis of the interview transcripts.

Interview settings and sampling

Interviews were conducted between July 6 and July 29, 2022. All participants included in the interviews had their vineyards in the heart of the wine region, in the small village of Gyöngyöstarján. By signing a consent form, each participant acknowledged that the interview would be audio recorded and interview data would be handled confidentially (See consent form in Appendix 3). Later, the audio files were converted into verbatim transcripts. These transcripts served as data for the thematic analysis. Interviews ranged from 70 to 120 minutes and took place at the wineries, except one case that was arranged in a café nearby the participant's home. The respondents received no compensation for taking part in the interviews.

Participants were sampled by purposive sampling. This technique is a common procedure in qualitative research to include information-rich cases in the study (Peterson, 2019). Etikan describes this sampling technique "*as nonrandom technique that does not need underlying theories or a set number of participants*" (Etikan, 2016, p. 2). Inclusion of participants depends on two key points. One the one hand, researcher's judgement on potential participants' information and knowledge relevant for the study. Secondly, there is also a large emphasize on participants' availability and willingness for participation.

In this research, being present in the domestic wine market with bottled wine products served as the primary criterion for choosing vine growers for participation. This decision was supported by two arguments. On the one hand, bottled wine is at the top of the grape and wine value chain. On the other hand, bottled wine is, in some ways always a personalized product, which leads the author of this study to assume that these producers follow careful farming practices with some level of anticipatory or adaptive mindset.. The idea behind this inclusion criteria was that those who bottle fine wine have more information-rich experience in adaptive measures than those smallholder vine growers who maintain their vineyards for supplementary income purpose. Participants were identified for this study through online sources and information, such as websites and social media channels.

Table 2 Descriptive characteristics of interview participants

	Participant 1	*Participant 2*	*Participant 3*	*Participant 4*
Gender	male	male	male	male
Age	45	30	50	29
Education	Agricultural engineers and wine technician	Viticulture and oenology engineer	Viticulture and oenology engineer	Golden wheat ear farmer (basic agricultural training)
Size of vineyards	7 hectares	16 hectares	5 hectares	22 hectares
Employment	Self-employment + seasonal workers if needed	Permanent employment of five workers	Self-employment + seasonal labour if needed	Permanent employment of five workers + seasonal workers

During the interviews, a copy of the map of the Matra wine region was used as a tool for facilitation purposes. The rationale behind this act was the hope that it might serve as a trigger for sharing anecdotes in relation to the subject being investigated. Viticulture and winemaking are, as mentioned earlier, very place-based and natural resource-based at the same time with personalised end-products (Mosedale *et al.*, 2016). That is nicely illustrated by the fact that each vineyard has a unique name that often conveys local specificity or historical context. Using maps during the interviews, they tried to appeal to this personalised attachment, hoping that it could bring up experiences that normal interview questions cannot do. Participants were not obliged to use the maps.

Development of interview guide

Interviewing usually involves asking open-ended questions to engage respondents in a conversation that proceeds to a pre-designed line of questions. The purpose of an interview is to get a deeper understanding of respondent's experience in relation to a research problem. There is a common categorisation between interview types based on their structure and formats. Formats range from structured through semi-structured to unstructured (Gubrium and Holstein, 2001). This research conducted semi-structured interviews with vine growing farmers. The most important feature of this type of interview is its flexibility. Although the interview is conducted along an interview guideline, it is not expected to follow a strict linear approach, as the method is open to deviation from question orders. From the interviewer's point of view, thorough preparation and good communication skills can be mentioned as expectations (Brinkmann, 2014). The flexibility of this method is particularly useful in mental mapping exercises.

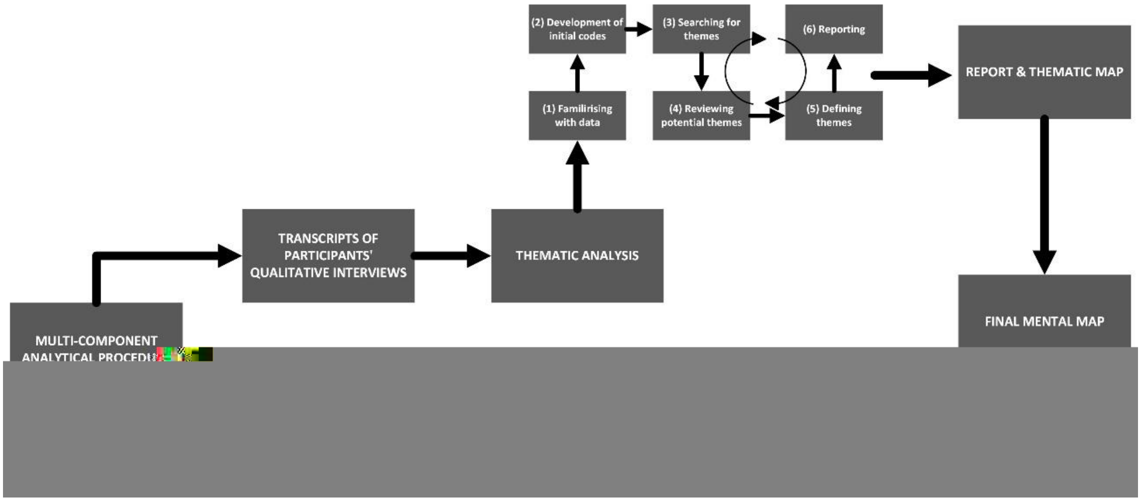
The interview guide used in this research was inspired by the works of Findlater et al. (2019) and Mitter et al. (2019) . In Findlater, Satterfield, and Kandlikar's work, there are thirteen thematic blocks of questions: farming experience; farm characteristics; future orientation; risk elicitation; manageability of risks; sources of information; specific concepts; crop rotation; soil disturbance; soil cover; conservation agriculture; climate change, systemic change. Their approach followed a broad to narrow narrative in the order of questions. Interviews started with questions concerning respondents' lives and farm characteristics, followed by a "risk-listing" exercise. After that, questions about how well or not well risks could be managed were standard follow-up questions. These questions always referred to the risks that had already been mentioned.

The work of Mitter et al. (2019) investigates farmers' individual cognition on climate change and adaptation in two Austrian regions. 29 semi-structured interviews were conducted, and they adopted Grothman and Patt's *Model of Private Proactive Adaptation to Climate Change* (2005) to structure farmers' climate change narratives; explore farmers' adaptation appraisal; and examine what influences farmers' adaptation intention. They consider two potential socio-cognitive pathways that can describe individuals' responses to climate change: adaptation intention and avoidance. Semi-structured interview guides started with a standard question ("*To start with, would you please share your view on climate change?*") to open participants' narration. Questions then touched upon four themes: perceived and expected changes in climate conditions; perceived and expected climate change-related impacts; adaptation measures already implemented or planned to be implemented in the future, and factors stimulating or impairing the implementation of adaptation measures (Mitter *et al.*, 2019). The interview guide is included in Appendix 2.

Multi-component analytical procedure to analyse qualitative data

A multi-component analytical procedure was developed to analyse the qualitative data gained from the interviews. The procedure included the thematic analysis of the interview transcripts, creation of a thematic map based on the thematic analysis and the combination of interviewees' cognitive maps. The final step of the procedure was when all these elements were taken together and synthesized in the form of one final mental model. This sub-section describes the major steps of this procedure, while Figure 5 illustrates it in the form of a flow chart.

Figure 5 Flowchart representation of the multi-component analytical procedure



The multi-component analytical procedure was based on conventional thematic analysis. This method is "…*"for systematically identifying, organizing, and offering insight into patterns of meaning (themes) across a data set. (…) This method, then, is a way of identifying what is common to the way a topic is talked or written about and of making sense of those commonalities."* (Braun and Clarke, 2012, p. 57). In this research, the process of thematic analysis was structured following Braun and Clarke's (2012) six-phase approach. In phase one, the author familiarizes himself with the data that, while making verbatim transcriptions of the audio recordings. Note-making of ideas coming up throughout this phase can trigger some early development of codes. Codes are the central elements of the second phase of thematic analysis. Coding is the process that aims to extract, describe, and interpret either semantic or latent meaning from raw textual data. This process involves mindful reading of the text trying to identify those sections that appear to be relevant for the research question (King, Horrocks and Brooks, 2019). Anything that describes the interviewee's perspective, opinion, or experience that relates to the topic under study is highlighted, together with a brief descriptive or interpretative comment consisting of some key words. The next (third) phase includes the identification of themes. Themes "*captures something important about the data in relation to the research question, and represents some level of patterned response or meaning within the data set*" (Braun and Clarke, 2006, p. 82). A crucial step in this stage is to condense the initial list of codes by collapsing and clustering them on the basis of a common characteristic or content. While this clustering process progresses, certain codes begin to cluster around particular topics, leading to the discovery or generalisation of themes. According to Braun and Clarke (2012), good themes are meaningful stand-alone units with certain interpretative attributes, but they also must be cohesive pieces of the greater whole, that tell the story of the data. This phase as well as the following phases of the analysis are inevitably iterative, intuitive and reflexive (King, Horrocks and Brooks, 2019). Phase 4 involves the review of potential themes, while Phase 5 aims to define and name the themes by determining what are the unique and specific content of each themes. This deep analytical work usually comes with selecting quotes to present certain themes and support the narrative of the analysis. These last three phases of this analysis are repeatedly carried out by returning to the text and going over the codes and themes on a regular basis as the research progressed. These phases yielded two major results. On the one hand, the final list of themes and a thematic map that presents that captures and presents the concepts and links that are relevant for the research questions. The sixth and last phases are taken up by writing up the results and conclusions of the thematic analysis, which in this case took place concurrently with completing this thesis. The thematic analysis was completed using qualitative analysis software NVivo 12©.

In parallel with the thematic analysis, a combined version of the cognitive maps from the interviews was created. In essence, this map contains all of the risks that the interviewees had mentioned and clustered on their mental maps depending on they are manageable or unmanageable.

Following the analytical considerations of some previous studies (Prager and Curfs, 2016; Findlater, Satterfield and Kandlikar, 2019; van Hulst *et al.*, 2020), the next step of the analysis used both the findings and the thematic map derived from the thematic analysis of the interviews, and the combined cognitive map for the creation of the final mental model. This final joint map is considered the main end-product of this study and is used to address the research questions as it uniquely combines and present the diversity and complexity that the qualitative segment of this research had captured. This diversity and complexity is the result of the fact that risks are rarely caused by a single effect but rather a network or chain of effects (Winsen *et al.*, 2013). In that sense, this multi-component analytical procedure allows to look at this landscape as a whole and see the main underlying details that determine farmers' risk-related decision making. This final map is believed to give a comprehensive overview of how respondents perceive risks on their farm, how these risks are related, and what adaptation steps might be able to address these risks.

5.4. Validity of the research

Research questions must be answered with validity, so any threats to validity can easily discredit results and the conclusion of the research (Schoonenboom and Johnson, 2017). This is equally relevant in qualitative and quantitative research; however, threats are treated using substantially different procedures (Onwuegbuzie and Johnson, 2006). This study follows a sequential mixed research design, meaning that quantitative and qualitative approaches sequentially follow each other across the stages of the research (Leech and Onwuegbuzie, 2009). According to Onwuegbuzie and Johnson, validity of findings derived from mixed method research is often affected by three problems: representation, legitimation, and integration. Maxwell (2009) argues that, the chosen methods have to deal with validity threats. However, the theoretical foundations can also offer guidance on how to check and rule out these threats. Maxwell also provides several procedures that are feasible to deal with validity issues. This section presents how this study will employ these procedures to address the problems of representation, legitimation, and integration. Hese procedures are intensive and long-term involvement; rich data; respondent validation; and integrity.

Legitimation problem "*refers to the difficulty in obtaining findings and/or making inferences that are credible, trustworthy, dependable, transferable, and/or confirmable*" (Onwuegbuzie and Johnson, 2006, p. 52). *Intensive and long-term involvement* can result in a lot of precious observations and experiences that can assist the researcher in contextualising the situation of the topic of interest. This study builds on and continues the author's earlier works, which show not only a long-term commitment to the subject, but demonstrates a long-term involvement as well (Biró *et al.*, 2017; Király, 2017, 2018; Tóth and Király, 2018; Király, Giuseppina and Tóth, 2022).

During the course of research, these observations gradually become data. Profound and accurate data collection enables the collection of *rich data*, that help capture deep insights and inferences on the subject of interest. This study uses various kinds of data including quantitative data from a cross-sectional survey of farmers, verbatim interview transcripts, and cognitive maps. This diversity allows to assume that quality of data will not hinder the maintenance of validity.

Respondent validation can handle the problem of representation that "*refers to the difficulty in capturing lived experiences using text in general and words and numbers in particular*" (Onwuegbuzie and Johnson, 2006, p. 52). *Respondent validation* is an often-neglected aspect of what determines the validity of a conclusion. Without respondent validation, there is a risk of misinterpretation of the responses obtained from participants. Interpretation of results derived from qualitative content analysis is highly prone to these threats. This research handles this threat by the mental modelling exercise that takes place in a co-creating setting allowing intensive discussion and collection of feedbacks simultaneously. This technique increases participants' engagement in the research process (van Hulst *et al.*, 2020).

The problem of integration stems from the inherent nature of mixed method research design: "*combining complementary strengths and nonoverlapping weaknesses of quantitative and qualitative research, assessing the validity of findings is particularly complex*" (Onwuegbuzie and Johnson, 2006, p. 48) issue. This research will seek to ensure that the employed methods compensate for one another's limitations. The survey provides a highly standardised, but broad spectrum of general experience, and opinions of a large group of farmers. This will be complemented by a highly detailed picture of the diversity of vine growers' values, beliefs, and goals linked to their risk perception and adaptation decisions. These two approaches together are assumed to formulate the integrity that the conclusions of this research can be built on.

CHAPTER 6: STUDY AREA: MÁTRA WINE REGION

This section introduces the Mátra wine region from the following perspectives: geography, climate, history, and the composition of grape varieties.

The region is located on the southern slopes of the Mátra Mountains, between the northern Great Plain and the mountains of northern Hungary. The wine region is located 50 kilometres south of the Slovak border and 60-100 kilometres north-east of Budapest. In 2022, the total land under vines was 6951 hectares. With this size, the region is the second largest wine region in Hungary after the Kunság wine region.

The wine region has a temperate continental climate. What makes its climate unique is that its vineyards are protected from the cool northerly winds by Mátra mountains, creating microclimates in some vineyards. Since rainfall is often deflected by the mountains, the region's climate is drier than one would expect. Most of the precipitation tends to fall in early summer, from May to June, while the second half of the summer tends to be dry. The bedrock in the wine-growing area is of volcanic origin (e.g. andesite tuff and riolite tuff), with significant marine sediment (e.g. sandstone). The soil types in the wine-growing area are more varied, including clayeforest soils, chernozem brown forest soils and humic sands (Mészáros, Rohány and Nagymarosy, 2012).

Following the Second World War, a vineyard reconstruction programe started in the 1960s, leading to the dominance of white grapes in the wine region. Local processing capacity had never been able to keep up with newly planted vineyards, forcing the region in the position of the country's primary source of grapes. Because there was not enough capacity to process the locally-grown grapes, the region became vulnerable to local and foreign business interests (Király, 2018).

But socialism also brought unprecedented wealth to those who started growing grapes in the so-called household plot system [háztájizás] organised by local cooperatives and state farms. One such household plot was cc. 0.3 hectares. The *household plot* as a local unit of land is still part of the local 'vineyard' language. After the collapse of socialism, the large-scale vineyards became extremely fragmented as a result of privatisation and land restitution, as was the case throughout the country. Previously, collectively farmed vineyards soon became privately-owned micro-plots (Király, 2018). In the early 2000s, the Mátra was characterised by a fragmented farm structure, underdeveloped agrotechnological and processing capacities, and last, but not least, a lack of flagship wine. In addition, the growers’ income position was severely impacted by the fact that wine grape sales remained very high, meaning that growers sold their produce to large-scale wineries rather than making wine from it (except wines made for their own consumption) (Magda and Sándor, 2004). Later, the household plot sized lands became the foundation for numerous new smallholding family wineries (Király, 2018). In the last three decades, the development of family wineries has given the Mátra wine region a new image, but the reconstruction from the legacy of socialism has not yet happened completely, so the region does not belong to the top Hungarian wine regions (Király, 2014). Totth and Szolnoki's (2019) survey confirms this: that the Mátra wine region ranks in the middle of the list of Hungarian wine regions in terms of consumer awareness.

Mátra wine region has a protected designation of origin under EC Regulation No 2019/33. According to this Regulation, wine products from the Mátra region that comply with the production and labelling rules laid down in the local product specification are considered as origin wines under the European Union's geographical indication system. In that sense, Mátra has both a protected designation of origin and a protected geographical indication (Candiago *et al.*, 2022). The region’s product specification strictly defines the list of authorised grape varieties. Following the last amendment of the product specification in 2016, nineteen white and nine black grape varieties are authorised in the wine region (HNT, 2016). There are two reasons why this list is important for vine growers. Firstly, in the case of new plantings, only the grape varieties on the list are eligible for Rural Development funding, so plantings of other varieties can only be carried out as self-financed investments. On the other hand, only wines of the varieties on the list may be marketed under the name of the Mátra or its sub-regions.

The land under active cultivation has decreased significantly in recent decades. In 2002, the area under vines cultivated was 8052 hectares (Magda and Sándor, 2004). In the 2010s, large number of vineyard owners took the once-only offer of EUR 6500 per hectare for grubbing-up their vineyards. This was funded by the EU's grubbing-up scheme. As a result, the total uprooted area in the Mátra was around 1,079 hectares. By 2022 the area under vines cultivated fell under 6000 hectares

According to data from the National Council of Wine Communities, 79% of this area is planted with vine grapes and there is a similar proportion for plantings. This makes Mátra wine region a white wine dominated region (HNT 2022).

