Doctoral School of Business and Management

THESIS SUMMARY

Gábor Király

Climate change adaptation research among vine growers: evidence from Mátra wine region

Ph.D. dissertation

Supervisor:

Prof. József Tóth, CSc

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Department of Agricultural Economics

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1. Background of the research and jistifucation of the topic

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, 2015a). 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, are also considered as being particularly resistant to change, restricted by tradition, support policies, and social and behavioural variables, limiting reactions to large paradigm shifts (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 behaviours (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 ahead 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 to examine 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 on mental modelling technique.

M personal motivation for conducting this research was my intention to build on those previous personal experiences and research findings, that I gained while doing a case study of the post-transitional development of Mátra wine region (Király, 2018). My practical motivation was fuelled by the intention to strengthen the methodological toolkit for assessing the role of human behaviour in adaptation practises. Last, but not least, my *intellectual goal* was to contribute to that enormous stock of knowledge on climate change adaptation that has been accumulated over the past decades (Nalau and Verrall, 2021).

On both global and local level climate change is having alarming impacts on agricultural and terrestrial food production (FAO, 2016). There is a vast body of knowledge about how vulnerable viticulture is affected by these impacts (Jones and Webb, 2010; Ashenfelter and Storchmann, 2016; van Leeuwen and Darriet, 2016; Santos *et al.*, 2020; Bezner *et al.*, 2022). When certain physical and biological factors are altered by climate change, the local climatic and soil conditions that determine the terroir of wine regions are inevitably altered. The most typical impacts that might lead to changes in cultivation circumstances are related to temperature, precipitation, and UVs. 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). That is why, 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 (Schultz and Jones, 2010). Precipitation plays another crucial role in grapevine development because water status needed for balanced development varies depending on the phenological stages. Excessive precipitation may lead to detrimental effects in quality, while drought can negatively affect volume (Van Leeuwen *et al.*, 2019). Last, but not least, excessive UV radiation affects the organoleptic properties of vine, including flavour and aroma attributes, and essentially leads to high alcoholic content and low acidity during maturation (Santos *et al.*, 2020).

In that regard, Hungarian vine growers will be very likely to face changed climatic conditions in their wine regions in the near future. Simulations made for the Carpathian Basin indicate that by the middle of the 21st century, the current spectrum of vine varieties will broaden, and the number of wine regions with favorable conditions for late and extremely late-ripening varieties will rise in Hungary. 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. It is also very likely that Hungarian vine growers may no longer have to face spring risk of frost at all. However, as frost becomes less frequent, growers must be prepared for significant heat-related damage as well (Mesterházy, Mészáros and Pongrácz, 2014; Mesterházy *et al.*, 2018). In light of these, research on climate change adaptation is required for the Hungarian viticulture and winegrowing industry as well.

Due to its vulnerability, viticulture has been at the forefront of climate change adaptation research for a long time (Sacchelli, Fabbrizzi and Menghini, 2016). Within these studies, there are more and more vulnerability-centred adaptation studies, which aim to explore, assess, and understand factors that influence individuals' vulnerability (Jones and Webb, 2010). These studies suggest that farming systems are ultimately managed by people who live and work in particular socioeconomic-ecological environments, and that this has a significant effect on their adaptive behaviour (Lereboullet, Beltrando and Bardsley, 2013).

This leads this summary to the conceptual framework of the research that stands on the theoretical underpinnings of behaviour-centred adaptation research. The central idea of this line of research can be linked to Goldman et al. (2018, p. 3) who pointed out that "*Human dimensions of climate change" broadly refers to human capacities, exposure, and response to climate change*". This insight stems from the recognition 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. Nevertheless, these differences have significant explanatory power in understanding various adaptive behaviours.

Among the many areas of application, climate change research has been late in finding and applying 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 that, 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 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).

Farmers' decisions are inevitably influenced by the perception risks. In agricultural economics, 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, conventional agricultural adoption research concentrates on factors that correlate with farmers' technology uptake. On the other hand, behavioural science aims to explain, model, and theorise human behaviour that is somehow deviating from standard economic theories (Streletskaya *et al.*, 2020). Behavioural science 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).

