Farm-level risk analysis of German apple production

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Wer nichts tut, tut nichts für die Zukunft.

Abstract

In Germany, apples are the most relevant fruit with respect to both, domestic production and consumption. Weather events and volatile prices make commercial apple production a risky business. Since apple production with an orchard lifetime of around 20 years is a long-term investment, future-oriented risk management is a prerequisite for economic success. In Germany, quality and yield are at risk from adverse weather events such as late frosts and hail. Especially in the south there is an increasing demand for appropriate frost insurance solutions, which were previously only available in neighboring countries. Besides weather-dependent risks, the effects of market risks, i.e. fluctuating sales prices, have to be considered when developing strategies. There are currently no studies on the development of an integrated cultivation strategy for German apple production that take the influence of risks into account.

This thesis provides new insights into the risk attitudes and risk perceptions of apple growers – the two determinants of risk behavior. Based on data collected from 134 apple growers in the two main production regions in Germany, a normative analysis is carried out by developing a utility-efficient decision model that indicates how apple growers should protect themselves against risks from a rational point of view. The model reveals which apple varieties and risk management instruments provide the most efficient combinations in apple production for a rational but risk-averse decision maker.

The results of the risk attitude analysis show that apple growers in Germany are less risk averse than anticipated. The stochastic dominance analysis is carried out on one hectare level and shows that frost irrigation and subsidized hail insurance are the most efficient instruments in the North, but the common practice of using hail nets remains the most favorable risk management strategy in the South. The results of the whole farm model are in line with these findings and show that the degree of risk aversion has only a minor influence on the portfolio of optimal cultivation strategies. In detail, apple production without frost irrigation may lead to high yield losses in northern Germany and subsidies do not compensate for the monetary loss that can occur in the South due to the lack of hail protection nets.

Keywords: risk attitude, risk perception, risk behavior, utility efficient programming, apple production

Kurzfassung

Äpfel sind hinsichtlich der einheimischen Produktion und auch des Konsums das bedeutendste Obst in Deutschland. Die Apfelproduktion ist risikoreich, da Wettereinflüsse und volatile Preise zu Verlusten führen. Die Produktionsdauer ist auf 20 Jahre ausgerichtet und erfordert eine vorausschauende Planung unter Berücksichtigung von Risiken. Hagel und Frost sind die primären Wettergefahren, die zu Qualitäts- und Ernteeinbußen führen. Insbesondere im Süden steigt das Interesse an geeigneten Frostschutzversicherungen, welche derzeit nur in den Nachbarländern angeboten werden. Zudem resultieren Marktrisiken aus volatilen Preisen und müssen ebenfalls berücksichtigt werden. Für die deutsche Apfelproduktion gibt es derzeit keine Studien zur Entwicklung einer ganzheitlichen Anbaustrategie, die den Einfluss von Risiken berücksichtigen.

Die Dissertation liefert neue Erkenntnisse zur Risikoeinstellung- und Risikowahrnehmung von Apfelproduzenten in Deutschland. Basierend auf den Daten von 134 Apfelproduzenten, erhoben in den beiden Hauptproduktionsregionen „Altes Land“ und „Bodensee“, wurde ein nutzungseffizientes Planungsmodell entwickelt und normative Analysen durchgeführt. Das Modell zeigt, welche Sorten und Risikomanagementinstrumente die effizientesten Kombinationen darstellen und den höchsten Nutzen aus Sicht rationaler, risikoscheuer Anbauer erzielen.

Die Ergebnisse zeigen, dass Apfelproduzenten in Deutschland weniger risikoscheu sind als erwartet. Die stochastische Dominanzanalyse auf ein Hektar Fläche verdeutlicht, dass eine Frostschutzberegnung in Kombination mit einer subventionierten Hagelversicherung die effizienteste Strategie im Norden ist und Hagelschutznetze das zu favorisierende Risikomanagement-Instrument im Süden repräsentiert. Die Ergebnisse des gesamtbetrieblichen Modells bestätigen diese Erkenntnisse und zeigen, dass der Grad der Risikoaversion nur einen geringen Einfluss auf das Portfolio der optimalen Anbaustrategien hat. Im Norden kann der Anbau ohne Frostschutzbewässerung zu hohen Ertragsverlusten führen. Verluste, die im Süden durch das Fehlen von Hagelschutznetzen entstehen, können durch Versicherungszahlungen und Subventionen nicht ausgeglichen werden.

Schlagwörter: Risikoeinstellung, Risikowahrnehmung, Risikoverhalten, Nutzeneffiziente Programmierung, Apfelproduktion

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I General Introduction

1 Introduction

This thesis is focused on risk management for apple production farms in Germany and examines utility-efficient risk management strategies for long-term planning. In particular, weather-related risks such as late frost and hail as well as market price fluctuations make apple production a risky business. The overall objective of this thesis is to support apple growers' decision-making in risk management, taking into account site-specific conditions and assuming rational behavior in an uncertain environment.

1.1 Fruit and apple production in Germany

Apple production is the most relevant branch of fruit production in Germany. Apple production contributes nearly 90% of the total tree fruit harvest and covers 70% of the fruit area under cultivation (see Figure 1) (Statistisches Bundesamt, 2017a, 2017b).

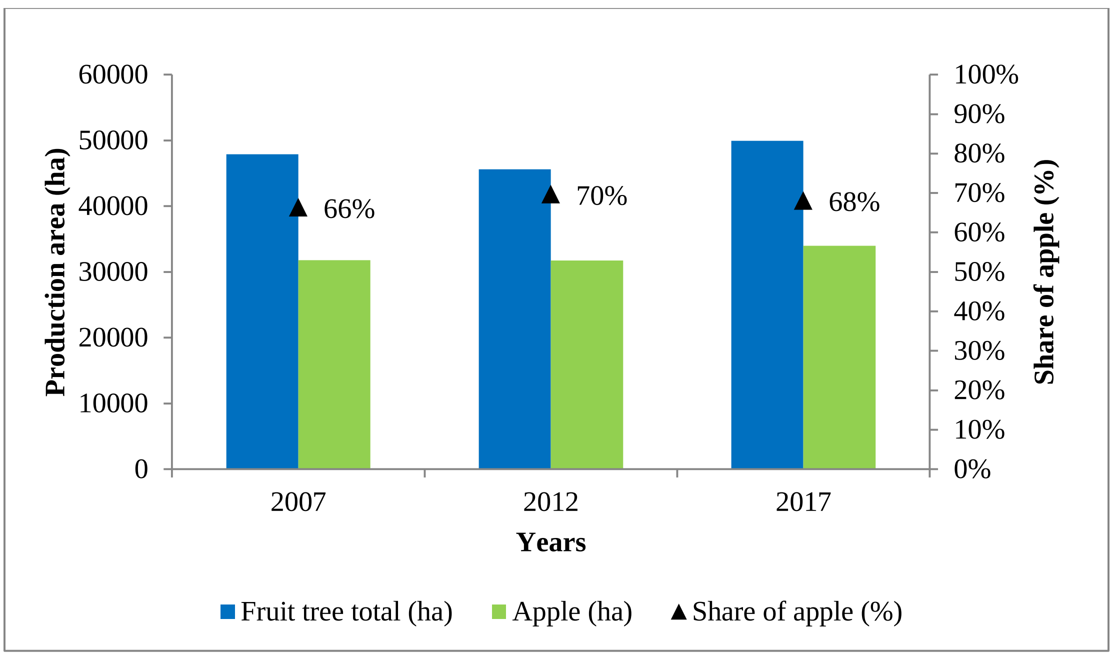

Figure 1. Share of apple producing area in Germany (Statistisches Bundesamt, 2017b).

Two large apple growing areas in Germany are the “Altes Land”, located in the lower Elbe region near Hamburg, and the Lake Constance region. Each region provides approximately 30% of the domestic supply. The “Altes Land” consists of 800 apple producing farms, forming an area of 10,000 ha and provides more than 2,000 full-time jobs in apple production, whereas the Lake

Constance region comprises an area of 8,000 ha with 1,600 growers employed (Büchele, 2013; Görgens, 2013).

Considering fruit consumption in Germany, the per capita consumption of apple shows a slight decreasing tendency, but with 19kg/capita/year, apples are still the most important fruit before bananas (about 11kg/capita/year) in 2015/16 (Statistisches Bundesamt, 2018). The self-sufficiency rate in years without severe weather events is approximately 42% (Bundesministerium für Ernährung und Landwirtschaft, 2014). Table 1 provides data concerning German apple production of the past decade (Statistisches Bundesamt, 2017a).

Table 1. Production area and harvest of apple in Germany (Statistisches Bundesamt, 2017a).

Year	Area (ha)	Yield (1000 t)	Yield per ha (dt/ha)
2007	31721	1070	337.3
2008	31800	1047	329.2
2009	31813	1070.7	336.6
2010	31819	835.0	262.4
2011	31608	898.4	284.2
2012	31640	972.4	307.3
2013	31647	803.8	254.0
2014	31465	1115.9	354.6
2015	31408	973.5	309.9
2016	31334	1032.9	329.6
2017	33913	596.7	175.9
Mean	31833	947	298.0
Stdev	676.1	146.4	49.3

The numbers show that apple production is subject to heavily fluctuating harvest yields. In 2017, late frosts and high temperatures during summer lead to a reduction in harvest of about 20% in the EU (Foreign Agricultural Service USDA, 2017). In Germany, the consequences were even more severe. The harvest of 596700 tons was about 42% below previous year's level and 37% below the 10-year average (Statistisches Bundesamt, 2017a).

Regarding production risks, hail and late frosts represent major factors, influencing yield and quality of apples (Gandorfer et al., 2016; Menapace et al., 2013). Here, the effects of climate change increase uncertainty and add to production risks. Some initial investigations have been conducted, addressing the effect of climate change on fruit production in Germany (Chmielewski and Blümel 2013; Hoffmann et al. 2012; Kemfert and Kremers 2009). Nevertheless, the frequency of extreme weather events and their associated impacts remain unclear. As hail is a local event, weather observation stations capture insufficient data, which are inappropriate for long-term statistical analysis. Thus parameters, characterizing the convective potential of the atmosphere, are serving as proxy data for hailstorm prediction. Focussing on the past decades, significant positive trends in convective parameters along with an increase in hail potential can be observed in Germany (Mohr and Kunz 2013).

Besides weather related risks, price risks, which are nearly uncontrolable by farmers, may arise from the global marketplace as well as from national and international policies, resulting in volatile market conditions (Hoag 2010, p. 13). Figure 2 shows the relation of yield and prices of apples in Germany between the years 2009-2015 (AMI, 2015, 2017). It reveals that apple growers are not necessarily able to recoup havest shortfalls by higher price levels due to global trade conditions.

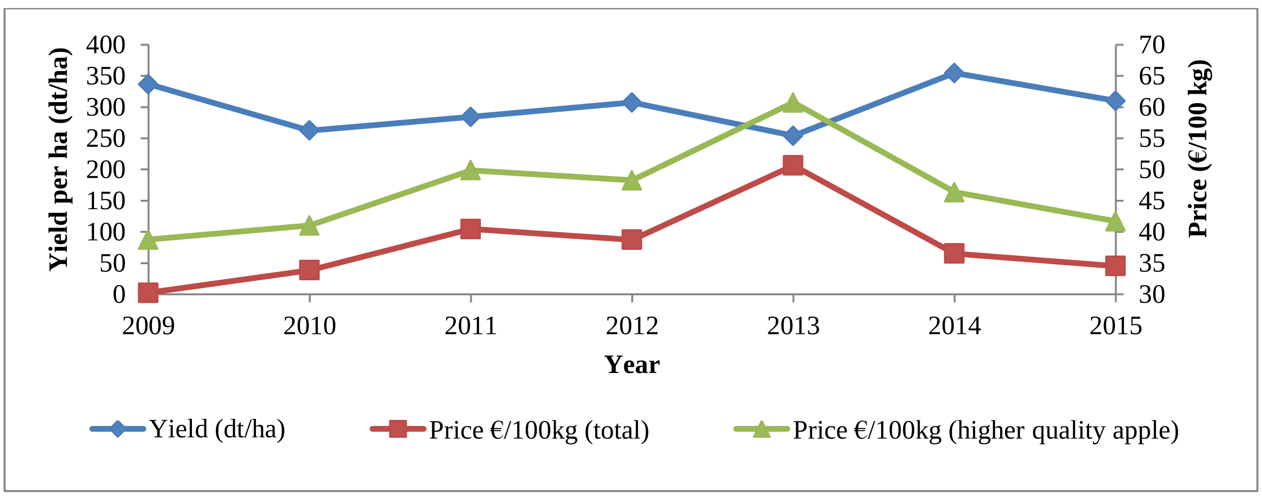

Figure 2. Yield (dt/ha) and price level of apple in Germany (AMI, 2015, 2017).

Furthermore, when considering different marketing channels, price volatility of apple tend to be higher if sales are realized via producer organisations (Gandorfer et al., 2017). In addition, business activities such as transportation and storage of goods are also associated with price risks (Hoag 2010, p. 13). On the other hand, producer price volatility of apples compared to strawberries is considered to be lower due to storage facilities and year-round marketing (Gandorfer et al., 2017).

1.2 Considering risk in apple production

As fruit production is a perennial crop, apple-growing requires long-term planning over a twenty-year period, which reduces the adaptability of variety use and risk management applications. Besides the individual perspective, assessing risk exposure and behavior of apple growers is also interesting from a political point of view. So far, the benefits of reducing preexisting, i.e. baseline, environmental uncertainty via political regulations are often disregarded. However, the associated benefit of reducing preexisting uncertainty increases with increasing risk aversion of the social group. However, the level of risk aversion is mostly unknown and due to the individual variation in risk aversion, a collective value cannot be specified. Thus, risk neutrality is commonly assumed and in this case a calculation with expected values is reasonable (Kaufman et al., 2014).

A deterministic crop budgeting model, based on expected values, has already been developed for an economic evaluation of apple production systems in Germany and mathematical optimization models for strategic apple production are presented in the literature (KTBL, 2010; Catalá et al., 2013). However, these approaches do not consider the effect of an uncertain environment and the individuals' degrees of risk aversion. Research on the factors influencing the risk behavior of apple growers has already been carried out in Italy (Menapace et al., 2013; Menapace et al., 2015), but an overall assessment of risk behavior is not available.

There exist several theories for the analysis of risk behavior. The most prominent ones are the subjective expected utility theory (SEU) and the prospect theory (PT). The SEU characterizes risk behavior of rationally acting individuals and has the advantage that it depends on two factors. Risk perception and risk preference both determine, which strategies persons choose to hedge against situations with uncertain outcomes (e.g. Hardaker 2000). Risk perception consists of the likelihood a person associates with a particular hazard (perceived probability) and the expectation of how detrimental the consequences of the threat will be to their aims, values and standard (perceived severity) (Lyle 2015). Risk preference, also known as risk attitude, is seen as a person's sensitivity to risks (Bocquého et al., 2013). More precisely, it characterizes the extent to which a person tries to avoid or likes to face risks (Dillon and Hardaker 1989, p. 134). According to the SEU, risk preference can be described by a utility function if the axioms ordering, continuity, and independence are met (Starmer 2000). However, individuals may violate these axioms and therefore reveal irrational behavior. Here, reference dependence (i.e. distinguishing between gains and losses) and probability weighting (distorted perception of objective probabilities) are two main factors causing discrepancies. As the prospect theory accounts for these anomalies, it may provide more reliable results for descriptive research approaches, aiming to explain risk behavior (Bocquého et al., 2013).

1.3 Research Objectives

The aim of the thesis is to develop a decision support tool that will serve as a risk management tool for apple growers in Germany. Due to the lack of knowledge about apple growers risk behavior, this thesis attempts to pursue a holistic approach by gaining insights in risk preferences and risk perception in order to optimize German apple production under risk. These data were compiled by face-to-face interviews with apple growers in the two main apple production regions of Germany (Altes Land, Lower Saxony and Lake Constance). Since the analytical purpose is prescriptive-normative, subjective expected utility theory (SEU) is assumed to be the appropriate theoretical basis for this research (Starmer, 2000).

In particular, the following objectives were pursued:

The degree of risk aversion is very heterogeneous and varies between individuals. Thus, a single value for characterizing the risk aversion of a social group cannot simply be defined (Kaufman et al., 2014). Even if some studies found that European farmers are risk averse (e.g. Meraner and Finger, 2017; Reynaud and Couture, 2012) this may not hold for apple producers in Germany. Furthermore, literature shows that method- and context-dependent effects may lead to biased results when eliciting risk aversion (e.g. Reynaud and Couture, 2012). The *first objective* of this work is therefore to adequately examine the risk attitude of apple growers in Germany.

Stochastic dominance analysis enables the ranking of risk management options according to their efficiency on the basis of risk perception data (in the form of cumulative density functions) and requires only minor assumptions about the degree of risk aversion. This approach was chosen to match the *second objective* and to distinguish efficient from inefficient combinations of varieties and risk management instruments. In order to refine the analysis, stochastic efficiency with respect to a function (SERF) was applied. Here, values of a utility function are converted by the inverse utility function into certainty equivalents (CE) for a given range of risk aversion coefficients.

The *third objective* is to develop a utility efficient programming (UEP) tool, which can be used to derive future-oriented risk management recommendations with a particular focus on region-specific, severe weather events. The development of the tool requires a sufficiently detailed database on risk perception and management options. Although there are few studies on the risk attitude and risk perception of apple growers, to our knowledge the findings have never been integrated into a model and subsequently evaluated. Using a whole-farm model, the aim is to derive efficient portfolios for different degrees of risk aversion as well as discount rates and to explain which risk management instruments are best suited to protect against adverse weather events.

1.4 Outline of the thesis

The data collected for this thesis provide previously unknown information on risk attitude and risk perception of German apple producers, both determinants of risk behavior. Since risk attitudes and risk perception are decisive factors influencing risk behavior, they are discussed in separate papers (I and II). The third paper (III) combines the information obtained and derives via utility-efficient modelling which risk management instruments are most efficient from a rational point of view, i.e. how apple growers should behave.

The first paper "Domain-specific and general risk aversion among German apple growers is low" addresses the *first objective* and deals with the subject of apple growers risk attitude in dependence of different domains and pay-off scales (chapter 2). As there is a general uncertainty as to which method is most reliable for the elicitation of risk attitudes, various methods have been applied. In detail, one general and two context-framed Likert scales as well as a standard and an income-framed Holt and Laury lottery (HLL) were applied to elicit apple growers risk attitude. The interrelations between different domains and methods are analyzed and discussed. The paper further points out whether real world behavior concerning risk management activities can be derived from the elicited risk attitude.

The second paper "Efficient farming options for German apple growers under risk - a stochastic dominance approach" comprises the *second objective*. It addresses the risk perception of apple growers with regard to yield and quality reductions due to severe weather events and fire blight as well as volatile prices (chapter 3). The evaluation of efficient production systems, considering different varieties, planting densities and risk management instruments, is conducted via stochastic dominance analysis and a SERF (Stochastic efficiency with respect to a function) approach on an one-hectare-area. The results show whether insurance solutions or on-farm risk management tools such as hail nets or frost irrigation are more efficient for the respective regions. Therefore, the second paper provides a form of pre-evaluation of efficient combinations of apple varieties and risk management tools.

The third paper "Rationalizing apple growers' decision making in Germany - a utility based whole farm programming approach" addresses the *third objective* and determines an optimal farm strategy taking into account the risks for a period of 20 production years (chapter 4). It is based on a more holistic approach than the second one as the utility model determines efficient portfolios of apple varieties and risk management instruments for different discount rates and risk aversion coefficients.

The last section provides a general discussion (chapter 5).

The questionnaire used for data collection is presented in the Appendix.

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II Testing context-specific and general framing in risk-preference elicitation tasks – an empirical approach

Abstract

This paper examines the behavioral validity of general and domain-specific self-assessments on Likert scales as well as of a standard and an income-framed Holt and Laury lottery (HLL). Our analysis is based on a survey conducted among 134 apple growers in Germany. Our results indicate that low payoff HLLs capture risk preferences in a financial context well, whereas the context-framed HLL is closely related to self-assessed general risk preference. However, they are unable to explain observed behavior with regard to participation in crop-yield insurance and the use of hail nets. In contrast, the self-assessment in the domain of yield and quality risks offers a simple elicitation method with a high explanatory power. In addition, the results indicate that lotteries with small outcomes and context-specific HLLs should be used with caution, because they may not be able to control for background risks sufficiently.

1 Introduction

Over the past years much research in agricultural economics has focused on risk and farmers' behavior towards uncertain circumstances. Sources of uncertainty, such as weather events and volatile prices, affect yields and income in agriculture (Ihli *et al.* 2013; Menapace, Colson and Raffaelli, 2013). Strategies farmers choose to secure themselves against situations with uncertain outcomes depend on their risk preferences and risk perceptions. Knowledge of these determinants of risk behavior is essential to adapt political programs and recommendations (Menapace, Colson, and Raffaelli 2013; Nielsen, Keil, and Zeller 2013). Stochastic dominance and parametric models allow recommendations for farmers as well as for agricultural policy programs to be derived. We used a stochastic dominance approach to identify efficient combinations of varieties and risk management instruments for German apple production (Röhrig, Hardeweg, and Lentz 2018). The next step for deriving relevant recommendations is to consider risk in a whole-farm setting by developing an utility efficient programming model. The model takes into account the influence of various factors, for instance dependencies between varieties, different risk management instruments and weather effects. However, utility efficient risk modelling requires information on risk preference, which is mandatory for parameterizing the utility function. This paper reports on the elicitation of risk preferences among German apple growers, which are to be used for parameterizing the utility efficient model.

The literature provides a number of different approaches to measure risk preference, which is also known as risk attitude and captures a person's sensitivity towards risks (Bocquého, Jacquet, and Reynaud 2013). Among a variety of elicitation techniques, self-assessments and experiments based on scales of consequences or probabilities can be applied (Ogurtsov, Van Asseldonk, and Huirne 2008; Abdellaoui, Driouchi, and L'Haridon 2011). Self-assessments offer a simple approach for the elicitation of risk attitudes. Many studies use this method by presenting Likert scales to respondents (e.g. Dohmen *et al.* 2011; Maart-Noelck and Musshoff, 2013; Nielsen, Keil and Zeller, 2013; Hardeweg, Menkhoff and Waibel, 2013; Menapace, Colson and Raffaelli, 2015). The major drawbacks of this method are that self-assessed risk attitudes are not incentive-compatible and scales might be defined in different ways by different respondents. Therefore, accidental findings may be obtained due to factors such as strategic motivation, inattentiveness, and self-serving bias in order to enhance personal self-esteem (Dohmen *et al.* 2011; Hardeweg, Menkhoff and Waibel, 2013). Furthermore, and in contrast to scale-based self-assessments, experiments allow risk aversion coefficients to be obtained and in consequence provide information on the curvature of the decision-makers' utility functions (Franken, Pennings, and Garcia 2014). However, deviating results, obtained using different methods as well as single method designs (e.g. Hudson, Coble and Lusk, 2005; Reynaud and Couture, 2012; Nielsen, Keil and Zeller, 2013) raise major concerns. One explanation might be that risk elicitation techniques differ in the kind of information collected. For instance, self-assessments, in contrast to experimental tasks, might not only capture risk preferences but also include information on self-insurance against risk. As a consequence, self-assessments might be better in predicting real-world behavior, whereas experiments capture inherent risk aversion (Hardeweg, Menkhoff, and Waibel 2013). Moreover, the results of Reynaud and Couture (2012) indicate that the payoff scale may affect the performance of an experimental approach and that risk preferences are context-dependent. As there is no consensus on the degree to which self-assessments is a useful tool for the elicitation of risk preferences, this paper aims to provide new evidence for this debate by examining whether different contexts influence the relationship between self-assessed risk attitude and experimental methods.

Apart from causing adverse effects, the framing of risk elicitation tasks may also provide the opportunity to improve risk elicitation. Holt and Laury lotteries (hereafter HLL), originally pioneered by Holt and Laury (2002), have already been used as context-framed tasks in developing countries. For instance, Charness and Viceisza (2011) applied a framed HLL in the context of yields and seeds to Senegalese farmers in order to reduce the cognitive burden of the tasks. In order to further investigate the performance of a context-framed HLL, we follow the route of Menapace, Colson and Raffaelli (2015) who find a framing and a payoff effect in hypothetical Eckel and Grossman (2008) lotteries (hereafter EGLs) when eliciting risk preferences of 98 apple farmers in Trento, Italy. Interestingly, their results suggest that framed lottery tasks show a high explanatory power when focusing on farmers' insurance participation, which leads to the conclusion that the choice of design elements such as context (context-dependent framing effect) and outcome scale (payoff effect) are crucial components in the development of risk-eliciting experiments (Menapace, Colson, and Raffaelli 2015). In addition, framed HLLs might be used to enhance the willingness to participate in the experiment.

In the context of perennial crops, uncertainty becomes even more relevant, which is why our research focuses on apple production. Given a production period of 20 years, short-term adaptions are difficult to realize and thus decisions have long-term consequences. Until now, only little information is available on farmers' long-term planning and the elicitation of risk attitude, considering developed countries.

For assessing the performance of context-framed elicitation techniques and their explanatory power regarding farmers' insurance participation and hail net use, we are first of all pursuing a quick and easy Likert-scale approach, implemented by Dohmen *et al.* (2011), who find deviations when people are asked to assess their risk attitudes for different contexts, although correlations are positive and highly significant (Dohmen *et al.* 2011). Similar observations are made by Vieider *et al.* (2014), who elicited risk attitudes of students from 30 countries with lotteries and self-assessments. According to the observations of these two studies, we assume the existence of a stable underlying risk trait. To gain more insights on domain-specific risk attitude for apple growers, we include two context-dependent questions on the subjects' "willingness to take risk" in order to analyze if self-assessments might be a suitable, simple method of eliciting risk attitudes for designated domains.

Second, we assess the transferability of results obtained with two modified HLLs and evaluate whether framing or payoff effects have an impact on apple farmers' elicited risk attitudes. Whereas the first lottery task represents a low payoff HLL, modifications of the context-dependent one includes percentages of average annual farm income. Since the literature states that HLLs in comparison to EGLs are less affected by a payoff effect (Reynaud and Couture, 2012), we are interested whether the findings of Menapace, Colson and Raffaelli (2015) can also be validated for HLLs.

Thirdly, we focus on the comparability of self-assessed and experimentally derived results and explore their explanatory power with regard to farmers' choice of risk management strategy by means of probit regression containing insurance participation and hail net use as dependent variables. So far, there is no clear consensus whether lotteries or self-assessment scales provide a more reliable tool for predicting real-world behavior. For instance, Franken, Pennings and Garcia (2014) find that self-assessments predict actual marketing choices better, whereas the results of Pennings and Smidts (2000) indicate a higher explanatory power for lotteries in comparison to self-assessments when focusing on actual market behavior. Hudson, Coble and Lusk (2005) observe that none of their measures, including direct assessments, open-ended question frameworks, and a fixed probability lottery, as well as several Likert-scale questions, is superior in explaining economic behavior in the fields of crop insurance or property insurance purchase, engagement in the futures market and gambling. Regarding insurance participation, Hellerstein, Higgins and Horowitz (2013) investigated the predictive power of a modified, incentive-compatible HLL, which has rather the character of an outcome-scaled gamble with a probability of p=0.5 for each outcome. Contrary to their expectation, they find that risk averse farmers tend to diversify less and are less likely to participate in crop insurance. They conclude that the predictive power of lottery choices is low for farming characteristics in developed countries, because lottery choices capture risk attitude on the basis of the risk protection that is already implemented. They further assume that background risk provides an explanation and simultaneously impairs the ability of lottery tasks to capture the attitude towards a risk that is correlated to other risks to which the individual is exposed (Hellerstein, Higgins, and Horowitz 2013). The effect of background risk was experimentally shown among numismatists in the study of Harrison, List and Towe (2007).

Menapace, Colson and Raffaelli, (2015) find a variation in the predictive power of framed and non-framed EGLs and self-assessments related to insurance participation, indicating a significant relationship between the context-dependent EGL and taking out insurance, which is not to be observed for the small-outcome lottery and the self-assessment (Menapace, Colson, and Raffaelli 2015). Therefore, context-dependent lotteries might provide a more appropriate elicitation tool for risk attitude related to actual behavior in the same context. Harrison, List and Towe (2007) provide an explanation for these results. They demonstrate that background risk influences decision-making in a between-subject test among numismatists. More specifically, they find that framed risk with little uncertainty (graded coins) did not lead to statistically significant differences in results in comparison to those obtained by a standard lottery with prize money. In contrast, a lottery with more uncertainty (ungraded coins) caused significantly higher risk aversion than observed for the standard lottery (Harrison, List, and Towe 2007). Similarly, Herberich and List (2012) find an increase in risk aversion in a survey among farmers and students when background risk is added to lottery tasks. Meraner and Finger (2017) suggest using context-dependent HLL and including indicators of applied risk managing tasks as a means to eliminate the effect of background risks, which leads us to re-examine the predictive power of the HLLs and self-assessments for insurance participation and hail nets installation under consideration of different contexts. To our knowledge this is the first study which compares a small-outcome and a context-dependent HLL for farm income in order to control for background risk and to find a reliable indicator of observed risk behavior.