Over the past 20 years, the composition of grape varieties in the area has gradually changed. In 2003, there were 35, while in 2022, there were 39 white grape varieties farmed on at least one household plot. Regarding black varieties, the number increased from 17 to 23 between 2003 to 2022. In that sense, the composition of varieties has been further diversified. The total area of both white and black varieties has decreased, which makes sense given that the total area has decreased as well. However, the rate of decrease was not equal: white varieties fell by 21 percent, while black varieties by 5 percent, indicating that white varieties have lost some of their dominance in recent years (HNT, 2022).

Changes in variety composition are shown through changes in the composition of the 10 most grown grape varieties (Table 3). Between 2003 and 2022, the composition of white varieties changed rather slightly: in 2003, the variety called Leányka was in the top 10, but by 2022 it dropped out and was replaced by Sauvignon Blanc. Leányka is a Carpathian Basin variety and a medium-ripening grape, while Sauvignon is an international variety and an early-ripening grape. Three white varieties increases their area in the last 20 years. The most notable increase was achieved by Irsai Olivér, which nearly doubled its area and moved from seventh to second spot in the top 10 ranking. Szürkebarát (pinot gris) and Tramini both expanded at roughly the same rates. By 2022, the Szürkebarát became the most widely grown white grape variety in the region. All three varieties are early ripening.

Table 3 The most grown white grape varieties in 2003 and in 2022

TOP10 in 2003	(ha)	TOP10 in 2022	(ha)
Müller-Thurgau	983	Pinot Gris	675
Chasselas	719	Irsai Olivér	575
Muscat ottonel	558	Müller-Thurgau	479
Olasz rizling	544	Muscat ottonel	411
Chardonnay	526	Tramini	354
Pinot Gris	425	Olasz rizling	347
Irsai Olivér	316	Chasselas	316
Leányka	249	Chardonnay	273
Tramini	241	Sauvignon Blanc	251
Grüner Veltliner,	228	Grüner Veltliner,	173

Sourc: Based on HNT data, own editing

A special mention should be made of the variety Irsai Olivé, which, according to national statistics, moved from the 20th to the 7th most grown variety over the past 20 years. At the national level, only the Kunság wine region has a larger area of this variety (KSH, 2020). The variety, which was developed in the 1930s with the intention of being used as a table grape, has since proven to be a pleasant, aromatic, light wine-producing variety (Mészáros, Rohány and Nagymarosy, 2012). The success of the variety is not a coincidence: Irsai Olivér has been highly popular among consumers over the past decade. This variety has a leading role in the slow transition towards the increasing consumption of fresh, fragrant, low-alcohol reductive wines (Tisza, 2019; Totth and Szolnoki, 2019; Ipacs, 2021).

In the case of black varieties, two varieties entered, other two dropped out of the top 10 between 2003 and 2022: two Carpathian Basin varieties, purple Kadarka and Rubintos, have been replaced by two international varieties, Syrah and Pinot Noir (Table 4). The latter produced the largest increase in area, with a nearly ninefold increase. Merlot, Blauburger, Turan and Cabernet Franc have also seen significant growth over the period, but the aforementioned Syrah is also noteworthy: this variety was not present in 2003 in the region, but in 2022 it was already being grown on 26 hectares.

Table 4 The most grown black grape varieties in 2003 and in 2022

TOP10 2003-ban	(ha)	TOP10 2022-ben	(ha)
Kékfrankos	477	Kékfrankos	521
Zweigelt	260	Cabernet sauvignon	174
Cabernet sauvignon	157	Zweigelt	133
Portugieser	90	Cabernet franc	103
Cabernet franc	66	Pinot noir	76
Turán	35	Merlot	49
Bíbor kadarka	26	Portugieser	49
Blauburger	26	Turán	46
Merlot	22	Blauburger	36
Rubintos	21	Syrah	26

Sourc: Based on HNT data, own editing

CHAPTER 6: RESULTS AND DISCUSSIONS

This chapter presents and discusses the results of research in four sub-sections. The structure of this section follows the order of the research questions. Accordingly, the results related to the quantitative research questions come first, and this is followed by a discussion of the quantitative results. After that, the results of the mental modelling are presented, and qualitative research questions are addressed by a discussion of these findings.

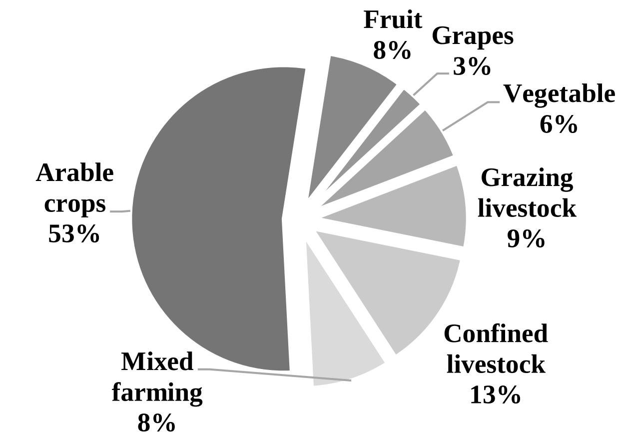
6.1. Survey results

Through the data collected by the farmer survey, the aim was to determine whether grape growers and farmers in other branches have different perceptions of climate change; whether grape growers and farmers in other branches have different adaptation behaviours; and whether there is a detectable relationship between farmers' perceptions of climate change and their adaptation behaviours. The rest of this sub-section is structured as follows: key variables related to farm characteristics, then variables related to perception and sensitivity to climate change, then the description of adaptation behaviour will be presented. This is followed by a number of statistical tests in an effort to address the three quantitative research questions.

6.1.1. Description of survey respondents

Firstly, the sample is presented through two generic variables. The first variable defines farm types, while the second defines farm sizes. Regarding the farm typology, the sample had a little bit more than half of the farms categorized in arable crop production. The second-most numerous group was in the sample, livestock farms, including grazing (9%) and confined livestock farms (13%), respectively. Eight percent of the sample consisted of respondents who had fruit plantations, while less than 10% of the farms were mixed (8%) or vegetable farms (6%). Vine growers made up the lowest proportion of the sample (Figure 6).

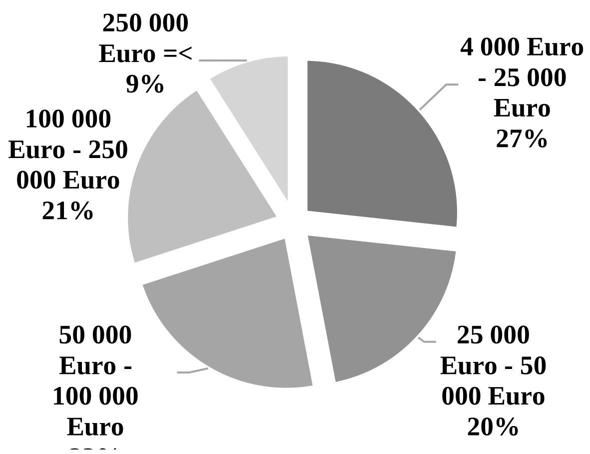
Figure 6 Distribution of respondents by farm type (N=300)



Source: own calculations based on AKI data

The sample was divided into groups depending on farm sizes. The farm size measurement was based on the holdings' standard output[2] (SO). In that sense, the sample is closely and equally distributed (Figure 7). 27% of farms producing between 4,000 and 25,000 SO represented the largest share. Farms with a value of between 50 and 100 thousand SO came as the second largest group. Farms with a value between 100 and 250 thousand and farms with a value between 25 and 50 thousand make up two fifths of the sample. The largest farms make up the smallest group in the sample; nearly one in ten of the sample's farms fell into the largest size category, which included those with an annual production value above 250 thousand. Distribution of respondents by farm size

Figure 7 Distribution of respondents by farm size

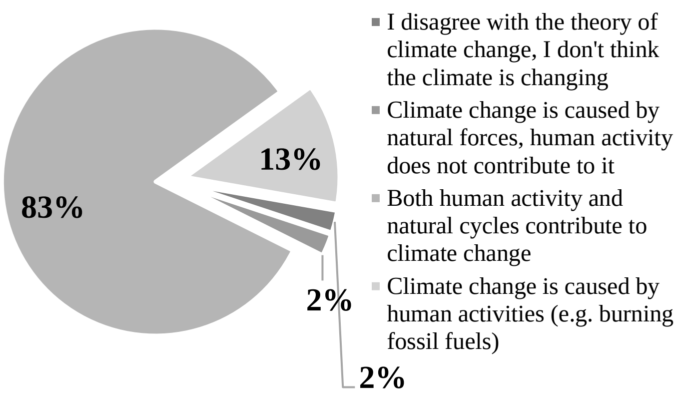


Source: own calculations based on AKI data

[2] Commission Regulation (EC) No 1242/2008 of 8 December 2008 establishing a Community typology for agricultural holdings. Source: https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:32008R1242&from=EN

The vast majority of respondents agreed with the theory of climate change. Over 80% of respondents said they agreed with the idea that human activity (e.g. burning fossil fuels) and natural cycles both contribute to climate change. Another 13% of respondents thought that only human activity was to blame for climate change. Just 2% of respondents said they disagree with the climate change.

Figure 8 Respondents' climate change belief



Source: own calculations based on AKI data

Participants' perceptions of and sensitivity to climate change were assessed by asking them to evaluate seven statements on a five-point Likert scale (Disagree -Agree) (See Table 1). Three out of the seven statements touched upon perceived weather variability, average temperature increase, and precipitation change over the past 10 years. The further four statements were related to changes in profitability, crop quality, yields, and investment decisions as a result of climate change. Appendix 4 includes the simple distribution of these seven variables. As a next step in analysing the survey data, these seven Likert-scale based variables were transformed into two index-type ratio variables by calculating the average of Likert scores. The first three variables provide the input for the Perception index, the last seven provided input for Sensitivity index. Descriptive statistics of the PERCEPTION and SENSITIVITY INDEX presented in Table 5.

Table 5 Descriptive statistics of Perception and Sensitivity index

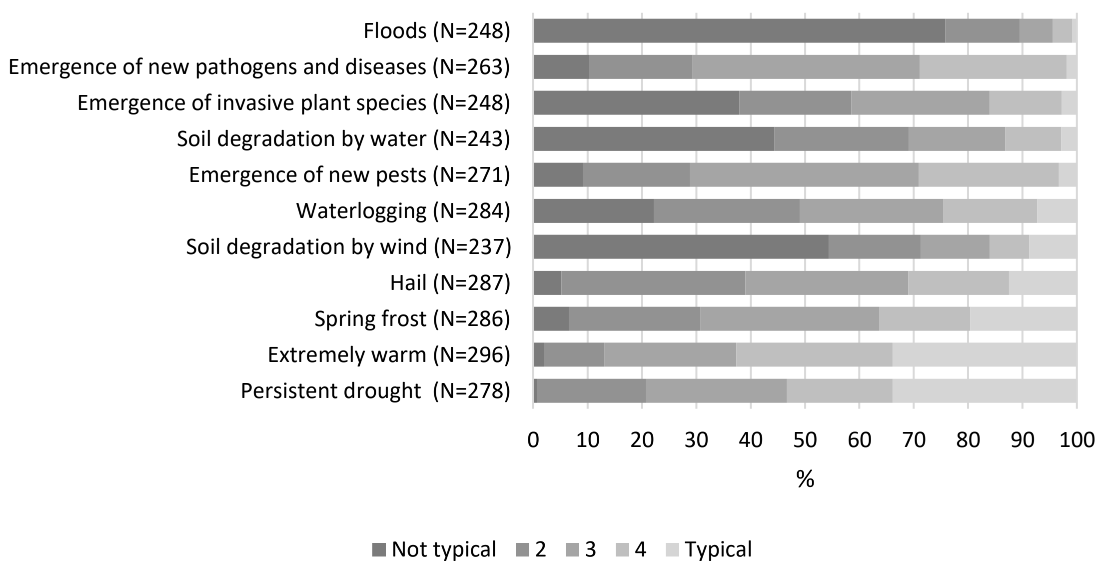
	Descriptive statistics					Shapiro-Wilk		
	N	**Mean**	**Std. Deviation**	**Minimum**	**Maximum**	**Statistic**	**df**	**Sig.**
PERCEPTION INDEX	300	3,42	0,89	1,33	5	0,966	300	0,00
SENSITIVITY INDEX	300	2,82	0,78	1	5	0,971	300	0,00

Source: own calculations based on AKI data

The comparison of the two means shows that the perception index's mean is higher than the sensitivity index's mean. It indicates that there is stronger agreement regarding weather variability, average temperature increase, and changes in precipitation than there is regarding specific climate change impacts. Table 5 also shows the test statistics of Shapiro Wilk test because the two indices do not follow normal distribution which means that only non-parametric procedures can be used for hypothesis testing.

Eleven climate change associated impacts that can be regarded as typical for the Carpathian Basin based on pertinent literature were also assessed. Respondents were asked to rate the impacts on a five-point scale based on how typical they are in their own respected environment. They also had the option to opt out if they did not wish to or were unable to respond.

Figure 9 Distribution of responses for each climate change impact

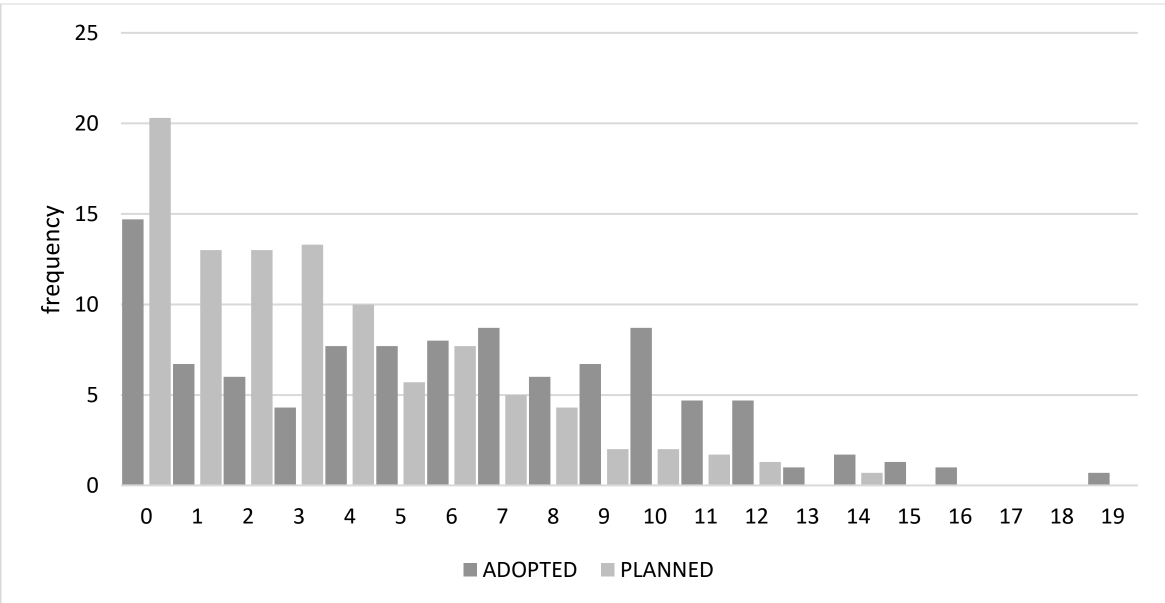


Source: own calculations based on AKI data

Figure 9 illustrates that persistent drought and extreme warm were the most frequently reported weather phenomena as rather typical: more than half of the respondents claimed that these phenomena had been experienced in relation to their farming activities. Spring frost was reported by one third of the respondents, making it another common phenomenon. Looking at the other end of the scale, 7 out of 10 respondents claimed that floods brought on by climate change are not at all a factor on their farms. Similarly, high levels of rejection were found for three other phenomena: the vast majority of respondents stated that soil erosion brought on by wind and water as well as the presence of invasive plant species were not common occurrences on their farms at all.

Farmers’ adaptation behaviour was examined by asking respondents to evaluate nineteen individual adaptation actions. In compiling the list of adaptation actions, the guiding principle was that they should be universal enough to be relevant adaptation options for the widest range of farm types in the Hungarian context. Detailed list of adaptation actions is included in Table 1. Respondents had two choices for expressing their opinions about a specific adaptation action: they could say they have already adopted it, or they could say they have not, but plan to do so in the next 5–10 years. These two responses were transformed by data reduction procedure into two separate variables, resulting in two scale variables: The number of adopted adaptation actions is presented by ADOPTED ADAPTATIONS, and the number of adaptation plans is presented by PLANNED ADAPTATIONS.

Figure 10 Frequency of the number of adaptation actions already adopted and planned



Source: own calculations based on AKI data

The average number of adopted adaptation actions was 5,96, whereas the average number of planned adaptation actions was 3,44. Figure 10 shows the distribution of these two variables, illustrating the frequency of the number of adaptation actions, respectively. The figure represents that while the distribution of adopted adaptation practises exhibits a roughly homogeneous pattern, that of planned adaptation actions exhibits a steady decline in distribution as the number of actions increases. Regarding the two extreme values of the variables. In both cases, there is a group of respondents who reported zero adopted (n=44) and zero planned (n=61) actions. The maximum number of actions for adopted adoptions was 19 actions reported by two respondents. And the maximum number of planned adaptations was 14 from two respondents.

6.1.2. Hypotheses testing

Testing Hypothesis 1: perception and sensitivity indices and farm characteristics

Farmers' perception and sensitivity were further assessed through the generic classifications given by farm type and size to identify potential cause-effect relationships and to test Hypothesis 1. What I wanted is to know whether there is any significant difference between certain farm types and sizes when considering climate change perception and sensitivity. Given that each index follows a non-normal distribution (See Table 5!), non-parametric Kruskal-Wallis tests were used instead of mean comparison. In a Kruskal-Wallis test, it is examined whether the central characteristics (mean rank) of a categorical variable. In other words, this test assesses whether "k" independent samples of a categorical variable differ in relation to a dependent variable. Kruskal-Wallis can indicate this difference, however, there is also a need for post-hoc test to identify which group or groups differ significantly. Table 6 and Table 7 provide a summary of the Kruskal-Wallis test results, and Appendix 4 contains the detailed outputs of the tests. The p value of the Kruskal-Wallis H statistic indicates whether there is a significant difference between groups of the categorical variables. In this case, p values show that the only statistically significant difference was found between farm types but not between farm size categories. This allows to suggest that a farmer's perception of climate change is influenced by the type of farm, but not by the size of the farm.