2. Research methodology

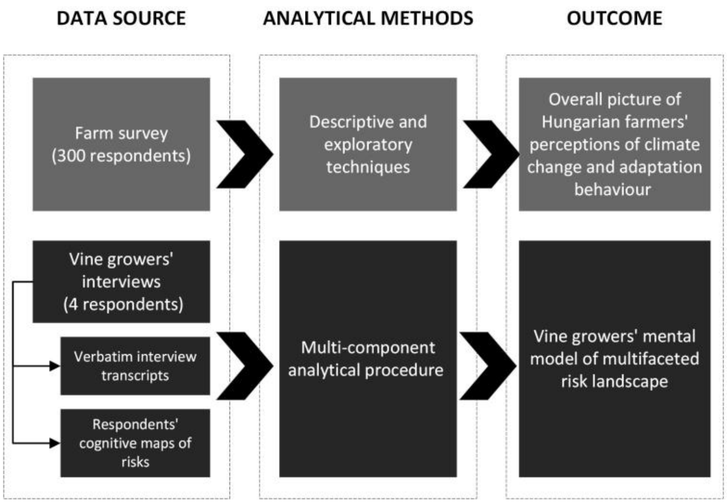
There are several individual-based analytical approaches that have the capacity to provide insights into the behaviour influencing factors (Stern, 2000; Grothmann and Patt, 2005; Ajzen, 2020). These approaches stand on a common ground in claiming that risk perception has a fundamental role in adaptation decision making. This has led to inquiries focusing on how people understand, perceive, communicate, and respond to climate change risks (Granderson, 2014).

2.1. Partially mixed sequential research design

This research also adopts such an individual-based analytical approach when investigating vine growers' climate adaptive-behaviour and while eliciting farm-level risks and management decisions. This aim will be fulfilled by applying a *partially mixed sequential research design*, in which a quantitative research segment (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 (Leech and Onwuegbuzie, 2009).

In that sense, 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 literature review carried out to provide an analytical foundation for this research revealed that risk elicitation based on a mental modelling approach has not yet been carried out 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. This analytical framework is presented in detail in the next sections and visualised in Figure 1.

Figure 1 Analytical framework of the research



2.2. Survey data

The thematic cross-sectional farmer survey was based on a sample of 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 were 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).

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

2.3. Mental modelling and vine grower interviews

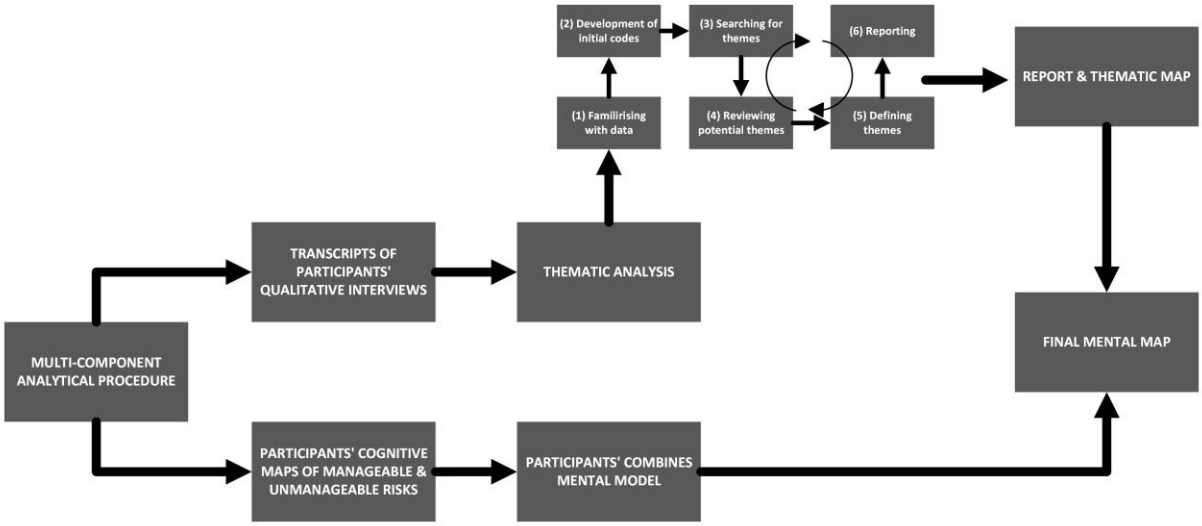
The qualitative research segment constituted a mental mapping exercise embedded in qualitative interviews with vine growers from the Mátra wine region. The mental mapping exercise included cognitive mapping and card sorting combined into an in-depth interview protocol based on inspirations gained from Findlater, Satterfield and Kandlikar (2019), Akimowicz, Cummings, and Landman (2016) Winsen et al. (2013) (Harper and Dorton, 2019). The protocol was structured as follows. As a first step, participants were asked to start talking about the risks they face in their day-to-day management. Each risk was documented on a card (e.g. on standard sticky notes) and placed on a white board. This exercise was practically a one-man brainstorming session facilitated by the interviewer. In the last step, participants were asked to group all the "risk-card" into two groups: manageable and unmanageable risks. In that sense, a cognitive map was created around two fundamental concepts: manageable and unmanageable risks. This exercise not only formed the basis for creating the cognitive map but also allowed participants to elicit their own mental models of risks, highlighting relationships, causalities, management, and adaptation responses. As a final step, a talk through' exercise led to the collaborative creation of a map by positioning and linking each card as the participant would like. This section of the study involved four winegrowers, resulting in four interviews and four cognitive risk maps.