The following section provides an outline of the experimental design. The results of the analysis are then presented and discussed, and finally conclusions are drawn.

2 Experimental Design

In order to analyze risk preferences of German apple growers, data were collected in winter 2013/2014 through face-to-face interviews. Farmers were surveyed in the two main production regions of Germany, located in the north, at the river mouth of the Elbe (Altes Land) and in the south, close to Lake Constance.

All participants were exposed to three self-assessments and two lottery tasks. Generally, incentivized lotteries are expected to explain real risk aversion better than hypothetical tasks. As insufficient funds restricted the number of incentivized experiments, half of the participants in each region were invited to take part in the incentivized low payoff experiment with a maximum payoff of €60. Before apple growers were asked to state their choices, a task specific explanation was provided, which is given in the appendix.

After eliciting risk attitude, a structured questionnaire was used to obtain socio-demographic and business-related characteristics as well as information on risk management instruments.

We assessed apple growers' risk perception as a further component of risk behavior in the same survey, which is not the scope of the present study.

Due to privacy protection, no official sampling frame for fruit farmers was accessible. As most farmers use the regional extension service or are members of producer organisations, we contacted around 500 farmers by invitation letters sent out by these organisations in their respective region and completed face-to-face interviews with 66 volunteering farmers from the north and 68 from the south.

It has to be stressed that production conditions differ between the two regions: late frosts have a major impact on apple yield and quality in the north, where nearly all of the sites are equipped with overhead irrigation, except for sites located near the river Elbe. In the south, damages due to hail are more important. Regarding the past ten production years, our data indicate that 63.2% of the apple growers in the south suffered from yield losses due to hail and 48.5% in the north. For late frosts, 54.4% of the southern apple growers reported losses in the same period and 66.7% of the northern farmers. As most apple growers already protect themselves against these major weather risks, the risk profile of the regions would differ even more strongly in the absence of protective interventions. Furthermore, sunburn poses an additional weather-related risk to fruit quality in both regions.

2.1 General and domain-specific self-assessment

For the self-assessments in general and for specific domains we use Likert scales, similar to those implemented by Dohmen *et al.* (2011). As suggested by Nielsen, Keil and Zeller (2013), we constructed a 10-point scale ranging from 1 (not at all willing to take risks) to 10 (very willing to take risks). This scale offers no opportunity to simply select a point in the middle. Besides a general assessment, subjects were asked to assess their domain-specific risk preference in the context of "securing against yield and quality reducing factors in apple production" and "financing". The original wording of the tasks, translated to English, is given below:

"Please characterize your willingness to take risks by considering the following scale".

	1	2	3	4	5	6	7	8	9	10	
Not at all willing to take risks	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	**Very willing to take risks**

Question 1 How would you characterize your willingness to take risks **in general**?

Question 2 How would you characterize your willingness to take risks **in the context of yield- and quality reducing factors which affect pomefruit production (pests and diseases excluded)**?

Question 3 How would you characterize your willingness to take risks **in the context of financing?**

2.2 Experimental elicitation of risk preferences

Experimental approaches to measuring risk preference differ in their representation of probabilities and outcomes and have been reviewed by Abdellaoui, Driouchi and L'Haridon (2011). The Holt and Laury Lottery (HLL) as an implementation of the probability-scaled approach is based on varying probabilities and constant outcomes (Holt and Laury 2002). In contrast, the Eckel and Grossman (2008) lottery uses constant probabilities and varying outcomes: each lottery consists of two payoffs A and B with probabilities p_A=p_B=0.5, and subjects are asked to choose one out of five given lotteries (Eckel and Grossman 2008). More recently developed frameworks of Abdellaoui, Driouchi and L'Haridon (2011) and Brick, Visser and Burns (2012) are also outcome-scaled approaches in which subjects are asked to decide between a certain outcome and a 50/50 lottery task for different decision rounds. A major disadvantage of tasks offering a sure outcome is their susceptibility to the certainty effect, which may lead to an overestimated risk aversion under non-expected utility behavior, as many persons prefer certain outcomes over lotteries (McCord and de Neufville 1986; Abdellaoui, Driouchi, and L'Haridon 2011). Thus, we chose the HLL approach consisting of a multiple price list, which offers two risky lotteries A and B to the subject, composed of two possible payoffs, x_A and y_A, as well as x_B and y_B, where one payoff is always larger, i.e. $x_A > y_A$ and $x_B > y_B$. Lottery A is less risky, since its payoffs are closer to each other than those of lottery B. The subject is asked to choose the preferred one out of the two given lotteries for 10 different decision rounds. With every round, the probability for gaining the higher payoff increases, making lottery B increasingly attractive. The switchpoint from lottery A to lottery B indicates the degree of risk aversion and can be used to calculate an interval for the coefficient of relative risk aversion of the individual (cf. Holt and Laury, 2002; Reynaud and Couture, 2012).

In the original small payoff gamble of Holt and Laury (2002), outcomes of $1.60 and $2.00 for lottery A and $0.10 and $3.85 for lottery B were offered. Table 1 shows the payoffs of the low payoff task and the context-dependent HLL, which were used in our survey for lotteries A and B as well as the corresponding probabilities.

Table 1. Modified Holt and Laury lottery (HLL) used in the experiment.

		Option A		Option B		Range of relative risk aversion coefficients
Prob. 1	Prob. 2	Payoff 1 (x_A)	Payoff 2 (y_A)	Payoff 1 (x_B)	Payoff 2 (y_B)	
9/10	1/10	25	40	5	60	r≤ -1.92
8/10	2/10	25	40	5	60	-1.92 <r≤ -1.16
7/10	3/10	25	40	5	60	-1.16 <r≤ -0.69
6/10	4/10	25	40	5	60	-0.69 <r≤ -0.32
5/10	5/10	25	40	5	60	-0.32 <r≤ 0
4/10	6/10	25	40	5	60	0 <r≤ 0.31
3/10	7/10	25	40	5	60	0.31 <r≤ 0.63
2/10	8/10	25	40	5	60	0.63 <r≤ 1.00
1/10	9/10	25	40	5	60	1.00 <r≤ 1.53
0/10	10/10	25	40	5	60	1.53 <r

Notes: Constant relative risk aversion coefficients were calculated given the assumption of a power utility function.

Lottery A offers €25.00 and €40.00, while lottery B provides €5.00 and €60.00 for the low payoff task. For the context-dependent task, the numbers were kept constant but were used to express respectively a 25% and a 40% increase in farm income for the payoff pair of lottery A and 5% and 60% for lottery B. Such increases of income can be interpreted as the result of uncertain income streams from business expansion. Figures 1 and 2 display the experimental design for the low payoff and the farm income lottery game. Before the experimental tasks started, respondents were informed that they should receive a payout determined by rolling two ten sided dice. The first one was used to determine the choice number, i.e. one of the ten decisions, and the second one was used to determine the associated outcome. For example, when focusing on decision round number two, numbers of 1 and 2 represent the 20% probability of winning the higher payoff.

Please choose your preferred lottery A or B for every of the ten decision rounds:

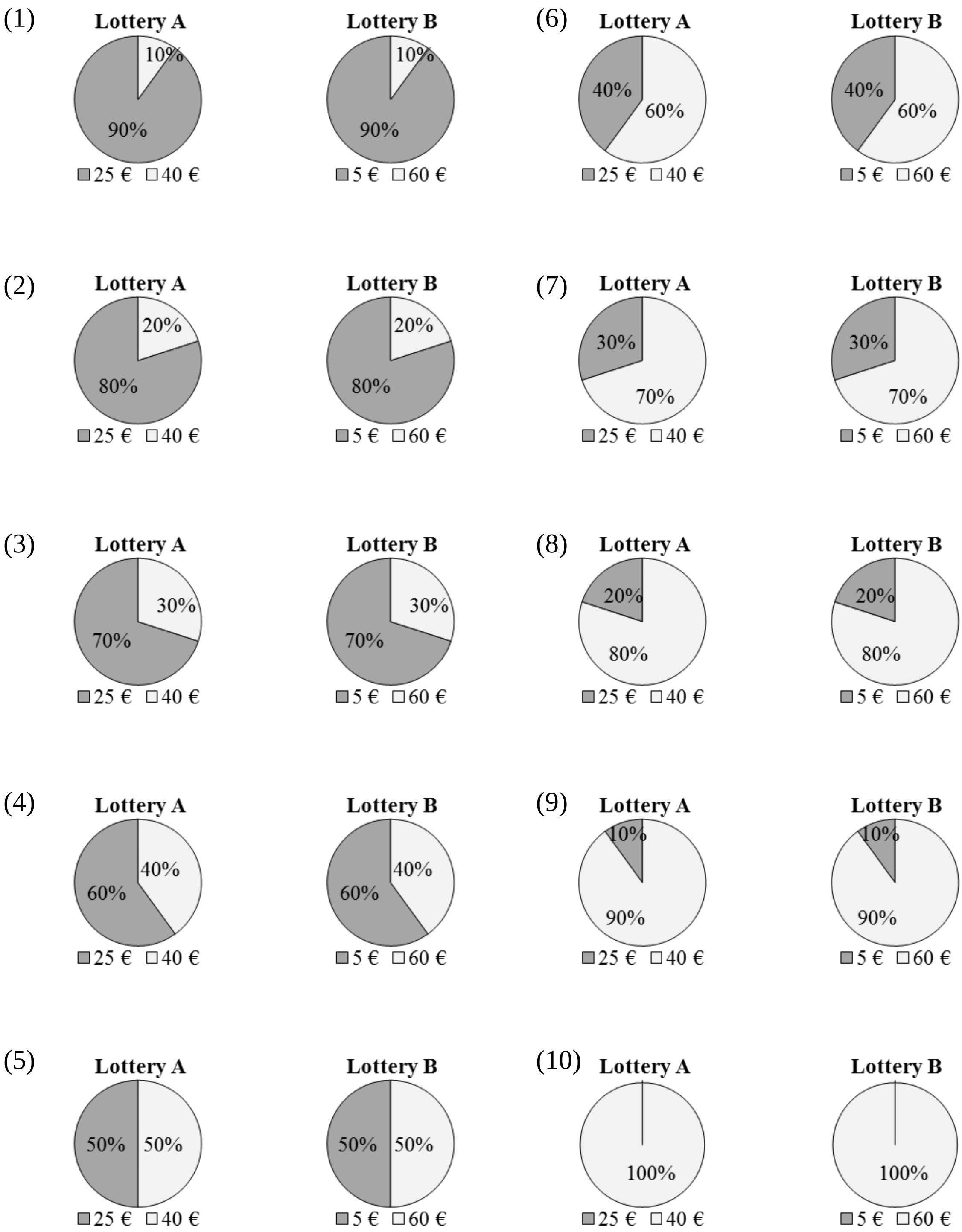

Figure 1. Design of the low payoff gamble.

Please note that consequences are now **<u>expressed in terms of percentage of average annual farm income and do not represent low payoffs.</u>**

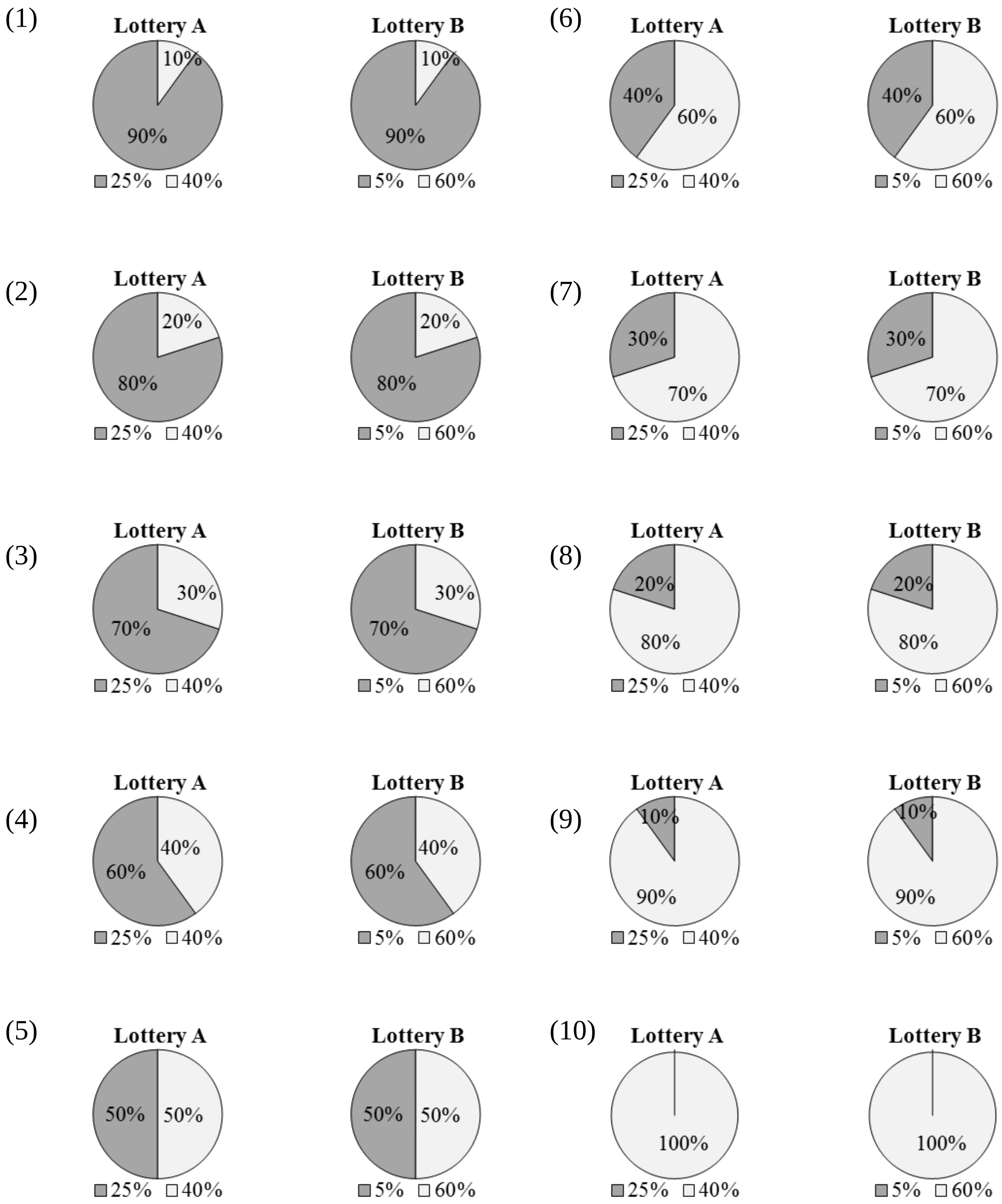

Figure 2. Design of the farm income gamble.

3 Results and Discussion

3.1 Descriptive statistics

Of the 134 farmers interviewed, 119 answered the survey completely and showed consistent choices in the experiment. For our analysis we decided to exclude the incomplete datasets in order to ensure the comparability of results. Table 2 presents the descriptive statistics of selected socio-demographic and business-related characteristics for this sample. Information on the educational background was collected on a five-rank scale. In total 68% of the participants are master craftsmen or technicians (rank number 4) and 19% hold a university degree (rank number 5), which shows that the level of education is high. Furthermore, the surveyed farmers have an average farming experience of about 24 years and the income share from apple production accounts for about 79% of total household income. Differences between the data obtained from the two regions are reflected in the p-values for Mann-Whitney U tests and χ^2-tests for dummy variables, respectively, in the last column. Accordingly, regions differ significantly for nearly all characteristics. As expected, the farm size in terms of apple production area is clearly larger in the north. As hail is a more frequent event causing high damage in the south, apple plantations are widely covered with hail nets, which explains the lower proportion of farmers participating in hail insurance in the south. The data further reveal that hail nets are not used in the north, as the solar radiation is lower and hail nets might lead to a deficient fruit coloring.

Table 2. Descriptive statistics of socio-demographic and business-related characteristics.

	All apple growers			North		South		Difference test
Number of participants	119			61		58		
	Mean	Std.dev	Median	Mean	Std.dev.	Mean	Std.dev.	p-value
Age	44.69	10.16	46.00	42.69	9.63	46.79	10.35	0.017
Married (dummy)	68.07%			60.66%		75.86%		0.075
Number of children	1.75	1.166	2.00	1.54	1.18	1.97	1.12	0.032
Farming Experience (years)	23.91	8.23	30.00	22.62	7.92	25.26	8.39	0.052
Education average rank	3.90	0.969	4.00	4.08	0.78	3.71	1.11	0.048
Apple production area (hectare)	19.95	12.48	18.00	21.66	8.65	18.15	15.41	0.000
Share of owned land (%)	64.71%	28.31%	66.67%	69.74%	29.89%	59.42%	25.75%	0.020
Number of years with yield losses due to hail (past 10 years)	1.21	1.43	1.00	1.06	1.36	1.36	1.50	0.220
Income share from apple production	78.66%	22.34%	85.00%	83.97%	17.60%	73.09%	25.40%	0.035
Participation in hail insurance (dummy)	51.26%			68.85%		32.76%		0.000
Use of hail nets (dummy)	37.82%			0.00%		77.59%		0.000

The p-values for differences between regions refer to Mann-Whitney-U-tests for interval scaled and ordinal variables and χ^2-test for dummy variables, respectively.

3.2 Elicited risk attitudes and their methodological dependencies

Table 3 contains information on the results obtained via different elicitation techniques. For a simpler comparison with the experiments, the Likert scales were recoded to indicate an increasing risk aversion with increasing numbers (1 indicates = highly risk loving and 10 = extreme risk averse attitude). Furthermore, the midpoints of the relative risk aversion intervals associated with the subject's switch to the riskier lottery serve for further analysis.

Table 3. Descriptive statistics of risk attitude measurement techniques.

	All apple growers			North		South		Mann-Whitney U test
Number of participants	119			61		58		119
Self-assessments	Mean	Std.dev.	Median	Mean	Std.dev.	Mean	Std.dev.	Sig.
General	5.143	1.633	5.000	5.180	1.478	5.103	1.794	0.858
Yield and quality risks	7.328	1.918	8.000	7.361	1.853	7.293	2.000	0.628
Finance	6.714	2.202	7.000	6.902	2.158	6.517	2.250	0.324
Lotteries								
Low payoff gamble non-incentivized	-0.298	0.857	-0.160	-0.236	0.833	-0.361	0.890	0.581
Low payoff gamble incentivized	-0.624	0.805	-0.505	-0.684	0.731	-0.558	0.888	0.380
Farm income gamble	0.039	0.847	0.155	0.056	0.779	0.021	0.919	0.836

Notes: Self-assessments are recoded to reflect increasing risk aversion with increasing value (1: fully prepared to take risk, 10: extremely risk averse). Results for lotteries are based on the midpoints of the range of relative risk aversion coefficients.

As we purposively excluded a midpoint, all self-assessments were made on a 10-point scale. The tendency is comparable among these scales, as their extremes are defined identically. In line with Maart-Noelck and Musshoff (2013), we further assume that the points on the Likert scale are equidistant. Therefore, a mean value for the general context of 5.143 indicates a slight willingness to take risk to risk neutrality. A value of 6.714, as obtained in the context of finance, represents risk neutrality to slight risk aversion. Moreover, we find that subjects characterized themselves as moderately risk averse (7.328) for yield and quality risks. The experiments reveal slightly risk loving behavior (-0.298) for the non-incentivized low payoff gamble, an enhanced risk loving behavior for the incentivized low payoff gamble (-0.624) and a slight risk aversion (0.039) for the farm income framed gamble. Thus only the self-assessment related to yield and quality risks clearly reveals risk aversion on average in our sample, whereas the stated preference in the domain of finance as well as the experiments indicate a slight tendency to risk aversion, with average risk aversion coefficients close to zero. This contrasts to most findings in the literature, which generally find clear risk aversion among samples of farmers. According to many studies farmers in developing countries are predominantly risk averse (Ihli *et al.* 2013; Nielsen, Keil and Zeller, 2013; Hardeweg, Menkhoff and Waibel, 2013) and similar observations are reported for farmers of developed countries (Meraner and Finger, 2017; Herberich and List, 2012; Reynaud and Couture, 2012). Comparable studies indicate that apple growers show risk aversion, when applying an EGL framed in terms of a farm income gamble (Menapace et al. 2015). However, only moderate degrees of risk aversion seem reasonable in the light of the rather moderate returns compared to the significant investments required in apple production as reported in farm performance statistics (Zentrum für Betriebswirtschaft im Gartenbau e. V., 2014). Concerning methodological aspects, the HLL in contrast to EGL provides a framework which is not affected by the above-mentioned certainty effect. Even if the certain outcome in the first gamble of the EGL were expressed as a probabilistic choice, this sure outcome might increase choices indicating risk aversion, and thus lower the proportion of individuals found to be risk neutral and risk loving. Based on these deliberations, our results add a new aspect on risk attitudes for a group of farmers in a developed country.

Even though the two regions provide distinct conditions for apple production, farmers' risk attitudes do not differ significantly according to Mann-Whitney U tests for self-assessments as well as for the experimental tasks. Furthermore, we were interested in the existence of deviations between the non-incentivized and incentivized low payoff gambles. The Mann-Whitney U test conducted for this purpose is significant (0.034, *p*-value) only for the low payoff gamble, but with respect to the subsequent farm income gamble, the results do not differ between groups who played the incentivized versus the non-incentivized gamble before. For the investigation of a framing and a payoff effect, a Wilcoxon signed-rank test for dependent samples was conducted. The test indicates significant differences (0.000, *p*-value) for the low payoff and farm income, which provides strong evidence for the existence of these effects and supports the observation of Menapace, Colson and Raffaelli (2015). Obviously, eliciting risk attitudes using experiments requires the consideration of context and payoff scale, independently of the type of lottery used.

Prior investigations further suggest the existence of a stable, underlying risk trait (Dohmen *et al.* 2011; Reynaud and Couture, 2012), but the generalizability of results obtained by different elicitation techniques still remains questionable. Recently, Vieider *et al*. (2014) and Meraner and Finger (2017) find incentivized lottery tasks to be significantly correlated with stated risk aversion in general as well as in the context-framed statements. In contrast, Nielsen, Keil and Zeller (2013) find that HLLs show significant, yet only low correlations with a self-assessment, and even negative correlations with hypothetical questions concerning price and yield variations. For the analysis of method- and context-dependent relationships we apply Spearman rank correlations (Table 4).

Table 4. Spearman correlations for risk attitude measurement techniques.

n=119	General	Yield and Quality	Financing	Low payoff gamble	Farm income gamble
General	1.000				
Yield and Quality	0.139	1.000			
Financing	0.294**	-0.029	1.000		
Low payoff gamble	0.096	-0.181*	0.248**	1.000	
Farm income gamble	0.221*	-0.042	0.165	0.553**	1.000

Notes: * and ** indicate 5% and 1% significance levels, respectively.

Multiple significant positive correlations support the idea of a stable, underlying risk trait. Noticeably, the self-assessment in general is significantly positively correlated with the self-assessment in the context of finance and the experiment framed in terms of a farm income gamble. As anticipated also results from the experimental tasks show a significant positive correlation.

For the farm income framed experiment the results are in line with those of the literature, as self-assessments are found to be appropriate for predicting behavior in outcome-scaled lottery tasks (Dohmen *et al.* 2011; Hardeweg, Menkhoff and Waibel, 2013) but contrasts the findings of Menapace, Colson and Raffaelli, (2015), who directly compare self-assessed willingness to take risks with results of their low payoff and farm income framed gambles and find only weak correlations for the farm income framed and even negative correlations for the low payoff gamble (Menapace, Colson, and Raffaelli 2015). As we further observe a significant positive relationship for the self-assessment referring to financing and the low payoff gamble, the context framed self-assessment seems to provide a suitable approximation for a subject's risk preference and may be a suitable and simpler elicitation technique than experiments. Similarly to our observations, Reynaud and Couture (2012) find that hypothetical lotteries are related to the context of investments when compared to the results of a psychological questionnaire. In contrast, the context-dependent self-assessment related to yield and quality risk exhibits no significant correlation neither with the other self-assessments nor with the farm income framed experiment and even a significant negative correlation with the low payoff gamble.

3.3 Is elicited risk attitude consistent with observed behavior?

In order to assess the predictive capacity of the measures for observed behavior in our sample, we conduct regression analyses trying to explain the utilization of specific risk management instruments as indicators of risk aversion. As hail nets are an appropiate management option only for apple production in the south, we consider insurance participation for the complete sample, whereas the use of hail nets is analyzed only for apple growers in the south in a separate probit regression (Tables 5 and 7), where the dependent variable equals one, if an apple grower participates in a hail insurance or uses hail nets and zero otherwise. Independent variables included are those presented in Table 2, which are assumed to be directly related to risk management decisions. As the Mann-Whitney U test was significant for the low payoff gamble, we further include a dummy variable indicating whether the experiment was incentivized. The associated average marginal effects (AMEs) are presented in Tables 6 and 8.

Table 5. Probit estimates for insurance participation as dependent variable.

Insurance (dependent) (n = 119)	General	Yield and Quality	Financing	Low payoff gamble	Farm income gamble
Risk aversion	0.051	0.294***	-0.034	-0.124	0.094
	(0.079)	(0.082)	(0.058)	(0.152)	(0.148)
Age	0.003	-0.001	0.002	0.005	0.002
	(0.020)	(0.020)	(0.020)	(0.020)	(0.020)
Farming Experience	0.036	0.045*	0.038	0.035	0.037
	(0.025)	(0.027)	(0.026)	(0.025)	(0.025)
Professional Education	0.270*	0.316**	0.275*	0.288*	0.261*
	(0.146)	(0.160)	(0.148)	(0.148)	(0.147)
Apple producing area (hectare)	0.004	0.008	0.002	0.003	0.002
	(0.010)	(0.011)	(0.010)	(0.010)	(0.010)
Share of owned land (%)	0.418	0.816*	0.462	0.451	0.425
	(0.451)	(0.495)	(0.451)	(0.450)	(0.450)
Past hail damage	0.158*	0.153	0.172*	0.157*	0.162*
	(0.095)	(0.100)	(0.097)	(0.095)	(0.094)
Region (1 = north)	1.015***	1.035***	1.043***	1.029***	1.026***
	(0.274)	(0.283)	(0.276)	(0.275)	(0.273)
Incentivized	0.236	0.203	0.257	0.245	0.265
	(0.270)	(0.284)	(0.267)	(0.269)	(0.266)
Constant	3.454***	5.888***	3.045***	3.437***	3.185***
	(1.079)	(1.420)	(1.095)	(1.058)	(1.038)
R^2	0.273	0.413	0.272	0.275	0.273
Log-likelihood	-68.833	-60.406	-68.866	-68.699	-68.836

Notes: *, ** and *** indicate p<10%, p<5% and p<1%, respectively. Self-assessments are recoded to reflect increasing risk aversion with increasing value (1: fully prepared to take risk, 10: extremely risk averse).

Table 6. AMEs for insurance participation as dependent variable.

Insurance (dependent) (n = 119)	General	Yield and Quality	Financing	Low payoff gamble	Farm income gamble
Risk aversion	0.020	0.117***	-0.014	-0.050	0.037
	(0.032)	(0.030)	(0.023)	(0.060)	(0.058)
Age	0.001	-0.001	0.001	0.002	0.001
	(0.008)	(0.008)	(0.008)	(0.008)	(0.008)
Farming Experience	0.014	0.018	0.015	0.014	0.015
	(0.010)	(0.011)	(0.010)	(0.010)	(0.010)
Professional Education	0.108*	0.126*	0.110*	0.115*	0.104*
	(0.060)	(0.067)	(0.061)	(0.061)	(0.060)
Apple producing area (hectare)	0.001	0.003	0.001	0.001	0.001
	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)
Share of owned land (%)	0.167	0.325*	0.184	0.180	0.170
	(0.180)	(0.196)	(0.181)	(0.180)	(0.180)
Past hail damage	0.063*	0.061	0.069*	0.063*	0.065*
	(0.037)	(0.040)	(0.038)	(0.038)	(0.037)
Region (1 = north)	0.388***	0.395***	0.398***	0.393***	0.392***
	(0.096)	(0.098)	(0.095)	(0.095)	(0.095)
Incentivized	0.094	0.081	0.102	0.097	0.105
	(0.108)	(0.113)	(0.106)	(0.107)	(0.106)
Constant	-	-	-	-	-
R^2	0.273	0.413	0.272	0.275	0.273
Log-likelihood	-68.833	-60.406	-68.866	-68.699	-68.836

Notes: *, ** and *** indicate p<10%, p<5% and p<1%, respectively. Self-assessments are recoded to reflect increasing risk aversion with increasing value (1: fully prepared to take risk, 10: extremely risk averse).