Table 6 Comparison of Perception and Sensitivity index means for farm types with Kruskal Wallis H test

		PERCEPTION INDEX v FARM TYPE	SENSITIVITY INDEX v FARM TYPE
Kruskal-Wallis H		13,142	10,183
df		6	6
Asymp. Sig. (p).		0,041*	0,117
Crop farms	**Means**	3,4813	2,7797
Fruit farms		3,5694	3,3958
Grape farms		3,0833	2,7500
Vegetable farms		3,8333	2,9861
Grazing livestock		3,2593	2,7870
Confined livestock		3,1053	2,6382
Mixed farming		3,3733	2,6800
Sample mean		3,4222	2,815

Relationship is significant at: *0.05 and **0.01 levels. Source: own calculations based on AKI data

Table 7 Comparison of Perception and Sensitivity index means for farm sizes with Kruskal Wallis H test

		PERCEPTION INDEX v FARM SIZE	SENSITIVITY INDEX v FARM SIZE
Kruskal-Wallis H		7,47	3,256
df		4	4
Asymp. Sig. (p).		0,113	0,516
4 000 Euro - 25 000 Euro	**Mean**	3,3333	2,9
25 000 Euro - 50 000 Euro		3,5464	2,877
50 000 Euro - 100 000 Euro		3,2319	2,8297
100 000 Euro - 250 000 Euro		3,5714	2,7262
250 000 Euro =<		3,5432	2,5926
Sample mean		3,4222	2,815

Relationship is significant at: *0.05 and **0.01 levels. Source: own calculations based on AKI data

Based on these results, only the relationship between the PERCEPTION INDEX and the FARM TYPE variables was further investigated. Three groups—vegetable growers, field crop growers, and fruit growers—reported stronger than average perception experiences when comparing group means with the overall sample means. The average perception value of grape growers was the lowest in the sample, while their the average sensitivity value was among the lowest ones.

To further determine differences between farm type groups, I used Kruskal-Wallis H post hoc tests for pairwise multiple comparisons. Four group pairs had significantly different perception scores, according to the pairwise correlation tests. These are grape and vegetable growers; confined livestock farms and arable crops farm and vegetable farms; and grazing livestock farm and vegetable farms. Appendix 4 contains the model's partial output. Obviously, the more clear-cut the differences between group means are, the more robust the model can be assumed to be. Results reject Hypothesis 1, as there is only one pairing (grape growers and vegetable growers) that showed a statistical difference in group means in the context of climate change perception. We can conclude that vegetable growers' climate change perception is significantly stronger than grape growers'.

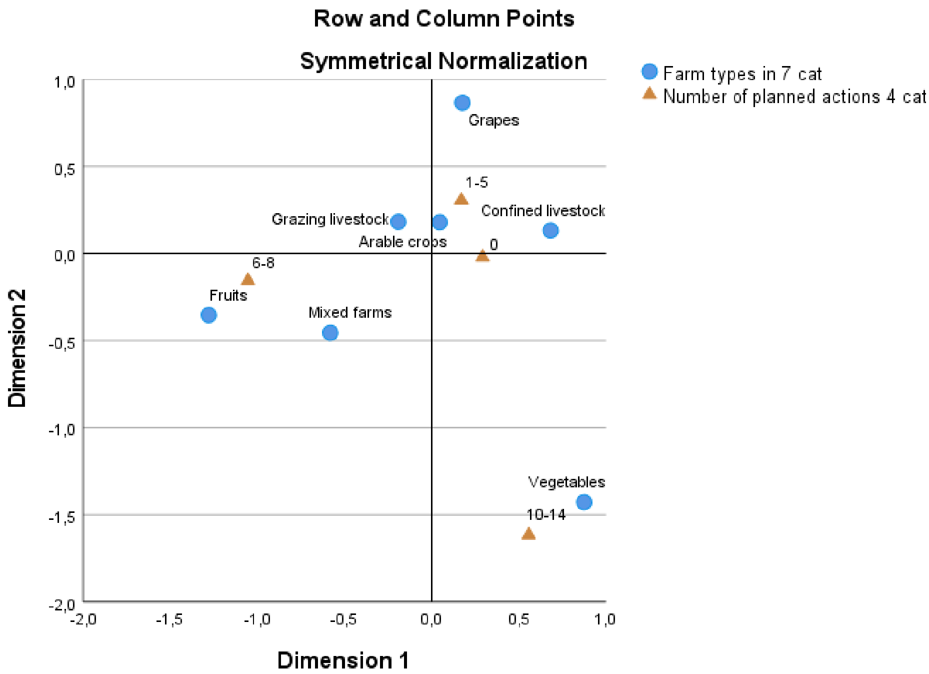
Testing Hypothesis 2: adaptation differences between farm characteristics

The relationship between farm characteristics and adaptation behaviour was explored through the adoption of correspondence analysis. This technique was applied to test the second hypothesis. Correspondence analysis is a variant of principal component analysis, with the exception that it is used for categorical data and calculates the Chi square to measure distances between profiles (Greenacre, 2010). In this sense, correspondence analysis enables the investigation of the potential relationship between the two variables that describe respondents' adopted and planned adaptation actions. However, in these analyses these two variables were transformed into categorical variables for ease of interpretation. Five categories for actual adaptation and four categories for planned adaptation were created from the responses. Appendix 4 contains the distribution of these derived variables.

Firstly, the dependency between farm types and adaptation actions was assessed. Contingency table of this analysis is included in Appendix 4. For testing of independence, the value of $\chi 2$ = 33,172 with p = 0,1 was calculated. This result indicates that there is no dependence between farm type and the number of applied adaptation measures.

In the next step, the planned adaptation actions and farm types were examined. In this comparison, more convincing results were found. For testing of independence, the value of $\chi 2$ = 34,826 with p = 0,01 was calculated. This indicates that there is clearly a dependence between farm type and the number of planned adaptation actions. Contingency table of this analysis is included in Appendix 4.

Figure 11 Correspondence analysis of Farm types and Nr of planned adaptation actions



Source: own calculations based on AKI data

Figure 11 shows that the results can be used to observe three interesting findings. Four types of farms (grazing and confined livestock, arable crops, and grapes) appear to think about adaptation planning in a roughly similar way. These four groups either have no plans to make any adaptations or have up to five adaptation actions planned for the next five to ten years. Those who work with fruit plantations or are engaged in mixed farming can be identified as groups of modest planners. These two groups mostly declared that they were planning to perform 6–8 adaptation measures. The most active planners in this comparison are the vegetable-growing farmers, whose majority sateted that they intend to use 10 to 14 adaptation practices in the future.

There was also an attempt to examine whether there is a relationship between the farm size and the number of adaptation actions adopted. Here again, the procedure followed the conventional steps of correspondence analysis. Procedure showed no significant relationship between the two variables (2 = 18.492 , p < 0.296). Similar results were obtained when the relationship between farm size and the number of planned adaptation practices were examined. That test also showed no significant relationship between the two variables (2 = 9.083, p < 696).

Regarding the second hypothesis, I can conclude that there is a difference between farm types in relation to how many adaptation actions they have already adopted and how many adaptation actions they are planning. However, results indicate that grape farms are not ahead of other types of farms in terms of the number of adaptation actions. The results show that there are farm types whose adaptation behaviour is more active, at least in terms of planning. Therefore, based on these results, the second hypothesis is rejected.

Testing Hypothesis 3: Relationship between perception and sensitivity and adaptation behaviour

The third and last hypothesis that was formulated in relation to the quantitative segment of this research was the positive association between farmers' perception and sensitivity and their adaptation behaviour. Correlation analysis was applied to assess these associations. Given that neither variable involved in the testing is normally distributed, Spearman rho correlation analysis was performed. Table 8 presents the results of this analysis. Positive association was found between the Perception index and Planned adaptations as well as the Sensitivity index and Planned adaptations. The correlation is not very strong, but the direction suggests that more adaptation planning happens when perception and sensitivity are high. A correlation of similar strength but with a negative sign was found between perception and sensitivity and the number of adaptation practices already adopted. It means that as perception and sensitivity increase, the number of adaptation practices adopted decreases. The results for both tests suggest a significant association, but because they also indicate an inverse correlation, their interpretation in relation to third hypothesis is challenging.

Table 8 Spearman correlation analysis between Planned and Adopted adaptation and Sensitivity and Perception index

		SENSITIVITY	**PERCEPTION**
PLANNED ADAPTATION	Correlation Coefficient	,172**	,195**
	Sig. (2-tailed)	0,003	0,001
	N	300	300
ADOPTED ADAPTATION	Correlation Coefficient	-,179**	-,204**
	Sig. (2-tailed)	0,002	0
	N	300	300

Correlation is significant at: *0.05 and **0.01 levels (two-tailed); diagonal italicised. Source: own calculations based on AKI data

6.2. Discussion of survey results

Like Capstick et al. (2015) claim, knowing and understanding public opinion on climate change, including perception, is a crucial element in what academia can provide for measures to address those changes that might be needed for successful adaptation and mitigation. In agricultural context, the importance of perception in adaptation studies has been confirmed numerous times: adaptation measures that farmers undertake are largely driven by what they perceive from climate change and how they are concerned about it (Grothmann and Patt, 2005; Adger *et al.*, 2009; Soubry, Sherren and Thornton, 2020; Bezner *et al.*, 2022).

6.2.1. SRQ1: Are there any differences between plantation farming and other sectors in terms of farmers' climate change perception?

This study has three sub research questions, whose discussions rely on survey data. In relation to Hypothesis 1, I examined whether grape farms have a stronger perception of and sensitivity to climate change than farmers in other sectors. Given that, this also implies that climate change perception and sensitivity of grape farmers in the sample are not significantly different from other farm types, there is not enough evidence to confirm this assumption

Although the sample didn't show many statistically plausible differences between grape growers and other types of farmers, it is important to note that vineyard farmers had the lowest group average for perception scores and one of the lowest for sensitivity scores compared to other types of farms. Given that vine grape farming has been described as a particularly climate-sensitive agricultural activity (Van Leeuwen and Seguin, 2006; Mosedale *et al.*, 2016), this is certainly a surprising result. Climate is a fundamental component of viticulture, which makes seasonal variability particularly significant for yield and quality. Given the lack of such comparative results in the literature, it may be worth exploring this finding further in an explicit comparative research setting.

Other pairings where evidence has been found for statistical differences suggest general differences between crop farming and livestock farming. Crop farmers perceived more climate change related impacts than livestock farmers. This might be a logical result, as it may make sense that crop farmers are more exposed, and as a result, perceive more adverse impacts, than a livestock farms working with confined and isolated systems, such as cattle or dairy stables or pig houses. However, this type of difference is not confirmed by the results reported in the literature. For instance, Bezner et al. (2022) summarize that livestock farmers' perceptions of increases in climate variability and occurrences of climate-related stressors do not differ from crop farmers' perceptions, and moreover, they aew consistent with the actually observed meteorological data. However, the opposite can also occur, as extremely hot weather in stables could only be mitigated by a cooling system, which can be a fundamental element of livestock farmers’ adaptation strategies (Derner *et al.*, 2018; Mikovits *et al.*, 2019; Schauberger *et al.*, 2019). In addition, there are research evince where farmers' opinions about climate change are influenced by the size of their farms, but not farm type. For instance, according to research by Foguesatto and Machado (2021) the likelihood that farmers will perceive climate change is significantly decreased as farm size increases. This distinction, however, was not evident in the study's sample. Nevertheless, it appears that this distinction between perceptions of climate change by farm type and farm size is an under-researched area within adaptation studies that could be covered and investigated in future research initiatives.

6.2.2. SRQ2: Are there any differences between grape farms and other sectors in terms of farmers’ climate change adaptation behaviour?

The second quantitative research question was whether there is a difference between farms’ adaptive behaviour depending on their types and sizes. Two variables were used to represent adaptive behaviour: the number of adaptation actions in use and the number of adaptation actions being planned. Two correspondence analyses were carried out to address this question, and the results revealed a significant relationship only between planned adaptation actions and farm types. Grape growers, with the lowest average perception score in the sample, appear to be planning their adaptation actions accordingly: they either did not plan any adaptive action or planned only the fewest possible. Fruit and vegetable farms demonstrated a greater likelihood for proactive planning, which makes the passivity of grape growers surprising. However, considering the first hypothesis, this result seems less surprising. In fact, it is indeed a consistent result. Low perception and sensitivity scores are, logically, associated with lower adaptation activity. This is in fact in line with the findings of several similar empirical studies on the relationship between perception and adaptation (Arbuckle, Morton and Hobbs, 2015; Li *et al.*, 2017; Mase, Gramig and Prokopy, 2017; Woods *et al.*, 2017; Mitter *et al.*, 2019; Wheeler, Nauges and Zuo, 2021). These studies imply that climate change perception affect decisions on adaptation, suggesting that stronger perceptions of impacts lead to stronger engagement in adaptation. This often-demonstrated correlation appears to have been produced by the vine growers in the sample.

6.2.3. SRQ3: Is there a statistically significant relationship between respondents' climate change perception and sensitivity and their adaptation behaviour?

The third sub-research question aimed to assess the direct association between perception and adaptation behaviour. Correlation analyses were performed to test whether there is a positive association between farmers perception and sensitivity and their adaptation behaviour. The analyses produced inconsistent results because the results draw a contradictory picture of farmers' adaptation behaviour. When actual adaptation is evaluated, it seems as though perception and sensitivity have negative impacts, but when planned adaptation is evaluated, the results show the opposite effect. In the literature, one can find a similar example of this inconsistency in farmers' adaptation behaviour. Justifications for such inconsistent result is provided by Abebe et al. (2022) who point out that it might be the effect of "perceived behavioural control" when actual and planned adaptation vary. When asked about their plans, individuals may consider other controlling factors than when asked about their actual actions. Presumably, they are more likely to promise outcomes that are unlikely to occur. Abebe et al. (2022) also claim that wording of survey question might also have some impact. To gain a deeper understanding of farmers' decision-making processes in the context of climate change adaptation, it may be beneficial to understand the gaps between planned and actual behaviour. Table 9 provides a summary of research findings in relation to quantitative research questions and hypotheses.

Table 9 Summary of research results in relation to quantiative research questions and hypotheses

Research question	**Hypotheses**	**Decision**
SRQ1: Are there any differences between vineyard farming and other sectors in terms of farmers' climate change perception?	Vine growers have stronger perception climate change impacts than farmers working in other sectors.	Rejected because there is no statistical difference in between how grape growers and other farmers perceived climate change with the only exception of the pairing of grape growers and vegetable growers.
SRQ2: Are there any differences between vineyard farming and other sectors in terms of farmers' climate change adaptation behaviour?	Vineyard farming is ahead of other sectors in the adaptation process.	Rejected because there are other farm types that show more activity in adaptation planning.
SR3: Is there a statistically significant relationship between respondents' climate change perception and sensitivity and their adaptation behaviour?	Farmers who perceive more of the impacts of climate change and farmers who are more sensitive to climate change impacts are more likely to engage in adaptation actions	Partially supported because there is a correlation between planned adaptation and perception and sensitivity, but there is inverse correlation between actual adaptation and perception and sensitivity.

6.3. Mental modelling results

This subchapter is structured around the thesis's qualitative research questions. These questions aim to explore the risk landscape of Mátra grape growers and show what implications can be drawn based on that regarding their adaptation behaviour. Data collection methods applied to answer these questions aimed to gather first-hand qualitative data from vine growers. This data gathering protocol included a semi-structured interview with vine growers and a cognitive mapping exercise embedded within. The analysis of this qualitative data followed a multi-component analysis procedure aiming to construct a mental model that captures the risk landscape of grape growers and supports the interpretation of growers' adaptation behaviour. The analytical procedure included the thematic analysis of the interview transcripts, the creation of a thematic map based on the thematic analysis and the combination of the interviewees' cognitive maps. The final step of the procedure was when all these elements were taken together and synthesized in the form of one final mental model.

The rest of this section describes the final mental model by presenting its risks, causes, and effects and how they are interlinked. Appendix 5 includes participants' cognitive maps, while Appendix 6 includes the thematic map. Last, but not least, the second part of this section provides a discussion of these results through addressing the qualitative research questions.