Táblázat 1 A kutatásban résztvevő szőlőtermelők jellemzői

	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

Qualitative data gathering was followed by a multi-component analytical procedure that had been developed to analyse the qualitative data gained from the interviews. The procedure was adapted to the purposes of this research using Prager and Curfs (2016), Findlater, Satterfield and Kandlikar (2019) and van Hulst (2020) as examples. The procedure included the thematic analysis of the interview transcripts, the 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 synthesised in the form of one final mental model. Figure 2 illustrates procedure in the form of a flow chart.

Figure 2 Flowchart representation of the multi-component analytical procedure



2.4. Research questions

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

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

Quantitatve 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 multifaceted landscape of risks in which vine farmers operate?

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

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

3. Research results

This section presents and discusses the results of research through two sub-sections: first, the results of the quantitative segment of the research are presented, and this will be followed by the qualitative results of the research are presented.
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 producers in other branches have different adaptation behaviours; and whether there is a detectable relationship between farmers' perceptions of climate change and their adaptation behaviours.

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

To test Hypothesis 1, I examined whether grape farms had a stronger perception of and greater sensitivity to climate change than farmers in other sectors. Testing was carried out using derived dependent variables (Perception Index and Sensitivity Index) and an independent variable describing the type of farm. Given that both Perception and Sensitivity indices followed non-normal distributions, non-parametric Kruskal-Wallis tests and post-hoc tests were used for mean comparisons. The average perception value of grape growers was the lowest in the sample, while their average sensitivity value was among the lowest. This is certainly a remarkable result, as the sample also included livestock farms. Following that, it is not surprising that the test results did not show significant differences between grape growers and other farm types. The only exceptions were grape growers and vegetable farms. In that pairing, vegetable farmers were the ones who reported significantly stronger perception and sensitivity**.** Considering that the literature describes vine grape farming as a particularly climate-sensitive agricultural activity (Van Leeuwen and Seguin, 2006; Mosedale *et al.*, 2016), this is certainly a surprising result that led me to reject Hypothesis 1.

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

The relationship between farm characteristics and adaptation behaviour was explored through correspondence analysis. This technique is a variant of principal component analysis with the exceptions that it is used for categorical data and calculates Chi square to measure distances between profiles (Greenacre, 2010).