Table 7. Probit estimates for hail nets as dependent variable.

Hail nets (dependent) (n = 58)	General	Yield and Quality	Financing	Low payoff gamble	Farm income gamble
Risk aversion	0.068 (0.124)	0.328** (0.129)	-0.018 (0.107)	-0.291 (0.268)	-0.545* (0.283)
Age	-0.012 (0.031)	-0.019 (0.033)	-0.010 (0.030)	0.004 (0.033)	0.017 (0.035)
Farming Experience	-0.040 (0.044)	-0.020 (0.045)	-0.039 (0.043)	-0.052 (0.046)	-0.068 (0.051)
Professional Education	0.261 (0.207)	0.136 (0.221)	0.246 (0.204)	0.289 (0.201)	0.311 (0.205)
Apple producing area (hectare)	0.065** (0.033)	0.048 (0.032)	0.060* (0.033)	0.065** (0.032)	0.064** (0.032)
Share of owned land (%)	1.300 (1.010)	1.636 (1.109)	1.224 (1.001)	1.575 (1.038)	1.533 (1.031)
Past hail damage	0.227 (0.172)	0.207 (0.175)	0.234 (0.174)	0.202 (0.169)	0.265 (0.176)
Incentivized	-0.153 (0.464)	0.051 (0.518)	-0.129 (0.464)	-0.169 (0.464)	0.145 (0.504)
Constant	0.801 (1.800)	2.534 (2.025)	0.345 (2.007)	1.285 (1.845)	1.573 (1.819)
R^2	0.278	0.451	0.272	0.296	0.358
Log-likelihood	-25.025	-20.695	-25.165	-24.6061	-23.109

Notes: *, ** and *** indicate p<10%, p<5% and p<1%, respectively. Self-assessments are recoded to reflect increasing risk aversion with increasing value (1: fully prepared to take risk, 10: extremely risk averse).

Table 8. AMEs estimates for hail nets as dependent variable.

Hail nets (dependent) (n = 58)	General	Yield and Quality	Financing	Low payoff gamble	Farm income gamble
Risk aversion	0.015	0.068***	-0.004	-0.063	-0.110*
	(0.027)	(0.031)	(0.024)	(0.061)	(0.061)
Age	-0.003	-0.004	-0.002	0.001	0.003
	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)
Farming Experience	-0.009	-0.004	-0.009	-0.011	-0.014
	(0.010)	(0.010)	(0.010)	(0.010)	(0.010)
Professional Education	0.057	0.028	0.054	0.063	0.063
	(0.047)	(0.048)	(0.046)	(0.045)	(0.043)
Apple producing area (hectare)	0.014*	0.010	0.013*	0.014**	0.013*
	(0.006)	(0.006)	(0.006)	(0.006)	(0.005)
Share of owned land (%)	0.284	0.341	0.271	0.343	0.309
	(0.203)	(0.219)	(0.206)	(0.210)	(0.193)
Past hail damage	0.049	0.043	0.052	0.044	0.053
	(0.037)	(0.038)	(0.038)	(0.036)	(0.036)
Incentivized	-0.034	0.011	-0.029	-0.037	0.029
	(0.104)	(0.109)	(0.107)	(0.105)	(0.102)
Constant	-	-	-	-	-
R^2	0.278	0.451	0.272	0.296	0.358
Log-likelihood	-25.025	-20.695	-25.165	-24.6061	-23.109

Notes: *, ** and *** indicate p<10%, p<5% and p<1%, respectively. Self-assessments are recoded to reflect increasing risk aversion with increasing value (1: fully prepared to take risk, 10: extremely risk averse).

The results of both probit regressions show that, except for the self-assessment for yield and quality risks, none of the measures of risk attitude provides a suitable indicator for farmers' observed behavior. For the latter, the positive coefficients and highly significant *p*-values (0.000 for insurance and 0.011 for hail nets as dependent variable) are noteworthy. According to the estimated marginal effects, the context-specific self-assessment for yield and quality risks is associated with a 11.7 per cent increase in probability regarding insurance participation and a rise of 6.8 per cent for using hail nets given a one-point increase on the Likert scale. Contrary to our expectations, the farm income gamble is no significant indicator for the observed behavior in the context of insurance participation (0.527, *p*-value), but shows a significant negative sign (0.054, *p*-value) when considering hail nets as dependent variable. In terms of marginal effects, a one-point increase of the relative risk aversion coefficient reduces the probability of using a hail net by 11%, which implies that risk averse apple growers tend to forego hail nets. Recollecting the idea of the farm income gamble, this result becomes more comprehensible. Total farm income is decreased by high investment cost and thus it is reasonable to assume that apple growers who are risk averse in the domain of farm income are less likely to install hail nets as these are associated with high costs.

Furthermore, the self-assessment in general and in the context of finance as well as the low payoff lottery provide no explanatory power in both regressions. For insurance participation *p*-values are far from significant (self-assessments: 0.517 for the general domain, 0.555 for finance; low payoff gamble: 0.413), which is also observable for the probit regressions with hail nets as dependent variable (self-assessments: 0.586 for the general domain, 0.869 for finance; low payoff gamble: 0.277). Similarly, Hudson, Coble and Lusk (2005) find only an open-ended question in the context of price to be significantly related to the probability of purchasing additional crop insurance, whereas an applied lottery task and seven self-assessments, addressing the general context as well as the domains of business and finance, reveal nothing significant (Hudson, Coble, and Lusk 2005). For the low payoff HLLs, an explanation is provided by Hellerstein, Higgins and Horowitz (2013) who conclude that lotteries are not suitable for eliciting deep-seated risk attitudes, due to the influences from background risk farmers are exposed to, and thus are inadequate to predict behavior in reality (Hellerstein, Higgins, and Horowitz 2013). Nevertheless, Menapace, Colson and Raffaelli (2015) show that context-framed EGLs can predict real behavior adequately, but as described for insurance participation, our expectation that context-framed HLLs might control background risk and provide a higher predictive power than a standard HLL with low payoffs, failed to appear. The correlation analysis of self-assessed and experimentally derived risk attitudes might give a hint on these obscurities. As mentioned above, the low payoff experiment shows a significant negative relationship, with the self-assessment addressing yield and quality risks, whereas a positive coefficient is obtained in the context of finance. Similarly, the farm income gamble is only positively correlated with the general self-assessment but not with the one addressing yield and quality risks. Thus it might be the domain-specific character of the technique in combination with its ability to account for background risks, which makes it successful in predicting real-world behavior. It is reasonable to assume that German farmers see insurance participation (as indemnities are based on ascertainment of yield and quality reductions) and the installation of hail nets in the domain of yield and quality and not as financial risk-protection tools. Especially the significant negative estimate for the farm income gamble in the probit regression concerning the use of hail nets suggest that financial risks have to be distinguished from yield and quality risks.

Regarding the socio-demographic and business specific variables, the findings are similar to those of the literature. Education is significant in all regressions conducted with insurance participation as dependent variable, whereas age and farming experience are non-significant. Only for the regression with self-assessment of yield and quality risks included, farming experience as well as the share of owned land are significant. Furthermore, past experiences with damages due to hail, is a significant predictor for insurance participation in nearly all of the regressions. In this context, the results reveal that the self-assessment of yield and quality risks may include information of past hail events, as the associated value is not significant in this regression. Furthermore, insurance is the only suitable risk management instrument for apple growers in the north to protect themselves against hail damage, whereas famers in the south may also install hail nets. With this in mind, the positive significant value for the region dummy is convincing. Regarding probit regressions, which consider hail net use as dependent variable, apple producing area is the only significant parameter in all regressions except for the one that contains the self-assessment for yield and quality risks. This information stands in close relation with the idea of cost reduction and the negative significant value of the farm income gamble. As catastrophic hail events on large production areas are associated with high monetary losses, insurances would be associated with an exorbitant insurance premium. Bocquého, Jacquet and Reynaud (2013) give one explanation for not insuring in spite of risk aversion. Under prospect theoretical aspects, the reference point, where persons who are risk averse in the domain of gains might switch to risk seeking behavior for losses, can lead persons not to participate in insurances, since the insurance premium can be seen as small but certain loss (Bocquého, Jacquet, and Reynaud 2013). Even if apple growers who exhibit risk aversion in the farm income gamble are less likely to install cost-intensive hail nets, not serving as disinvestments, the dimension of the production area is an additional factor, which explains the endorsement of hail nets installation and the rejection of insurance participation.

4 Concluding remarks

Framing and payoff effects cause deviating results in scale-based self-assessments and in experimental approaches. Future work on risk elicitation should thus consider these parameters thoroughly. In order to gain more insights into the underlying relationships, experimental lottery tasks with varying frames and payoffs seem advisable. Despite the difficulties arising from framing and payoff effects, the consideration of these effects provides a promising avenue for an improvement of risk elicitation techniques and precise frameworks could lead to more reliable results. The results of our study provide good reasons to assume that apple growers in developed countries are less risk averse than anticipated. Furthermore, our regression analysis shows that only one of five applied techniques obtains reliable predictors of observed behavior for risk management strategies in apple production. Besides the effect of background risk, it seems that experiments based on Holt and Laury fail to clearly capture the domain of yield and quality risk, but are rather related to the context of finance. Further research is needed to investigate whether deviations between observed behavior and elicited risk attitudes can efficiently be controlled under the consideration of framing and payoff effects as well as background risks.

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Appendix

Lottery with low payoffs

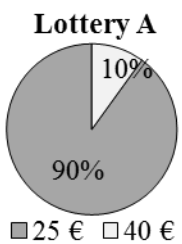
The following method focuses on your investment-behavior and is conducted in order to assess your risk preferences. The data analyses will reveal if apple growers likes to face risks or try to avoid them.

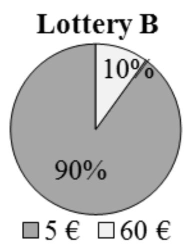
Supplement for the non-incentivized task:

This is a hypothetical lottery and we kindly ask you to empathize with these decisions.

The task consists of ten decisions. For every decision-round we will ask you to choose one of the two given lotteries (lottery A or lottery B).

Here is an example - which option do you prefer?



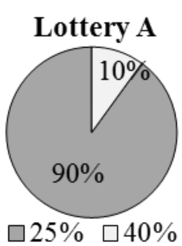


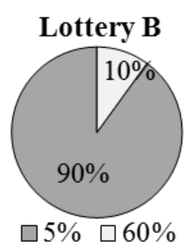
If you choose lottery A, you would have a 90% chance to win 25€ and a 10% chance to win 40€.

Lottery framed as farm income gamble

As before, you will be asked to choose one of two given lotteries which differ in the associated consequences. The first lottery referred to low payoffs, whereas the upcoming one represents the percentage of average farm income.

Which option would you prefer?





If you choose lottery A, you would have a 90% chance to achieve an income, which exceeds the average annual farm income by 25% for the upcoming harvest and a 10% chance to achieve an income which is 40% higher than the average.

III Efficient farming options for German apple growers under risk - a stochastic dominance approach

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Abstract

For a sustainable economic performance of apple production, the determination of efficient farming options considering production risk is crucial. Relying on a permanent crop, apple producers are less flexible to react upon disturbances. Based on data of 134 apple producers operating in the two main production areas in Germany, we compare and determine efficient production options. Furthermore, appropriate RMIs (risk management instruments) are identified using stochastic dominance criteria. In addition, we use SERF (Stochastic Efficiency with Respect to a Function) to evaluate farming options for defined ranges of relative risk aversion. The results indicate that Red Prince is the most efficient variety in the north and subsidized hail insurance with frost irrigation is superior to frost irrigation as single RMI. In the south Braeburn should be chosen by rational decision makers, but the tested insurance solutions are not as efficient as the common practice of producing apple under hail nets.

Keywords: crop insurance, risk perception, risk management, historical data approach

1 Introduction

Apple production is a challenging business. Aspects of pests and diseases, changing market demands as well as weather conditions and volatile prices are predominant sources of risk, which have to be considered during the planning phase of an apple orchard (Menapace *et al.* 2013; Catalá *et al.* 2013). Due to the high complexity, this article focuses on the latter two issues of farm planning for apple production, as they represent two of the key risks (Ahmed and Serra 2015).

Farmer organizations have repeatedly pleaded for state subsidization of multi-peril insurance for fruit production. The debate was revived most recently by the occurrence of unusually strong late frosts in April 2017 inflicting severe damage on fruit and wine production especially in Southern Germany. The debate is often based on incidental information and – even when referring to risk – mostly ignores the nature of risk, which may be due to the complexity of the phenomenon and lacking data. This paper contributes to closing this gap for apple production. Therefore, farmers' risk perception is compiled and distributions of the net present value of different risk management strategies for apple production are calculated. The results indicate that a multi-peril insurance even with subsidies is dominated by other combinations of RMI. This explains the relatively low adoption of frost insurance in Southern Germany and provides evidence in favor of market-based solutions without government interference.

For German apple growers, available risk management strategies to cope with weather-related risks are hail nets and frost irrigation. In the north of Germany subsidies for these risk management strategies are not available, whereas in the south hail nets are subsidized up to 50% by producer organizations (Dirksmeyer *et al.* 2014, p. 59-60). In addition, hail insurance that protects against revenue loss is available in both regions. For hail insurance, no governmental subsidy schemes exist (Bielza Diaz-Caneja *et al.* 2009). Even if producer organizations subsidize insurance policies, farmers, especially in the south of Germany, often decide not to participate in hail insurance, as high premium rates are common.

Political programs to support apple growers in reducing risk require information on farmers' risk behavior. According to the subjective expected utility framework, risk perception besides risk preference, is the main factor determining risk behavior. The former is the probability an individual associates with a particular uncertain situation and the likelihood to be susceptible to a specific event (e.g. Pennings *et al.* 2002). Knowledge of apple producers' risk perceptions provides essential information for the development of political programs (Menapace *et al.* 2012).

Deterministic crop budgets for an economic assessment of apple production systems in Germany are available (KTBL, 2010). However, no information is available on which risk management strategies are the most promising ones and whether new strategies, for instance combined hail-frost insurances, could provide appropriate instruments for apple growers in Germany. This article aims to evaluate combinations of different production systems (i.e. choice of variety and planting density) and RMIs according to their economic performance under different levels of apple growers' relative risk aversion. The insights are also of political relevance as calculations of agricultural policy measures often rely only on cost-benefit analyses, based on weighted average values in terms of money and do not consider the effect of risk aversion. As a result, inappropriate conclusions are drawn when designing risk mitigation programs (Kaufman, 2014). For an in-depth risk analysis, a survey assessing perceived risk of German apple farmers in the two most important production regions (Altes Land, Lower Saxony and Lake Constance) has been conducted. After combining the data obtained from this survey with historical information stochastic dominance relations were applied in order to determine appropriate farming strategies.

2 Literature Review

Up to now only a very limited number of studies deal with apple growers' behavior towards risk in industrialized countries. Menapace *et al.* (2014) analyzed risk perception of apple farmers in Italy in the context of climate change hazards at province level. For a long-term perspective of twenty years, respondents believing in climate change stated significantly higher probabilities for suffering from weather and disease related effects, than non-believers, whereas perceptions for the short-term view did not differ significantly (Menapace *et al.* 2014). Results of their survey further indicate a strong effect of different heuristics in farmers' decision making processes. These are mental simplifications which reduce the complexity within decision-making processes. A significant effect was observed for availability heuristics (use of experience from the past for future decisions), representativeness heuristics (alignment of unfamiliar events with familiar ones) and biased assimilation (preexisting attitudes that lead persons to acquire indications which support their opinion and to reject indications against it) (Menapace *et al.* 2012).

For conventional and organic apple production in the Pacific Northwest of the U.S. Chen *et al.* (2007) compare the risk reduction properties of a multi-peril crop insurance covering yield shortfalls to an income-based insurance, focusing on deviations of income as a product of yield and prices. Their analysis is based on historical price and yield data. In the context of government subsidies, they find, that an income-based insurance would be more cost efficient than multi-peril crop insurance. However, as the associated certainty equivalents reveal, the income-based insurance provides a lower welfare, with only one variety-dependent exception (Chen *et al.* 2007).

The use of historical data as the single source for probability estimates is, however, not advisable for risk analysis that addresses an uncertain future. The predictions may be insufficient, because underlying circumstances might change over time. Therefore, an appropriate risk analysis should include subjective probability estimates as well (Hardaker *et al.* 2004, p. 62-63; Lien *et al.* 2011). The historical data approach (Hardaker *et al.* 2004, p. 80-82) allows one to combine historical data and the farmers' subjective probability estimates to reproduce the correlation structure and therefore to account for stochastic dependencies (Hardaker *et al.* 2004, p. 168-169). Lien and Hardaker (2001) use this technique to evaluate the appropriateness of different subsidy schemes for the Norwegian agricultural sector with a utility-efficient programming model and Lien *et al.* (2011) apply it for the calculation of gross margins of a typical Norwegian lowland farm.

For capturing risk, it is recommended to work with probability distributions (Hardaker, 2000; Lien, 2003). Clancy *et al.* (2012) use a stochastic budgeting model in their work. In comparison to deterministic models, this approach is more appropriate to consider various uncertainties, as for example volatile prices, yields, costs and weather conditions, all factors, which are simultaneously affecting revenues and profits in farmers' reality. For all variables of interest, stochastic budgeting assigns probabilities to values, resulting in probability distributions (Lien *et al.* 2007a; Clancy *et al.* 2012).

Ranking farming options according to their efficiency under consideration of the associated cumulative density functions (CDF) and underlying farmers' risk attitudes may be achieved by applying stochastic dominance criteria (SD), stochastic dominance with respect to a function (SDRF) or stochastic efficiency with respect to a function (SERF). Presuming a positive marginal utility, a ranking based on first degree stochastic dominance (FSD) is appropriate, if CDFs do not cross. If the condition $F_a(x) \leq F_b(x)$ for all x with at least one strict inequality is met, farming option a dominates option b independently of the underlying risk attitude. However, if an intersection exists, second order SD (SSD) needs to be applied. It requires risk aversion for all values of *x*, which means that the associated utility function is positive with a decreasing slope. Under SSD option *a* dominates option *b* if $\int_{-\infty}^{x*} F_a(x)dx \leq \int_{-\infty}^{x*} F_b(x)dx$ for all x* with at least one strict inequality (Smidts, 1990, p. 125-126; Hardaker *et al.* 2004, p. 147-150). Similar to SSD, where limits regarding risk attitude (r) are set as $0 < r < \infty$, SDRF defines also positive, but more restrictive boundaries for risk attitude ($r_1 < r < r_2$), which allows a stricter discrimination (Hardaker *et al.* 2004, p. 153). Harper *et al.* (2013) apply SDRF for an evaluation of apple varieties, namely Crimson Gala, Ginger Gold and Fuji, as well as training systems with respect to their associated net returns for an eight year harvest period. Data for the analysis were obtained during a ten-year field experiment in Pennsylvania (USA). They observe that higher net returns are afflicted with higher risk. SDRF analysis further indicates that growers, independent of their risk attitude, prefer Fuji as cultivar. (Harper *et al.* 2013).

For SERF-analysis values of a utility function are converted by the inverse utility function into certainty equivalents (CE) for a given range of risk aversion coefficients. CEs have the advantage that they can be expressed in monetary terms. The CE is the sure payment which provides the same utility as a risky prospect (Hardaker *et al.* 2004, p. 153-155; Lien *et al.* 2007a). Similar to SDRF, SERF relies on a range of risk aversion coefficients, but with the additional assumption that parameters of risk aversion remain constant for varying levels of payoffs (Hardaker and Lien 2010). Recently, Schenk *et al.* (2014) applied SD as well as SERF for assessing Australian farmers' decision making concerning crop-choice, focusing on five arable crops and pasture, given uncertain amounts of water supply. Similarly, Clancy *et al.* (2012) considered the previously mentioned methods for their evaluation of the economic efficency regarding biomass crops in Ireland.

Up to now investment decisions for apple growers in Germany have not been analyzed considering the main sources of risk, different risk management tools and alternative risk protection strategies. The objective of this study is therefore to determine the most efficient farming options by applying stochastic dominance criteria and SERF to data of net present values for investments in apple orchards.

3 Data and Methods

To obtain a stochastic ranking of farming options, the deterministic budget is extended in order to calculate cumulative distribution functions (CDFs) of the net present value (NPV) for apple orchard investments. The NPV is calculated over 16 years of full bearing for a combination of one hectare of a certain variety and the respective risk management strategies by summing up the discounted net cash flows simulated for each year. The juvenile phase of the orchard in the initial three years after planting is considered as a deterministic component of the NPV. For risk ranking, stochastic dominance criteria are subsequently applied to the CDFs.

3.1 Survey Sample

Apple production on owner-operated farms in Germany is concentrated in two regions, the Altes Land, located in the north at the mouth of the river Elbe, and the Lake Constance area in the south near the Alps. As the distance between these areas amounts to 900 kilometers, climatic conditions are different. In the north especially late frosts lead to higher yield and quality reductions, whereas in the south hail events are more frequent and pose a major risk to fruit quality.

During the winter season 2013/2014, the apple growers were first contacted by local extension and research stations. A number of 500 growers in each region received an invitation letter or a call for participation in the newsletter of producer organizations. Starting with 16 volunteers in the north and 3 in the south, a pyramid scheme was used to acquire further participants. In the end, data of 66 farmers from the north and 68 from the south were collected through two-hour face-to-face interviews. Besides information on farmers' risk perception, details on their risk attitude were obtained.

3.2 Elicitation of Subjective Probabilities

For the elicitation of probabilities, the estimation of probabilities based on the experience technique was applied, as it only requires three values and in consequence, represents one of the simplest question frameworks (Hoag, 2010, p. 212-213). However, only estimations of yield under normal conditions were successfully elicited with this technique, resulting in a Program Evaluation and Review Technique (PERT) Distribution. In contrast, when focusing on losses and quality reductions due to weather related risks as well as prices, the pretest revealed, that farmers do not feel comfortable to assign a minimum, maximum and modal value. As applied in the work of Menapace *et al.* (2013), the fixed value method was used in this study in order to assess distributions. To achieve a reduction in bias, farmers were asked to recall the frequency of occurrence for different events in the past 10 years, before they stated their estimates for the upcoming decade in both frameworks. A time interval of ten years was set, since longer time intervals might result in a lower willingness to participate and a decline in attention during the interview. After recapitulation of the past, farmers were asked to indicate their expectations for the upcoming production years by allocating ten years to given intervals of losses and prices, respectively. These absolute frequencies were converted into relative ones and the midpoints of the given intervals were used for further calculations. In order to evaluate the preventive effect of RMIs, apple growers were asked to give their estimates for all circumstances, i.e. under absence and existence of the RMIs. An example is given in Figure 1.

Please state the number of years in which yield losses occurred due to hail by focusing on the last ten years: ____ No. of years

Your expectation for the next ten years: How often will hail lead to the following losses (%). Please allocate ten years to the given intervals:

Loss due to hail (%)	Absolute (estimation)	Relative (calculated)
0%	7	0.7
1-4%		
5-9%		
10-19%		
20-29%		
30-39%	2	0.2
40-49%		
50-59%		
60-69%		
70-79%	1	0.1
80-89%		
90-100%		

If your expectation is based on the existence of hail nets, which losses would you expect under the absence of hail nets?

Loss due to hail (%)	Absolute (estimation)	Relative (calculated)
0%	5	0.5
1-4%		
5-9%		
10-19%		
20-29%		
30-39%		
40-49%		
50-59%		
60-69%		
70-79%		
80-89%		
90-100%	5	0.5

Figure 1. Application of the fixed value method related to the survey design.

3.3 Parameter setting for SERF

SERF analysis requires the choice of a utility function, which is not a trivial task. With focus on terminal wealth constant relative risk aversion (CRRA) is recommended as it is unaffected by different levels of wealth. In contrast, constant absolute risk aversion (CARA) is more convincing for transitory income, which is relatively small in relation to wealth (e.g. Hardaker and Lien, 2010). As apple farms in Germany are less diversified and wealth is predominantly determined through a long term success of the orchard, CRRA will be used in this study, represented by the following functional form of utility (Eq. (1)).

$$(1)\ U = \frac{1}{(1-r_{r(W_T)})} W_T^{(1-r_{r(W_T)})} \quad, W_T > 0$$

Where

W_T is total wealth

$r_{r(W_T)}$ is relative risk aversion related to total wealth

CRRA implies constant relative risk aversion and in consequence decreasing absolute risk aversion as the absolute amount of money for risk-investments increases with increasing wealth, whereas the relative proportion remains constant.

As described in Lien *et al.* (2007b) the total wealth is assumed to be $W_T = W_0 + W_s$. Where W_0 is the non-stochastic wealth, equaling 45,000 € per hectare, and W_s is the stochastic wealth of apple production.

Even if the simulation is based on a one hectare level, which is relatively small compared to whole-farm wealth, annual gain from one hectare is seen as a permanent source of income. Upscaling of the area planted leads to a large portion of terminal wealth and thus, the relative risk aversion coefficient is assumed to be constant (cf. Hardaker *et al.* 2004, p. 112).

The range of risk aversion coefficients of 0 to 3.00 is set according to the results of the risk attitude analysis. Risk attitude was elicited with a hypothetical, farm profit-framed Holt and Laury lottery (HLL), originally pioneered by Holt and Laury (2002). About half of apple growers exhibited risk aversion, characterized by risk aversion coefficients above zero (Table 1). In this paper we follow a normative approach in order to give advice how risk averse farmers should behave under uncertainty. Thus, only data of risk averse farmers are provided. In this context, 38 percent of risk averse apple growers can be described as nearly risk neutral with risk aversion coefficients close to zero, whereas the others indicated stronger tendencies to risk averse behavior.

Table 1. Elicited relative risk aversion coefficients.

Risk aversion coefficient	Absolute Frequency	Relative Frequency (%)	Level of risk attitude
0.155	25	38%	Risk aversion level 1
0.470	15	23%	Risk aversion level 2
0.815	14	22%	Risk aversion level 3
1.265	3	5%	Risk aversion level 4
2.000	8	12%	Risk aversion level 5
n	65	100%	

3.4 Description of the model and calculation of key variables

The risk model was developed in MS EXCEL (Microsoft Corporation, Redmond, WA, USA). Regarding the key variables of the model, parameters, which are substantial risky determinants of revenue, were set as stochastic ones (cf. Clancy *et al.* 2012). As reported by Bravin *et al.* (2009), yield and quality have an important impact on farm profit, whereas production costs are less important. Therefore, it was decided to treat production costs (except for those proportional to yield) as deterministic variables, which can be taken from the literature (KTBL, 2010), whereas yield and quality under non-hazardous conditions of production, as well as prices and weather related impacts, i.e. frosts, hail and sunburn, are considered as stochastic variables. In addition, the event of fire blight (*Erwinia amylovora*), a bacterial infection, is included as a stochastic variable in the simulation as a rare but severe event. After combining historical yield and price data with subjective probabilities, the Palisade add-in @Risk for Latin hypercube simulation (@Risk 6.0 Industrial Edition, Palisade Corporation, Ithaca, NY, USA), an advancement of the Monte Carlo simulation, is used to generate probability distributions for stochastic variables of interest. For the simulation, 5000 iterations were performed. Figure 2 shows the program flow of the simulation model, which is described in detail, afterwards.