6.3.1. The mental model of vine growers

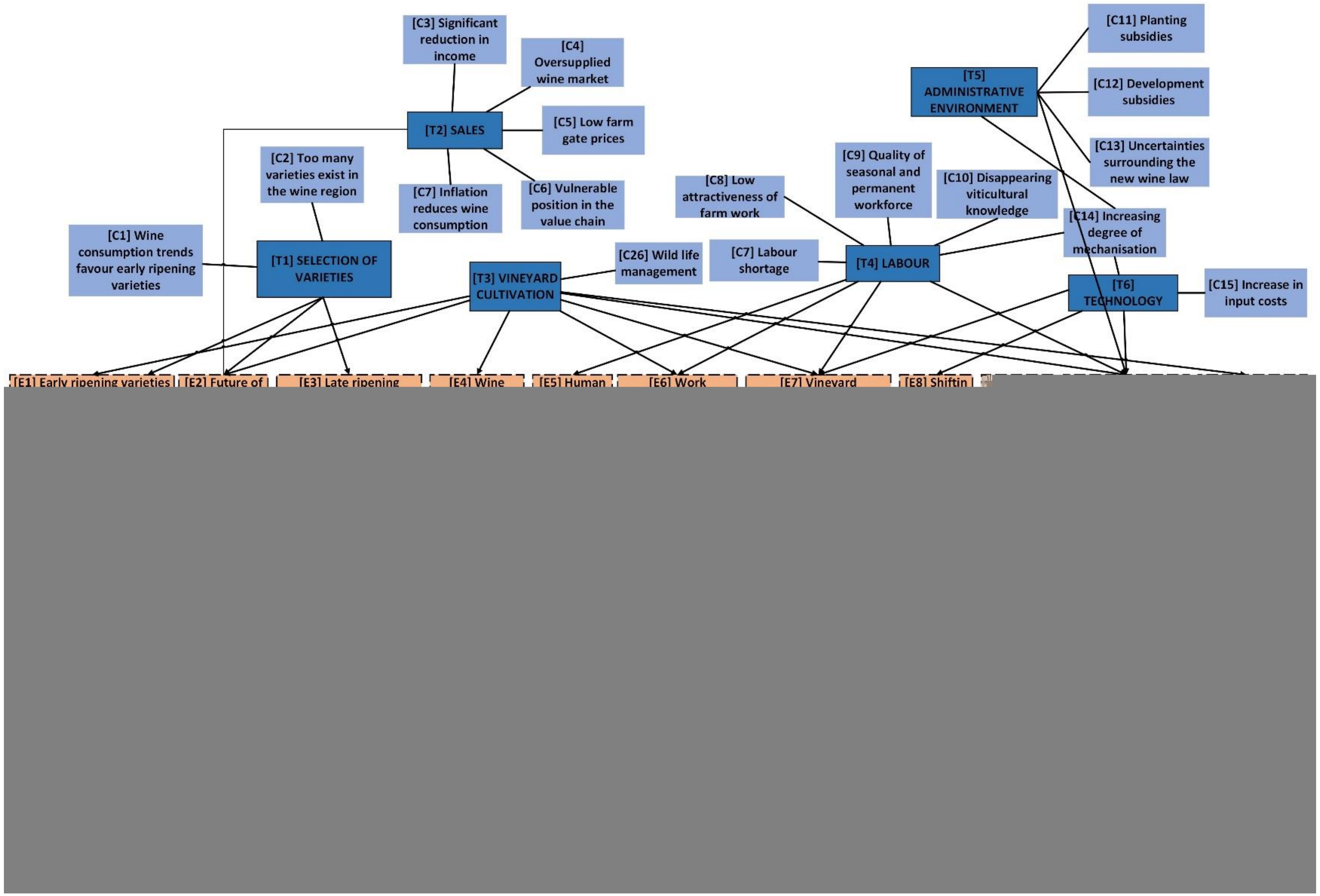
The complete model is presented in Figure 12. Findings of the analysis were classified into three aggregated concepts (T - risk types, C - causes and E - effects) based on the classification used by Winsen et al. (2013). The model is presented as a network of these interlinked concepts. Risks related and unrelated to climate change were divided into two major categories. The former is indicated in green and the latter in blue in the model. For climate-related risks, four types of risks were classified: heat stress, drought, UV radiation, and lack of winter frosts. Six risk types were identified as non-climatic: these are risks related to selection of varieties, sales, vineyard cultivation, labour, the administrative environment, and technology. The factors (pale blue and green rectangles) that best describe each type of risk were assigned as causes. In accordance with the focus of this research, I have identified eleven effects whose occurrence is attributed to multiple causes of risk. These elements, given that they are linked to multiple causes of risks define the multifaceted and networked nature of this risk landscape. They are shown as rectangles in the model with dashed lines and presented in Table 10.

Table 10 List of effects as results of multiple causes of risks

ID	**Multi-risk effects**
[E1]	**Early ripening varieties are becoming more challenging to cultivate**
[E2]	**Future of irsai Olivér is uncertain**
[E3]	**Late ripening varieties are becoming easier to cultivate**
[E4]	**Wine quality is hard to maintain**
[E5]	**Human health constraints**
[E6]	**Work management difficulties**
[E7]	**Vineyard cultivation is becoming more difficult**
[E8]	**Shifting harvest dates**
[E9]	**Yield loss**
[E10]	**Plantation planting is becoming more difficult**
[E11]	**Increasing wildlife damage**

Staying in line with the research questions, the focus of this section is on these eleven effects. Furthermore, the most typical adaptation steps, constraints, or opportunities are also presented in this section. Along with these descriptive presentations, direct quotes from the participants will also be used for demonstration purposes.

Figure 12 Multi-faceted risk landscape of vine growers presented as a network of risks, causes and effects



6.3.2. Multi-risk induced effects for vine growers

The effects most connected in this risk network are those related to plantation cultivation [E7] and planting [E10]. Each climate change related risk had an impact on grape farming and created uncertainty around farmers' decisions. The absence of rainfall [T7] was one of the main climatic risks and was mentioned in the narratives of all participants as a risk that had a significant impact on cultivation. It should be noted that the interviews were conducted during the worst drought in decades, with almost half of the average rainfall missing (Toreti A. *et al.*, 2022). However, the fact that none of the participants referred to the 2022 drought as an outlier in this context, but rather as a continuation of multi-year trend, is a significant finding. This trend shows that summers are significantly getting drier. In essence, this proves that the perception of risks from rainfall shortages is accurate and supported by multiple years of experience. The precipitation deficit is described as "*worrying*," "*critical*," and "*extreme*," which highlights how serious participants consider the situation to be. The most extreme view on this is that plantations could likely experience a significant loss of stocks the following year if precipitation does not start to go back to normal distribution by the winter and spring of next year.

> “*Next year, I expect that stressed or diseased vines will not sprout or will die during the year. Even if everything gets back to normal, and we have a wet winter and spring, even then. If we this drought stays for long, it may not just be stressful, but it may be more than that, it may be more significant. So 10 - 20 percent at least, but 30-40 percent loss of stocks at worst can occcure. If the same drought continues next year.*" (Participant 1)

Grapes are perennial plants, so they adapt well to suboptimal conditions. Thanks to its root system, which extends down to a depth of ten meters, it can reach moisture in the soil that other plants cannot. This is a key component of the adaptive capacity of vine farms. However, during extremely dry periods, vines also have a tendency to start vegetating, showing signs of slowed or stopped shoot development as well as shriveling and drying of the berries [C21] [C22]. These can all directly lead to severe yield loss [E9]. But even this significant drought does not mean that a sudden rainfall would make the situation any better. In fact, regardless of the severity of the rainfall deficit, the seasonally normal amount of rainfall would do more harm than good once ripening has started. This is due to the fact that a sudden rainfall [C16] would raise crop protection costs, which were already unusually low when interviews were made due to the drought. Given the sharp rise in the costs of input materials [C15], this unforeseen pesticide application would put growers in a particularly challenging position financially.

> "*The advantage of dry weather is that there are fewer pesticides, because prices of pesticides have been slowly increasing by more than 40%, so I have played with the idea of what the hell would happen if we had a rainy weather now, because then crop protection would cost three times more, because now the fact that five-time spraying of one hectare is around 100.000 is a ridiculous cost.*" (Participant 4)

The lack of rain is even more of a factor in participants' decisions when it comes to planting. Planting in extreme drought increases the risk of vines not surviving due to the lack of water in the soil. However, vines may be less likely to be resistant if direct irrigation is applied after the planting. Not to mention the additional work that such an irrigation procedure would demand, which would be a difficult task given the severity of labour shortage that will be presented later [C7]. The productive lifespan of a vine plantation can last from 20 to 40 years, which means that planting is explicitly identified as a long-term, strategic decision. This gives weight as well as uncertainty over the decisions: the training-systems can be changed, vines roots can be replaced or grafted, but these are expensive and difficult interventions.

> "*So that after 2 years of drought, I should plant next spring, I'm very worried. I can't start watering because then it will be a miserable piece of crap and even more vulnerable to drought, so I will plant it and I will order more grafts next year. I have nothing else to do, since it's so dry, I think planting is a pretty risky idea now.*" (Participant 4)

Excessive UV radiation [T8] is another climatic factor that makes it difficult to maintain plantations, because UV radiation can cause sunburns on berries and leaves [C23]. The bigger problem is the burning of berry skin because a burn mark increases the possibility that the damaged berry will later start rotting, which would result in the loss of the entire cluster and, consequently, a reduction in yield and quality. Aside from that, excessive UV radiation decreases the effectiveness of pesticides by causing them to burn onto the leaves rather than being absorbed [C17]. The canopy of the plant is used by participants as a protective measure against excessive UV radiation. This approach contradicts decades of practice of leaf removal, when the goal of canopy pruning was to create a beneficial micro-climate around in cluster zone with maximising air movement to prevent fungal diseases and allowing sunlight for biosynthesis. "*So I don't know, 10 years ago we used to be picking leaves and sorting shoots. Now we don't do that anymore. Because even so, what comes out of the canopy is easily burned*." (Participant 1)

Heat stress, as a general climate related risk [T9], also has a significant impact on vineyard cultivation. The main problem with extreme heat stems in the phenological characteristics of vine plants. Heat waves accelerate the ripening process [C24], which might have a detrimental effect on the nutritional value of the grapes and later the wine [C20]. As a result of extreme heat and dehydration, grape barriers shrivel and become too rich in sugar, but low in acidity. This results in unbalanced and flat wines as the acidity that would later serve as the spine of the wine is weakened. Making wine from such raw materials is much more challenging [E4] because it is very difficult to artificially achieve the right balance of acid and sugar through oenological interventions (e.g. by adding water to the grape must).

There is no protection against heat stress that participants currently apply. The above-mentioned foliage management can reduce the impact of excessive heat, but it cannot help substantially. Shading nets and other sunscreen materials are not in use at all. The only adaptation option is if they start harvesting earlier. Harvesting time for grapes is mostly defined by the final maturity stage, so shifting harvesting times is essentially growers' response to changing circumstances. According to all participants, the beginning and the end of harvest [E8] have both been shifted forward by weeks, as a result of warming and heat waves. Therefore, the issue is not that harvesting is taking longer, but rather that all varieties are ripening faster, which means that harvesting is also ending earlier than it used to. This was often shared in the form of childhood anecdotes:

> "*I often mention this at wine tastings that the harvest used to begin on first of September when I was in primary school. Now the average is mid-August, so it at least two weeks earlier. And we work with the same varieties*." (Participant 1)

The key, non-climatic element in vineyard cultivation is the labour [T4]. Lack of labour is such a widespread issue that affects the entire agricultural sector, not just viticulture. However, it is not a coincidence that this risk was often reported to be posing more challenges than climate related risks. Wine grape production has been always very labour intensive. It is characterised by a number of work phases such as harvesting, pruning, leaf removal, grapevine tying, and suckeing that traditionally require intensive, manually performed work. The labour-type causes that most strongly affect vineyard cultivation is labour shortage [C7] and the poor quality of labour locally available [C9].

There are a wide range of adaptation options to deal with workforce-related difficulties. In the case of farms with small areas (the threshold was set at 5-10 hectares by the participants), vineyard works can be rescheduled, or postponed [E6] (e.g. to the weekends), or delayed depending on the availability of workforces. Such small farms frequently use family members' work or hire people for whom working in vineyards is merely a secondary source of income. For farms larger than 10 hectares, these solutions are not suitable. For them, permanent or regular seasonal employment are the best options. Although seasonal vineyard work used to be a common additional source of income in the wine region, this solution is becoming less and less available. Participants mentioned that the local labour market's demographic composition is the reason why their labour demand can be hardly satisfied by local resources. The typical description of the situation tells that only elder residents, aged fifty, sixty, and not infrequently seventy, are available for seasonal vine work. However, their numbers are decreasing naturally, which is a concern for participants because it is difficult to find young vineyard workers with equivalent or comparable training as their elder peers. By training, participants did not refer to competencies and skills acquired in formal settings, but the practical knowledge people gained during many decades of regular or seasonal work in the vineyards. In addition to the difficulties in planning vineyard work [E6] with the available workforce, a a substantial threat is that this essential viticultural knowledge will be lost without being passed on with the inevitable ageing of the elderly [C10]. The "*old uncles and aunts*", who very likely represent the last generation of vineyard workers, have a very different work ethic compared to the younger generations. These often-recurring comparisons regularly highlight sharp differences in competencies:

> "*People who have been doing this all their lives, for instance in cooperatives and they worked in vineyards, and they are basically simple peasant-like people who not only have the ability to work, but they want to work and it's a matter of honour for them to do it rightly, so yes, if they take on something, they will do it. Now this group has almost entirely disappeared*" (Participant 3)

These comparisons provide a stark contrast to potential workers who could still be considered for seasonal jobs and are available locally or nearby. Participants' poor experiences are mainly associated with untrustworthiness, unreliability, and low work morale [C9]. These employer-employee relationships generate a range of frustrations, which are further heightened when they are accompanied by significant wage demands or even damages caused in the vineyards.

Permanent, full-year employment is one way for adaptation to labour shortages for farms larger than 10 hectares. Maintaining such permanent teams not only provides security in vineyard cultivation, but also makes all other types of work, such as wine production or general maintenance predictably manageable. However, finding the right labour is not an easy task, not only because of the tight supply discussed above, but also because of other wineries looking for good workers too. However, if an employee performs well, farmers are increasingly willing to keep them. They can do this with the provision of benefits, the provision of tools for own usage (e.g. trucks for transportation personal belongings) pay rises and, most importantly, long-term contracts).

> "*From our side, what's a positive thing is that we have a team of five people who understand viticulture, they are demanding and reliable in their work. We practically work with them the whole year, and they are a great treasure for us. It's also good that they've reached a level of expertise in viticulture and winemaking as well that allows them to help us with winemaking and bottling, which is very important*." (Participant 2)

Mechanisation is yet another strategy for coping with labour shortage [C14]. According to participants' estimations, between sixty and ninety percent of vineyard work could be replaced by technology. However, there was general agreement that complete mechanisation is not a goal that should be pursued in viticulture. Nevertheless, there was a clear causal relationship between a labour shortage and mechanisation, which is one of the most prevalent adaptation strategies in this context. There are both high-tech and low-tech examples of mechanisation in participants' activities. The most typical example of the former is the use of grape harvesters, which have become a common sight in the wine region during the harvesting season. The use of harvesters not only offsets significant amount of labour when it is usually more difficult than usual to find available workforce, but also contributes significantly to the quality of the final product. In essence, it radically reduces the time the raw material (grape must) spends between the plantation and the winery, thereby preventing oxygen- and heat-induced uncontrolled fermentation of the must [E4]. Due to the high cost of purchasing and maintaining such a technology, only farmers who have reasonably large land holdings can afford this adaptation option. Smaller farms can use it as a service, but doing so also requires adaptation: they need to have plantations designed and planted considering potential vineyard mechanisation.

> "*We don't really have a solution to that [*labour shortage*], all we will be able to do is try to replant our plantations as much as possible. So we might end up having to buy [metal] posts that are twice as expensive. We will see. Or we'll put more wood post in. Because even the wood will hold up well. So you can use the combine quite well for 15-20 years, then the problems start.*" (Participant 1)

The advantage of small farms over large farms is that not all technological improvements involve the use or purchase of expensive machinery. This has been particularly evident in the case of deadheading applied to stop vein development. Weeks of drought this summer halt shoot development so much that walking through the rows with a pair of hedge clippers was more productive than using a pruning tractor. This not only saved fuel but also avoided unnecessary topsoil erosion. In most cases, modern plantings now use training systems with aluminum posts. One participant provided an insightful example of how this technology is designed to help famers by allowing them to move the wire up and down to align the shoots. This technique saves both time and labour for the farmer. This participant claimed he had first encountered this technique twenty years ago when he was working in vineyards in Germany, but his peers in the Mátra have yet to adopt it. This is also a noteworthy finding because modern plantings automatically have this simple function, requiring no additional investment other than the recognition of the advantage of using it.

> "*In Hungary, they don not move the wire, but the shoots are put between the wires. That means they need one day to finish with one household plot [cc 0,3 hectare]. And in Germany, where we learnt this, they take the wires down and put them back up as the shoots grow. It's true that you have to lift the wire three times, so you have to do it three times in three weeks. But it is atill much quicker.*" (Participant 1)

Working in the vineyards during heat waves draw attention to the growing concern over the risks to human health [E15]. This is because of the physical nature of vineyard works: outside work exposed to heat stress without very limited options to mitigate this effect. Planning for full day working days is no longer feasible during the worst heat waves because the conditions in the plantations become intolerable. One solution is shortened workdays in the hottest days. As a result, for example, working days in July last from 5 am. to 10 am., because physically they cannot last any longer [E6].

> *"...so here we're basically working from 5 am to 9 or 10 and often we don't even go out in the evenings. Okay, thank God it's not this hot in May and June, when most of the work needs to be done in the vineyard. But now in July we work from 5 am to 10 am and then we come in."* (Participant 1)

It is clear that this aspect of vineyard work plays a significant role in why job seekers find this type of work unattractive [C8]. Working at dawn or at night, when the temperature is more tolerable, is an additional option for machine-dependent work. Examples include harvesting and spraying, as well. This way growers can either prevent pesticides to burn on the leaves, and heat-related deterioration of grape must.

The sharp increase in the prices of input materials is another crucial factor when new plantings are being planned and performed [C15]. Participants reported a drastic increase in the prices of the most important inputs, such as grape stakes, metal or wooden posts, wire and fuel. Despite the fact that vine planting has been supported by a well-functioning subsidy scheme, it can have a strong impact on participants' planting intentions [C11]. A plantation plan and a budget must be prepared as part of the application for such subsidies. However, it might happen that by the time the application is approved, the price of some materials may have risen so much that the original budget can no longer be met. In such instances, the extra expense must be handled by the farmers. It can be even worse if it turns out that the fund for plantation subsidies is used up after the order for grafted vines had been submitted for the vine nursery. Such an order must be made and paid for in the year prior to planting. Once shipped, grafted vines cannot be stored, in the hope that subsidies will be available again soon. They must be planted as soon as possible; however, in such a case, they will no longer be eligible for subsidies.