Grape growers, with the lowest average perception score in the sample, appeared to be planning their adaptation actions according to this low score: they either did not plan any adaptive action or planned only the fewest possible. Fruit and vegetable farms demonstrated a greater likelihood of proactive planning, which made the passivity of grape growers even more surprising. However, considering the first hypothesis, this result seemed less surprising. In fact, it is indeed a consistent result. Low perception and sensitivity scores, logically can be 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, 2015b; 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 affects decisions on adaptation, suggesting that stronger perceptions of impacts lead tostronger engagement in adaptation actions. This often-demonstrated correlation appears to have been represented by the vine growers in the sample, and led me to reject Hypothesis 2.

3.3. 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 as they drew a contradictory picture of farmers' adaptation behaviour. When actual adaptation was evaluated, it seemed as though perception and sensitivity had negative impacts, but when planned adaptation was evaluated, the results showed 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 questioned about their plans rather than their actual actions, people might be influenced by other controlling factors. Presumably, in such inquires, they are more likely to promise outcomes that are unlikely to occur. This is related to an often-cited bias in relation to the validity of survey data on future climate change actions. This method is often criticised when asking people about future adaptation plans, because such questionnaires are based on declarations and not observations, so it can never be guaranteed whether adaptation plans will be implemented or not (Graveline and Grémont, 2021).

Táblázat 2 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.

The rest of this sub-section summarises the results of the qualitative segment of this research. First, the main characteristics of the mental model are presented to explain and visualises the participants' multi-faceted risk landscape, then the qualitative research questions are addressed.

The complete model is presented in Figure 3. Elements of the model were classified into three aggregated concepts (T - risk types, C - causes and E - effects) following the classification used by Winsen et al. (2013). The multi-component analytical procedure used participants' cognitive maps of manageable and unmanageable risks and the thematic analysis of farmers' qualitative interviews. When building the model, one criterion was used. The only way to establish a link between the different elements was possible only through the risk groups. 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 can be accurately monitored and tracked in the model. This enabled the model to represent an interconnected network of risks, causes and effects.

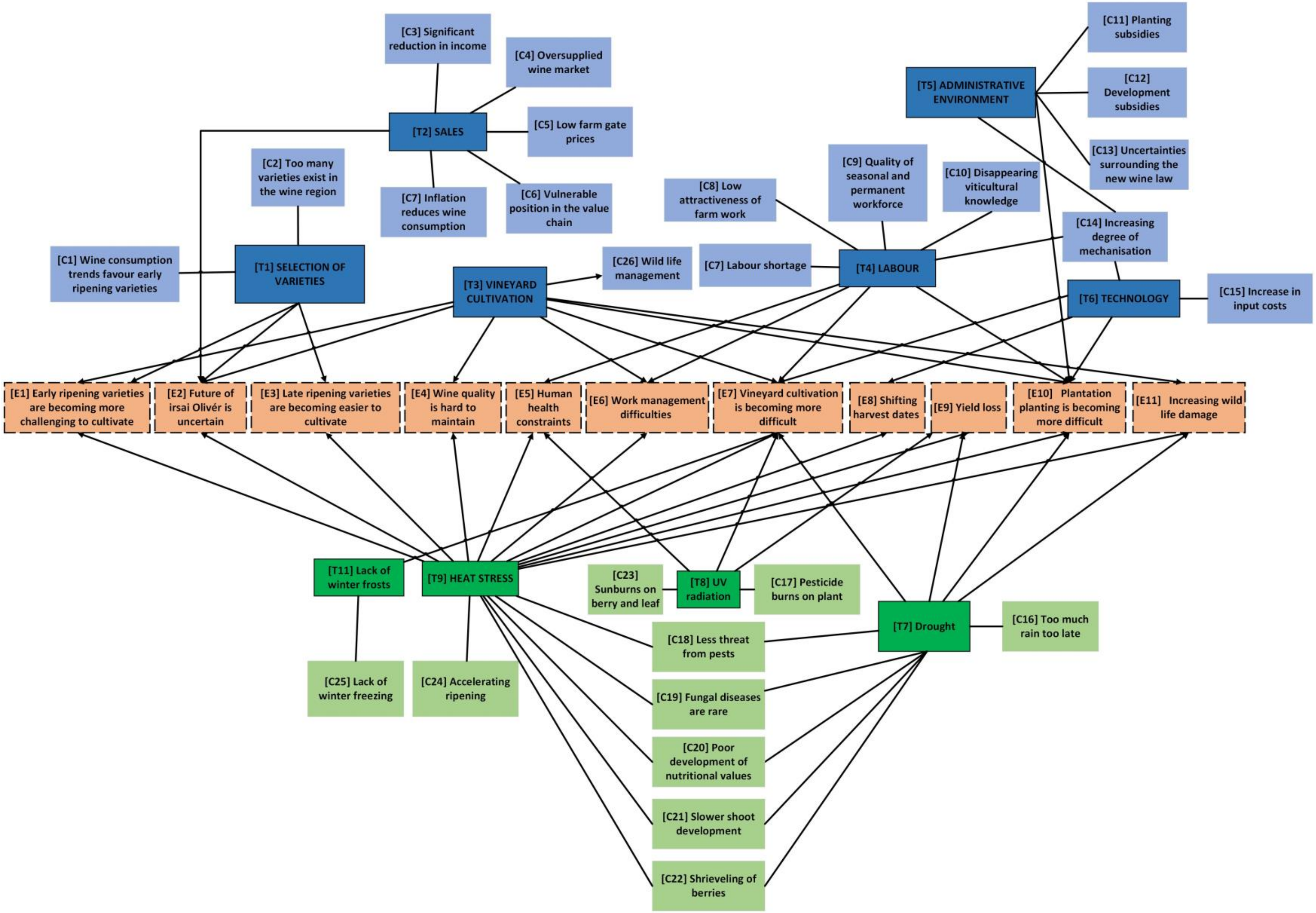
3.4. SRQ4: What are the main characteristics of the multi-faceted landscape of risks in which vine farmers operate?