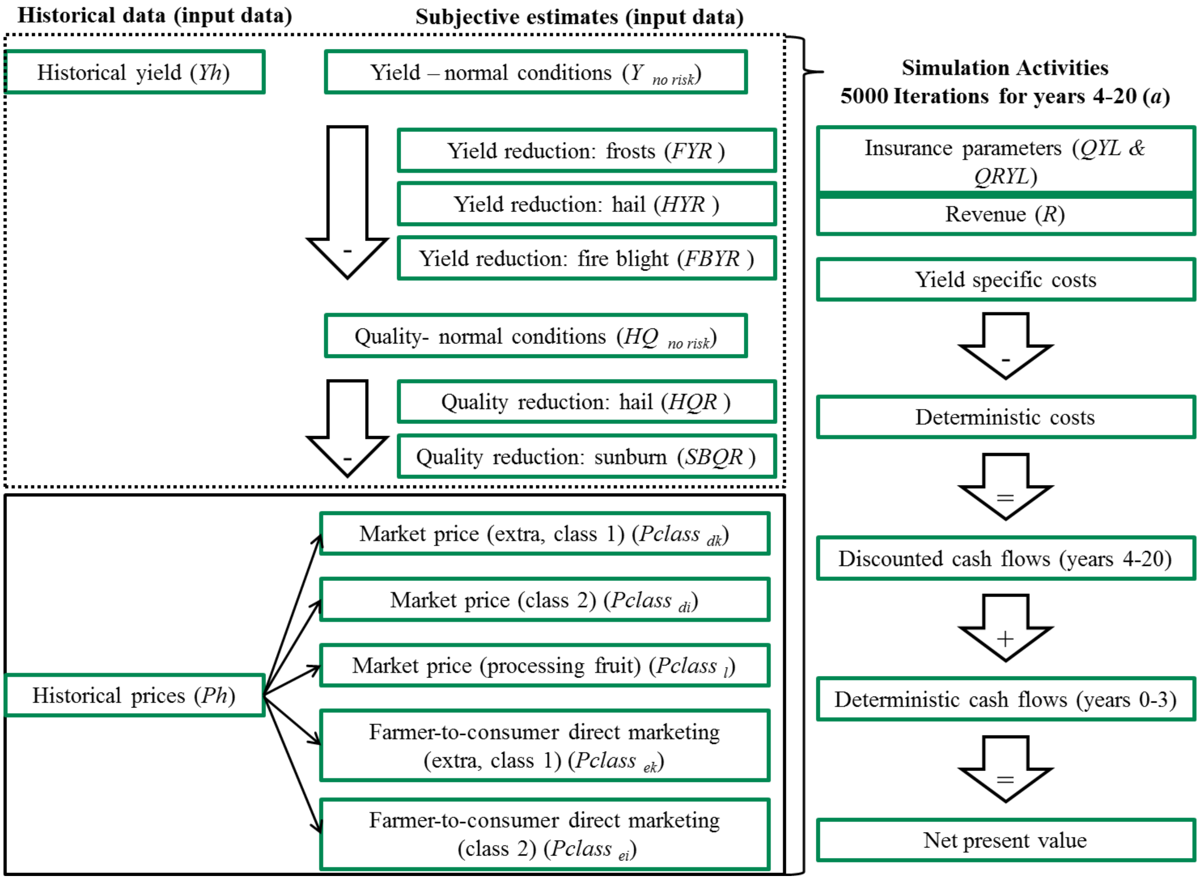

Figure 2. Schematic overview of the model's input data and stochastic calculations.

The historical data approach was used for implementing stochastic dependencies between subjective risk perceptions of yield and price variables (Hardaker *et al.* 2004, p. 80-82). As the focus is on region-specific hazards rather than single farm simulations, the means of the subjective estimates were determined. Price data for years 1993-1996 were obtained from ZMP (1998, p. 77-79), for 1997-2001 from ZMP (2002, p. 68-69), for 2002-2006 from ZMP (2006, p. 25-27), and for 2007-2012 from AMI (2013, p. 74-76) and adjusted for inflation, using the consumer price index with 2010 as the base year, provided by the Federal Statistical Office (2014). Yield data were taken from the Landesbetrieb für Statistik und Kommunikationstechnologie Niedersachsen (2008, 2012).

Eq. 2 provides an example for the combination of historical prices with subjective estimates.

$$(2)\ P_{vy} = E[Ps_v] + \{\left[Ph_{vy} - E[Ph_v]\right] / \sigma[Ph_v]\} * \sigma[Ps_v]$$

Where

$E[Ps_v]$ is the expected value E of the subjective price estimation P_S of the variety v

Ph_{vy} is the historical price of variety v in year y

$E[Ph_v]$ is the expected value of the historical price P_h of the variety v

$\sigma[Ph_v]$ is the standard deviation of the historical price P_h of the variety v

$\sigma[Ps_v]$ is the standard deviation of the subjective price estimation P_S of the variety v

The following calculations of yield and qualities under the consideration of risky events are based on subjective estimates. Risk-adjusted yield ($Y_{after\ risk}$) and the percentage of high quality apples *(HQ)* of the actual year a are calculated as follows (Eq. (3, 4)).

$$(3)\ Y_{a\ after\ risk} = Y_{a\ no\ risk} * (1 - FYR_a) * (1 - HYR_a) * (1 - FBYR_a)$$

Where frosts (FYR), hail *(HYR)* and fire blight *(FBYR)* may lead to yield reductions.

$$(4)\ HQ_{a\ after\ risk} = HQ_{a\ no\ risk} * (1 - HQR_a) * (1 - SBQR_a)$$

Where HQR indicates quality reductions due to hail and $SBQR$ due to sunburn.

For the yield and quality reductions due to severe weather events, two additional assumptions were made. First, events of hail may lead to a considerable decrease in revenue if quality classes extra, one and two become apples for processing purposes. However, it was assumed that hail has a similar impact on both quality classes and thus only apples for processing purposes were distinguished from higher quality apples (*HQ*). This simplification is justified by price adjustments. If adverse weather events lead to widespread damages, the price level of class two commonly equals those of classes extra and one. Thus, it was decided not to differentiate between hail damage of classes one and two separately, but instead reduce the percentage of both quality classes equally. As a consequence, the model realizes revenue reduction and accounts for higher market prices of class two simultaneously. Second, in reality frosts affect yield and quality of apples. Nevertheless, the pretest revealed that apple growers are more concerned about yield losses due to frosts. In consequence, questions addressing quality reductions due to frosts were not answered and therefore frost-related quality reductions are not considered in the model.

Insurance indemnity payments are generally related to quantitative and qualitative losses. The actual yield after spring frost provides the basis for the calculation of quantitative yield loss (QYL) due to hail (Eq. (5)). In addition, quality-related yield loss ($QRYL$) is calculated after subtraction of frost and hail related yield loss (Eq. (6)).

$$(5)\ QYL_a = Y_a\ (1 - FYR_a) * HYR_a$$

$$(6)\ QRYL_a = Y_a\ (1 - FYR_a) * (1 - HYR_a) * HQ_a * HQR_a * Q_{Quota}$$

Where $QRYL$ indicates the amount of high quality apple HQ_a is the share that becomes processing fruit after hail (HQR_a). This value is further multiplied with Q_{Quota}, which is determined as a loss ratio of 70% and represents a common rating, applied by an insurance company in Germany (Vereinigte Hagel, 2017).

The sum of quantitative and qualitative losses due to hail, divided by expected yield after excluding the effect of losses from spring frosts, result in the total loss ratio from hail ($TLRH$). As the model is confined to the years of full harvest, the expected yield is calculated as a mean of production years four to twenty (Eq. (7)).

$$(7)\ TLRH_a = \left[(QYL_a + QRYL_a) * \left[\frac{1}{16} * (\textstyle\sum_{a=4}^{20} Y_a\ *\ (1 - FYR_a))\right]^{-1}\right] * 100$$

The total sum insured equals expected revenues as a mean of the production years four to twenty, considering the higher quality classes extra, one and two and their respective market prices. If the decision maker participates in frost insurance, indemnity payments for covering frost damages are subtracted. Multiplying the sum insured with the $TLRH$ leads to the total amount of economic loss. A percentage of this economic loss represents deductibles, which are paid by the apple grower. For deductibles conventional calculations considering the $TLRH$ of a single year were used (Vereinigte Hagel, 2017). After deductibles have been subtracted, the value of the economic loss equals the indemnity payment.

For the calculation of the hail insurance premium, the basic insurance premium (IP) equals 10% of the sum insured in the north and 21% in the south. As the insurance premium has to be adjusted in order to consider the extent and the variation of overall damages, it is further multiplied with a correction factor. For the first nine years of full harvest, the factor equals 100% and for the following years it is determined on the basis of the average $TLRH$ observed during the ten previous years.

The calculation of parameters regarding frost insurance follows the same procedure as explained for hail. The sum insured equals the calculated sum insured for hail. Only information of yield losses due to frosts (Eq. (8)) and the total loss ratio of frosts ($TLRF$) (Eq. (9)) are required for the calculation of the insurance premium and indemnity payments.

(8) $QYF = Y_a * FYR_a$

(9) $TLRF_a = [QYF_a * (\sum_{a=4}^{20} Y_a * 16^{-1})^{-1}] * 100$

In line with existing frost insurance schemes deductibles are not calculated. Furthermore, information on quality reduction is not available and therefore not considered in this study. For frost insurance 7% and 2% represent the basic insurance premium levels for the north and south, respectively. As for hail, the premium is multiplied with an adjustment factor, which is set at 100% for the first nine years and relies on the average $TLRF$ of the previous ten years, afterwards. Finally, the amount of annual indemnity-payments is obtained as $TLRF$ is multiplied with the sum insured.

Even if frost insurance as RMI has not been established for apple production in Germany, it is already available as a RMI in neighboring countries. Thus, it is suggested as an alternative to frost irrigation in the north and as a supplement in the south.

Revenues are calculated as shown in Eq. (10).

(10) $R_a = \sum_{c=d}^{e} \sum_{j=k}^{i} [(Y_{a\,after\,risk} * HQ_{a\,after\,risk}) * (1 - S_a) * Qclass_{ja} * Pclass_{cja}] + [Y_{a\,after\,risk} * (1 - HQ_{a\,after\,risk})] * Pclass_{la} + \sum_{c=d}^{e} \sum_{j=k}^{i} (Y_{(a-1)\,after\,risk} * HQ_{(a-1)\,after\,risk}) * S_{(a-1)} * Qclass_{j(a-1)} * (Pclass_{cja} * f_{cj})$

R indicates revenue, *S* the amount of apples stored and $Qclass_j$ the percentages of the classes extra and one (*k*) as well as class two (*i*) of higher quality apple. $Pclass_{cj}$ are the corresponding prices for qualities, referring to the two distribution channels *c*. Traditionally, apple growers can sell the fruits directly to consumers (market *d)* or via the wholesale market *e*. Furthermore, the variable $Pclass_l$ represents the price for processing quality (l). The price increase after storage is further considered by means of the factor f, which was calculated according to data provided by AMI (2014). Here, higher prices for stored apples are variety specific for the classes extra and one and are calculated as an increase of 4-12% of the price occurring in the actual year. In a last step direct, variable and fixed costs are subtracted from operating and non-operating (i.e. indemnities and subsidies) revenue. Costs associated with harvest and sorting of apples are considered as yield-dependent costs. Discounting with a rate of 4 percent and summation of the discounted cash flows leads to the NPV of the farming options. An overview of the cost calculation is provided in the supplementary material (Table S1).

The farming scenarios include varieties, which are common in the considered production areas. In the north of Germany, mainly the varieties Braeburn, Elstar Jonagored, and Red Prince are produced, whereas in the south Braeburn, Elstar, Jonagold, and Gala are the predominant ones, usually grown on M.9 rootstocks. These varieties provide the basis for the analysis of one hectare of certain farming options over a period of 16 years of full bearing capacity. To evaluate the effect of already existing as well as non-established risk management tools, the following scenarios for common varieties of each region are compared.

The first step determines the optimal planting density for each variety under standard risk management strategies. In the North, frost irrigation is usually installed, whereas in the south hail nets serve as a standard risk management strategy. The best options determined in the first step, are further analyzed in a second step. For the north frost irrigation, combined with a hail insurance (F+HI) is considered and for the south hail insurance (HI) is analyzed as an alternative for hail nets. The preferred options are further considered in a third and last step of the analysis, where the focus lies on a hypothetical set of combined hail-frost insurance (HI+FI) for both regions.

As currently available subsidies cover up to 50% of installation costs and insurance premium costs, a two-step simulation, with and without subsidy payments is performed. For the subsidy schemes the following assumptions were made: In the south the material for hail nets, the installation costs of frost irrigation systems and insurance premiums are subsidized at a rate of 50%. In the north, the calculation is based on the sum insured multiplied by a distribution factor as laid down in the subsidy scheme of the producer organization. This distribution factor represents 1% of total apple sales and claim settlements, divided by the sum insured over all enterprises. Subsidies may not exceed the costs of the insurance premium and the sum insured may not be higher than 20,000 €/ha.

4 Results and Discussion

It is of particular interest how apple growers can protect themselves against farm risk in open field production. For this purpose, a stochastic budgeting model was developed, which considers weather-extremes as well as price risks for miscellaneous varieties of apple and planting densities.

An example of the results of the simulation model is shown in Table 2, where fruit yields are measured in decitonnes (dt). The columns indicate the simulation results of the calculated mean, the standard deviation (Stdv), the coefficient of variance (CV), as well as the 5% and 95%-percentiles and the associated Minimum (Min) and Maximum (Max). The total revenue is calculated based on the operating revenue, representing the revenue achieved through sales activities, plus insurance indemnity payments and subsidies. The sum insured is calculated by taking the expected yield achieved without extreme weather events multiplied by market prices. In the case of Red Prince, simulated with 3300 trees per hectare, the sum insured exceeded the maximum of 20,000 €/ha. As a subsidized scenario is represented, the simulation is calculated under consideration of the maximum mentioned above. The monetary loss due to weather events is calculated by multiplying the sum insured with the total loss ratio (cf. Eq. 7 for hail and Eq. 9 for frost). For calculating the amount of hail related indemnity payments, deductibles which are determined by the total loss ratio have to be subtracted as described above. Costs of the insurance are set with a basic premium rate of 10%. After nine production years, the average total loss ratio determines an adapted premium rate, which represents a variable component in the model. Multiplying the sum insured with the distribution factor of 0.0424, which is a 4-year average stated by the producer organization (C. Greisiger, personal communication), average subsides of 848€ are calculated in the scenario below.

Table 2. Red Prince with 3300 trees/ha, frost irrigation and a subsidized hail insurance (north).

Red Prince 3300 HI sub 10% IP	Mean	Stdev	CV	0.05 Perc.	0.95 Perc.	Min	Max
Net present value (€/ha)	109688.96	20416.93	0.19	77193.81	145020.98	38497.16	187930.53
Annuity (€/ha/a)	8071.11	1502.31	0.19	5680.06	10670.90	2832.69	13828.26
Direct costs (€/ha)	11304.78	1107.72	0.10	9155.60	12884.90	7869.46	13276.55
Variable costs (€/ha)	4493.12	735.20	0.16	2951.56	5466.56	1212.52	5466.56
Fix costs (€/ha)	4023.32	426.07	0.11	3272.73	4642.44	2180.23	5107.31
Total yield (dt/ha)	575.40	123.15	0.21	317.18	738.45	25.88	738.45
Classes extra and one (sold per year) (dt/ha)	433.03	134.40	0.31	168.82	633.29	20.18	711.93
Class two (sold per year) (dt/ha)	25.95	32.54	1.25	0.00	96.67	0.00	162.56
Processing fruit (sold per year) (dt/ha)	105.85	112.50	1.06	13.27	338.86	0.68	706.50
Percentage stored (%)	0.95	0.01	0.01	0.93	0.97	0.91	0.97
Percentage of market sales (%)	0.87	0.01	0.01	0.85	0.89	0.84	0.90
Market price classes extra and one (actual year) (€/dt)	42.88	7.55	0.18	30.17	54.64	30.17	54.64
Wholesale market price classes extra and one (actual year) (€/dt)	165.67	26.21	0.16	121.52	206.50	121.52	206.50
Operating revenue (€/ha)	30679.52	10615.82	0.35	12178.06	48064.85	2161.86	60522.03
Total revenue (€/ha)	33505.10	11205.97	0.33	14456.56	52252.22	3197.35	74242.38
Discounted profits (€/ha)	11247.15	9336.99	0.83	-4542.63	27184.53	-14341.62	47598.98
Sum insured (€/ha)	20000.00	0.00	0.00	20000.00	20000.00	20000.00	20000.00
Indemnity payments hail (€/ha)	1976.87	3430.25	1.74	0.00	10042.48	0.00	20000.00
Insurance premium hail (€/ha)	2000.00	0.00	0.00	2000.00	2000.00	2000.00	2000.00
Subsidies (€/ha)	848.71	0.00	0.00	848.71	848.71	848.71	848.71

Four region-specific varieties under common practice are part of the first analytic step. Figure 3 displays the CDFs of NPVs for one hectare of the respective option for the north. In general, higher planting densities of a variety clearly dominate the lower densities in the sense of FSD, but also show higher variation.

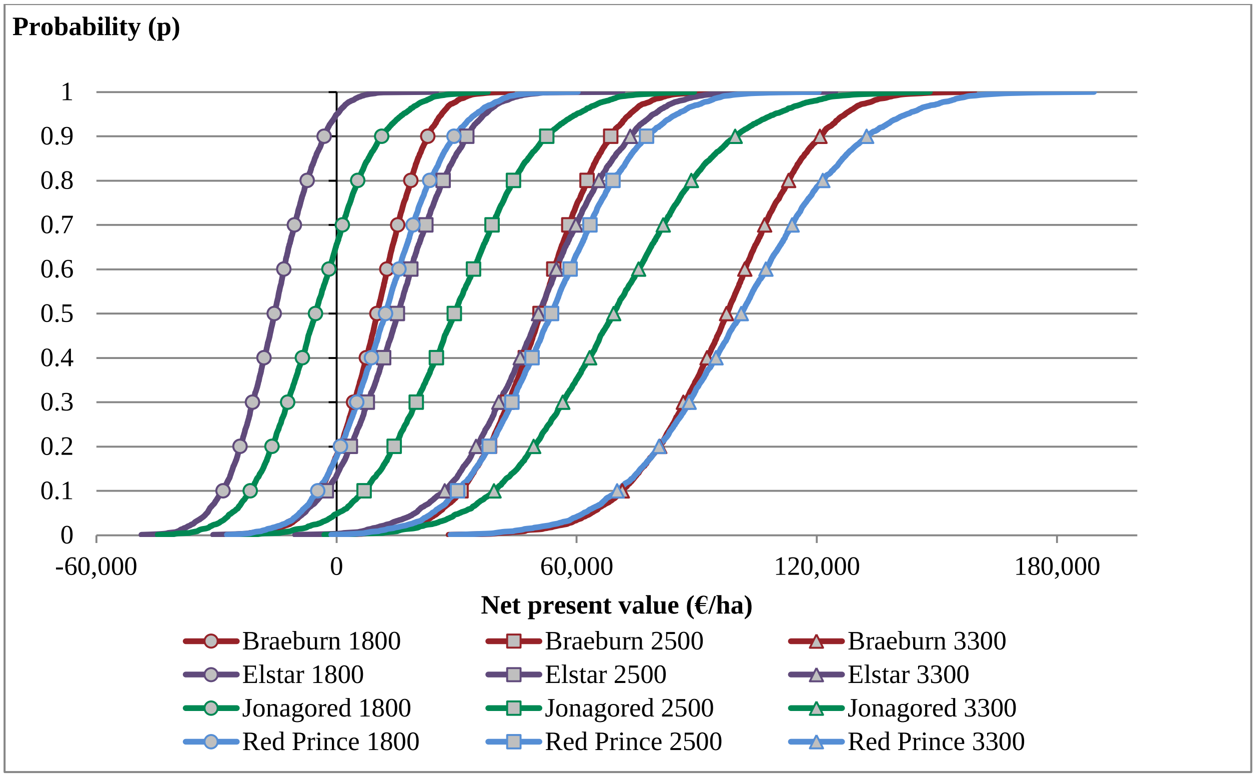

Figure 3. Basic scenario with frost irrigation (north).

Notably, the varieties of Elstar and Jonagored at a density of 1800 trees per hectare can be considered as less efficient, since the probability to achieve a positive NPV is small. Comparing varieties planted at the same density, Braeburn and Red Prince dominate Elstar as well as Jonagored in the sense of FSD. In comparison to Red Prince, Braeburn indicates a steeper curve and is thus less risky. Furthermore, Red Prince at 2500 trees per hectare dominates Elstar in terms of SSD, as their associated curves cross close to p = 1.0. In contrast, the discrimination of the most efficient option among Braeburn and Red Prince at 3300 trees per hectare is not possible with FSD and SSD. Later, SERF helps to achieve a clearer differentiation. On the basis of these results, Braeburn, Jonagored as well as Red Prince at 2500 and 3300 trees per hectare will be part of the further analysis. Results of the second analytic step for the north are given in Figures 4-6.

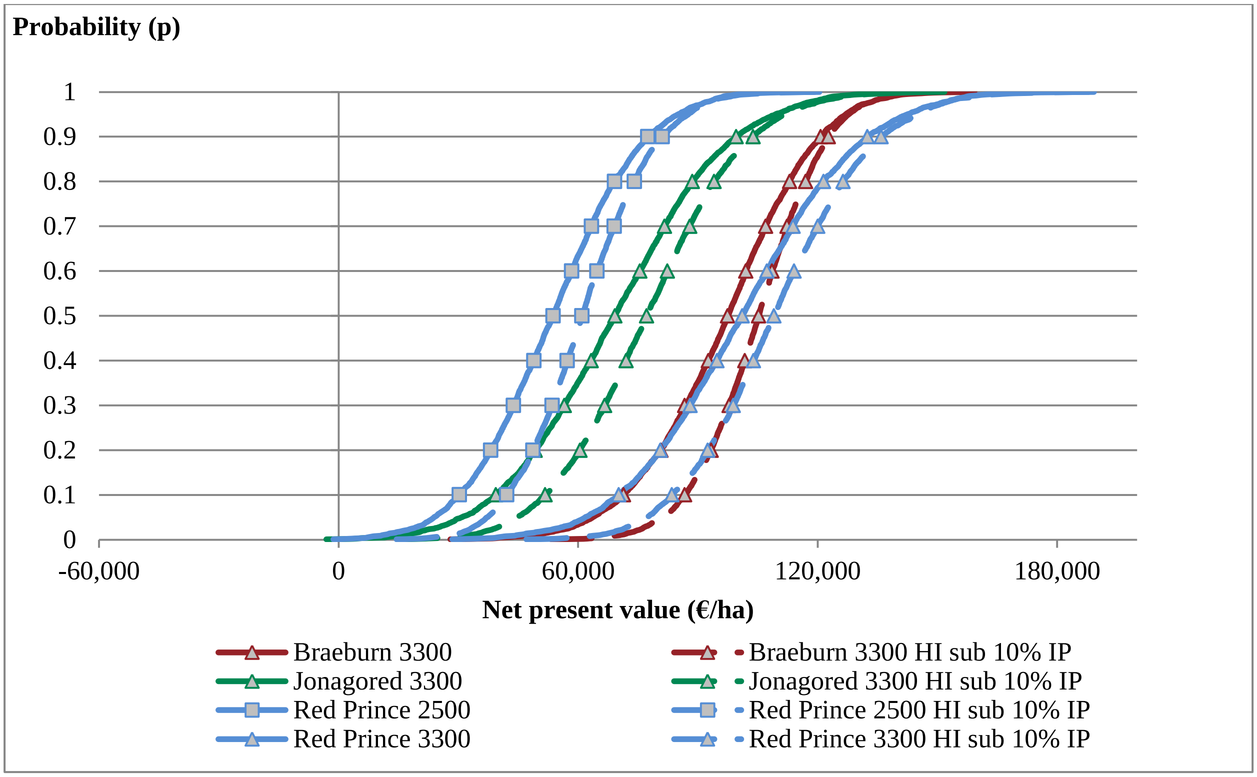

Figure 4. Subsidized hail insurance (HI sub) at a 10% insurance premium-level (IP) with frost irrigation (north).

As indicated in Figure 4, insured crops of all varieties dominate the associated common production practices in terms of SSD. This effect arises from both, insurance and subsidies, where the latter amount to about 850 € per hectare on average. However, with respect to Jonagored and Red Prince at a planting density of 3300 trees per hectare the associated curves cross more than once in their upper range and thus, the application of stochastic dominance criteria does not lead to a final ranking.

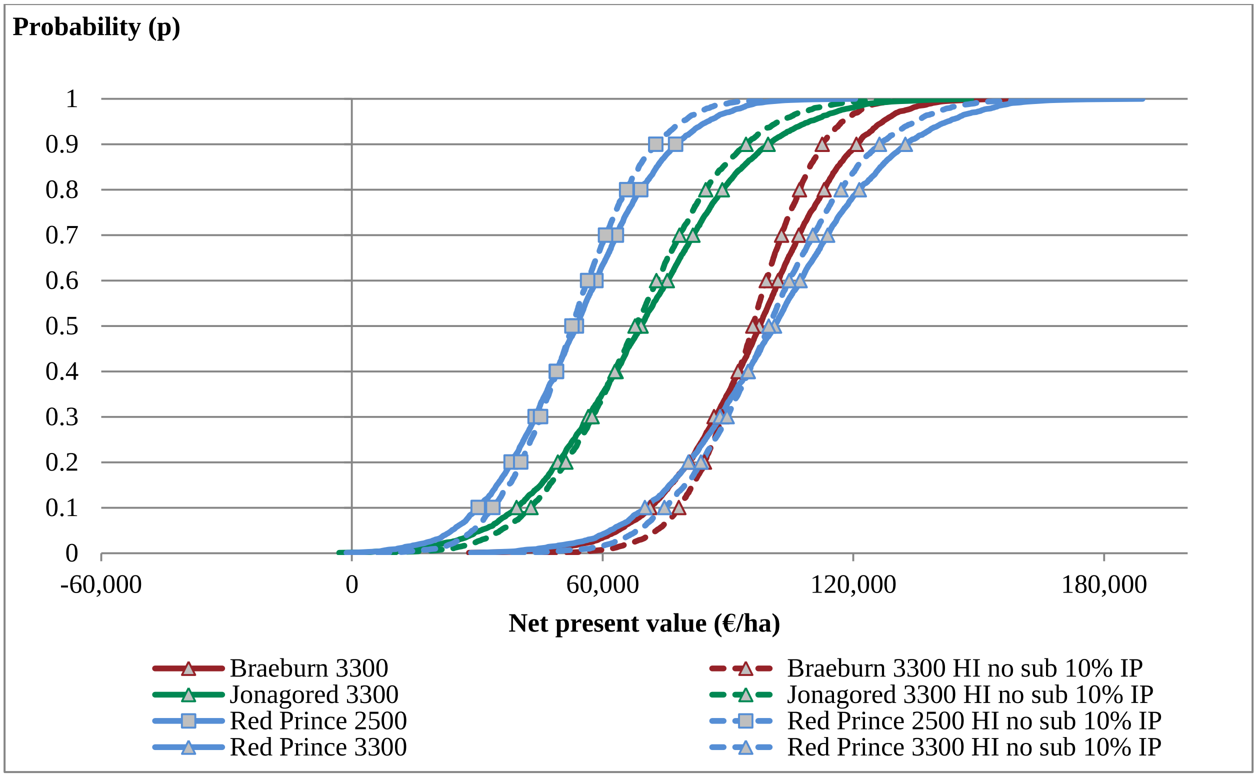

Figure 5. Unsubsidized hail insurance (HI no sub) at a 10% insurance premium-level (IP) with frost irrigation (north).

Figure 5 presents the results of unsubsidized hail insurance. As can be seen, insurance policies without subsidies reduce risks as the associated curves become steeper in comparison to those of the basic scenario. Again, it is not possible to judge the performance of insurance according to FSD or SSD.