There was a strong consensus among participants that the impact of warming could lead to an increase in late-ripening grape varieties in the coming years and decades [E3]. Participants revealed that this adaptation has not yet taken place but is rather seen as a possibility that is still subject to some degree of uncertainty. However, when asked about the future of early-ripening varieties in the wine region, vine growers relied much more on their on-the-ground experience. In this regard, Irsai Olivér [E2] was the variety that was most frequently mentioned. It is the earliest maturing variety of the grapes grown in the Mátra wine region, and it is the one with which the harvest begins. This characteristic makes the cultivation of Irsai Olivér quite risky. The risk of producing Irsai Olivier is essentially twofold. On the one hand, the wine produced from it will administratively belong to the previous vintage if the harvest takes place before the last day of July. The reason for this is that the new wine market year starts on August 1. This is not something that is unlikely to happen as one participant recalled an extremely hot year, 2018, when the harvest of the variety started on 28 July. The other aspect that makes the cultivation of this variety risky is its adaptive capacity to warming. Participants tend to agree that the cultivation of the variety may not be sustainable due to warming after the next ten years because heat damage causes lower sugar accumulation and breaks down acidity. The more the grape is damaged, the harder it is to intervene the fermentation process with oenological practices to produce the type of wine consumers expect from this variety [E4].

> "*Well, we can't keep growing Irsai because we're going into the Mediterranean climate and there's no acid left in them, they burn, or we can harvest them for the previous vintage. (...) If you harvest in the last week of July, it technically belongs to 2021 vintage. In 10 years, we'll be like Brazil, where they have two harvests in one year.* " (Participant 4)

There is no evidence that producers intend to stop working with Irsai Olivér and plan to replace it despite their perceptions that climatic conditions are not changing in favour of this variety. On the contrary, some growers had new plantations or planning to have new plantings. There was one who even invested money in the renovation of an old Irsai plantation. The apparent contradiction is resolved by looking at how participants perceive the market position of the variety. Due to its easy-to-drink and easy-to-enjoy wines, Irsai Olivér has become one of the most popular wines over the past 15 years [C1].

> *"...but basically, wine consumption in Hungary is also gradually declining for red wines. It's not coincidence that Eger, Villány and Szekszárd are coming out with white wines, because they can't sell enough red wines. And they are planting now white vine. You know, if a big red wine dominant region*

> *says that they are going to certificate Irsai Olivér, then there is something wrong there*." (Participant 4)

According to participants' reports, the continuous demand from consumers is the reason why Irsai Olivér has consistently been one of the most profitable grape varieties: not only does the producer receive a predictably above-average gate price for it as raw material, but it also enjoys a good price when sold as wine. So, despite the certainty of the unsustainability of this variety, and the frequently voiced negative comments of wine makers about its less sophisticated wines, it is likely to remain a stable and dominant part of the wine region's varietal selection for the next years or decade.

Interestingly, lack of rain is not seen as an only negative impact on vineyard cultivation. Extreme heat, combined with drought, creates such an unfavourable environment for certain grape pests and diseases that they may not even appear during the growing season [C18]. This is obviously of great importance for plant protection, as it means that fewer and less frequent interventions are needed to control these pests and diseases. The phenomenon is a relatively new experience, and it reinforces the importance of the distribution and timing of rainfall for growers. It is assumed that these typical pests (e.g. grapevine moth) die in their larval stage due to the heat and drought. The situation is similar for fungal diseases (e.g. downy mildew disease), which are a frequent risk of cool and moist weather [C19].

> "*The interesting thing about the summer is that up until now, we have had to protect against grapevine moths both as adult moths and as larva every year. We no longer need to control the moth this year because it has vanished, dried up, burned out, in its a larva stage*." (Participant 2)

The positive impact of heat can help mitigate another common climate change risk. The link between the lack of winter freezing and the presence of certain pests is well known [C25]. Winter freezing is essential for vine plants for proper development because it eliminates pests. However, it is more and more common, that some pests are able to survive in mild winters, with the consequence that they appear with much larger populations in the beginning of the growing season. In cases of severe infestations, this may require significant crop protection and may lead to yield losses. It may well be that extreme heat and lack of rainfall will help farmers mitigate this risk in the future. However, this is still more of a unique experience for the participants, but they may have to learn to incorporate this into their adaption methods in the future.

Vine growers have very little room for adaptation to the lack of precipitation. At most, irrigation has been considered a theoretical solution to replace rainfall. Vineyards in Hungary have never been in need of irrigation, so this practice has never really become widespread. Farmers have been able to cope with previous droughts. However, vineyard irrigation is likely to become a more popular adaptation option in the future, but participants identified a number of barriers that make this highly unlikely.

Due to the mountainous nature of the wine region, huge investments in infrastructure, such as wells, reservoirs, canals, and pumping stations, would be required. These are investments that can only be planned with a top-down approach and financed from central budget. Individual investments at the plantation level would probably never pay off economically. In addition, participants are not even sure if they would be able to get permits for such things like drilling wells under the current regulations.

> "*Watering would be nice, but we won't be able to manage it. So, if it stays as dry as this year, it would not cope with that anyway. It would take a huge investments and community investments to get irrigation pipes, backbone lines built and so on. So, one by one, it doesn't work." (Participant 2)*

*However, it cannot be said that vine growers are comp*letely toolless in the face of persistent drought. Applying organic mulch or planting annual or perennial cover (mostly grass) in vine inter-rows is one adaptation option that seems to have started spreading among farmers. The main advantage of this technique is that it is said to reduce evaporation of the soil, so there is more water left there for the vines. Secondly, it prevents soil erosion caused by sudden rainfalls. However, there is still some ambiguity surrounding the application of this method. One grower continues to follow a family tradition that originated from his grandfather that inter-rows must be kept cultivated and clear of any grass. A more reasonable argument was that allowing another crop to compete with the vine for water would have cause detrimental impact. The transition between adoption and non-adoption was represented by the participant who planted only every second row with a special mix of grass. The uncertainty about cover crops may have been exacerbated by the drought in 2022, which was so severe that the grass mixture sown as a cover crop could not grow properly and therefore, probably could not perform its function at all.

There were also mentioned two additional adaptation techniques that can mitigate the effects of drought. These are spraying with water and foliar feeding and fertilisation. The latter exploits the ability of vine plants to take up nutrients through their foliage. In effect, foliar feeding and fertilisation provide conditioning substances through the foliage that help the vine plants to grow when there is hardly anything that plants can take up from the soul due to rainfall deficiency. Spraying with water follows the same logic as foliar fertilisation, except that nothing other than water is applied. This solution is usually applied a couple of days before harvest starts. This small amount of water, applied in the last days, results in a significant increase in yields because barriers can absorb water, which naturally helps to balance nutritional values. The latter means that, with this last-minute added water vine plants can reduce the amount of sugar and acidity to a level where they can be made into wine more safely. It is in fact an adaptive intervention that utilises a natural ability of the vine plant. The origin of the practice is twofold. On the one hand, family anecdotes told us that, in the old days, vine growers used to irrigate vineyards the night before the harvest in the hope of higher yields. However, nature is also worth keeping an eye on because it can teach things like:

> *"...I experienced the practical benefits last year, because last year the quality was good, the quantity was good, but the drought caused the grains to be 30% drier, but once or twice a 5 millimetre rain caught it and the next day from must weight of 24 and acidity of 10, it went down to must weight of 21,5 and acidity of 7,2. So it absorbed a lot, and I can say that then it's worth putting out that 1500 litres of water on one hectare.*" (Participant 4)

Participants' reports consistently mentioned wildlife damage [E11] as a cause that makes vineyard cultivation difficult [C26]. This is hardly a new phenomenon, as there has always been a certain amount of wildlife damage, as the wine region is surrounded by game-rich forests from the north. It is not a new phenomenon, that is evident from the fact that producers have learned to live with it over the years. However, the situation has worsened in recent years, leading to increasing extent of damage and crop losses. The phenomenon is thought to be caused by the overpopulation of wildlife, especially larger mammals, and drying up of natural water sources in the forests. It is believed that careless management by the hunting companies are to blame for the overpopulation. While the drying up of water sources is a direct consequence of the increasingly severe droughts: if there is no rainfall, animals have no access to water in the forests. The most exposed and unprotected vineyards provide an excellent source of food and moisture for wild animals. They destroy not only juicy berries but also fresh shoots.

> "*I might add to that that not only in vineyards but also in everywhere else in the forests they can do tremendous damage. I've been out in plantations in the evenings and early mornings recently. Never precedented size of herds and packs of 30 to 50 have been observed. There was no such thing before. So we had 6-8-10, those kind of numbers*". (Participant 2)

The description of the situation is often characterised by inertia, frustration, and resignation. Inertia is caused by the difficulty of wildlife control. Fences provide protection for a short period of time because these large mammals can easily jump them over. Moreover, the cost of fencing plantations would be extremely expensive. It was mentioned as a temporary solution that the ends of the rows in exposed plantations can be fenced off, so by sacrificing the outer rows, at least they cannot enter the rows. The frustration comes from the bitter and pointless disputes with the hunting companies, which are said to be using all means at their disposal to avoid having to pay compensation to farmers for their damage. It seems that farmers either accept their losses or they deliberatively try to avoid wildlife exposed areas when planning to purchase new plantations.

> "*No, because I do not plant next to the forests. I'm not buying land that's wildlife-damaged. There was one recently that I would have loved to buy, but I didn't eventually*." (Participant 4)

Among the sales related risks [T2], the most prominent problem is the low farm gate prices of grapes [C5], which creates major operational risk for farms. The consensus view is that farm gate prices have not risen significantly for several years. "The grape prices are not going up, but rather down, or at least stagnating. So I can show you prices from 10 years ago or maybe even 15 years ago, as they are this year or were last year and will be this year" (Participant 1). Some varieties, like Irsai Olivér, that can be sold well and are always in high demand, and have predictably good market position. In addition to the obvious operational risks, reports of low prices also suggest that producers feel their positions vulnerable in the value chain [C6]. This sense of vulnerability is fuelled by unfair market conditions, in addition to low prices. Particularly, there have been several instances of traders in the bottled wine market being inflexible in their reactions to farmers' intention to price increases. Furthermore, grape and wine traders' stock management practises tend to share or entirely push market risks to the farmers.

> "*And then they are yelling at me if I want 20 forints more for a bottle of wine., while he's playing for a triple profit. I can accept that there are circumstances in which I must bear some of the expenses. The problem is when I can't see that compromise from others. So that they can sell it for that much, but that they won't give me more because they have costs, and they need profit. I need that profit too. I have to support my family, and I am talking about my employees' families. And I want to stay in this business next year too*." (Participant 4)

Another important feature of the sales related risks is excess supply, both in the grape and wine markets [C4]. Market surplus is caused by the abundance of grapes available and the extremely wide variety of grape varieties, which is a historical feature of the wine region [C2]. This is also reflected in the diverse variety composition of individual farms, which is usually the legacy of previous generations' vineyard management decisions and a deliberate diversification strategy. This type of diversification is regarded by the participants as a helpful component in their farm management practices, because there are always other varieties to save the business if one does not produce well. However, it is challenging to develop a clear development and marketing strategy for the wine region [C4] on the basis of such a diverse range of varieties. There was one case of on-farm diversification. The aim of this expansion of activities was to create a pick-your-own orchard.

There were two causes identified as being related to sales risks: a significant reduction in income due to the pandemic [C3] and expectations related to deceasing wine consumption due to inflation [C7]. The first one was fuelled by the experience with the COVID pandemic and accompanying restrictive measures. Participants suffered a 30-50% drop in sales due to restrictions on HORECA[3] sector. Wine tasting events ceased, and local sales decreased significantly. Adaptations to the unprecedented situation included, for example, launching of online sales or coming up with new way of wine packaging. Two participants started bag-in-box packaging during the COVID pandemic. One bag-in-box usually contains 3 litres of wine, that is equivalent to six bottles. The advantage of this

[3] The term HORECA is applied to the hotel and restaurant sector (HOtel, REstaurant, CAfé)

packaging for the consumer is that the vacuum bag with the tap preserves the wine longer, meaning that the large quantity remains fresh for a longer time. It seems that this feature became a key factor for consumers during lockdowns.

> "*Well, for example, we have changed the packaging, so started packaging bag-in-boxes. We can work with a better price/value ratio, so we can generate more sales. But it also means that I am going after the consumer to some extent.*" (Participant 4)

Another issue related to sales is fuelled by the expectations of a fall in wine consumption [C7]. In most cases, post-COVID recovery has reached or surpassed pre-COVID sales levels. However, participants are also aware that, in the current inflationary environment, wine will likely be among the beverage products that consumers will begin to "shop down," i.e. seek out lower-quality and less expensive products. At least, that is what participants anticipate, and this situation will be difficult to manage, much like the consequences of the pandemic. Regarding adaptation options, bag-in-box packaging could be a solution here too, since larger quantities can be sold at one time. In addition to that, it also offers a way to reduce input costs.

Under the label of administrative environment [T], I identified those factors that do not necessarily pose risks but can create uncertainty and sometimes difficulties for farmers. For example, subsidies [C12] have particular importance for mechanisation, but eligibility is often subject to conditions that are difficult for farms to meet. Conditions often include compulsory job creation, energy investment or complex technological development. For large farms, these may be achievable criteria, but for small farms they are unrealistic to reach. In addition, the administrative burden of such projects is also enormous, and payments are extremely slow, often with annual delays. Circumstances can result in absurd situations, such as the case of a producer who, three years prior, had also installed solar panels to become eligible for a subsidy for wine barrel purchase: "And then I'm not talking about a lot, a 12 million investment with a 50 percent subsidy. I'm already thinking about replacing those barrels, but we haven't got the money yet." (Participant 4)

Legislation about wine production and sales determines the administrative environment. Participants often mentioned the uncertainty surrounding the new wine law [C13]. The new legislation, which was adopted in 2020 but will only enter into force gradually, is perceived by farmers as a potential challenge to adapt to and a source of uncertainty, mainly because of the stricter penalties and the mandatory, soon-to-be-introduced online administration.

> "*The legislation, now the new wine law and all the new things that come with it, when almost everything becomes electronic, that's another challenge. Let's hope we can make it. It's an unknown territory right now.*" (Participant 1)

6.4. Discussion of results from mental modelling

The results, including the elements and links of the mental model, have been presented in the previous section. This section will discuss and address these results and answer the three qualitative research questions. The section is structured as follows. The key aspects of the multifaceted landscape of risks will be described first, followed by the presentation of interactions between climate change risks and other non-climatic change induced risks. Lastly, characteristics describing the adaptive behaviour of Mátra grape growers will be presented.

6.4.1. SRQ4: What are the main characteristics of the multi-faceted landscape of risks in which vine farmers operate? (SRQ4)

With this sub-question, the focus is on the mental model, which is the end-product of the multi-component analytical procedure. This procedure used participants' cognitive maps of manageable and unmanageable risks and the thematic analysis of participants' qualitative interviews. When building the model, one principle was used. The only way to establish a link between the different elements was possible only through the risk groups (Figure 12). This principle had to be applied to prevent the model from becoming too extensive and complicated (Winsen *et al.*, 2013). On the other hand, this approach also ensured that multi-risk induced effects could be accurately monitored and tracked in the model.

For climate-related risks, four types of risks were identified: heat stress, drought, UV radiation, and lack of winter frosts. Six risk types were identified as non-climatic: these are risks related to selection of varieties, sales, vineyard cultivation, labour, the administrative environment, technology. This is in line with studies with similar foci that risk environment for those working in the winemaking industry is influenced by a variety of factors and climate change is just one of these factors (Mosedale *et al.*, 2016). The analysis revealed that 10 climatic causes and 17 non-climatic causal factors contributed to the risks faced by participants. This led me to the conclusion that participants' perception of risks is more influenced by non-climatic causes than by climatic causes.

Looking at the details of the mental model, it is consistent with the existing empirical knowledge regarding the composition of non-climatic risk factors (Hardaker *et al.*, 2004; Belliveau, Smit and Bradshaw, 2006; Komarek, De Pinto and Smith, 2020). Three of the five common risk types (production, market, institutional, financial and personal) were identified in participants' interviews. Production related risk includes selection of varieties [T1], vineyard cultivation [T2] and labour [T4] and technology [T6]. Market related risk includes sales risks [T2], while the administrative environment [T6] belongs to institutional risks. Regarding climate change associated risks, these all belong to production risks following textbook definition of risk in agricultural studies (Komarek, De Pinto and Smith, 2020). This dominance of production risks corresponds with the discourse of agricultural risks that highlights production and market risks in empirical research. This is in line with Komarek, De Pinto and Smith’s recent review (2020), in which they found that two-thirds of risk related studies from the last 50 years focused solely on production risk type.

Regarding climatic factors, there were no differences between the findings of this study and those that have been reviewed above. What the participants mentioned can all be captured in these empirical studies dealing with climate change impacts both in European and non-European wine region (Van Leeuwen *et al.*, 2019; Santos *et al.*, 2020; Naulleau *et al.*, 2021). The only exception is perhaps the decreased intensity and frequency of winter frosts. This phenomenon, however, is consistent with the projections made for climate change in the Carpathian Basin (Mesterházy, Mészáros and Pongrácz, 2014; Mesterházy *et al.*, 2018). There is limited scientific evidence of the phenomenon from studies based on farmers’ perceptions. However, the causal link between warming temperatures in winter and reduced winter mortality of plant pathogens has been explored and assessed by other studies (Ashenfelter and Storchmann, 2016; Tóth and Végvári, 2016). Others have demonstrated that winter frost affects the vegetative and berry development of grapevines (Holland and Smit, 2010). Furthermore, it also has implications for winter work because freezing affects the life cycle of grape plants, that vine growers must take into consideration when planning winter pruning, for instance (Neethling, Petitjean and Quénol, 2017).

The answer to the question is therefore that the participants' mental model does not contain any element that is significantly different from what we already know empirically. The multi-component analytical produced a heterogeneous and complex risk landscape in which Mátra vine growers operate. Based on that, we can conclude that multiple risks acting concurrently have an impact on participants' decision-making. However, two (financial and personal) of the five conventional risk types listed in the agricultural risk literature, were not found in the participants' interviews.

Another important outcome is that mental modelling has proven to be particularly well suited to elicit and visualize the participants' diverse and complex risk landscape. As Winsen et al. (2013) explained, classic risk maps do not present connections, while mental mapping takes links into account as well. This is an extremely useful aspect of mental models in the interpretation of results, not to mention their exploitation when informing public policy in support of climate change adaptation (Findlater, Satterfield and Kandlikar, 2019).