For climate-related risks, four types of risks were identified: heat stress, drought, UV radiation, and lack of winter frosts. Six types of non-climatic risk were identified: these were risks related to selection of varieties, sales, vineyard cultivation, labour, the administrative environment, and technology. This is in line with studies with similar foci meaning that the 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). 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 (Winsen *et al.*, 2013; Findlater, Satterfield and Kandlikar, 2019). They are shown as rectangles in the model with dashed lines.

Looking at the details of the 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 the 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.

The overall structure of the model and the difference between the number of climate change related and not related risks and causes led me to the conclusion that participants’ mental model does not contain any elements that are significantly different from what we already know empirically. The multi-component analytical procedure produced a heterogeneous and complex risk landscape in which Mátra vine growers operate.

Figure 3 Multi-faceted risk landscape of vine growers presented as a network of risks, causes and effects



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

The multi- component analytical procedure identified eleven effects as the results of multiple climatic and non-climatic causal factors. These eleven effects are included in Table 1.

Table 1 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

In addition to identifying multi-causal effects, the research focused primarily on how producers reacted to them. The research results indicated that farmers are engaged in two adaptation options to address 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. 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 mechanization, reflect the trends of modernization and professionalisation. Mechanization as a form of modernisation is seen as an adaptation strategy has been the subject of the discourse on vineyard modernizations 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 mechanization. However, there is less reference to the causal link between climate change and mechanisation, so when the quality of the harvest enhancing effect of mechanical harvesting is emphasised by participants of this study, it can be seen as a novel result in the discourse. The other link between mechanization and labour is that vineyard mechanization, similarly to any other agricultural sector, increases the need to employ skilled employees to operate machines (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 showed 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 because of the increasing need for skilled labour to cope with the complexity of modern technology-driven agriculture (Schuh *et al.*, 2019). 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 the most 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 adaptation measures can be grouped into two groups: short term decisions characterised by reactive responses and long-term decisions characterised by strategic responses (Neethling, Petitjean and Quénol, 2017). Regarding vineyard cultivation, this study learned about a number of short-term forms of adaptation, such as leaf removal, water spraying prior to harvest, and an early start to harvest. These practises do not require significant management amendments or substantial investments. Such adaptation practises were also 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 plantings, however, growers must make such infrastructure decisions that will determine the future of their vineyards for decades. In that sense, it is crucial to consider the expected conditions under which new plantations will be cultivated, considering changing climatic conditions based on experience. Nevertheless, this aspect does not seem to be a key factor in the participants' decisions. Limited direct references were made regarding the fact that growers make long-term strategic decisions in relation to potential or current climate change impacts to mitigate the vulnerability of their farms. Site selection, for instance, was rather considered in the context of avoiding wildlife damage. In relation to vineyard design, adaptation efforts were driven by the need to make training systems 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 can be observed from the fact that Irsai Olivér, this light, aromatic, early ripening variety, continues to play a major role in farmers' plans, despite the fact that this grape variety is anticipated to become increasingly risky to produce in the wine region. The 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 white wines in domestic wine consumption trends (Totth and Szolnoki, 2019). This is also reflected in the national and regional statistics (KSH, 2020). As Mosdale et al (2016) argue, 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, not just goes against this thought, but it goes against participants' perception. In that respect, the conclusion is that participants' decisions tend to be driven by market trends, which can be identified as short-term profit-maximizing behaviour.