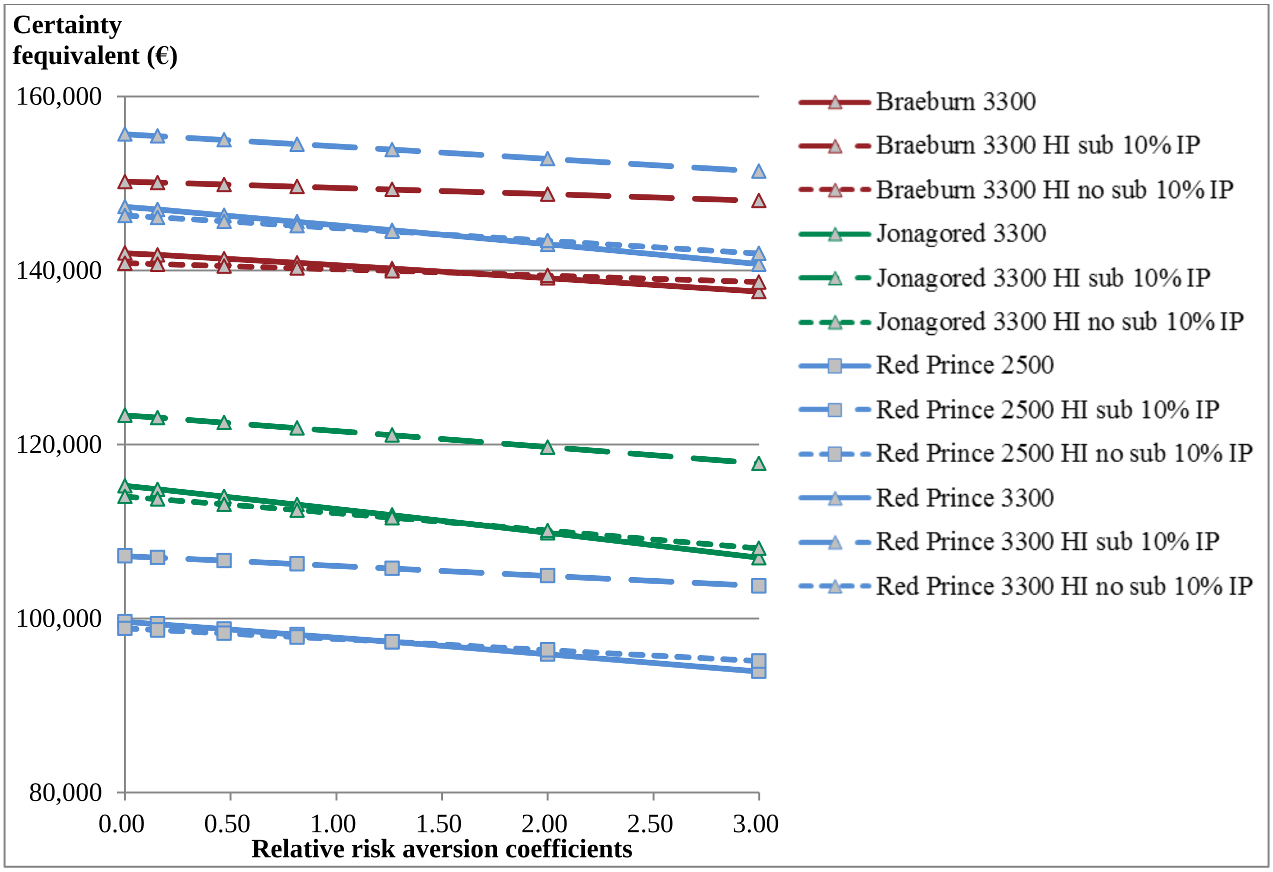

Figure 6. SERF analysis with the basic scenario, subsidized hail insurance (HI sub) and unsubsidized hail insurance (HI no sub) at a 10% insurance premium-level (IP) (north).

The SERF analysis (Figure 6) reveals that for slightly risk averse decision makers, the basic production practice, with frost irrigation as the only RMI, is more appropriate, whereas for risk averse persons an unsubsidized hail insurance provides slightly higher CEs. Nonetheless, a combination of frost irrigation and subsidized hail insurance provides the most efficient risk management strategy, irrespective of the variety. The SERF-analysis further shows that in the basic scenario with frost irrigation, Red Prince provides the most efficient option in the north over a wide range of relative risk aversion ($0 \leq r_r \leq 3$). These results are explained by the average yield-level of Red Prince exceeding those of Elstar and Braeburn. In addition, Red Prince attains higher net revenues than Jonagored due to slightly higher prices as well as lower variable costs. In contrast, an elevated price level causes higher revenues of Braeburn whereas yield is relatively low. As Braeburn is afflicted with smaller standard deviations in revenue as well as in direct and fixed costs, its CEs remain more stable across different risk aversion coefficients in comparison to Red Prince. The results further suggest that Jonagored is less efficient despite its high yield level, since it yields lower prices in the market. Furthermore, the standard deviation of the NPV for Jonagored is similar to the one obtained for Red Prince and likewise results in a considerable CE as well as utility reduction when risk aversion increases. The high yield-level of Jonagored as well as of Red Prince result in higher direct costs, as storage and harvesting costs are increased.

These results indicate that rational apple growers in the north should combine frost irrigation with subsidized hail insurance. However, data shows that 30% of the apple growers, who are already members in a producer organization, do not participate in hail insurance. This observation can possibly be explained with the effect of reference dependence. As described by Bocquého *et al.* (2013), prospect maximizers might be risk averse for gains, but show risk-seeking behavior in a context of losses. They accept the possibility to suffer a high loss instead of paying a certain amount of insurance premium regularly (Bocquého *et al*. 2013). Furthermore, the results of SERF show that unsubsidized hail insurance only leads to a slight increase in efficiency. In consequence, it is not worthwhile for slightly risk averse growers to combine frost irrigation with unsubsidized hail insurance. Nevertheless, the reduction of standard deviation in NPV amounts to 4520.75€/ha on average for the highest planting densities. This leads to a slight increase in efficiency compared to the basic scenario, given a high risk aversion. Please note, that the unsubsidized hail insurance was simulated without a restriction of the sum insured (20,000€/ha), which leads to higher indemnity payments as well as to a higher decrease in NPV standard deviations.

The results of NPV-CDFs calculated for the south are illustrated in Figures 7-8. Apparently, apple growers in the north achieve higher revenues than in the south. These differences stem from deviations of yield estimates, which are variety specific and amount to 59 and 89 dt per hectare for Braeburn and Elstar, respectively. An explanation might originate from an overestimation of yield risks. As the results of Menapace *et al.* (2014) indicate, persons who experienced specific risks in the past, show a significant increase in their associated risk perception for future events. An additional question in our survey captures the influence of the two main weather related risks in the past ten years. In the north, 28.8% stated that the operating income of the enterprise was severely or more than severely affected due to hail, whereas in the south even 48.5% indicated a strong impact of hail. In contrast to yield risks, differences in price levels for market prices are quite small and between 5 to 10 € per dt, whereas variations of wholesale market prices up to 40 € per dt have presumably a higher effect on revenue.

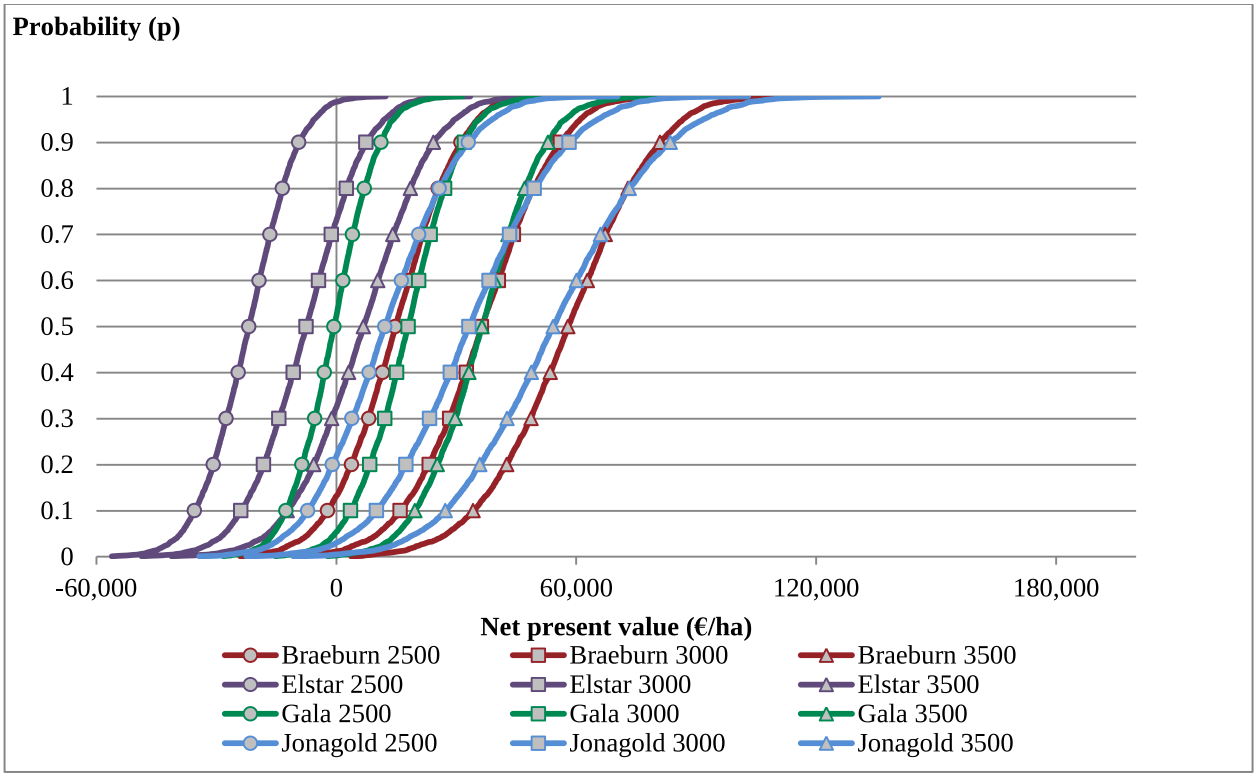

Figure 7. Basic scenario with hail nets (south).

In the basic scenario for the south, Braeburn Gala and Jonagold are more profitable than Elstar at equivalent planting densities and dominate the latter in the sense of FSD. Thus, results suggest that Elstar does not provide an efficient option in either area, as it shows a lower level of yield and therefore lower revenue. The reason for the low yield of Elstar may in part be explained by its high tendency for alternate bearing (Untiedt and Blanke, 2001; Atay *et al.* 2013). As a consequence, it is reasonable to suppose, that yield estimates of Elstar lie below of those of other varieties. Furthermore the basic scenario for the south shows that the CDFs for Jonagold indicate a higher risk, as their course is not as steep as the curves that represent the other varieties. Similar to the north, all varieties simulated at the highest planting density of 3500 trees per hectare dominate the lower ones in sense of FSD. When focusing on the highest planting density, Jonagold is dominated by Braeburn in terms of SSD. However, no clear ranking according to FSD or SSD is observable when focusing on Braeburn at 3000 trees per hectare as well as on Gala and Jonagold at 3500 trees per hectare. Thus, Braeburn at 3000 trees per hectare together with Braeburn, Gala and Jonagold at 3500 trees per hectare are considered in the second part of the analysis.

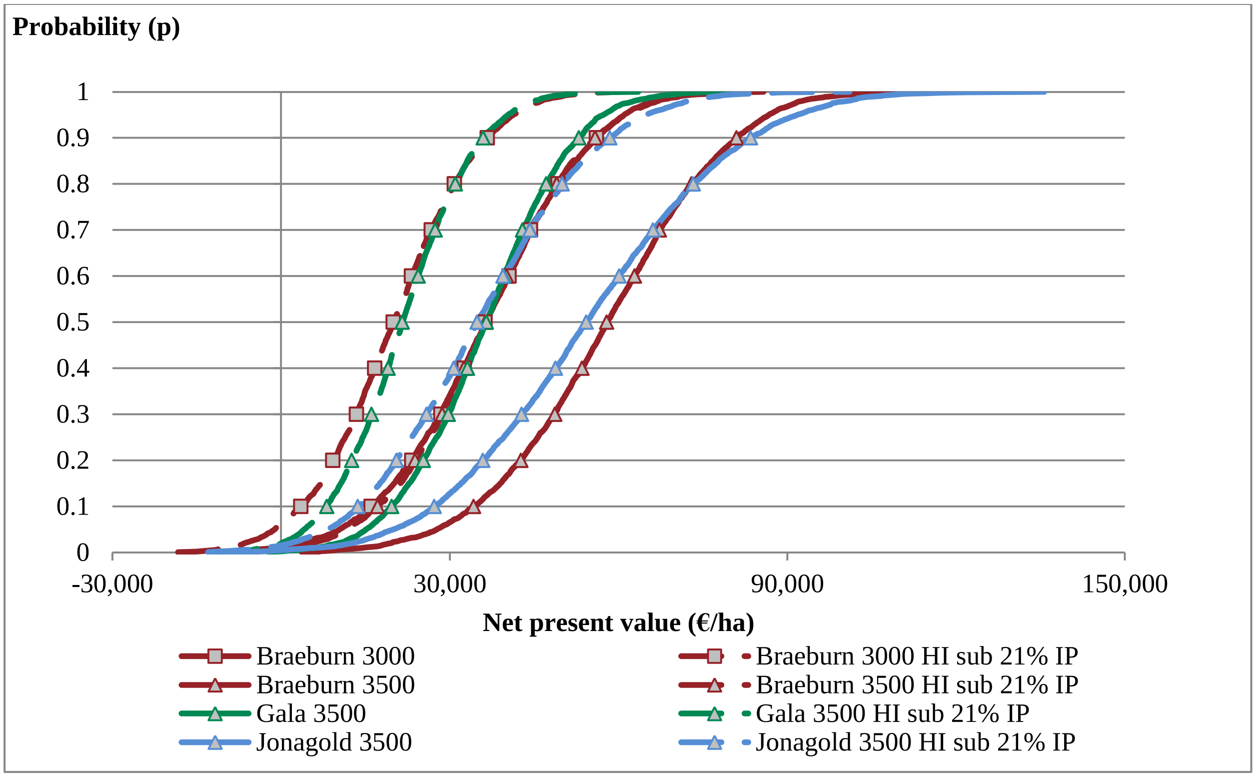

Figure 8. Subsidized hail insurance (HI sub) at a 21% insurance premium-level (IP) as an alternative for hail nets (south).

Figure 8 shows the results for hail insurance as an alternative choice to hail nets in the south. Despite subsidies covering 50% of the premium, hail insurance seems to provide no appropriate solution, since the variety specific comparison of the RMI reveals a decrease in efficiency. However, hail insurance combined with high density and profitable varieties as Braeburn or Jonagold at 3500 trees per hectare appear as efficient as Braeburn at 3000 trees or Gala at 3500 trees per hectare. One may recognize that distances between the basic scenario and subsidized hail insurance for Braeburn at a planting density of 3500 trees per hectare are larger than for 3000. This effect stems from an increase of expected yield, which is coupled with higher premium costs. Average values, obtained for a planting density of 3500 trees per hectare, indicate that indemnity payments and subsidies do not meet revenue loss occurring without hail nets, which leads to a financial loss of about 632€. Furthermore, direct costs increases up to 19.90%.

With respect to unsubsidized hail insurance all basic scenarios dominate their analogs with unsubsidized hail insurance according to FSD.

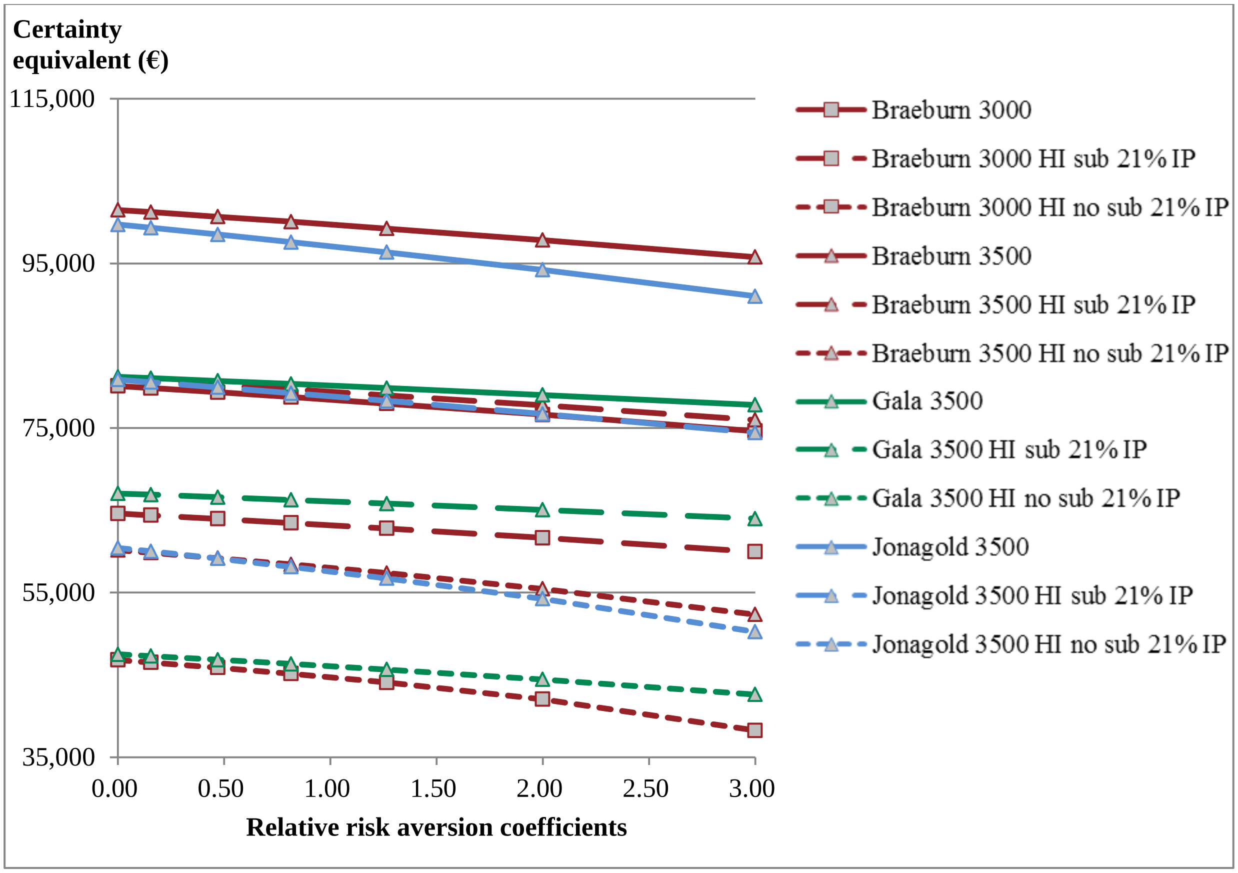

Figure 9. SERF analysis with the basic scenario, subsidized hail insurance (HI sub) and unsubsidized hail insurance (HI no sub) at a 21% insurance premium-level (IP) (south).

Figure 9 summarizes the results for the south in terms of CEs. Generally, subsidized hail insurance in the south is less efficient than growing the same variety under hail nets. Subsidized hail insurance can only compete with the basic scenario, if the apple grower is risk neutral to slightly risk averse and chooses varieties characterized by a high yield or an elevated price level. For risk neutral apple growers, subsidized insurance solutions of Braeburn and Jonagold at 3500 trees per hectare are as efficient as the production under hail nets of Braeburn at 3000 trees and Gala at 3500 trees per hectare. However, as the SERF analysis reveals for Gala, the underlying risk attitude may be important. As Gala at 3500 trees under hail net is still afflicted with lower risks it shows higher CEs for risk averse individuals, who should give priority to this option. This result makes evident that regardless of the variety specific decrease of standard deviation achieved by the participation in insurance, the general risk of a variety has to be taken into account. Furthermore, the results indicate that without subsidies, hail insurance would be clearly dominated by common practice with hail nets and thus provides no reasonable alternative. Therefore, subsidies appear as a certain and non-negligible source of revenue.

The results further suggest that Braeburn is the most efficient variety due to its higher price level, even if the average yield of Braeburn is below that of Gala and Jonagold. Regarding the NPV's standard deviations, Jonagold shows the highest and Gala the lowest risk. Compared to Jonagold, standard deviations of Gala regarding the operating revenue, as well as the direct, fixed and variable costs are smaller. Similarly, Braeburn shows a lower standard deviation with respect to the operating revenue. Consequently, and as the SERF analysis reveals, Braeburn is afflicted with lower risk and risk averse individuals should opt for Braeburn instead of choosing Jonagold. With respect to costs, Jonagold shows higher fixed and variable costs, as its high yield leads to higher labor costs for harvesting.

As mentioned before, risk management instruments for apple growers against weather related risks are rare. Thus, subsidized hail-frost insurance as a (so far) hypothetical alternative was implemented. The associated CEs are plotted together with subsidized hail insurance and the basic scenario in figures 10 and 11. Figure 10 - presents the results for the north at a 7% insurance premium level for frost insurance. The insurance premiums were obtained by a comparison of average premium costs and indemnity payments.

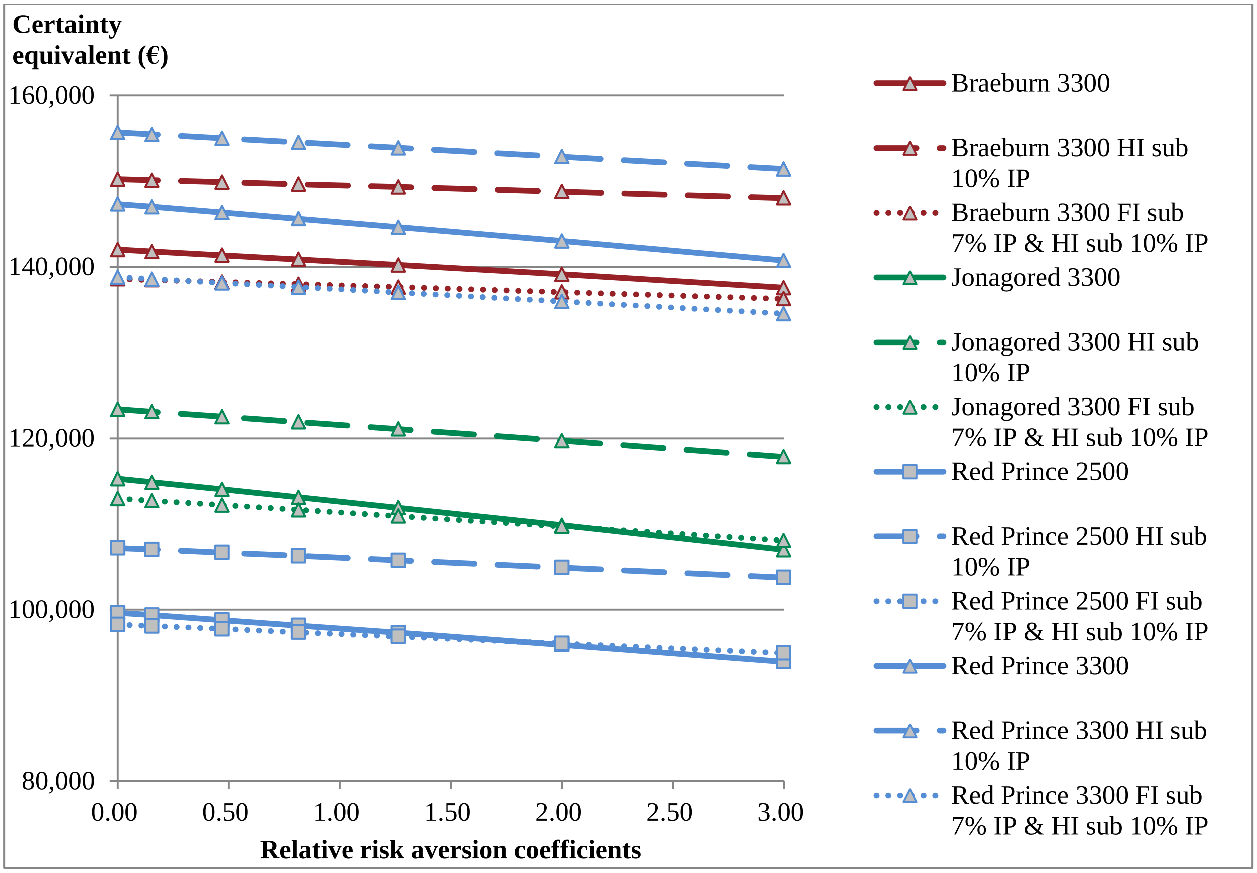

Figure 10. SERF analysis with the basic scenario, subsidized hail insurance (HI sub) at a 10% insurance premium-level (IP) and combined frost-hail insurance (FI sub & HI sub) at a 7% insurance premium-level (IP) for frost (north).

In the north, frost-hail insurance generally does not provide an efficient alternative to frost irrigation. The results suggest that subsidized, combined frost-hail insurance in the north is only attractive for very risk averse decision makers, even though the effect is variety-specific and depends on the planting density, as can be seen for Braeburn and Red Prince at 3300 trees per hectare. Only extremely risk averse decision makers would obtain slightly higher CEs compared to the basic scenario of Red Prince at 2500 trees per hectare and Jonagored at 3300 trees per hectare. However, a disruption in the capability to supply regular customers with apples might jeopardize the business relationships in real life and apple growers are expected to prefer frost irrigation systems rather than insurance solutions.

In the south the basic (and most commonly found) farming options remain the most efficient ones, compared to subsidized insurance solutions (Figure 11). A combined frost-hail insurance with a 2% insurance premium would lead to slightly higher incomes due to subsidies, whereas damages due to late frosts are marginal and indemnity payments for high density plantations amount to 300€ in average. The CEs of the combined hail-frost insurance are close to those of single hail insurance, although the associated values always lie above due to the assumption of higher subsidy payments. Thus, the added value of a hail-frost insurance is low.

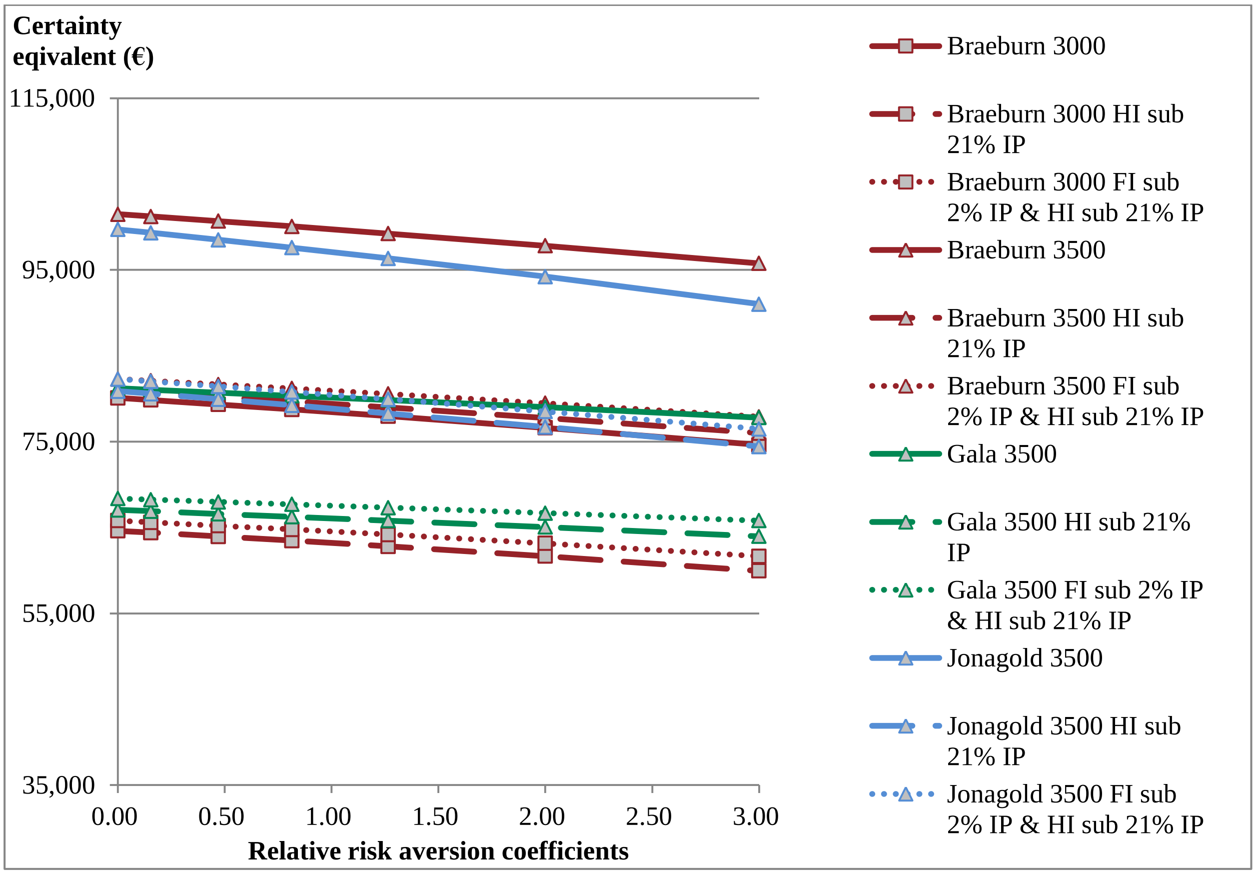

Figure 11. SERF analysis with the basic scenario, subsidized hail insurance (HI sub) at a 21% insurance premium-level (IP) and combined frost-hail insurance (FI sub & HI sub) at a 2% insurance premium-level (IP) for frost (south).