6.4.2. SRQ5: What is interaction between risks associated with climate change and other non-climatic risks? (SRQ5)

The multicomponent analysis identified eleven effects as the results of multiple climatic and non-climatic causal factors. Although it was not intended to quantify the extent of each risk, given the difficulty of doing so using qualitative methods (Winsen *et al.*, 2013), participant responses indicated that, in this multifaceted risk environment, labour related risks play a greater role in their management decisions than climate change related risks. This is well reflected in the evidence that their adaptation decisions have been focused on long-term solutions to labour related problems. As a consequence, the effects of climate change have not yet induced such long-term changes, as producers appear to be able to continue their activities with the available skills and resources. Accordingly, labour shortage was a major theme in all narratives. The labour shortage in the agricultural sector is not novel phenomenon. Adverse labour market trends have been affecting agricultural sectors for a long time. Numerous reasons have been identified that contributes to disrupted labour flows in the sector, such as the ageing workforce, the continuously increasing wage demand, the low work ethic and lack work experience (Hamza *et al.*, 2021).

The results clearly demonstrated that participants must make compromises in order to adapt to the labour shortage. Participants estimated that the threshold is approximately 10 hectares, above which it is unavoidable to employ seasonal labour or increase permanent employment. It is inevitable because a lack of workforce makes daily operations unmanageable and impedes development. Daily operations are affected by labour availability and warming which creates difficulties because warming quickens plant development and shortens phenological transition periods and might require rapid interventions in cultivation. This illustrates the importance of permanent employment, especially during harvest when the maturity times of different varieties are increasingly overlapping. Farmers cannot influence grape's maturity; they can only adapt to it. In such cases, even a single day's delay can have an adverse impact on quality and quantity, so leaving ripening grapes "out in the field" is a risk that farmers need to manage. Vine growers also have to think about another aspect of viticulture, which is that heat waves in the summer make it harder to work outside. This adverse impact is projected to grow as heat stress events will become more intense and frequent, making physical labourers even more vulnerable to heat stress (Bezner *et al.*, 2022).

The results indicate that participants are engaged in two adaptation options to moderate labour related risks. One is their attempt to establish stability in their employment. This is accomplished by occasionally employing "*permanent casuals*," or, in other words, individuals who are dependable and regularly available for casual or seasonal work without an annual commitment. But for larger farms, full-year employment seems to be the adaptive option that may solve permanent labour shortages. The other adaptation option is mechanisation. The level of mechanisation has noticeably increased in recent years. In this regard, the situation has changed dramatically over the past three decades if we look at how mechanisation was perceived in 1991: "*many important parts of the work process cannot be mechanised at all or have a high cost overhead (e.g. harvesting) that production cannot bear*" (Bodnár, 1991, p. 27). Nowadays, mechanisation can range from the most basic tools—like manual trunk cleaners or electric pruning shears—through different vine cultivator machines to the grape harvester, which appears to be cutting-edge technology being applied in the wine region in this regard.

Both options, long-term employment solutions and mechanisation, reflect the trend of modernisation and professionalisation. Mechanisation as a form of modernisation as an adaptation strategy has been the subject of the discourse on vineyard modernisations for a long time (Kaan Kurtural and Fidelibus, 2021; Sun *et al.*, 2022). These reports have mostly highlighted rising wage costs, labour shortages, cost – effectiveness, and timing as the multiple reasons for advancing mechanisation. However, these studies also point out that technology does not completely eliminate the need for seasonal manual vineyard labour. This is also in line with participants' view on mechanisation. There is less reference to the causal link between climate change and mechanisation, so when the quality enhancing effect of mechanical harvesting is emphasized by participants of this study, it can be seen as a new element in the discourse. The other link between mechanisation and labour is that vineyard mechanisation, similarly to any other agricultural sector, increases the need to employ skilled employees to operate machineries. (Kaan Kurtural and Fidelibus, 2021).

In studies on the professionalisation of agriculture, it appears that agricultural professionalisation can be seen as a source of adaptive capacity that helps face increasingly tangible ecological and market risks (Wolf, 2008). Results have shown that finding and retaining trained personnel in the long term for large farms seems easier and more profitable now than finding seasonal workers year-by-year for labour-intensive work phases. Permanent employment of skilled labour is in fact a sign of professionalisation. An important outcome of professionalisation is that farms today increasingly need skilled labour to cope with the complexity of modern technology-driven agriculture (Schuh *et al.*, 2019). This complexity is expected to grow with precision farming, robotisation, digitalisation of supply chains, and decision-support systems becoming more common in agricultural production (Bock *et al.*, 2020). However, it is also important to note that participants do not need so-called "ready-to-work" workers who have everything about the vineyard in their hands. On the contrary, candidates could follow a learning-by-doing process, but participants rarely encounter the motivation and perseverance needed.

Findings also show that vineyard cultivation [E7] and the process of planting [E10] are other challenging areas of participants' activities. These are without a doubt the fundamental activities of vineyard farms, which appear to be affected by numerous concurrent climatic and non-climatic risks. Vineyard cultivation decisions tend to be short term decisions characterised by reactive responses. Strategic and long-term responses rather feature in decisions upon vineyard planting as they are decisions for the future (Neethling, Petitjean and Quénol, 2017). Regarding vineyard cultivation, this study has learned about a number of short-term adaptations, such as leaf removal, water spraying prior to harvest, and an early start to harvest. These practices do not require significant management amendments or substantial investments. Such adaptation practices were frequently identified in other empirical studies (Lereboullet, Beltrando and Bardsley, 2013; Neethling, Petitjean and Quénol, 2017; Van Leeuwen *et al.*, 2019; Santos *et al.*, 2020). In case of planting, however, vine growers must make infrastructure decisions that will determine the future of their farms for decades. In that sense, it is crucial to consider the conditions under which new plantations will be cultivated, considering changing climatic conditions based on experience. However, this aspect does not seem to be a key factor in participants' decisions. Limited direct references were made regarding the fact that farmers make long-term strategic decisions in relation to current or potential climate change impacts to mitigate the vulnerability of their farms. Based on similar empirical investigations, these long-term strategic adaptations might include site selection, vineyard design, or plant material choice, or combinations of these (Naulleau *et al.*, 2021). In this case, site selection, for instance, was considered in the context of avoiding wildlife damage. In relation to vineyard design, adaptation efforts were driven by the need to make training system suitable for mechanical harvest. And last, but not least, decisions about grape varieties clearly seemed to be driven by market opportunities rather than long-term adaptation strategies.

This latter one can be observed from the fact that Irsai Olivér continues to play a major role in participants' plans, despite the fact that this grape variety is seen as becoming increasingly risky to produce in the wine region. Growers' confidence in the variety's popularity and market position appears unquestionable, and they have no intention of giving up cultivating it. Irsai Olivér has been a driving force behind the growing popularity of fresh, fragrant white wines in domestic wine consumption trends (Tisza, 2019; Totth and Szolnoki, 2019; Ipacs, 2021). This is also reflected in the national and regional statistics. Over the past 20 years, the variety has risen from the 20th to the 7th most prevalent variety nationally by land use. Only the Kunság wine region cultivates Irsai Olivér on a larger area, than the Mátra wine region (KSH, 2020). Irsai Olivér rose to the second-most popular white variety in the region by 2022, as its area nearly doubled since the millennium (HNT, 2022). As Mosdale et al (2016) argue that the economic viability of a wine farm is determined not only by the size of the vineyard and the yields, but also by harvest quality. Planning with Irsai Olivér, however, goes against this thought and the perception of participants. In that respect, participants' decisions tend to be rather driven by current market trends, which can be identified as short-term profit-maximizing behaviour. This, however, masks a contradiction, since newly planted vineyards are supposed to remain both economically and ecologically productive for decades, even under unprecedented climate conditions, to make the investment pay off (Neethling *et al.*, 2019). This is not guaranteed with Irsai Olivér. In that regard, participants' attitudes do not fit into climate resilient approach, in which the essence of adaptation decisions is based on the recognition that such farm management practices should be adopted that contribute to effective and successful adaptation to climate change at the farm level (Acevedo *et al.*, 2020).

In addition, when growers decide about the cultivation of new varieties, they could rely on the great phenological diversity of vine cultivars. This would offer them great potential for producing with greater certainty even under changing climate conditions (Naulleau *et al.*, 2021). But it seems that the Mátra vine growers prefer not to take advantage of this opportunity and not to try other varieties. Numerous scientific findings have already demonstrated that changes of grapevine cultivar in response to changing climatic conditions can become unavoidable (Schultz and Jones, 2010). However, it is not a straightforward decision, as Neethling et al. (2017) pointed out. In their study, French vine growers saw changing grapevine cultivar as one of the last potential step in their adaptation strategies, simply because they see many other practices they could apply in response to changing climate conditions. However, there is already empirical evidence that climate change has forced grape growers to change varieties. For instance, Lereboullet (Lereboullet, Beltrando and Bardsley, 2013) reports that producers started uprooting Chardonnay and start planting alternative Mediterranean varieties that were believed to be more resilient to water stress. However, it is also likely that complex problems will be solved by complex adaptations. Zhu, for example, investigated whether vineyard design (relocating vineyards uphill) and the introduction of a drought-resistant variety together lead to higher economic efficiency (Zhu *et al.*, 2016). In this regard, participants from the Mátra wine region have a unique attitude because they show very limited adaptation intentions to a risk, that they already perceive and suspect that it will get worse in the near future.

The problem of wildlife damage was also highlighted in participants' narratives. Human-wildlife conflicts may include conflicts when human activities are adversely affected by wildlife or when human activities adversely affect wildlife (Madden 2010). Participants identified two reasons why wildlife damage occurs. On the one hand, there is the issue of overpopulation of animals, which is seen as the hunting companies' mismanagement. Summer droughts, on the other hand, force animals to look for alternative water sources, and unprotected vineyards offer a good opportunity for that. Despite the fact that human-wildlife conflicts are increasing and escalating worldwide, the number of studies linking climate change to wildlife management and agricultural production is very limited. The very few studies on the role of climate change have described that as people and animals are adapting to new weather patterns, it is likely that novel interactions will occur and severity of these interactions is expected to rise (König *et al.*, 2020). It's likely that some signs of this can be seen in the Mátra wine region. However, this local conflict is only seemingly taking place between producers and animals. Considering that wildlife management in Hungary is a regulated activity, with legally appointed actors, it is in fact more of a human-human conflict. The conflict has been made particularly visible and damaging by animals seeking water in the summer drought. The issue would certainly require further investigation to explore the unknown aspects of the situation. This might require a trans-disciplinary focus, for instance involving conservation biology, agriculture, wildlife management.

6.4.3. SRQ6: What characteristics define vine growers' adaptation behaviour in relation to the identified risk landscape? (SRQ6)

The adaptive behaviour of the participants was twofold. On the one hand, despite all the identified risk factors, participants appeared confident that they can carry on with their viticulture activities. This confidence is probably due to the fact that they have not yet noticed a level of damage caused by climate change or other risks that would have made them doubt if their activities are still profitable and sustainable. Despite all their risks perceptions, participants will be able to maintain their activities with the competencies and tools at their disposal. This is clearly in line with climate projections made for Hungarian wine sector in the light of changing climate conditions. These suggest that not only the Mátra, but each Hungarian wine region will remain within the optimal range for the most significant climatic drivers (Szenteleki, Horváth and Ladányi, 2012). However, it is also clear from participants' reports that adaptation is inevitable and has already begun.

However, when it comes to adaptation to changing climatic conditions, this study came across with fewer indications of participants' confidence. There was always a feeling of uncertainty in participants' responses, regardless of whether adaptation measures were being planned or were already in place. This is not a novel finding because uncertainty has been a frequent notion in other empirical studies in this field of inquiry (Fraga *et al.*, 2013; Lereboullet, Beltrando and Bardsley, 2013; Sacchelli, Fabbrizzi and Menghini, 2016; Neethling *et al.*, 2019). However, it received limited attention in the Hungarian context (Szenteleki, Horváth and Ladányi, 2012). This study identified two types of uncertainty. Either participants responded to uncertain situations by adaptation, or they were uncertain whether to take or not take adaptation measures.

The participant who recently started to reduce vineyard areas provided the strongest evidence of adaptation to uncertain conditions. The reason for this step was the cumulative effects of the interlinked risks in vineyard cultivation as described extensively above: labour shortage, selection of variety, and climate change impacts. In other words, conditions achieved a point where it was no longer economically feasible for this producer to continue producing certain varieties (e.g. *olasz rizling, hárslevelű, kékfrankos, chardonnay*). However, even this one producer is able to continue his activity and produce wine because he will be able to purchase the grapes he needs from other growers. He has mitigated the risk to his own farm by abandoning some of his plantations, but he has done so because other producers can continue to produce with the same quality and quantity.

Another adaptive response to uncertainty was taken by a participant who is planning to start a so-called pick-your-own fruit orchard in addition to his winery. This new activity will be agriculture-based, so it will be subject to all the potential risks brought on by climate change, though it also mitigates risks associated with labour shortages and market sales. Moreover, future visitors might generate an increase in wine sales as well. On-farm diversification can be a potential method to adapt to climate change and many other agroecological and socioeconomic challenges (van Zonneveld, Turmel and Hellin, 2020).

Uncertainty was present in those examples when participants lacked understanding of the impacts of climate change. This was the case, for instance, when participants tried to find a connection between heat stress and the lack of grape vine pathogens during summer heats. Participants also spoke ambiguously about the introduction of varieties better adapted to warming without mentioning any particular variety that might suit future climatic conditions. The practice of mulching, which some claimed could be a solution to preserve soil moisture while others claimed it was an unnecessary rival to the vine plants, was surrounded by skepticism and uncertainty. Views on irrigation can be added to this list by emphasizing that those who did not rule out the possibility could not tell with certainty that it was even feasible in the Mátra wine region.

Participants also expressed uncertainty about their decisions to planting or not to planting. These uncertainties were generated around the current drought, and the expectation of rainfall next year and the choice of potential new varieties. Although planting is a strategic decision for the long term, in the context of the severe 2022 drought, it is also a tactical decision to decide whether to plant in the severely dried soil. The source of participants' uncertainty is that they do not know what to expect in 2023. However, they are aware that some of the freshly planted rootstocks would be at a significant risk of drying out due to the severe water shortage that already exists in the soil.

Although there seems to be a consensus that climate change may generate suitable conditions for late maturing varieties in the wine region, no specific varieties were mentioned to accompany these views. Varietal statistics for the wine region show that some medium-ripening black grape varieties, such as Pinot noir and Syrah emerged and increasingly gained land in the last twenty years, but even their combined area is so small compared to the total area that it does not indicate a paradigmatic shift in the view growers' behaviour.

In conclusion, the following points can be made to address the research question concerning the characteristics of vine growers' adaptation behaviour. Climate-related risks carry less weight in adaptation decisions than labour-related risks, particularly labour shortage. Labour related adaptation measures tend to be long-term strategic decisions, while climate change related adaptation measures aim to make tactical responses. Adaptation measures, such mechanisation and permanent employment aim to tackle labour related difficulties and are evidence of growers' modernisation and professionalisation efforts. By contrast, vineyard cultivation and planting have mainly triggered only short-term adaptation measures. While the former is in line with findings of other empirical studies, and clearly shows that growers have started taking adaptation measures, the latter seems contradictory in this context. Although growers clearly perceive that warming and lack of rainfall will have a significant impact on the cultivation of some varieties, their mindset does not seem to be shifting towards potential long-term strategic adaptation measures.

CHAPTER 7: CONCLUSION

This chapter presents the concluding remarks of the research by formulating the main thesis of the dissertation. In addition, research limitations are also presented, and questions are formulated that could guide further research in this field.

7.1. Concluding remarks

This research aimed to enhance what is known about vine growers' climate-adaptive behaviour considering the multi-faceted risk landscape in which they operate. This aim was fulfilled by adopting a *partially mixed sequential dominant* research design, in which a quantitative research segment (large sample of survey data) demonstrated the overall picture of Hungarian farmers' perceptions of climate change and adaptation behaviour which was followed by an individual-based mental modelling approach used to conduct a risk elicitation exercise embedded in qualitative interviews with vine growers from the Mátra wine region.

Conceptually, this research is a vulnerability-centered adaptation study with a focus on climate adaptive-behaviour. The point of departure for this research was that climate change induce risks will be exacerbated, leading to increasing engagement in risk-mitigating, or in other words adaptation actions (Anwar *et al.*, 2013). The various individual based analytical approaches stemming from this interdisciplinary field of climate adaptive-behaviour research have a common element in their focus: adaptation studies need to focus more on the human dimension of climate change because individuals' decisions are inevitably influenced by the perception of risks, and many other factors, such as personal values, emotions, cognitive biases, social experiences, and relationships (Clayton *et al.*, 2015; Brown *et al.*, 2017; Sok *et al.*, 2021). This research intended to contribute this emerging field of studies by assessing vine growers' adaptation behaviour through the lenses of multi-faceted nature of risk perception and risk assessment (Winsen *et al.*, 2013; Findlater, Satterfield and Kandlikar, 2019). This research intention was driven by the following overarching research question:

”What does the risk landscape for Mátra vine growers look like from the perspective of climate change adaptation?”

Based on the results of the quantitative segment of this research, the following general portray can be drawn about Hungarian farmers' perceptions of climate change and adaptation behaviour: they accept the theory of anthropocene climate change, have already perceived some of the impacts of climate change; however, these impacts have not affected their sensitivity substantially, but they have already engaged in certain adaptation measures and have been planning to do so intensively.

However, this general picture looks different if grape growers are compared to other farmers. The literature review led to the assumption that, given the sensitivity of grape plants to seasonal variation and the restricted spatial and climatic suitability of grape cultivation, it was predicted that grape growers would be at the forefront of adaptation because of how strongly the impacts of climate change would affect them. The survey results, however, reveal that vine growers in the sample are generally less conscious of changes and feel less affected. However, the consistent finding is that their adaptation activity is also low, particularly when compared to other plantation growers, such as fruit or vegetable farmers.