The problem of wildlife damage was also highlighted in participants' narratives. It is not just people, but wild animals are adapting to new weather patterns as well. These new patterns are likely to lead to an increased number of interactions and increased severity of these interactions (Madden, 2010; König *et al.*, 2020). In Mátra wine region, these unexpected interactions become very frequent during summer droughts as animals from game-rich neighboring forests, especially larger mammals are forced to look for alternative water sources, and unprotected vineyards offer a good opportunity for that. The issue would certainly require further investigation to explore the unknown aspects of the situation. This might require a trans-disciplinary focus, involving conservation biology, agriculture, wildlife management.

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 played a greater role in their management decisions than climate change related risks. This is well reflected in the evidence that their adaptation decisions were rather focused on long-term solutions to labour related problems, while climate change impacts have not yet induced such long-term amendments in vineyard management. This point was further explored by the sixth and final sub-research question.

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

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. Accordingly, the adaptive behaviour of the participants was twofold. On the one hand, despite all the identified risk factors, participants appeared confident that they could 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 perceptions of risks, 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 the Hungarian wine sector in 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.

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 the 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 has not been discussed 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.

Evidence of adaptation to uncertain conditions in vineyard cultivation was shown in a couple of instances. The strongest evidence came from a grower who recently reduced the area of his vineyard. However, even this participant was able to continue producing wine because he could purchase the quality of grape needed from other growers. 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 potential risks brought on by climate change, though it also mitigates risks associated with labour shortage and market sales.

Participants spoke about the introduction of varieties better adapted to warming without mentioning any particular variety that might suit future climatic conditions. In other words, it is unclear which grape variety can adapt to changing conditions and fit into the wine region's overall strategy. Views on mulching, which some claimed could be a way to preserve soil moisture while others claimed it was an unnecessary rival to the vine plants, were surrounded by skepticism and uncertainty.

There seems to be a consensus that climate change may generate suitable conditions for late maturing varieties in the wine region, but no specific varieties were mentioned to accompany these views. Participants also expressed uncertainty about decisions to plant or not to plant new plantations. 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.

In conclusion, climate risks are still seen as manageable with the available solutions, but there appears to be considerable uncertainty regarding what should be done. In this regard, it is clear that climate change adaptation in the Mátra wine region has already begun. However, in addition to climatic risks, participants' activities are concurrently affected by other risks, as illustrated by mental model of participants' risk landscape. It has also been evidenced, that non-climatic risk factors, such as labour shortages, now have a greater influence on management decisions. Adaptation to labour shortages is characterised by professionalisation and modernization, but adaptation to climate change does not yet reflect this. Regarding climate change, multiple forms of uncertainty have been identified in this research as an underlying characteristic of participants' adaptation behaviour. It suggests that if the climate situation worsens, the adaptive capacity of participants might be insufficient to cope with changes in climatic conditions.

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