In 2017 frosts caused high damage in fruit and wine yards, located in the south of Germany. Coble and Barnett (2012) describe that ex post disaster assistance via direct payments in the United States reveal that these payments in contrast to insurance programs do not provide a support in sense of risk protection. In order to reduce the demand of ex post disaster payments, subsidies for insurance contracts clearly represent an incentive to increase the number of insurance contracts (Coble and Barnett 2012). Therefore, a subsidized multi-peril insurance could provide an appropriate solution to cope with damages due to frosts and hail. For example, a commercial multi-peril insurance is available for apple production in the Netherlands covering frost and hail damages in combination with other weather-related risks. This insurance receives a government subsidy up to 65% of the insurance premium (Berkhout et al. 2016, p.16). In contrast, our results indicate that the added value of a multiperil-insurance is low considering the estimated risk situation. Nevertheless, the effects of climate change may increase the occurrence of late frosts and multi-peril-insurances could become more relevant.

Finally, a potential criticism regarding the use of the net present value as the stochastic investment criterion should be addressed. Using the NPV implies an aggregate evaluation of the total simulation results over the economic life of the apple orchard, which tends to level the effect of a catastrophic year that could have caused bankruptcy. This could lead to an underestimation of the true risk. In line with Clancy *et al.* (2012), it is assumed that each variety on a 1 ha basis only represents a rather small percentage of farming activities and farmers' wealth, whose failure would not likely lead to insolvency of the enterprise. Also from a marketing perspective, apple growers are required to produce a certain mix of apple varieties to meet their customers' demands, which precludes the recommendation of a single variety.

5 Conclusions

Results of the present study reflect observed behavior in reality, where apple growers successfully apply available risk management strategies in their respective regions.

In the north, Red Prince appears as the most efficient variety. Furthermore, subsidized hail insurance would provide benefits for risk averse farmers in general, whereas an unsubsidized hail insurance is only more efficient if the apple grower is highly risk averse. In the south, none of the considered RMI provides a more appropriate alternative to common practices of using hail nets when the same variety and planting density are considered. Even if recent events of frost damages in the south arousing thoughts of developing multi-peril insurance programs, the results reveal that additional benefits under the present circumstances are low. As for the north, also in the South more efficient varieties could be identified. Braeburn is the most efficient variety and appropriate for slightly to highly risk averse individuals. Identifying efficient combinations of variety, planting density and RMI is only a first step, however, as diversification reduces farm income risk further and takes into account the customers' requirement of a certain product mix. As a consequence, future work should utilize whole-farm risk programming to capture the interaction between varieties as well as constraints to the implementation of risk management strategies by considering additional requirements, such as pollination management and farm-specific restrictions As the present paper aims to discuss RMIs universally applicable to apple producing orchards, restrictions as farm debts cannot be generalized and thus are not discussed. Future work may include these topics and considering farm debt repayment activities during catastrophic years which could lead to bankruptcy.

With respect to the hypothetical subsidized frost-hail insurance, variety specifications as well as the planting density have to be considered when interpreting the results. For high-yielding varieties in high density plantings, this insurance concept seems to be inappropriate. Otherwise, when considering very risk averse apple growers, using less intensive production systems, it may lead to a slight increase of efficiency compared to an ordinary frost irrigation. A subsidized, hypothetical multi-peril insurance covering frost and hail would lead to slightly higher net incomes than observed for the subsidized hail insurance alone in the south, due to its additional transfer payments. But nevertheless, the production of high yielding varieties catching good prices in high density plantations under hail nets still remains the most efficient option.

Apple growers of other European countries however have access to multi-peril insurance policies, which are often subsidized by the government. To analyze the effect of different risk management concepts, future work should compare European multi-peril insurance concepts, which cover a broad extent of weather-related risks.

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Appendix

Table S1. Cost overview for Red Prince with 3300 trees/ha, frost irrigation and a subsidized hail insurance (north).

Parameters	**Simulated means (€/ha)**
Direct costs	
Fertilizer	90.20
Plant protection	788.70
Installation of frost irrigation	697.35
Water for Frost irrigation	286.40
Additional direct costs (Control activities)	51.00
Costs hail insurance	2,000.00
Storage costs	3,403.88
Wholesale market activities	3,765.59
Interest rate (50% of interest rate = 4%)	221.66
Sum of direct costs	11,304.78
Variable costs	
Wage seasonal workers (planting, irrigation, hail net installation, sorting and harvest excluded)	450.00
Machine costs (planting, irrigation, hail net installation and harvest excluded)	570.40
Costs related to frost irrigation activities – machines	16.86
Wage for harvest - seasonal workers	1,593.04
Costs for harvest – machines	281.82
Wage for sorting - seasonal workers	1,498.43
Interest rate (50% of interest rate = 4%)	82.57
Sum of variable costs	4,493.12
Fixed costs	
Wage permanent workers (planting, irrigation, hail net installation, sorting and harvest excluded)	1,028.48
Machine costs (planting, irrigation, hail net installation and harvest excluded)	491.10
Costs related to frost irrigation activities – machines	7.36
Wage related to frost irrigation activities - permanent workers	137.93
Wage for harvest - permanent workers	488.00
Costs for harvest – machines	211.59
Wage for sorting - permanent workers	861.18
Wage for taking responsability - manager (≙ 2.6% of revenue)	797.67
Sum of fixed costs	4,023.32

IV Rationalizing apple growers' decision making in Germany - a utility based whole farm programming approach

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Abstract

Commercial apple production is exposed to various sources of risks. This paper presents a normative utility-efficient programming (UEP) approach, calculating optimal farm plans for apple growers in two different regions of Germany. It takes weather-related quality and yield risks, as well as price risks into account. It is based on risk attitude and risk perception collected from a sample of 134 apple growers. After combining subjective estimates of the apple growers with relevant historical data, input data for the UEP-model were derived from Monte-Carlo simulations. The UEP-model determines optimal portfolios, consisting of combinations of apple varieties and risk management instruments. The results indicate that the degrees of risk aversion affect optimum farming strategies only to a minor extent. They also provide evidence that farmers would benefit from a combined frost-hail insurance, whereas the absence of frost irrigation systems may cause high yield-losses in the northern part of Germany.

Keywords: utility-efficient programming, risk aversion, risk management, crop insurance, certainty equivalent

1 Introduction

Extreme weather events are the most critical and omnipresent source of risk in open field production. Adverse weather effects entail production risks due to yield and quality reductions as well as market risks which result from fluctuating volumes. Thus, appropriate risk management strategies are mandatory for an economically successful apple production. In this context, yield and quality are acknowledged as the main drivers for economic success in apple production (Bravin *et al*. 2009). However, effects of climate change on yield and quality risks in apple production are uncertain so far, which increases planning uncertainties. For example, simulation results for German apple orchards published by Hoffmann *et al.* (2012) indicate no considerable increase of blossom-damage due to late frosts in general terms, whereas the absolute increase of late frost risk depends on site-specific characteristics. As farm-specific adaptions to climate change are associated with additional costs, analysis on region-specific effects is required (Thomson *et al.* 2014).

For an evaluation of farming strategies, the economic assessment of a whole-farm strategy rather than of single farming options is suggested, since focusing on single crop investment decisions may lead to an overestimation of production and price risks. Furthermore, whole-farm planning can take competition for naturally constrained farm resources into consideration (Lehmann *et al.* 2013). With respect to time, resource-constraints implemented in inter-temporal models allow for resource allocation over the whole planning period. Furthermore, a discount rate enables risk analysts to value current against future income streams (Pandey and Hardaker 1995; Janssen and van Ittersum 2007). For a comprehensive review of commonly applied planning models regarding perishable and non-perishable crops the reader is referred to Ahumada and Villalobos (2009).

Being a permanent crop, apple production requires long-term planning that considers the consequences of the initial investment decision over the whole economic life cycle of the orchard, which is aptly summarized by the NPV as an indicator of profitability (Catalá *et al.* 2013). As the flexibility of adjustments regarding risk management instruments (RMI), i.e. sequential decision making, is restricted, risk management in apple production thus focuses on non-embedded risk, which means that apple growers have to decide *a priori*, at the beginning of the production period, how to lower their risks (Dorward, 1999; Hardaker *et al.* 2004, pp. 186-187).

Although the selection of appropriate apple varieties as well as the choice of the suitable RMI is non-trivial, this investigation tries to determine the most efficient strategies under risk by focusing on both factors. To our knowledge this study is the first to develop a decision support tool for a whole-farm strategy under risk, addressing apple production in Germany.

In order to create a prescriptive whole-farm model, a mathematical programming approach is applied. The model performs efficiency-analysis under the maximization of apple growers' utility, considering discounted cash flows for a production period of 20 years and taking weather-related risks into account. Additional constraints, i.e. the production area, farm diversification, as well as available protection systems against weather-related impacts for risk reduction, are further implemented. Referring to insurances, hail insurance (HI), which already exists, as well as a hypothetical combined frost-hail-insurance (FI sub & HI sub) for transferring yield and quality risks outside the farm are considered.

2 Literature Review

For the assessment of long term strategies the net present value (NPV), a proceeding of the dynamic capital budgeting, serves as the predominant evaluation technique in terms of profit maximization unless decisions are reversible. Recently, Catalá *et al.* (2013) maximized NPV with a mixed integer linear programming model when focusing on 20-year apple and pear production in Argentina (Catalá *et al.* 2013). However, the conventional NPV is calculated based on deterministic average values, addressing a risk neutral decision maker and multi-period returns are aggregated to a present value under loss of chronological reference. As a consequence, risk as well as liquidity constraints in the single periods are not taken into consideration (Bocquého and Jacquet 2010).

An extension of dynamic capital budgeting is the real options approach (ROA). In contrast to the NPV, ROA is appropriate when investment-decisions are characterized by uncertainty, irreversibility and temporal flexibility, i.e. that the decision maker has the option to wait and defer the investment. The option to postpone the investment includes opportunity costs as an additional value, especially if returns are uncertain. If an investment is realized, this value can represent sunk costs, as it eliminates the option to realize alternative investments. In the case of postponing the investment, the loss of profit is captured. As ROA additionally accounts for these opportunity costs, the investment trigger shifts upwards (Dixit and Pindyck, 1994, pp. 6-9; Ihli *et al.* 2014). Supplementary to the option of deferment, other real options exist. For an overview please refer to Trigeorgis (1996, pp. 2-3). Wolbert-Haverkamp and Musshoff (2014) apply the traditional NPV as well as the ROA for explaining farmers' investment behavior when determining the effects arising from conversion of arable land to short rotation coppice. They find that ROA in comparison to NPV better explains farmers' inertia to convert rye into short rotation coppices (Wolbert-Haverkamp and Musshoff 2014). Furthermore, Ihli *et al.* (2014) compare the ROA and the NPV criterion when predicting German farmers' investment and disinvestment behavior. Their results indicate that neither criterion exactly predicts experimentally observed decision making. However, the ROA is superior in explaining farmers' real behavior (H. J. Ihli, Maart-Noelck, and Musshoff 2014). In our case we assume that the ROA provides no additional advantage, due to the following lines of thought. In apple production, insurances are not considered to serve as a disinvestment opportunity and hail nets (HN) as well as overhead irrigation for frost protection (IFP) are not easily reversible. Furthermore, these investments are supposed to be made during the establishment phase of the orchard and in consequence, temporal flexibility is not given. Furthermore, the installation of HN during the establishment phase reduces the establishment costs as the HN-construction may serve in addition as wire frame. Consequently, the NPV is supposed to provide a sufficient basis for the economic assessment of a whole-farm strategy in apple production.

As mentioned before, the traditional NPV disregards farmers risk attitude. Therefore, alternative concepts have been developed. One approach allowing portfolio choice in farm planning under risk is quadratic risk programming, also known as the expected value-variance framework (EV). It determines the efficient frontier, representing efficient portfolios, by maximizing the expected value or minimizing the variance (Ogurtsov *et al.* 2008; Hardaker *et al*. 2004, p. 193). Applications of the EV in agricultural economics include the assessment of weather derivatives with respect to potential restrictions of water use. The study of Buchholz and Musshoff (2014) reveals that index-based weather insurance may compensate economical disadvantages resulting from water quotas as well as higher water prices in Germany. Bobojonov and Aw-Hassan (2014) also apply the EV for modelling the impact of climate change on arable farm income for countries in central Asia. Their results indicate that market liberalization could lead to an increase in revenues as well as a higher exchange of farm inputs and thus provide a strategy to cope with risks related to climate change (Bobojonov and Aw-Hassan 2014).

Earlier investigations used MOTAD as a simplification of EV analysis. MOTAD is a linear programing model, approximating the EV efficient frontier, by maximizing the expected value of a performance indicator under reduction of the associated mean absolute deviation, which is included as a restriction (Hardaker *et al.* 2004, pp 197-199). However, in recent years linear programming has lost its relevance as software is available to perform nonlinear programming (Lien *et al.* 2011). By applying MOTAD, Waibel *et al.* (2001) investigate the risk associated with the transformation of a conventional apple production into an organic one. They conclude that risk averse farmers should diversify as variety specialization leads to a higher expected annuity but also to an increase of the associated variance, i.e. risk (Waibel *et al.* 2001). With a related approach Mouron and Scholz (2008) evaluated farm income of twelve apple producing farms in Switzerland on basis of mean, standard deviation and skewness. Even though a programming model is not implemented in their investigation, the parameters allow them to draw several conclusions. They find that differences in management and predominantly high investment in pre-harvest hours, strongly influence the average income as well as the associated standard deviation. Interestingly, their correlation analysis reveals that the higher the average income, the lower the variability of income. Furthermore, one third of the farms reveal a low ability to compensate low income and mitigate the impact of catastrophic events (Mouron and Scholz 2008).

Alternatively to EV, the subjective expected utility framework (EU) allows farm planning under risk, even if the data distribution is non-normal (Lien *et al.* 2011). This approach determines an optimal portfolio by maximizing the EU of a subject for a given risk attitude (Ogurtsov *et al.* 2008). Even if UEP applied for an extended time frame is judged to be sophisticated (Hardaker *et al.* 2004, p. 238), Bocquého and Jacquet (2010) conduct a multi-period EU maximization approach, when assessing the economic effect of miscanthus- and switchgrass-adoption for a cereal farm in France. Furthermore, they apply the discounted utility (DU) framework where the discounted sum of instantaneous utilities is calculated. Contrary to NPV, this framework takes liquidity constraints during the production period into account and the decision makers preferences for regular incomes. Additionally, they implement a combination of EU and DU and address uncertainty as well as liquidity constraints simultaneously (Bocquého and Jacquet 2010). Nonetheless, there are some critiques referring to the DU-model, as it is predominantly used because of its simplicity and its similarity to the traditional discount rate formula, although its empirical validity has never been confirmed (Frederick *et al*. 2002; Meyer 2013).

Even though the EV method is widely used, it lacks theoretical justification. If one rejects the idea of increasing absolute and relative risk aversion with a growing wealth and thus the application of the quadratic utility function, the negative exponential (CARA) utility function represents an alternative. With CARA, normality assumptions become an essential prerequisite for consistency with EU (Lien *et al.* 2011; Ogurtsov *et al.* 2008). However, when focusing on catastrophic events, the assumption of normality does not hold. In addition, specification errors of the standard deviation may lead to an improper estimation of the distribution tails and risks might be over- or underestimated. Thus, in contexts where catastrophic risks are important, the EV is inappropriate (Ogurtsov *et al.* 2008; Ermoliev, *et al.* 2000). On the contrary and according to the developer of the mean-variance analysis, the above mentioned preconditions are not required for EV to hold and can rather be seen as sufficient conditions. Even under more relaxed assumptions, the EV can approximate the results of EU well (Markowitz 2014). For example, Lien *et al.* (2011) demonstrate that the results of the EU and EV-framework show only minor and negligible deviations. Furthermore, their results indicate that risk modelling leads to unstable results due to sampling bias, if programming is only based on few observations (Lien *et al.* 2011).

As the whole-farm approach described in this paper leads to the evaluation of cash flows, which are relatively large in comparison to farmers' total wealth, the power utility function, implying constant relative risk aversion (CRRA), provides a more appropriate evaluation of risk preferences than CARA. Considering the insights provided by the discussed literature, we choose the EU framework for our analysis.

3 Model approach

A prescriptive multi-period utility-efficient programming model for an ex-ante optimization, considering uncertainty of prices and yields for sixteen years of full bearing is developed. The model considers the stochastic nature of annual cash flows CF_{TC} for 20 years of orchard lifetime (T) by incorporating 100 drawings C for the variables yield, prices, costs and non-operating revenue from a Monte-Carlo simulation model for each activity, i.e. combination of variety, planting density and risk management measures (Röhrig *et al.* 2018). Since the respective drawings originate from identical iterations of the simulation model, stochastic dependencies between the variables are reflected in the cash flow data CF_{TC}. To maintain numerical feasibility, cash flows CF_{TC} are scaled to units of 10,000 Euro z_{TC} (Eq. 1), which are used as the argument for the utility function (Eq. 2).

$$z_{TC} = CF_{TC} / 10{,}000 \qquad (1)$$

Since all drawings C at p=.01 are equally likely, the expected utility of the portfolio is calculated according to Eq. 3 with the utility function presented in Eq. 2. As mentioned above, we assume CRRA utility with initial wealth, which is set regionally specific at 160,000€ in the North and

75,000€ in the South, respectively. Relative risk aversion coefficients (hereafter r) regarding wealth $r_r(w)$ are set according to apple growers' risk attitude elicited via a farm profit-framed Holt and Laury lottery, originally pioneered by Holt and Laury (2002).

$$U_{TC} = ((nonrisk/10{,}000) \; + \; z_{TC})^{(1-r)} * 1/(1-r) \qquad (2)$$

Where

U_{TC} = Utility of total wealth per year T and draw C

$nonrisk$ = initial, non-stochastic wealth

z_{TC} = scaled, discounted cash flow

r = relative risk aversion coefficient

$$EUY_T = \sum_{C=1}^{100} (p * \; U_{TC}) \qquad (3)$$

Where

EUY_T = Expected utility per year T

p = Probability representing the occurrence of each draw C

With respect to the utility function, the power utility function was selected, implying constant relative risk aversion (CRRA). The function considers that uncertain cash flows determined for the whole-farm strategy are in total large relative to farmers' wealth. As the model takes a long term perspective, wealth w is a product of annual income y and the capitalization factor k, therefore the same *r* may be applied for wealth and income ($r_r(w) = r_r(ky) = r_r(y)$) (Hardaker *et al.* 2004, pp. 112-113). After obtaining the EUY_T, the inverse of the expected utility results in the associated certainty equivalent (CE_T). Finally all certainty equivalents are summed up to a total CE, calculated for the whole production period. The UEP model was solved with GAMS/CONOPT3.

All variables included in the cash flow calculation CF_{TC} are variety specific and were calculated by considering six different varieties *V* (Eq. 4).

$$CF_{TC} = [(\sum_{v=1}^{n} oprev_{TCV} + nonoprev_{TCV} - cdet_{TCV} - cvar_{TCV} - cadd_{TCV} - cstorage_{TCV}) - cdirectsale_{TC}] * (1+i)^{-t} \qquad (4)$$

Where

CF_{TC} = Discounted cash flow per production year

$oprev_{TCV}$ = operating revenue as product of apples sold and associated prices

$nonoprev_{TCV}$ = non-operating revenue including indemnity payments as well as subsidies

$cdet_{TCV}$ = deterministic costs (i.e. costs for fertilizer, plant protection, insurance, material for hail net installation)

$cvar_{TCV}$ = variable costs (variable wage and machinery costs for sorting and harvesting)

$cadd_{TCV}$ = further costs (fixed wage and machinery costs referring to frost irrigation activities and harvesting)

$cstorage_{TCV}$ = storage costs – referring to qualities extra one and two

$cdirectsale_{TC}$ = costs for direct sale to consumers, calculated per year over all varieties and apples sold

As higher discounting leads to a reduction of the cash flow variance, the cash flow calculation was carried out for discount rates i = 0.04, 0.06 and 0.08. For the north, a planted area of 20ha per farm is assumed and for the south 15ha. As establishing costs of 26187 €/ha north and 26715 €/ha in the south are considered to be equal for each apple variety, these are excluded from the analysis. Furthermore, variations in the cultivation plan, as tree removal and re-cultivation are not included. An overview of the most relevant parameters is given in Table 1.

Table 1. Overview of relevant parameters serving as input data for cash flow calculation.

Parameter	Unit	Source
Yield	dt/ha	Yield estimates of apple growers combined with historical data, stochastic @risk model
Prices	€/dt	Price estimates of apple growers combined with historical data, stochastic @risk model
Costs	€/ha	Kuratorium für Technik und Bauwesen in der Landwirtschaft e.V. 2010, stochastic @risk model
Non-operating revenue	€/ha	Stochastic @risk model
Discount rate	%	i= 0.04, 0.06, 0.08
Relative risk aversion coefficients (*r*)	-	0, 0.2, 0.4, 0.6, 0.8, 1.2, 1.4, 1.6, 1.8, 2

Variables which are relevant for the calculation of the discounted cash flows are area of planted apple, amount of processing fruits, amount of stored fruits, storage costs, and the sale specifications. Here, the common distribution channels for apple in Germany, i.e. the wholesale market or the direct sale to consumers are considered.

The availability of land is set to a fixed value of 15ha in the south and 20ha in the north. Furthermore, pollination requirements are considered. For large-scale production, triploid and diploid varieties have to be established in a mixed orchard planting (Way, 1995, p. 6) therefore a minimum of 7% of compatible varieties is required. As 43% of the apple growers sell a share of apples direct to consumers, a minimum restriction of 1ha of each variety is set to ensure a diversified product portfolio.

The programming tool further considers different production options per variety, therefore the amounts of stored fruits as well as those of processing fruits have to be aggregated in order to represent the total amount of apple per variety. Processing fruits are only assumed to be sold at the wholesale market but not direct to consumers. Storage costs are calculated for higher-quality apples, which are generally stored in controlled atmosphere, or at least in cold storage for a short-term warehousing, assuming average storage costs of 7.66€ per dt (KTBL, 2010). According to the numbers stated by apple growers, an average loss of 5% is assumed during storage.

Values obtained from the survey suggest that direct sales activities in average amounts to 13% for high quality apple in the north and 17% in the south. Therefore, these values are used as maximum restrictions for direct sales activities in the model. The model structure is shown in Figure 1.

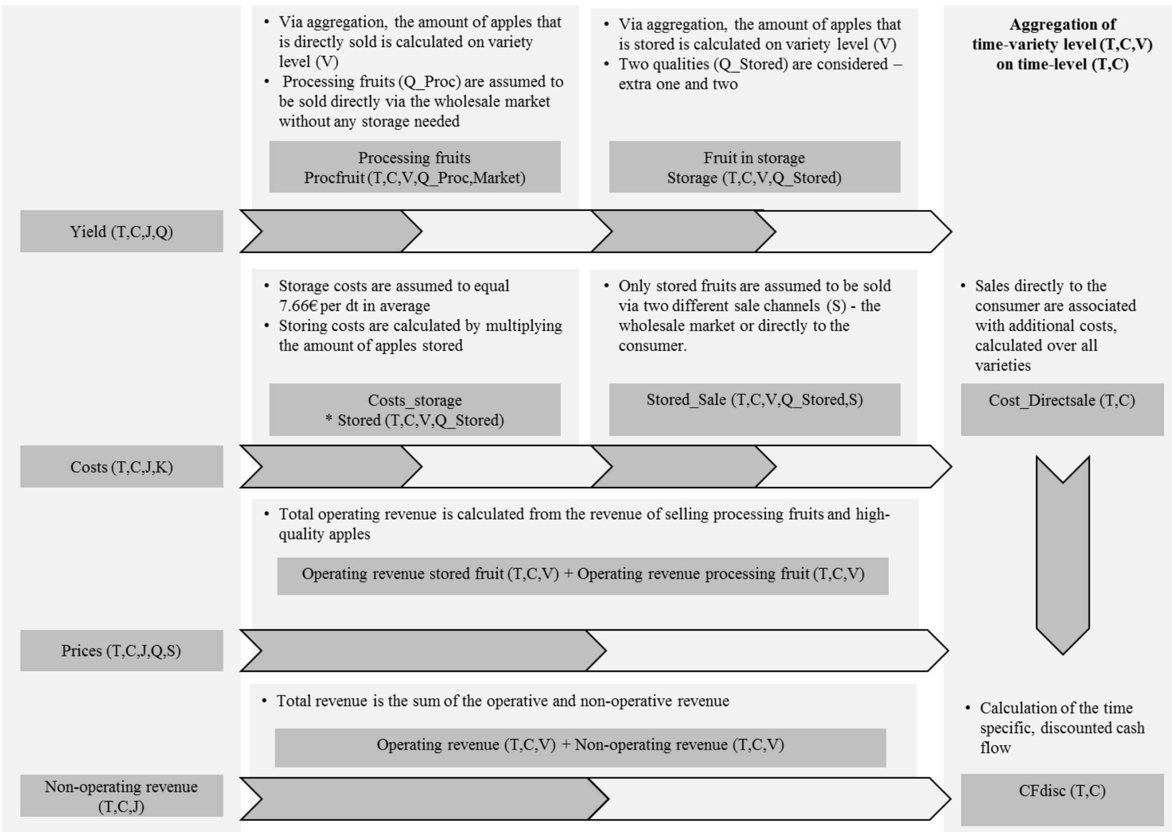

Figure 1. Model structure. T, years 0-20; 100 drawings C, J, variety plus RMI; V, variety independent of RMI; Q quality, Q_stored, high quality apples which are stored; Q_Proc, apples serving as processing fruits; S sale channel; Market, sale via wholesale market; K, costs (incorporates direct, additive and variable costs).

Eighteen different activities per region are defined in the UEP-Model. When insuring apple against hail, insurers generally require that the complete pome fruit area is covered. As a consequence, two separate scenarios per region were calculated - with and without insurance schemes. Insurance premiums (IP), applicable to all varieties per region, were implemented as fair premiums i.e. that calculated indemnity payments equals insurance costs. In order to consider transaction costs, additional costs of 30% of the fair premium were added.

Indemnity payments regarding hail damages are calculated as total loss ratio from hail (*TLRH*) and represent both, quantitative yield losses (*QYL*) as well as quality-related yield losses (*QRYL*) due to hail (Eq. 5). As the juvenile phase of the orchard, i.e. the initial three years after planting, is considered as a deterministic component, the average standard yield was calculated for the time period of years four to twenty.

$$TLRH_a = \left[(QYL_a + QRYL_a) * \left[\frac{1}{16} * (\textstyle\sum_{a=4}^{20} Y_a \ * \ (1 - FYR_a))\right]^{-1}\right] * 100 \qquad (5)$$

Where

Y_a = Yield for each year 4- 20

FYR_a = Frost-related yield loss, which usually occur before damages due to hail

QYL = Quantitative yield losses

QRYL = Quality-related yield losses

Similarly, parameters regarding frost insurance were calculated. However, for frost only yield related damages are considered and as current insurance schemes for combined hail-frost insurances suggest, no deductibles for frost are calculated. For indemnity calculation, the sum insured equals the calculated sum insured for hail and indemnities for frost damages are subtracted from the total sum insured before hail indemnities are calculated (for a more detailed description of the calculations, please refer to (Röhrig *et al.* 2018).

For the north the activities included in the model can be characterized as follows.

(1) Variety Boskoop with 3300 trees per hectare and IFP.
(2) Variety Braeburn with 3300 trees per hectare and IFP.
(3) Variety Elstar with 3300 trees per hectare and IFP.
(4) Variety Holsteiner Cox with 3300 trees per hectare and IFP.
(5) Variety Jonagored with 3300 trees per hectare and IFP.
(6) Variety Red Prince with 3300 trees per hectare and IFP.

Activities 1-6 are further implemented in combination with subsidized HI (10% of the sum ensured equals the insurance premium) (Activities 7-12) and subsidized FI sub & HI sub (7% premium for frost and 10% premium for hail), which provides an alternative to IFP (Activities 13-18).

For the south following sets are considered.

(1) Variety Boskoop with 3500 trees per hectare and HN (grey).
(2) Variety Braeburn with 3500 trees per hectare and HN (grey).
(3) Variety Elstar with 3500 trees per hectare and HN (grey).
(4) Variety Gala with 3500 trees per hectare and HN (grey).
(5) Variety Jonagold with 3500 trees per hectare and HN (grey).
(6) Variety Jonagored with 3500 trees per hectare and HN (grey).