Having this in mind, it is especially intriguing to interpret the findings of the qualitative segment of the research. Participants’ multi-faceted risk landscape demonstrates that there are interactions between climatic and non-climatic risks, and these interactions result in effects whose occurrence is attributed to multiple causes of risk.

Despite the participants' diverse and complex mental models, the presence of a double pressure stood out from the results: one from the risks posed by the impacts of climate change, and another from the risks related to labour. The most obvious consequence of labour-related problems is that fewer and fewer people are willing and able to work in viticulture, which is a very labour-intensive activity. And risks that come with climate change, such as severe heat stress, lengthy droughts, and excessive UV radiation will likely pose severe challenges for grape cultivation. Although the interaction of these two types of risks generates significant adaptation needs by exerting effects that should be addressed by a complex risk management approach, participants’ responses do not reflect this complexity. More precisely, participants’ responses indicate that in their multi-faceted risk landscape, labour-related risks have a greater influence on their risk management decisions than climate change related risks. This is well reflected in the evidence that their adaptation decisions have been focused on long-term solutions to labour related problems, but only short-term decisions characterise their climate change adaptation behaviour.

Participants' responses (mechanisation and long-term employment) to the labour shortage are consistent with the narratives of modernisation and professionalisation. By engaging in these activities, participants can increase their farms' adaptive capacity, which could be advantageous if production risks worsen. In the meantime, the effects of climate change have not yet induced such long-term amendments in management practices, but rather ad-hoc interventions whose aim is to react to year-to-year weather variability. However, contrary to what the survey's findings suggest, participants' moderate adaptation activity is not due to the fact that they do not perceive the changes or do not feel that their activities are sensitive. The opposite is true: participants have been perceiving most of the same effects as their peers in wine regions around the world. They have perceived shifts in weather patterns and describe them as changes in trends, rather than stand-alone extreme events. Even their outlook for the future is determined by the anticipation of the escalating climate situation.

However, despite all their perceived risks, participants still find themselves able to maintain their activities and keep cultivating grapes. This is because, on the one hand, climate risks are still seen as manageable with the available solutions, which consist primarily of tactical interventions. However, on the other hand, there appears to be considerable uncertainty regarding what should be done and how it should be done, so even these tactical interventions are surrounded by uncertainty. Multiple forms of uncertainty have been identified in this research, suggesting that if the climate situation worsens, the adaptive capacity of participants might be insufficient to cope with changes in climatic conditions.

7.2. Limitations

In this research, qualitative interviewing involved participants, which may raise a quality criteria problem. This is related to the notion of saturation, that has become a frequently used quality marker in qualitative research. When saturation is reached, it means that the right breadth and depth of data have been collected (O'Reilly and Parker, 2013). This research did not reach the saturation point where the author could claim to have explored, discussed, and interpreted the subject as thoroughly as possible. This realisation came about not because this research failed to meet any predefined criteria for sampling (e.g. minimum number of interviews), but rather because the author's impression was that further exploration would be needed to fully explore the topic. The time framework within which this research was conducted did not allow the expansion of the empirical data for further exploration. However, this does not mean that the results of the research are invalid, as the thematic analysis and the mental model were carried out based on information from participants whose selections were justified based on both appropriateness and adequacy considerations (O'Reilly and Parker, 2013).

Another limitation that this research needs to be clear about is related to the challenging task that interviewing farmers about climate change might bring about. There are much empirical evidence explaining why farmers have varying and often conflicted attitudes towards climate change communication (Morrison, Hine and D'Alessandro, 2017). Robertson and Murray-Prior (2016) identified five reasons why it is difficult to engage with farmers when talking about the likely impacts of climate change on their farms and potential adaptation actions as their responses to impacts. The first reason is that climate change is a slow-moving phenomenon, and projections are dubious. Empirical findings demonstrate that farmers' climate-specific responses are also influenced and biased by recent weather experiences (Nguyen *et al.*, 2016; Fierros-González and López-Feldman, 2021). The second reason is related to the "*here and now*" type of decision-making that deeply characterises farm management. Management decisions are made on a daily basis in response to weather, cost, and price fluctuations. Moreover, strategic planning rarely extends beyond ten years and, therefore, long-term projections of severe or shocking impacts fall beyond the planning timeframe of farmers. The third reason that explains farmers' reluctance to keep pace with negative climate change impacts is their techno-optimist mindset. The fourth reason is a reflection of the fact that farmers are usually offered to follow strategies that are incremental and biophysical. The fifth reason states that the debate around climate change has become deeply politicised. This contested dialogue therefore inevitably biases people's views and thinking on climate change related issues (Robertson and Murray-Prior, 2016).

In this research, recent weather experiences may indeed have influenced participants' views on climate change issues, as the interviews took place in the middle of the worst drought in a century. Furthermore, the lack of strategic vision was identified in the participants' reports, but it was not explored whether this could be explained by their techno-optimistic attitude or their uncertainty around potential adaptive solutions. Climate change as a politically contested topic was not referred in the interviews. The participants expressed their affirmative belief in the existence of climate change, without voicing any political opinions.

7.3. Recommendations for further actions

Throughout the analysis and writing process, a number of ideas have emerged that I think are worthy of further exploration. The exploration of these ideas could be an exciting continuation of this research:

- deeper understanding of how participants' uncertainty influenced their adaptive capacity;
- heuristic-type decision-making practices in farmers' risk management behaviour in the context climate change adaptation;
- description of participants' adaptation practices through their self-efficiency assessment.

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APPENDIXES

Appendix 1

Farmer survey

Az Agrárgazdasági Kutató Intézet a Magyar Földtani és Geofizikai Intézet megbízásból kérdőíves felmérésen alapuló kutatást végez a hazai gazdálkodók körében. A felmérés célja, hogy feltárja az éghajlatváltozással szembeni üzemszintű alkalmazkodási stratégiákat, ennek alapján javaslatokat fogalmazzon meg a gazdálkodók ellenállóképességének fokozását elősegítő szabályozási, támogatási környezet kialakítására.

Az alábbi kérdések az Ön gazdaságának helyszínén tapasztalt éghajlati változások feltárására irányulnak. Kérem, mielőtt válaszol ezekre a kérdésekre, gondoljon arra, hogy a helyi időjárás változékonysága természetes jelenség. A helyi éghajlat változásának értékelésekor olyan sok éves változásokra gondoljon, amelyek egyes időjárási elemek (napsugárzás, hőmérséklet, csapadék, szél) átlagos gyakoriságát, valószínűségét érintik.

1. Gazdálkodásom helyszínén az elmúlt 10 évben az időjárás…

…egyértelműen változékonnyá vált.				…egyáltalán nem lett változékonyabb.	Nincs válasz / Nem tudom
1	2	3	4	5	99

2. Az elmúlt 10 évben a termelési ciklusok szempontjából fontos időszakokban az átlag hőmérséklet…

…egyértelműen emelkedett.				…egyértelműen csökkent.	Nincs válasz / Nem tudom
1	2	3	4	5	99

3. Az elmúlt 10 évben termelési ciklusok szempontjából fontos időszakokban az éves csapadékmennyiség…

…egyértelműen növekedett.				…egyértelműen csökkent.	Nincs válasz / Nem tudom
1	2	3	4	5	99

4. A változó éghajlati adottságok miatt gazdaságom jövedelmezősége…

…nagy mértékben romlott.				…nagy mértékben javult	Nincs válasz / Nem tudom
1	2	3	4	5	99

5. A változó éghajlat adottságok miatt a terményeim minősége…

…nagy mértékben romlott.				…nagy mértékben javult.	Nincs válasz / Nem tudom
1	2	3	4	5	99

6. A változó éghajlati adottságok miatt gazdaságomban a terméshozam…

…nagy mértékben csökkent.				…nagy mértékben javult.	Nincs válasz / Nem tudom
1	2	3	4	5	99

7. A változó éghajlati adottságok (…) befolyásolták beruházási döntéseimet az elmúlt 10 évben

…nagy mértékben…				…egyáltalán nem…	Nincs válasz / Nem tudom
1	2	3	4	5	99

8. Véleménye szerint változó éghajlati adottságok, hogyan érintik a teljes magyar mezőgazdaságot? (Mennyire hasonlóak mások gondjai?)

9. **A változó éghajlat hatásai közül melyek azok, <u>amelyek már jelentkeztek a saját gazdaságában</u>? (Kérjük csak abban az esetben jelöljön be választ, ha az releváns az Ön gazdaságában!)**

	Hatások	**Egyáltalán nem jellemző**				**Nagyon jellemző**	**Nincs válasz / Nem tudom**
a	**Tartós szárazság**	1	2	3	4	5	99
b	**Víz általi talajpusztulás**	1	2	3	4	5	99
c	**Szél általi talajpusztulás**	1	2	3	4	5	99
d	**Belvíz**	1	2	3	4	5	99
e	**Árvíz**	1	2	3	4	5	99
f	**Jégeső**	1	2	3	4	5	99
g	**Invazív növényfajok megjelenése**	1	2	3	4	5	99
h	**Új kártevők megjelenése**	1	2	3	4	5	99
i	**Új kórokozók, betegségek megjelenése**	1	2	3	4	5	99
j	**Extrém meleg**	1	2	3	4	5	99
k	**Tavaszi fagy**	1	2	3	4	5	99
l	**Egyéb, és pedig:**						

10. **Kérem, válassza ki, hogy az alábbi állítások közül melyikkel tud <u>a leginkább egyetérteni!</u> (Csak egy választ jelöljön meg!**

a	**Nem értek egyet az éghajlatváltozás elméletével, szerintem nem változik az éghajlat.**	□
b	**Az éghajlat változása mögött természeti erők állnak, az emberi tevékenység ehhez nem járul hozzá.**	□
c	**Az éghajlat változásához mind az emberi tevékenység, mind pedig a természeti ciklusok hozzájárulnak**	□
d	**Az éghajlat változását emberi tevékenységek (pl. fosszilis tüzelőanyagok égetése) idézték elő**	□

A következő néhány kérdés annak feltárására irányul, hogy mit tudott tenni eddig annak érdekében, hogy a változó éghajlati adottságokkal szemben megvédje a gazdaságát.

11. **Kérem, jelölje meg, hogy <u>az alábbi alkalmazkodási gyakorlatokat</u> alkalmazza-e, vagy tervezi-e a bevezetésüket? (Kérjük csak abban az esetben jelöljön be választ, ha az releváns az Ön gazdaságában!)**

	Beavatkozás	**Már alkalmaztam**	**Tervezem alkalmazni a következő 5-10 évben**	**Nem tervezem**	**Nincs válasz / Nem tudom**
a	A vetésszerkezet megváltoztatása	1	2	3	4
b	Talajművelési feladatok ütemezésének változtatása	1	2	3	4
c	Mélyszántás alkalmazása	1	2	3	4
d	Talajlazítás alkalmazása	1	2	3	4
e	Mulcsolás alkalmazása	1	2	3	4
f	Forgatás nélküli talajhasználat	1	2	3	4
g	Termelés helyének megváltoztatása	1	2	3	4
h	Öntözésfejlesztés	1	2	3	4
i	Új trágyázási gyakorlatok	1	2	3	4
j	Időjáráshoz igazított növényvédelem	1	2	3	4
k	Új fajták használata (növény és/vagy állat)	1	2	3	4
l	Talajvíz védelmi műveletek	1	2	3	4
m	Talajeróziót megelőző műveletek	1	2	3	4
n	Jég- és fagyvédelmi fejlesztések (jégháló, hőlégbefúvó, melegítő berendezések)	1	2	3	4
o	Szellőzés vagy hűtés fejlesztés	1	2	3	4
p	Időjáráshoz igazított takarmányozás	1	2	3	4
q	Agrometeorológiai adatok, előrejelzések használata (sajátmérés, nyilvános, vásárolt)	1	2	3	4
r	Kiemelt biztosítások időjárás károkra	1	2	3	4
s	Pénzügyi tartalékolás				

t	Egyéb, és pedig:

12. **Amennyiben Önnek volt termőföldet érintő beruházási jellegű fejlesztése, kérem jelölje meg, hogy az saját tulajdonú vagy bérelt földterületen történt meg! (Kérjük csak abban az esetben jelöljön be választ, ha az releváns az Ön gazdaságában!)**

	Fejlesztés	**Saját tulajdon**	**Bérelt**	**Nincs válasz / Nem tudom**
a	Öntözésfejlesztés	1	2	3
b	Talajvíz védelmi fejlesztés	1	2	3
c	Talajeróziót megelőző fejlesztés	1	2	3
d	Egyéb, és pedig:			

13. **Kérem, válassza ki az Önre leginkább igaz állítást! (Csak egy választ jelöljön meg!)**

a	Megfelelően felkészültnek érzem a gazdaságomat, hogy a változó éghajlati adottságok mellett is folytatni tudjam jelenlegi tevékenységemet	□
b	Mérsékelt változtatásokat kell tennem a gazdaságomban, hogy a változó éghajlati adottságok mellett is folytatni tudjam jelenlegi tevékenységemet	□
c	Jelentős mértékű módosításokat kellene végrehajtanom a gazdaságomban, hogy a változó éghajlati adottságok mellett is folytatni tudjam jelenlegi tevékenységemet.	□

14. **Melyek azok a tényezők, amelyek hátráltatják abban, hogy gazdaságát megfelelően felkészítse a változó éghajlati adottságokra. Kérem jelezze, hogy mennyire tartja igaznak a következő állításokat! Válaszait <u>1 – től 5 – ig terjedő skálán adhatja meg, ahol az 1 – es azt jelenti, hogy egyáltalán nem ért egyet, az 5 – ös pedig azt, hogy teljes mértékben egyetért.</u>**

a) A vonatkozó tudás és/vagy szakértelem hiánya hátráltat abban, hogy megfelelően alkalmazkodjak a változó éghajlati adottságokhoz.

Egyáltalán nem igaz				**Teljes mértékben igaz**	**Nincs válasz / Nem tudom**
1	**2**	**3**	**4**	**5**	**99**

b) A rendelkezésre álló saját tőke hiánya hátráltat abban, hogy megfelelően alkalmazkodjak a változó éghajlati adottságokhoz.

Egyáltalán nem igaz				Teljes mértékben igaz	Nincs válasz / Nem tudom
1	2	3	4	5	99

c) Pályázati lehetőségek hiánya hátráltat abban, hogy megfelelően alkalmazkodjak a változó éghajlati adottságokhoz.

Egyáltalán nem igaz				Teljes mértékben igaz	Nincs válasz / Nem tudom
1	2	3	4	5	99

d) A bonyolult jogszabályi /engedélyeztetési környezet hátráltat abban, hogy megfelelően alkalmazkodjak a változó éghajlati adottságokhoz.

Egyáltalán nem igaz				Teljes mértékben igaz	Nincs válasz / Nem tudom
1	2	3	4	5	99

e) A megfelelő technológia hiánya hátráltat abban, hogy megfelelően alkalmazkodjak a változó éghajlati adottságokhoz.

Egyáltalán nem igaz				Teljes mértékben igaz	Nincs válasz / Nem tudom
1	2	3	4	5	99

f) A megfelelő munkaerő hiánya hátráltat abban, hogy megfelelően alkalmazkodjak a változó éghajlati adottságokhoz.

Egyáltalán nem igaz				Teljes mértékben igaz	Nincs válasz / Nem tudom
1	2	3	4	5	99

g) Az együttműködő gazdatársak hiánya hátráltat abban, hogy megfelelően alkalmazkodjak a változó éghajlati adottságokhoz.

Egyáltalán nem igaz				Teljes mértékben igaz	Nincs válasz / Nem tudom

1	**2**	**3**	**4**	**5**	**99**

e) A felsoroltakon kívül meg tud még nevezni olyan tényezőt, ami hátráltatja abban, hogy megfelelően alkalmazkodjon a változó éghajlati adottságokhoz? Ha igen, kérjük írja le!

15. Jellemzően <u>honnan tájékozódik / honnan szerez tudomást</u> az alkalmazkodási gyakorlatokról? Több választ is megjelölhet!

	Tájékozódás fóruma	X-elje a megfelelő választ!
a	Nyomtatott szaklap	□
b	Internetes szakmai oldal	□
c	Rádió, tv, egyéb sajtótermékek	□
d	Szakmaközi szervezet	□
e	Nemzeti Agrárgazdasági Kamara	□
f	Független szaktanácsadó	□
g	Kiállítás/vásár	□
h	Oktatási intézmény	□
i	Más gazdálkodó	□
j	Inputforgalmazó / Integrátor	□
k	Szakmai bemutató	□
	Egyéb, és pedig:	

16. Kérem jelölje meg, hogy az alábbi állítások közül melyiket tartja magára jellemzőnek! (<u>Csak egy állítást jelöljön meg!</u>)

a	**A gazdálkodásommal kapcsolatos döntések meghozatalában nem szoktam gazdatársaim, illetve szaktanácsadók ajánlásait figyelembe venni, igénybe venni.**	□
b	**Szokatlan vagy váratlan esemény vagy kár esetében igénybe szoktam venni gazdatársaim, illetve szaktanácsadók ajánlásait.**	□
c	**A gazdálkodásommal kapcsolatos döntések meghozatalában rendszeresen kikérem gazdatársaim véleményét és igénybe veszem szaktanácsadók segítségét.**	□

17. Egyéb megjegyzések az éghajlatváltozás a és mezőgazdaság témájával kapcsolatban:

KÖSZÖNJÜK, HOGY VÁLASZAIVAL SEGÍTETTE MUNKÁNKAT!