Similarly to the north the scenarios of the south were also calculated for a subsidized HI (21% insurance premium) and subsidized FI sub & HI sub (2% premium for frost and 21% premium for hail). As subsidies cover up to 50% of installation of HN and insurance premium costs, following assumptions were made: In the south the material for hail nets and insurance premiums are subsidized by 50%, up to an absolute ceiling of 12,000 €/ha for hail nets. In the north, the calculation is based on a multiplication of the sum insured with a distribution factor. This distribution factor represents 1% of the marketed production and claim settlements, divided by the sum insured over all enterprises. Subsidies may not exceed the costs of the insurance premium and the sum insured is limited to 20,000 €/ha. It is assumed that the installation of frost irrigation systems is not eligible for subsidies.

Unsubsidized insurances are not considered in this work as subsidized schemes are available in both regions. Furthermore, the work of Röhrig *et al.* (2018) has shown that unsubsidized hail insurance in combination with frost irrigation in the north, provides only slightly higher benefits than frost irrigation alone, given a high level of risk aversion. In the south unsubsidized hail insurance generally results in lower utilities when compared to hail nets (Röhrig *et al.* 2018), representing only an alternative if hail nets are not permitted. Thus, we expect unsubsidized insurance solutions not to be part of an optimal farm plan when subsidized ones are available. A separate frost insurance was not integrated either, as even the combination of a multi-peril frost-hail insurance has not achieved the utility of frost irrigation as single risk management tool, considering the production of high-yielding varieties on an area of one hectare (Röhrig *et al.* 2018). In addition, comparable, multi-peril insurance schemes for securing against frost and hail damages are available for instance in Austria, where insurances refer to the same sum insured for hail and frost damages.

Labor and cash resources are not limited in the model because liquidity can be managed by formal credits at reasonable costs and fruit farms generally are creditworthy. Besides this assumption, apple growers have access to labor and thus the question of manpower during work peaks is not addressed (cf. Dorward, 1999; Janssen and van Ittersum, 2007).

4 Generating Input Data for utility efficient risk programming

The next section provides details on weather-related risks and region specific risk management strategies. In the following two sections, the elicitation of risk perception as well as the implementation of stochastic dependencies and stochastic simulation of probability distributions is described, from which input data for the model were generated.

Apple production in Germany mainly concentrates on two production regions, namely "Altes Land", which is situated in the northern part, near the river mouth of the Elbe and the area of Lake Constance, located 900 km towards south, close to the Alps. Climatic conditions promote the occurrence of different risks causing yield and quality reductions of apple. Late frosts frequently cause yield loss in the north, but also damages due to hail. Considering the past ten production years, data of the survey show that 63.2% of the apple growers in the south suffered from yield losses due to hail and 48.5% in the north. For late frosts 54.4% of the southern apple growers reported associated yield losses and 66.7% of the northern farmers. Besides these major weather-related risks, sunburn may cause quality reductions. In this context, HN are not suited for the production of high quality apple in the north, as light absorption reduces the fruit coloring. Thus, apple growers in the north can only choose hail insurance to hedge against hail-related risks. In contrast, IFP allows mitigating late frosts as well as sunburn, which makes IFP a mandatory instrument in the north. In the south hail is seen as a predominant source of risk and HN are mainly installed for securing against severe yield and quality reductions. Dark-colored HN protect apples from sunburn due to UV absorption as a side-effect.

For assessing these region specific sources of risk, farmers' risk attitude and perceptions were elicited in winter 2013/2014. Apple growers were first contacted by local extension and research stations, which sent invitation letters or a call for participation, disclosed in the newsletter of the producer organizations. Finally, surveys with 66 apple growers in the north and 68 in the south were conducted via face-to-face interviews lasting for about two hours.

Capturing future uncertainty in apple production requires an ample set of data on parameters like yield, price, quality and losses. For eliciting farmers' perceptions of yield risk, the estimation of probabilities based on the experience technique was applied, which only requires solely the minimum, maximum and modal value of the relevant parameter (Hoag 2010, pp. 212–213). However, the pretest revealed that farmers were uncomfortable applying this technique for the areas of specific yield losses and apple prices. Thus, according to the approach of Menapace *et al.* (2013), these parameters were determined by applying a modified fixed value method based on the strength of conviction technique, which means that farmers are not asked to state probabilities, directly (Senkondo 2000, pp. 31-32). Before apple growers were asked to make their estimates for future events, they were requested to recall the frequency of different events, occurring during the past 10 years, in order to obtain less biased input data. Afterwards, apple growers' were asked to state their expectations for the upcoming production years by allocating ten years to intervals, which contain values that represented losses and prices. Finally, these absolute frequencies were converted into relative ones (cf. Röhrig *et al*. 2018). An example is given in Figure 2.

Please state the number of years in which yield losses occurred due to frost events by focusing on the last ten years:
____ No. of years

Your expectation for the next ten years: How often will frost lead to the following losses (%). Please allocate ten years to the given intervals:

Loss due to frost (%)	**Absolute (estimation)**	**Relative (calculated)**
0%	9	0.9
1-4%		
5-9%		
10-19%		
20-29%	1	0.1
30-39%		
40-49%		
50-59%		
60-69%		
70-79%		
80-89%		
90-100%		

If your expectation is based on the existence of frost irrigation, which losses would you expect under the absence of frost irrigation?

Loss due to frost (%)	**Absolute (estimation)**	**Relative (calculated)**
0%	8	0.8
1-4%		
5-9%		
10-19%		
20-29%		
30-39%	1	0.1
40-49%		
50-59%	1	0.1
60-69%		
70-79%		
80-89%		
90-100%		

Figure 2. Application of the modified fixed value method related to the survey design.

Apple variety specific distributions of quality, weather related losses and prices were constructed, using the midpoints of the given intervals and the calculated, relative frequencies. A correlation structure, considering intra- and intertemporal dependencies of yield and prices related to different varieties, has been implemented via the historical data approach, which combines elicited yield and price distributions with historical data (Hardaker *et al.* 2004, pp. 80-82). Historical price data were used from ZMP and AMI (ZMP (1998: 77-79), ZMP (2002: 68-69), ZMP (2006: 25-27) and AMI (2013: 74-76)). Furthermore, price data was corrected for inflation, applying the consumer price indices of the year 2010, provided by the Federal Statistical Office

(2014). Yield data were obtained from the statistical office of the federal state (Landesamt für Statistik Niedersachsen, 2017). Afterwards, MS EXCEL allows deriving distributions of parameters for cash flow calculations by applying the Palisade add-in @Risk for Latin Hypercube simulation.

5 Results and Discussion

Apple growers have to face weather-related risks throughout their daily business. Thus, a whole-farm model based on UEP was developed in order to assess the effects of different RMI. The perceived yield losses related to frost in the north and hail in the south with and without on-farm risk management tools are displayed in Figures 3 and 4.

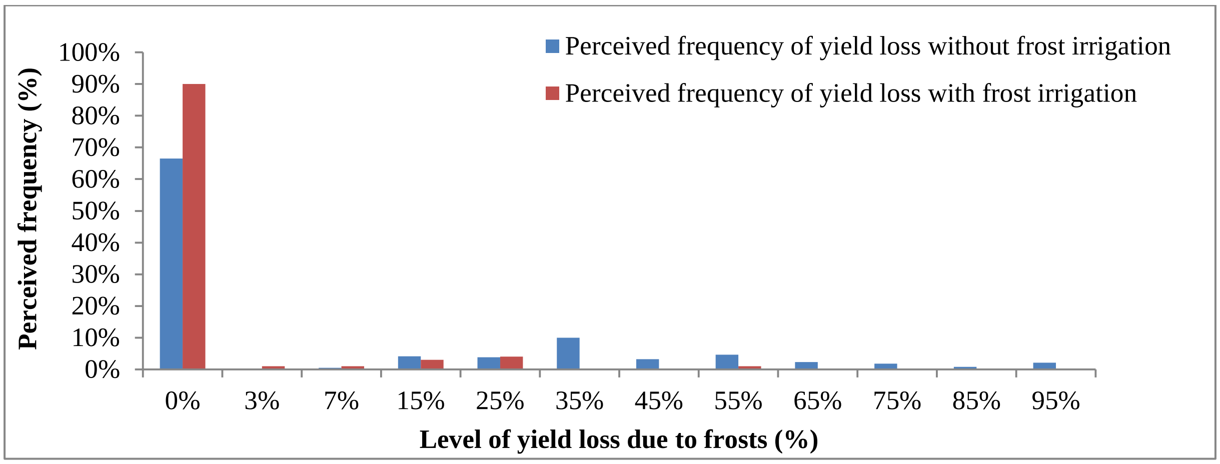

Figure 3. Perceived yield loss due to frosts (north).

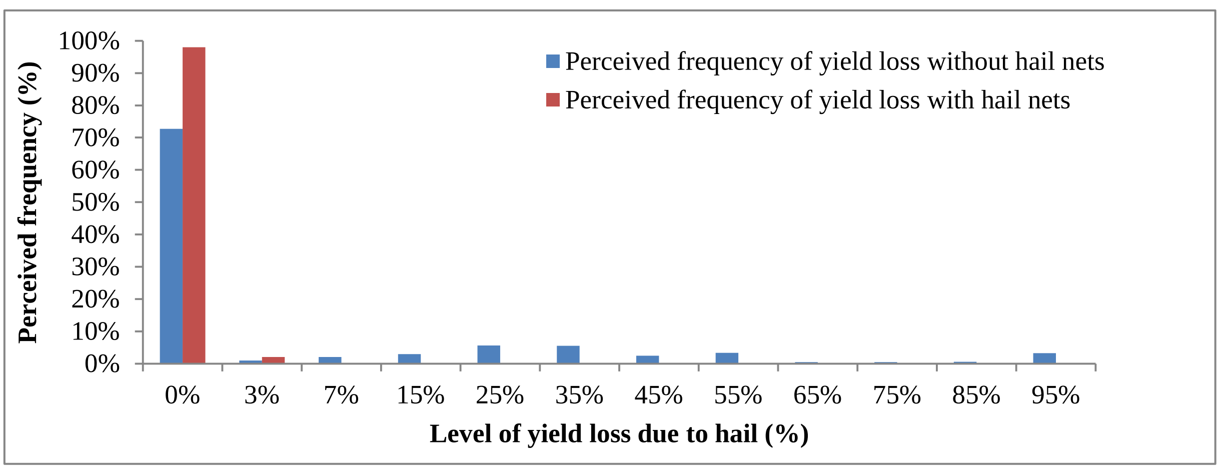

Figure 4. Perceived yield loss due to hail (south).

Table 2 provides an example of the results of the simulation model for a Red Prince scenario with frost irrigation and subsidized hail insurance for the north. It shows the calculated mean, the standard deviation (Stdv), the coefficient of variance (CV), as well as the 5% ($Q_{.05}$) and 95% ($Q_{.95}$) percentiles and the associated Minimum (Min) and Maximum (Max) in decitonnes (dt) or on hectare-level (ha). In case of a subsidized hail insurance, the sum insured may not exceed 20,000 €/ha in the north, otherwise subsidies are not paid out. For Red Prince, simulated with 3300 trees per hectare, the value of 20,000 €/ha is restrictive and represents the maximum.

Table 2. Variety specific data for Red Prince IFP & HI sub obtained for apple production in the north.

		Mean	Stdev	CV	$Q_{.05}$	$Q_{.95}$	Min	Max
Deterministic costs	€/ha	4603.92	0.00	0.00	4603.92	4603.92	4603.92	4603.92
Variable costs	€/ha	4494.39	735.97	0.16	2951.56	5466.56	1167.38	5466.56
Fixed cost	€/ha	3965.53	500.01	0.13	3014.11	4696.66	1938.45	4925.67
Total yield	dt/ha	575.61	123.28	0.21	317.18	738.45	18.32	738.45
Classes extra and one	dt/ha	442.92	144.87	0.33	171.57	651.22	3.14	719.99
Class two	dt/ha	26.50	35.24	1.33	0.00	101.89	0.00	165.60
Processing fruit	dt/ha	106.19	112.96	1.06	13.27	324.33	0.58	705.85
Market price processing fruit (current year)	€/dt	11.38	3.92	0.34	5.24	19.35	5.24	19.35
Market price classes extra and one (stored)	€/dt	48.02	8.46	0.18	33.79	61.20	33.79	61.20
Market price class two (stored)	€/dt	31.98	9.84	0.31	17.30	53.28	17.30	53.28
Farmer to consumer price classes extra and one (stored)	€/dt	185.52	29.37	0.16	136.10	231.28	136.10	231.28
Farmer to consumer price class two (stored)	€/dt	86.81	22.51	0.26	53.21	135.54	53.21	135.54
Sum insured	€/ha	20000.00	0.00	0.00	20000.00	20000.00	20000.00	20000.00
Indemnity payments hail	€/ha	1980.44	3401.74	1.72	0.00	9707.88	0.00	20000.00
Insurance premium hail	€/ha	2000.00	0.00	0.00	2000.00	2000.00	2000.00	2000.00
Indemnity payments frosts	€/ha	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Insurance premium frosts	€/ha	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Hail insurance costs	€/ha	2600.00	0.00	0.00	2600.00	2600.00	2600.00	2600.00
Frost insurance costs €/ha)	€/ha	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Subsidies hail insurance	€/ha	848.71	0.00	0.00	848.71	848.71	848.71	848.71
Subsidies frost insurance	€/ha	0.00	0.00	0.00	0.00	0.00	0.00	0.00

The variety specific portfolio for apple production in the north with IFP as single RMI is displayed in Figure 5. As can be observed, the variety Red Prince covers the largest portion of the entire portfolio. With respect to *r* near zero, the other varieties are included with solely at the minimum level of 1ha required by the market portfolio restriction, whereas Red Prince should be produced on an area of 15 ha. At a risk aversion coefficient *r* = 0.6, diversification starts with increasing shares of Braeburn and Holsteiner Cox (see Figure 5). In this context, the varieties Braeburn and Holsteiner Cox substitute Red Prince, as they show the lowest coefficient of variation (CV) and allow for the highest mean NPV after Red Prince (see Table 3). Furthermore, diversification declines when high levels of risk aversion are reached. Based on its mean NPV, Jonagored would be the next best option, but the CV of Jonagored is higher than those of the other favored varieties, which explains the stagnation of diversification for higher degrees of risk aversion (see Figure 5).

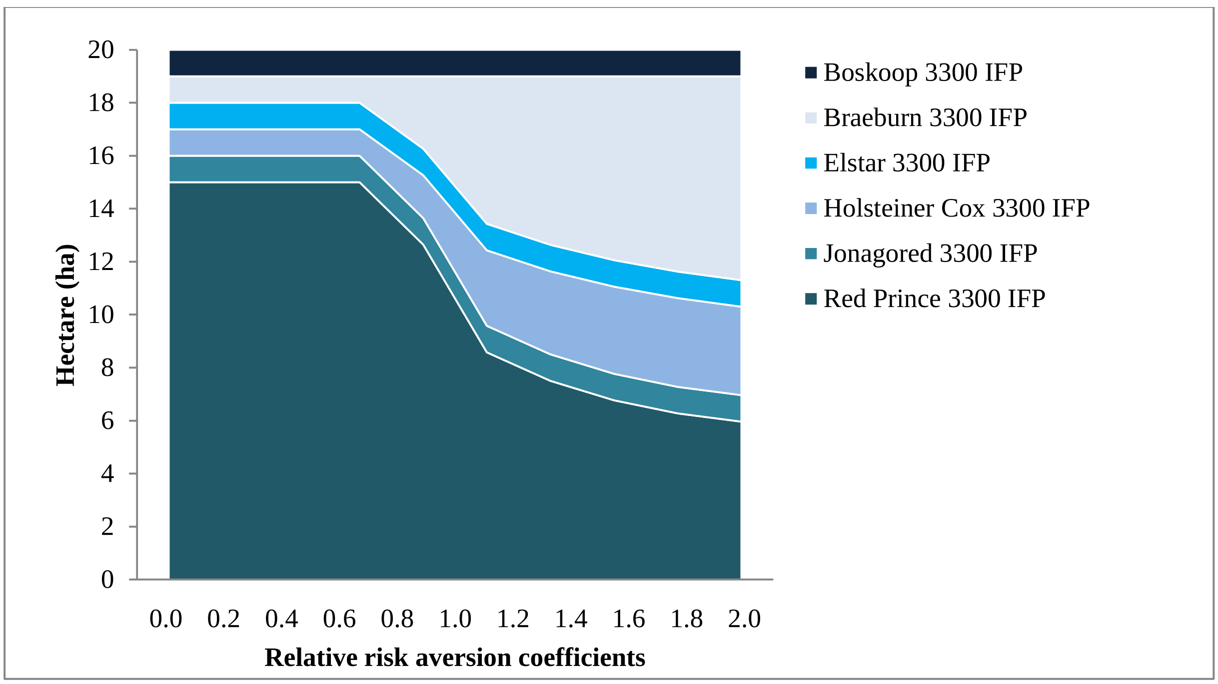

Figure 5. North **-** results for IFP as RMI and a 4% discount rate as discounting factor.

Table 3. Variety specific data – NPV[1] per ha (4% discount rate as discounting factor) for apple production in the north, obtained with linear programming (Solver CPLEX).

	NPV Mean	NPV Stdev	CV
Boskoop IFP	39	52	1.32
Braeburn IFP	113	75	0.67
Elstar IFP	75	60	0.80
Holsteiner Cox IFP	115	73	0.64
Jonagored IFP	87	94	1.08
Red Prince IFP	120	87	0.73
Boskoop IFP & HI sub	39	46	1.17
Braeburn IFP & HI sub	114	54	0.48
Elstar IFP & HI sub	76	51	0.68
Holsteiner Cox IFP & HI sub	114	55	0.48
Jonagored IFP & HI sub	88	88	1.00
Red Prince IFP & HI sub	121	74	0.61
Boskoop FI sub & HI sub	42	44	1.04
Braeburn FI sub & HI sub	110	51	0.46
Elstar FI sub & HI sub	74	55	0.74
Holsteiner Cox FI sub & HI sub	109	53	0.49
Jonagored FI sub & HI sub	84	84	1.00
Red Prince FI sub & HI sub	112	70	0.62

[1] NPV in 1,000€.

A comparison of insurance-based risk management strategies, applied as a combination of IFP and subsidized hail insurance (IFP & HI sub) as well as a combined frost-hail insurance (FI sub & HI sub) is given in Figure 6. The question arises, whether a permanent payment against frost damage is worthwhile if the availability of goods is endangered due to the absence of frost irrigation. Obviously, the appropriateness of FI sub & HI sub increases with the individual's degree of risk aversion, but a combination of IFP & HI sub still remains the dominant risk management strategy. Even the proportion of FI sub & HI sub is smaller than those of IFP & HI sub, this RMI seems to be the appropriate tool for diversification, given that revenues are not significantly reduced due to the absence of IFP. In the model this is specifically the case for Elstar and Boskoop, both varieties show an increased tendency for alternate bearing and thus lower average yield levels (e.g. Winter, 2002, pp. 100-101). For these varieties the revenue loss under abandonment of IFP is smaller than for the high yielding varieties like Red Prince and Holsteiner Cox, which are also attaining high prices. In this context, Braeburn shows a moderate yield level but relatively high prices, whereas Jonagored is a high yielding variety but prices, especially those for the class extra and one, are below those of Red Prince and Holsteiner Cox. This explains why Braeburn and Jonagored with FI sub & HI sub as RMI become part of the portfolio when higher *r* are considered. These findings support the idea to provide a subsidized FI sub & HI sub in Germany as an appropriate RMI. Especially for low yielding varieties or those sold at lower prices, the absence of IFP can be compensated through indemnity and subsidy payments of the FI sub & HI sub. This option might be interesting, in particular for apple growers who do not have access to water springs like the river Elbe to obtain water for IFP.

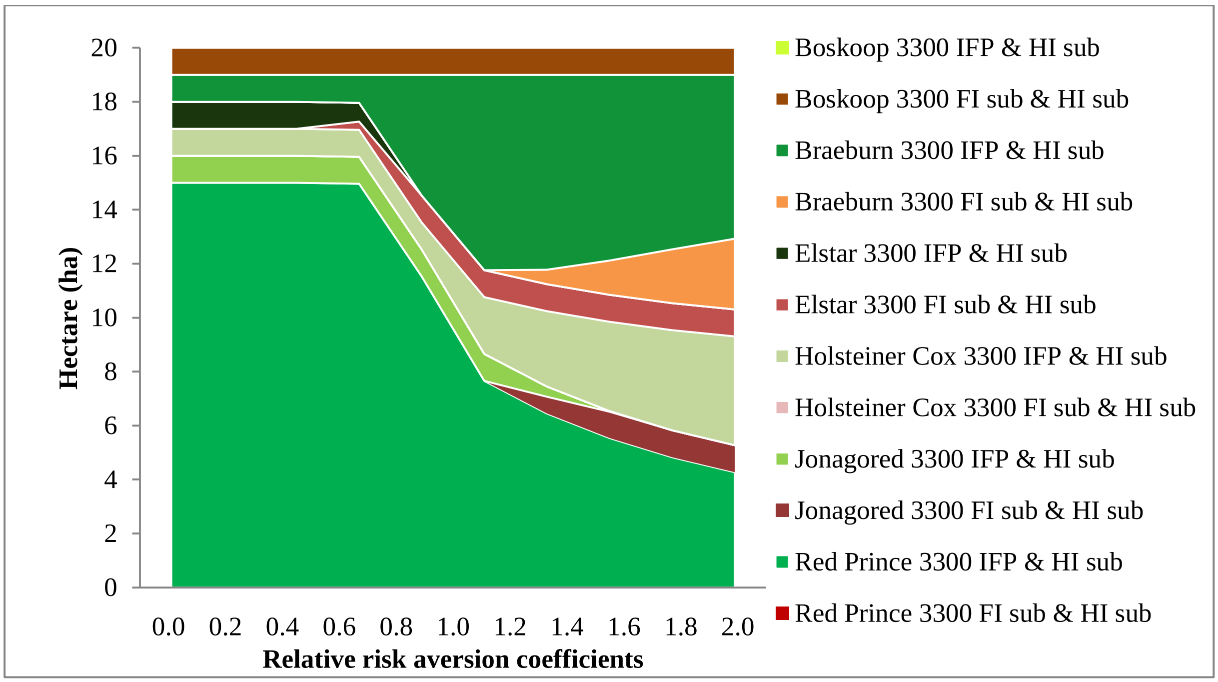

Figure 6. North- results for FI sub & HI sub as well as IFP & HI sub as RMI and a 4% discount rate as discounting factor.

As increasing discounting rates lead to the reduction of variance (Lien *et al.* 2007), additional simulations were performed for discount rates of 6% and 8% in order to capture the effects on the optimal whole farm plan. By increasing discount rates, diversification effects occur at higher levels of risk aversion. For IFP as single RMI, the substitution of Red Prince begins at higher *r*, which holds also for the insurance scenario (cf. Figures 5,6,7,8). However, the influence on the portfolio's composition is negligible. As observed for a discount rate of 4%, the differentiation of the portfolio declines for high *r*. Regarding the highest *r* applied, all scenarios equally show that Red Prince is included with only about one third of the area, compared to the area which should be cultivated by a risk neutral apple grower, characterized by *r* of 0.

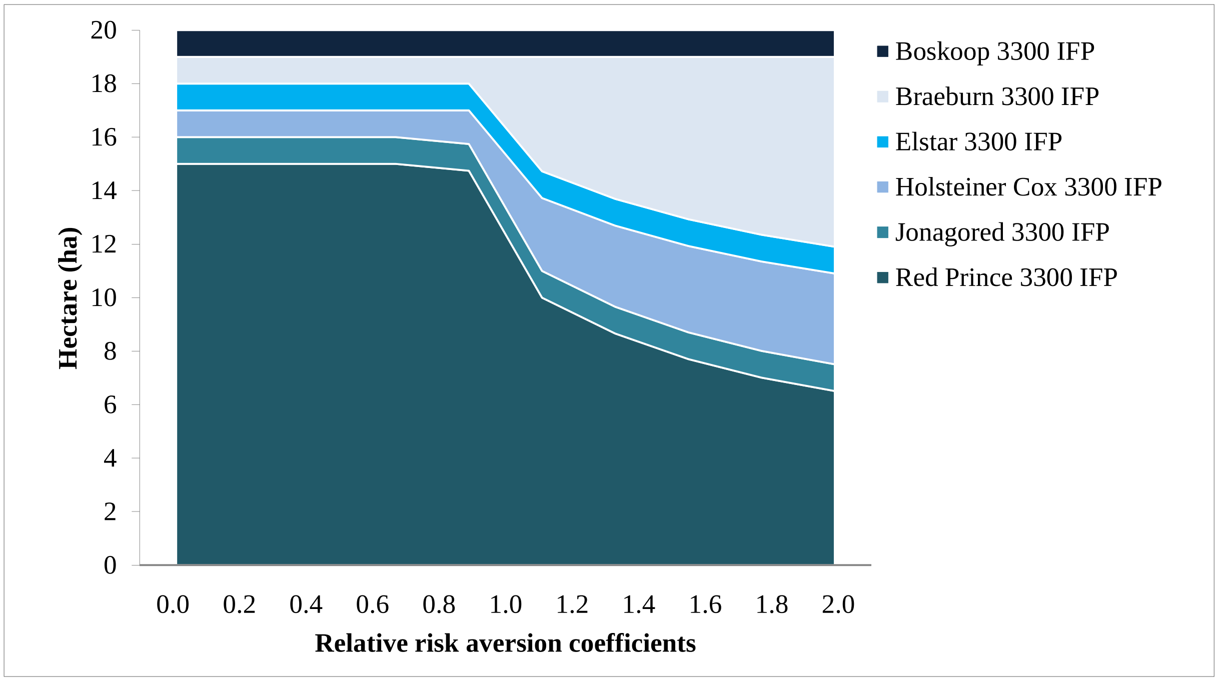

Figure 7. North- results for IFP as RMI and an 8% discount rate as discounting factor.

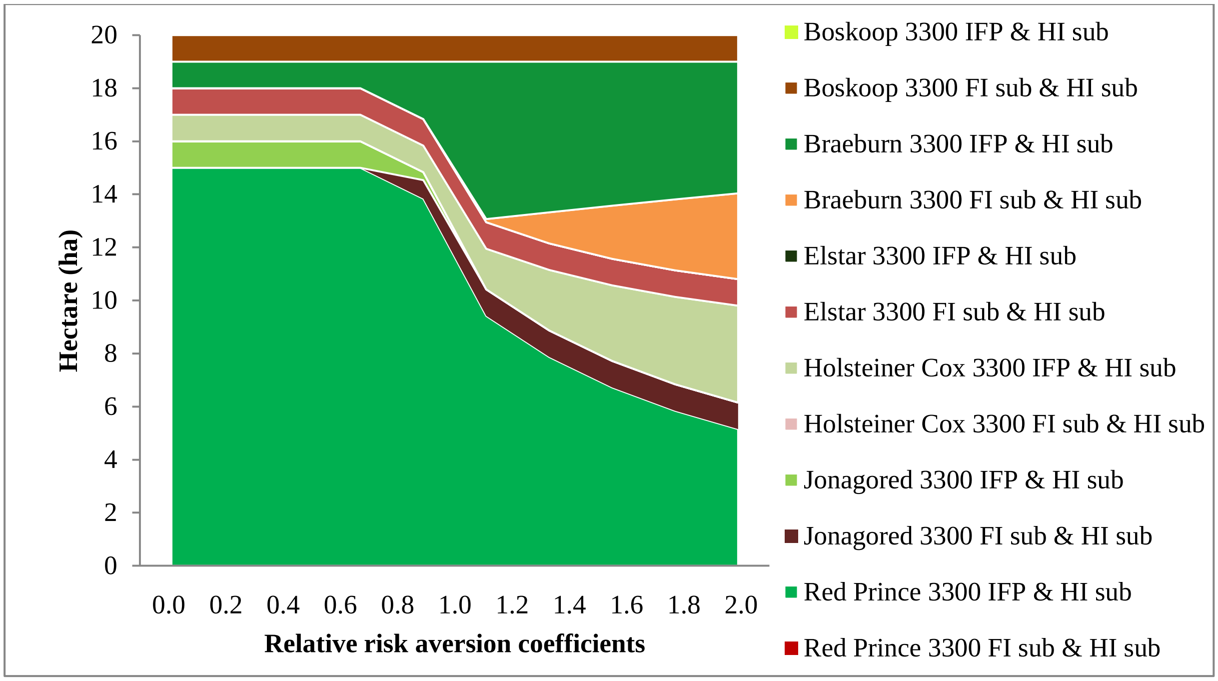

Figure 8. North- results for FI sub & HI sub as well as IFP & HI sub as RMI and a 8% discount rate as discounting factor.