Appendix 2

Interview guide

1. *My project deals with risks that grape and wine producer potentially face in Matra wine region. To start with, would you please share the elements that you find the most important in relation to your farm and your farming experience?*
2. *Next, I'd like to talk to you about the risks or concerns that you face as a farmer. They might be of concern this week, next month, next year, or in ten or twenty years. These sticky notes will be used to list each risk on this sheet of paper.*
   2.1. [Prompt to get more details] *You've mentioned that …, which are probably short-term risks. Can you think of any other short-term risks?*
   2.2. [Prompt to get more details] *You've mentioned that … which are probably long-term risks. Can you think of any other long-term risks?*
3. *Next, I would like to ask you to explain why these risks are problems for your farm and what causes them?*
4. *How would you say that these risks interact with each other?*
5. *Next, I would like to ask you to help me organise these sticky notes into two groups. The first group should include risks that are manageable, while the second group should include risks that are unmanageable.*
   5.1. *What makes these risks manageable / unmanageable?*
   5.2. *What can you do to manage these risks?*
   5.3. *What have you done to manage these risks?*
   5.4. *Do you see yourself successful in managing or adapting to these risks?*
   5.5. *What conditions should be met to be more successful in managing or adapting to these risks?*
   5.6. *What do you think will be the most important risk in the coming year?*
   5.7. *Which do you think will be the most important risks on each side in ten or twenty years?*
6. [if climate change related risks have not been mentioned] *What comes to mind when you hear the term "climate change"?*
   6.1. *Would you say that the risk of climate change, the effects of climate change on your farm, is a manageable risk or an unmanageable risk?*
7. *Would you like to add something we have not discussed yet?*

Appendix 3

Consent form for interview participants

HOZZÁJÁRULÓ NYILATKOZAT

"Üzemtípusok, kihívások, adaptációs irányok és ezek hatása a magyar vidékre" című kutatás során készített interjúkhoz, fókuszcsoportos megbeszélésekhez

Kutatás rövid bemutatása:

A kutatást a Nemzeti Kutatási, Fejlesztési és Innovációs Hivatal (NKFI) támogatja. Azonosító szám: 132975. E projekt fő célja a különböző gazdaságtípusok alkalmazkodóképességének vizsgálata a változtatást egyre sürgetőbbé tévő kihívások közegében. A fenyegetések különböző irányokból származnak – úgy, mint klímaváltozás, piaci körülmények, munkaerőpiac – és megsokszorozódva, egymás hatásait felerősítve jelentkeznek üzemi szinten: rövidtávon azonnali túlélési intézkedéseket, hosszabb távon tudatos felkészülést, adaptív tervezést kívánnak meg.

Kérjük, jelölje be a megfelelő négyzeteket!

	Igen	**Nem**
Részvétel		
A kutatásról, annak céljáról tájékoztattak		
Hozzájárulok az interjú készítéséhez/ fókuszcsoportos megbeszélésen való részvételhez		
Hozzájárulok felvétel készítéséhez (hang, fénykép, videó)		
Tájékoztatást kaptam, hogy hozzájárulásomat a későbbiekben visszavonhatom		
Személyes adatok kezelése		
Személyes adataimat (például a telefonszámomat, címemet) a kutatásban részt vevők kezelhetik. (Az adatkezelés az interjúalanyok megkereséséhez, a kapcsolat-tartáshoz és a későbbi utómunkálatokhoz kötődik – személyes adatok harmadik félhez nem kerülhetnek.)		

Résztvevő neve... Dátum ....

Kutató neve... Aláírás...
Dátum.....................................

Appendix 4

Statistical appendix

PERCEPTION INDEX	**Over the past 10 years, the weather has clearly become more variable**		Strongly disagree	2	3	4	Strongly agree	Total
		%	13,3	11	26	26,7	23	100
		N	40	33	78	80	69	300
	Average temperatures have clearly risen over the past 10 years		Strongly disagree	2	3	4	Strongly agree	Total
		%	10,7	15,7	21,3	31	21,3	100
		N	32	47	64	93	64	300
	Annual rainfall has clearly decreased over the last 10 years		Strongly disagree	2	3	4	Strongly agree	Total
		%	0,7	13,3	35,7	31	19,3	100
		N	2	40	107	93	58	300
SENSITIVITY INDEX	**The changing climate has reduced the profitability of my farm**		Strongly disagree	2	3	4	Strongly agree	Total
		%	4,7	23	53,7	12,3	6,3	100
		N	14	69	161	37	19	300
	Because of the changing climate, the quality of my crops has deteriorated		Strongly disagree	2	3	4	Strongly agree	Total
		%	7	34	44,7	12,3	2	100
		N	21	102	134	37	6	300
	Due to changing climatic conditions, yields on my farm have decreased		Strongly disagree	2	3	4	Strongly agree	Total
		%	6,3	27,7	44	17,3	4,7	100
		N	19	83	132	52	14	300
	Changing climate has influenced my investment decisions over the past 10 years		Do not agree at all	2	3	4	Strongly agree	Total
		%	21,3	25	22	17	14,7	100
		N	64	75	66	51	44	300

Descriptive Statistics

	N	Mean	Std. Deviation	Minimum	Maximum
Perception_index	300	3,4222	,89023	1,33	5,00
FARM_TYPE_7	300	2,8067	2,25527	1,00	7,00

Ranks

	FARM_TYPE_7	N	Mean Rank
Perception_index	arable crop	160	157,23
	fruit	24	162,73
	grape	8	116,38
	vegetable	18	191,06
	grazing livestock	27	132,54
	confined livestock	38	118,66
	mixed	25	145,24
	Total	300	

Test Statistics[a,b]

	Perception_index
Kruskal-Wallis H	13,142
df	6
Asymp. Sig.	,041

a. Kruskal Wallis Test

b. Grouping Variable: FARM_TYPE_7

Descriptive Statistics

	N	Mean	Std. Deviation	Minimum	Maximum
Sensitivity_index	300	2,8150	,78309	1,00	5,00
FARM_TYPE_7	300	2,8067	2,25527	1,00	7,00

Ranks

	FARM_TYPE_7	N	Mean Rank
Sensitivity_index	arable crop	160	150,10
	fruit	24	191,54
	grape	8	137,75
	vegetable	18	177,75
	grazing livestock	27	139,48
	confined livestock	38	131,24
	mixed	25	139,30
	Total	300	

Test Statistics[a,b]

	Sensitivity_index
Kruskal-Wallis H	10,183
df	6
Asymp. Sig.	,117

a. Kruskal Wallis Test

b. Grouping Variable: FARM_TYPE_7

Descriptive Statistics

	N	Mean	Std. Deviation	Minimum	Maximum
Perception_index	300	3,4222	,89023	1,33	5,00
Farm size in 5 categories (SO)	300	2,6533	1,31361	1,00	5,00

Ranks

	Farm size in 5 categories (SO)	N	Mean Rank
Perception_index	4 000 Euro - 25 000 Euro	80	142,04
	25 000 Euro - 50 000 Euro	61	162,39
	50 000 Euro - 100 000 Euro	69	131,96
	100 000 Euro - 250 000 Euro	63	165,94
	250 000 Euro =<	27	160,06
	Total	300	

Test Statistics[a,b]

	Perception_index
Kruskal-Wallis H	7,477
df	4
Asymp. Sig.	,113

a. Kruskal Wallis Test

b. Grouping Variable: Farm size in 5 categories (SO)

Descriptive Statistics

	N	Mean	Std. Deviation	Minimum	Maximum
Sensitivity_index	300	2,8150	,78309	1,00	5,00
Farm size in 5 categories (SO)	300	2,6533	1,31361	1,00	5,00

Ranks

	Farm size in 5 categories (SO)	N	Mean Rank
Sensitivity_index	4 000 Euro - 25 000 Euro	80	155,93
	25 000 Euro - 50 000 Euro	61	152,84
	50 000 Euro - 100 000 Euro	69	158,75
	100 000 Euro - 250 000 Euro	63	141,01
	250 000 Euro =<	27	130,20
	Total	300	

Test Statistics[a,b]

	Sensitivity_index
Kruskal-Wallis H	3,256
df	4
Asymp. Sig.	,516

a. Kruskal Wallis Test

b. Grouping Variable: Farm size in 5 categories (SO)

Pairwise Comparisons of FARM_TYPE_7

Sample 1-Sample 2	Test Statistic	Std. Error	Std. Test Statistic	Sig.	Adj. Sig.[a]
grape-confined livestock	-2,283	33,536	-,068	,946	1,000
grape-grazing livestock	-16,162	34,704	-,466	,641	1,000
grape-mixed	-28,865	35,020	-,824	,410	1,000
grape-arable crop	40,850	31,234	1,308	,191	1,000
grape-fruit	46,354	35,197	1,317	,188	1,000
grape-vegetable	-74,681	36,634	-2,039	,041	,871
confined livestock-grazing livestock	13,879	21,700	,640	,522	1,000
confined livestock-mixed	-26,582	22,202	-1,197	,231	1,000
confined livestock-arable crop	38,567	15,558	2,479	,013	,277
confined livestock-fruit	44,071	22,479	1,961	,050	1,000
confined livestock-vegetable	72,398	24,668	2,935	,003	,070
grazing livestock-mixed	-12,703	23,929	-,531	,596	1,000
grazing livestock-arable crop	24,688	17,937	1,376	,169	1,000
grazing livestock-fruit	30,192	24,187	1,248	,212	1,000
grazing livestock-vegetable	58,519	26,234	2,231	,026	,540
mixed-arable crop	11,985	18,541	,646	,518	1,000
mixed-fruit	17,489	24,638	,710	,478	1,000
mixed-vegetable	45,816	26,650	1,719	,086	1,000
arable crop-fruit	-5,504	18,872	-,292	,771	1,000
arable crop-vegetable	-33,831	21,433	-1,578	,114	1,000
fruit-vegetable	-28,326	26,882	-1,054	,292	1,000

Each row tests the null hypothesis that the Sample 1 and Sample 2 distributions are the same.
Asymptotic significances (2-sided tests) are displayed. The significance level is ,050.
a. Significance values have been adjusted by the Bonferroni correction for multiple tests.

	Frequency	Percent
0	44	14,7
1-5	97	32,3
6-10	114	38
11-15	40	13,3
16-19	5	1,7
Total	300	100

	Frequency	Percent
0	100	33,3
1-5	126	42
6-8	57	19
10-14t	17	5,7
Total	300	100

Correspondence Table

	Number of adopted actions 5 cat					
Farm types in 7 cat	0	1-5	6-10	11-15	16-19	Active Margin
Arable crops	24	51	63	21	1	160
Fruits	4	11	7	1	1	24
Grapes	3	4	1	0	0	8
Vegetables	3	10	3	1	1	18
Grazing livestock	1	6	13	6	1	27
Confined livestock	4	9	16	9	0	38
Mixed farms	5	6	11	2	1	25
Active Margin	44	97	114	40	5	300

Summary

					Proportion of Inertia		Confidence Singular Value	
Dimension	Singular Value	Inertia	Chi Square	Sig.	Accounted for	Cumulative	Standard Deviation	Correlation 2
1	,276	,076			,691	,691	,050	-,005
2	,144	,021			,187	,878	,058	
3	,105	,011			,099	,977		
4	,051	,003			,023	1,000		
Total		,111	33,172	,100[a]	1,000	1,000		

a. 24 degrees of freedom

Overview Row Points[a]

Farm types in 7 cat	Mass	Score in Dimension	Inertia	Contribution

					Of Point to Inertia of Dimension		Of Dimension to Inertia of Point		
		1	2		1	2	1	2	Total
Arable crops	,533	,045	,194	,004	,004	,140	,078	,753	,831
Fruits	,080	-,746	-,407	,014	,161	,092	,853	,132	,985
Grapes	,027	-1,459	1,057	,021	,205	,207	,761	,207	,968
Vegetables	,060	-1,084	-,697	,026	,255	,203	,763	,164	,927
Grazing livestock	,090	,738	-,717	,020	,177	,322	,670	,328	,998
Confined livestock	,127	,651	,159	,017	,194	,022	,859	,027	,885
Mixed farms	,083	-,112	-,155	,009	,004	,014	,033	,033	,066
Active Total	1,000			,111	1,000	1,000			

a. Symmetrical normalization

Overview Column Points[a]

Number of adopted actions 5 cat	Mass	Score in Dimension		Inertia	Contribution				
					Of Point to Inertia of Dimension		Of Dimension to Inertia of Point		
		1	2		1	2	1	2	Total
0	,147	-,555	,515	,020	,163	,271	,612	,274	,886
1-5	,323	-,483	-,080	,025	,273	,015	,846	,012	,858
6-10	,380	,371	-,009	,017	,189	,000	,828	,000	,828
11-15	,133	,830	-,037	,029	,332	,001	,887	,001	,888
16-19	,017	-,838	-2,480	,019	,042	,713	,166	,757	,924
Active Total	1,000			,111	1,000	1,000			

a. Symmetrical normalization

Correspondence Table

Farm types in 7 cat	Number of planned actions 4 cat: 0	1-5	6-8	10-14	Active Margin
Arable crops	52	73	28	7	160
Fruits	6	6	11	1	24
Grapes	2	5	1	0	8
Vegetables	7	6	1	4	18
Grazing livestock	8	12	6	1	27
Confined livestock	18	16	2	2	38
Mixed farms	7	8	8	2	25
Active Margin	100	126	57	17	300

Summary

Dimension	Singular Value	Inertia	Chi Square	Sig.	Proportion of Inertia: Accounted for	Cumulative	Confidence Singular Value: Standard Deviation	Correlation 2
1	,269	,072			,624	,624	,059	,134
2	,192	,037			,318	,942	,079	
3	,082	,007			,058	1,000		
Total		,116	34,826	,010[a]	1,000	1,000		

a. 18 degrees of freedom

Overview Row Points[a]

Farm types in 7 cat	Mass	Score in Dimension: 1	2	Inertia	Contribution: Of Point to Inertia of Dimension: 1	2	Of Dimension to Inertia of Point: 1	2	Total
Arable crops	,533	,046	,180	,004	,004	,090	,076	,829	,905
Fruits	,080	-1,279	-,353	,038	,486	,052	,932	,051	,983
Grapes	,027	,176	,865	,005	,003	,104	,042	,720	,762
Vegetables	,060	,874	-1,428	,036	,170	,637	,340	,646	,986
Grazing livestock	,090	-,191	,182	,002	,012	,016	,555	,357	,912
Confined livestock	,127	,682	,132	,020	,219	,011	,790	,021	,811
Mixed farms	,083	-,582	-,455	,011	,105	,090	,696	,304	1,000
Active Total	1,000			,116	1,000	1,000			

a. Symmetrical normalization

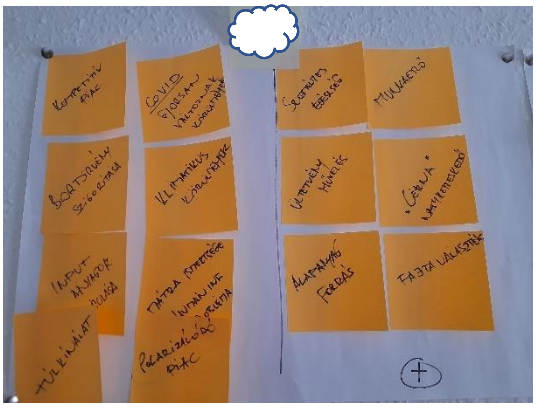
Overview Column Points[a]

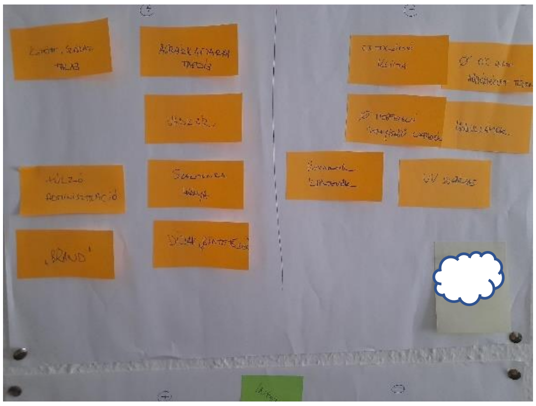
Number of planned actions 4 cat	Mass	Score in Dimension		Inertia	Contribution				
					Of Point to Inertia of Dimension		Of Dimension to Inertia of Point		
		1	2		1	2	1	2	Total
0	,333	,292	-,021	,011	,106	,001	,668	,003	,670
1-5	,420	,170	,306	,013	,045	,204	,251	,578	,829
6-8	,190	-1,054	-,156	,058	,784	,024	,984	,015	1,000
10-14	,057	,557	-1,616	,034	,065	,771	,140	,839	,979
Active Total	1,000			,116	1,000	1,000			

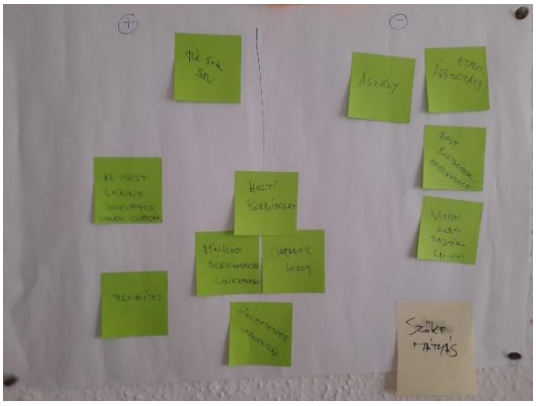
a. Symmetrical normalization

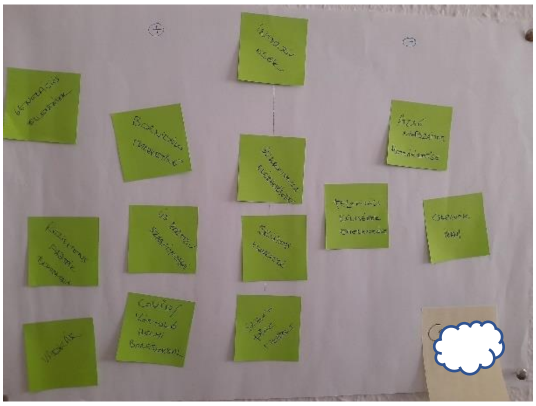
Appendix 5

Participants' cognitive maps of manageable and unmanageable risks









Appendix 6

Thematic map of thematic analysis of interview transcripts