The CEs of the north concerning the basic scenario with frost irrigation and the insurance scenario are given in Figure 9. As theoretically expected, the CEs are decreasing with increasing *r* due to the enhanced concavity of the associated utility functions. Furthermore, higher discounting rates generally lead to lower CEs. As can be seen in Figure 9, the CEs related to the insurance-based portfolio, indicated by the dashed lines, descent not as strong as those of the IFP scenario. This implies that a combination of traditional IFP with insurance solutions generally results in higher expected utilities. Since the CEs of the whole planning period are comparable to NPVs, annuities, directly derived from the CEs, can be seen as the expected cash flow per year. The analysis further indicates that insurance solutions may lead to higher annuities in the north, even if only slight risk aversion is assumed (see Figure 10). Thus, indemnity payments and subsidies offset additional costs of insurance participation.

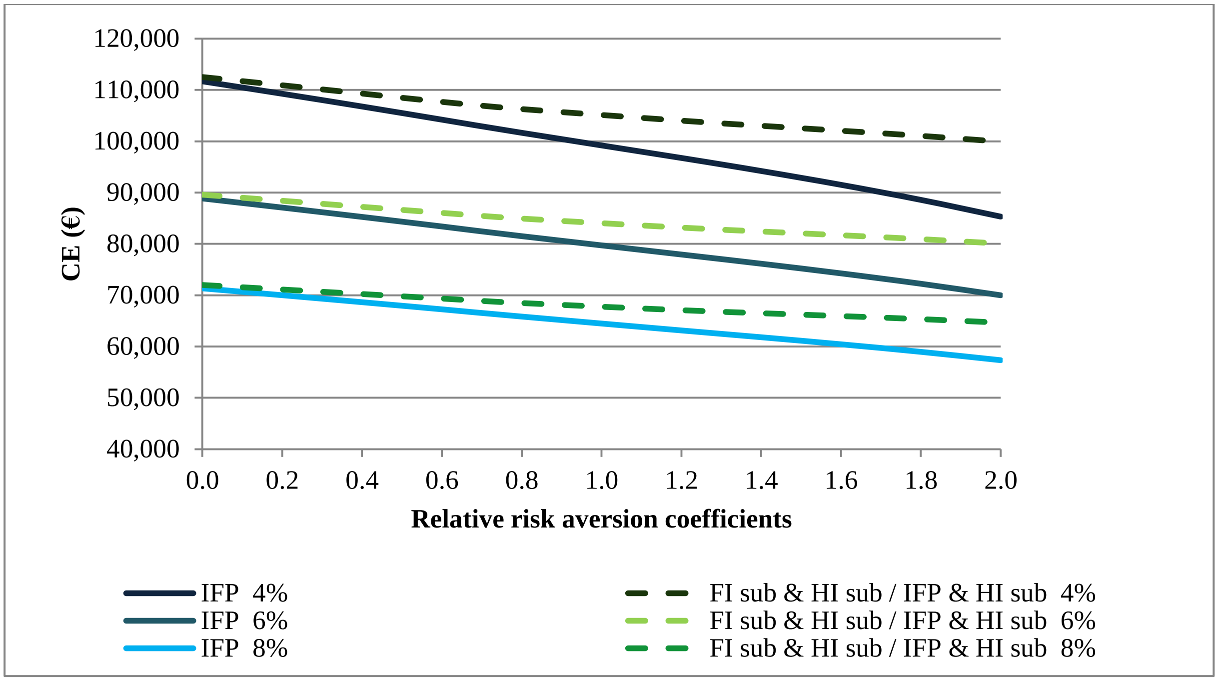

Figure 9. North - Certainty equivalents (CEs) of the portfolios IFP and FI sub & HI sub / IFP & HI sub as RMI.

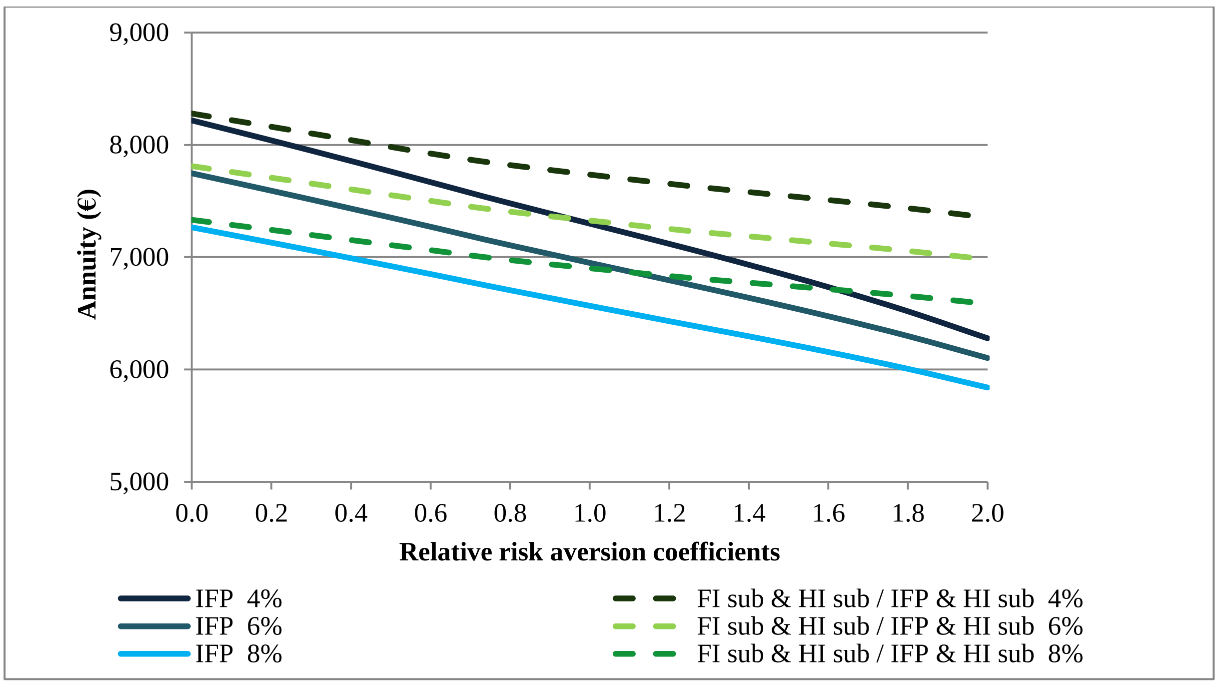

Figure 10. North - Annuities of the portfolios IFP and FI sub & HI sub / IFP & HI sub as RMI.

Similar results were obtained for apple production in the south, usually realized with HN as risk management strategy, revealing a non-relevant effect of the discounting rate. Contrary to the result obtained for the north, higher risk aversion nearly has no impact on the portfolio composition in the south and only minor diversification activities are observed (see Figure 11). Braeburn represents the most favorable variety with an area of 10ha for all *r* with only slight differences. These observations made for the south are in line with the results obtained by Lien and Hardaker (2001), who found nearly no changes in optimal farm plans when applying relative risk aversion *r* in the range of 0.5 to 4. As indicated in Table 4, this variety provides the lowest CV as well as the highest mean NPV, which explains its dominance within the calculated portfolio. Nevertheless, under consideration of a high risk aversion of *r* =1.6 and above, Braeburn is substituted by Jonagold, which is characterized by a high NPV but a moderate CV (see Table 4). Portfolios obtained for insurance solutions as an alternative for HN in the south revealing that FI sub & HI sub is the preferred insurance concept (Figure 12).

Table 4. Variety specific data on the NPV (per ha) (4% discount rate as discounting factor) obtained for apple production in the south, obtained with linear programming (Solver CPLEX).

	NPV Mean	NPV Stdev	CV
Boskoop HN	11	25	2.30
Braeburn HN	54	59	1.09
Elstar HN	19	55	2.92
Gala HN	31	45	1.47
Jonagold HN	49	74	1.53
Jonagored HN	31	56	1.81
Boskoop HI sub	2	26	11.46
Braeburn HI sub	37	46	1.24
Elstar HI sub	10	44	4.43
Gala HI sub	22	38	1.76
Jonagold HI sub	35	61	1.74
Jonagored HI sub	21	45	2.16
Boskoop FI sub & HI sub	3	25	9.45
Braeburn FI sub & HI sub	38	45	1.19
Elstar FI sub & HI sub	10	41	3.95
Gala FI sub & HI sub	22	37	1.67
Jonagold FI sub & HI sub	35	57	1.62
Jonagored FI sub & HI sub	22	42	1.95

[1] NPV in 1,000€.

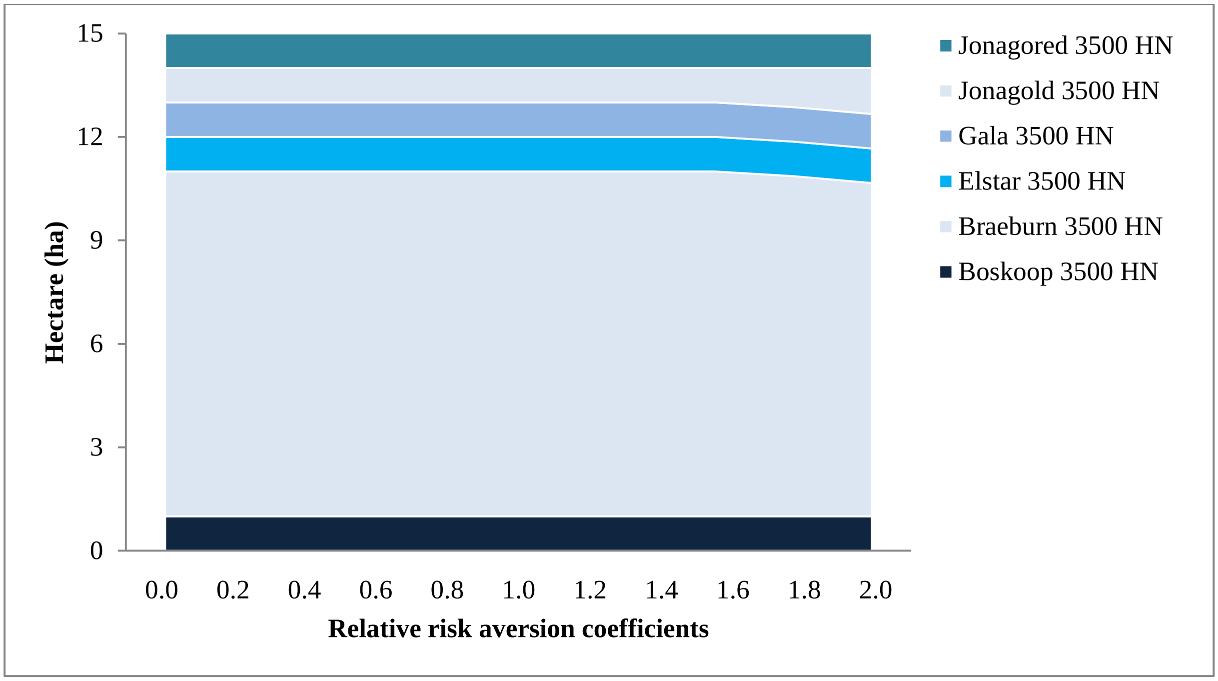

Figure 11. South - results for HN as RMI and a 4% discount rate as discounting factor.

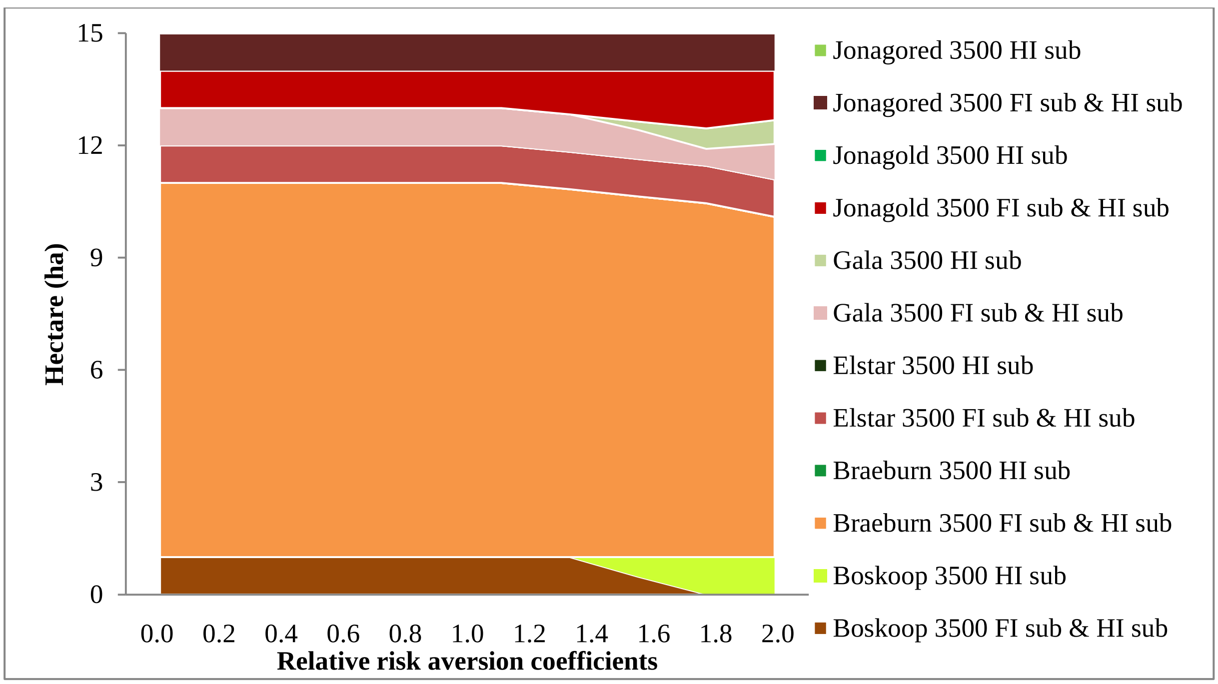

Figure 12. South - results for FI sub & HI sub as well as HI sub as RMI and a 4% discount rate as discounting factor.

Figure 13 depicts the related CEs obtained for the south. Generally the CEs and annuities of the south are only half the size of those calculated for the north. The reason for this deviation can be found when comparing yield and price estimates. In the south apple growers stated lower yields per hectare as well as lower prices regarding direct sale activities. With respect to yield, an overestimation of yield risks might be a source of these divergences. In this context, Menapace *et al.* (2014) find that farmers, who experienced specific risks during the preceding years, show a significant increase in stated probabilities associated with future risks. In total 28.8% of the northern apple growers in the survey indicated that the enterprise was severely or more than severely affected due to hail, whereas 48.5% of the apple growers in the south stated that hail caused serious losses in the past. Thus, bias occurring due to events of the past might be a reasonable explanation. Comparable to the north, the CEs also decline with increasing risk aversion and, again, the decrease is smaller for the insurance-based portfolio. This effect arises from a reduction in variance of CEs when considering insurances as RMI. Nevertheless, when focusing on the same discounting rates, the related CEs of the insurance-based portfolio are all located below the ones associated with the HN solution. However, the associated annuities, shown in Figure 14, allow a clearer differentiation. The HN solution is always superior compared to the farming strategy based on insurances. In monetary terms, the absence of HN would result in a monetary loss of 1,000€ per hectare. Similar results are reported in the study of Gandorfer *et al.* (2016), analyzing the hedging efficiency of HN and HI for Bavarian apple orchards in Germany, assuming relative risk aversion ranging from 0-4. When considering hail damage in 6 of 10 years, indicating high hail risk, HN are associated with the highest CEs, independent of the apple growers' degree of relative risk aversion. However, HI becomes more attractive for risk averse apple growers with low initial wealth producing on areas with medium hail risk, i.e. 2 of 10 years with hail damage (Gandorfer *et al.* 2016). Observations in reality supports the plausibility of the results presented in this work, as most of the apple production area in the south is covered with HN.

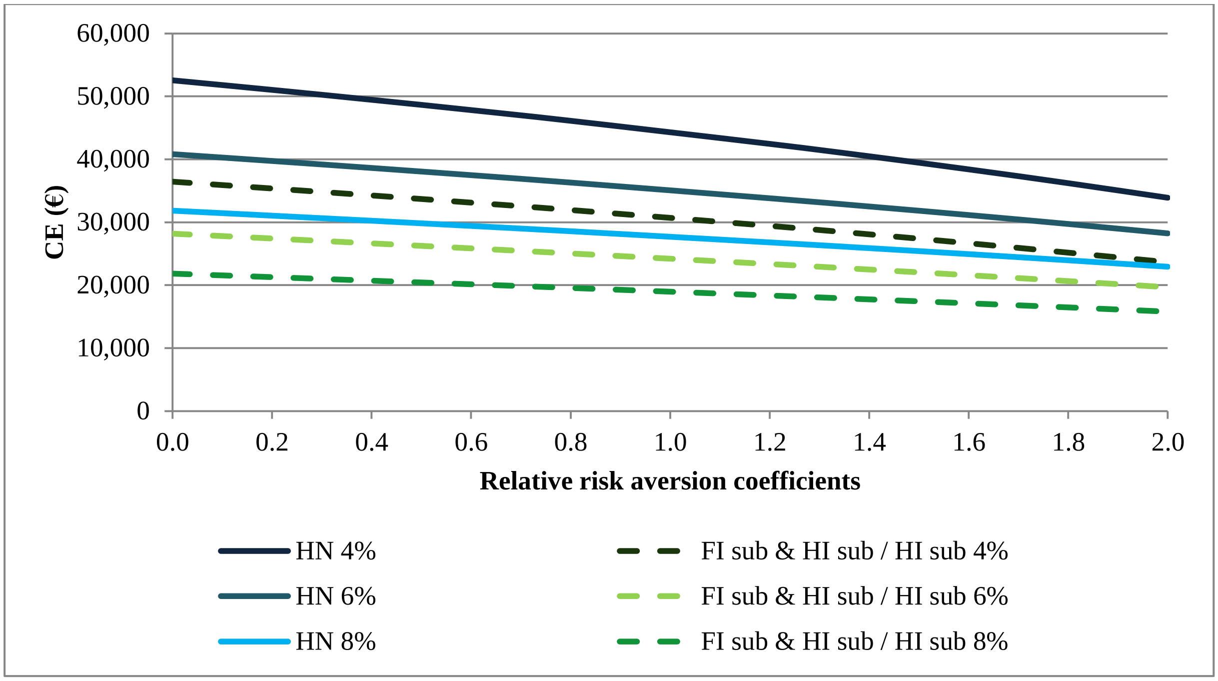

Figure 13. South - Certainty equivalents (CEs) of the portfolios HN and FI sub & HI sub / HI sub as RMI.

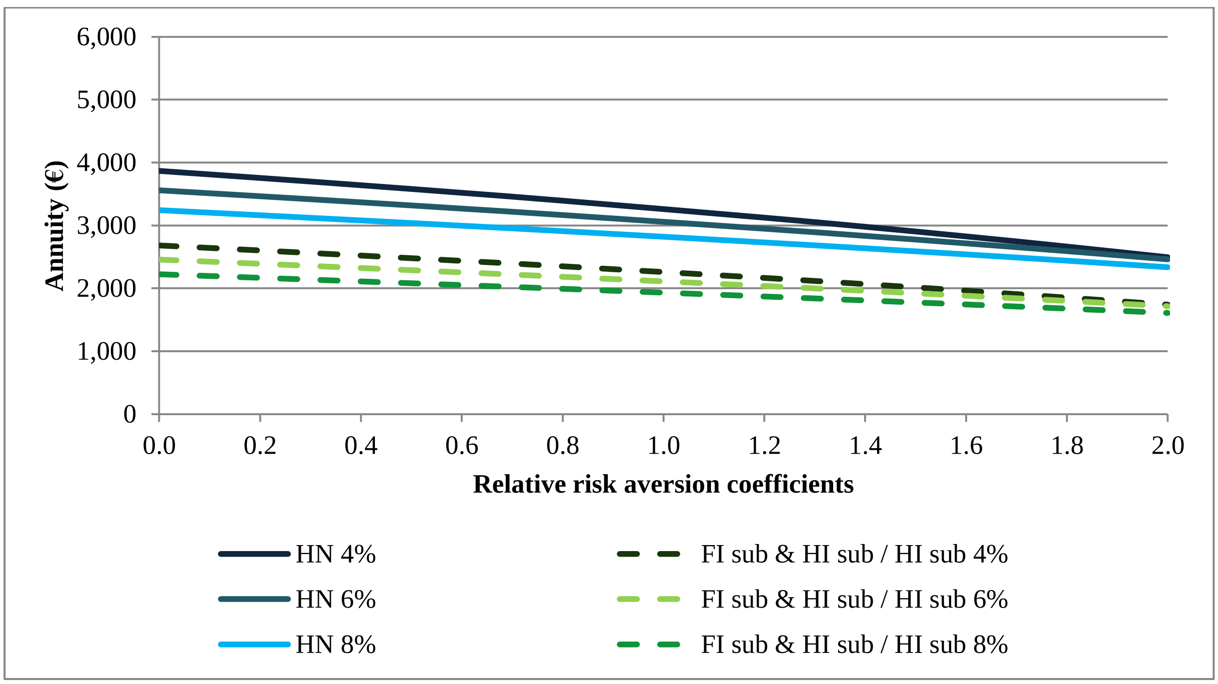

Figure 14. South - Annuities of the portfolios HN and FI sub & HI sub / HI sub as RMI.

Based on the estimates obtained from both regions, Boskoop is the variety with the least favorable characteristics. In this context, stated yields in the north as well as prices of the quality class extra and one are lower than those of Elstar, whereas yield of Boskoop in the south is higher than for Elstar, which results in increased variable and fixed costs. Furthermore, market prices are slightly below those of Elstar. The sum insured is based on market prices, which also influences the amount of insurance costs, indemnity payments and subsidies. As the market prices of Boskoop are low, indemnity payments and subsidies are less compared to those of other varieties. This explains the proportional decline of the mean NPV for Boskoop when switching from HN production to insurance solutions as RMI, which is higher in comparison to other varieties. As the mean NPV of Boskoop is low, the CV calculated for HI and FI sub & HI sub is high (Table 3). Nevertheless, Boskoop together with Gala is the variety, which is included in the portfolio with subsidized hail insurance (see Figure 12). One explanation is that for these two varieties the switch from combined frost-hail insurance to a single hail insurance causes the lowest loss in terms of mean NPV (cf. Table 3).

Several conclusions referring to the conception of apple production risk models can be deduced from this work. Stronger specifications on variety depended distribution strategies, i.e. sale channels, could represent activities more distinctly. With respect to the models restrictions referring to production area, the minimum production of 1 ha per variety may overestimate the target-amount of selling a broad range of varieties direct to the consumers. Here, a fine graduation of absolute amounts of apples directly sold to the consumers would reflect reality more precisely. In this case, volatile amounts of yield under normal production conditions should be modeled via a change constraint programming. However, it is assumed that in reality apple growers calculate with average yield per hectare, conceding this simplification in the present model.

The utility-valuation is made on discounted cash-flow level, which describes variations of wealth better than on a higher aggregated net present value level. However, the UEP approach does not allow an evaluation of liquidity constraints and therefore no conclusions regarding financing activities can be drawn. This work could be advanced by considering additional hazards, for example human or institutional risks, and farming activities, as tree removal and replanting of orchards or other agricultural activities. In addition, further farm specific restrictions may be introduced, as for example pest management and work peaks during harvest.

6 Conclusion

This study addresses the effect of risk attitude on apple growers' production portfolio. Since uncertainty is prevalent in apple production deterministic models are not adequate for determining a long term strategy. To gain insights into the influence of risk attitude on apple growers' production plan, we developed an expected utility model. This model considers different varieties, as well as available risk management instruments (hail nets, hail insurance and irrigation for frost protection) and a hypothetical frost-hail insurance. The calculations are carried out for two different regions of Germany, exposed to different weather related risks, and using three different discount rates. The analysis reveals that the degree of risk aversion shows only marginal effects on the composition of portfolios and is thus not to be assumed as one of the main drivers regarding diversification in apple production. Nevertheless, at high levels of risk aversion, portfolio composition is influenced. If different RMI strategies are available, they however become part of the portfolio, as can be seen from the results we obtained for the northern part. In this context, the concept of combined frost-hail insurance would especially be interesting for low yielding varieties or for those achieving only low prices. With respect to these, revenue losses occurring without overhead irrigation for frost protection are acceptable and the combined frost-hail insurance allows a diversification of the farming strategy. In the south the production under hail nets remains the most favorable production strategy. Losses occurring without hail nets are not completely compensated by indemnity payments and subsidies. However, as long as the current subsidy schemes are paid, insurances can be a rational choice for apple growers, who operating in uneven terrain or who are not allowed to install hail nets.

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V General Discussion

1 Discussion

The dissertation focuses on decision-making under risk in German apple production and aims to derive rational and utility-efficient recommendations for apple variety selection and risk mitigation based on elicited data on apple growers' risk attitudes and risk perception. The first paper deals with the degree of risk aversion of German apple growers, the second paper analyzes efficient combinations of varieties and risk management instruments using stochastic dominance analysis and the third paper addresses the development and application of a whole farm planning model under risk. The following objectives and research questions were examined in the three different papers of the dissertation:

Elicitation of risk attitude of German apple growers (*first objective*)

- *Are German apple growers risk averse?*
- *Do method- and context-dependent variations of the elicitation techniques lead to different results?*
- *Are the results obtained on risk attitudes suitable for predicting observed behavior in the context of risk management?*

Distinguishing between efficient and inefficient combinations of varieties and risk management instruments based on risk perception data (*second objective*)

- *What are the most efficient farming options for defined ranges of relative risk aversion?*
- *Could a hypothetical hail-frost insurance increase the apple growers' welfare?*

Development of a whole farm model under consideration of risks (*third objective*)

- *What are the most efficient sets of combinations of varieties and risk management tools for rational and risk averse decision makers*
- *Does the degree of risk aversion influence the composition of the optimal portfolios?*
- *Do different discount rates of long-term investments have an impact on the recommended portfolios?*

1.1 Risk aversion

The elicitation of the risk attitude of apple growers is the subject of the first part. Available literature dealing with the elicitation of farmers risk attitude in developed countries is still scarce. Reynaud and Couture (2012) showed that the results of the elicited risk attitudes of French farmers are susceptible to payoff effects, task effects and that context is a relevant factor to be considered. Similarly, the results of Menapace et al. (2015) reveal a framing and a payoff effect in hypothetical, outcome-scaled Eckel and Grossman (2008) lotteries (hereafter EGL). In addition they found that different measurement instruments are poorly correlated in determining the risk preferences of 98 apple farmers in Trento, Italy. Contrary, Meraner and Finger (2017) found the context-dependent HLL to be significantly correlated to self-assessments and business statements. On the basis of these findings, one general and two domain specific Likert scales as well as a small outcome and context-framed Holt and Laury lottery (HLL) for farm income were used in this thesis to elicit the risk attitudes of apple growers in Germany. Outcome scaled price lists (EGL) were not considered as they contain a certain outcome, which might strengthen the so called certainty effect and tempt persons to choose the sure payment instead of the uncertain option (McCord and de Neufville 1986; Abdellaoui et al. 2011).

In line with the literature, the results of the present work also reveal a task-, framing- and payoff-effect. Both the Likert scales as well as the HLLs show deviating results when obtained for different domains. Furthermore, when comparing the low payoff and farm income HLLs, framing and payoff-effects significantly affect the elicited risk attitudes. However, the results contain several significant correlation coefficients for self-assessments and HLLs, which reinforces the existence of a stable underlying risk trait, initially detected by Dohmen et al. (2011).

Contrary to the expectations, the results provide good reasons to believe that apple growers in developed countries are less risk averse. Referring to the lottery tasks, only the farm income gamble revealed slight risk aversion. Additional information on the average rate of returns supports this assumption. Comparing rates of return for fruit farms to those of other horticultural farms specializing on vegetable or ornamental plant production, fruit farms achieve clearly lower rates of return on average for the period 2010/11 to 2015/16 (see Figure 1) (Zentrum für Betriebswirtschaft im Gartenbau e. V., 2012-2017). This shows that apple producers are used to taking risks, as they invest substantial amounts in fruit orchards with substantially fluctuating return flows without being compensated by a risk premium in terms of higher average rates of return compared to e. g. ornamental production with its more uniform revenues.

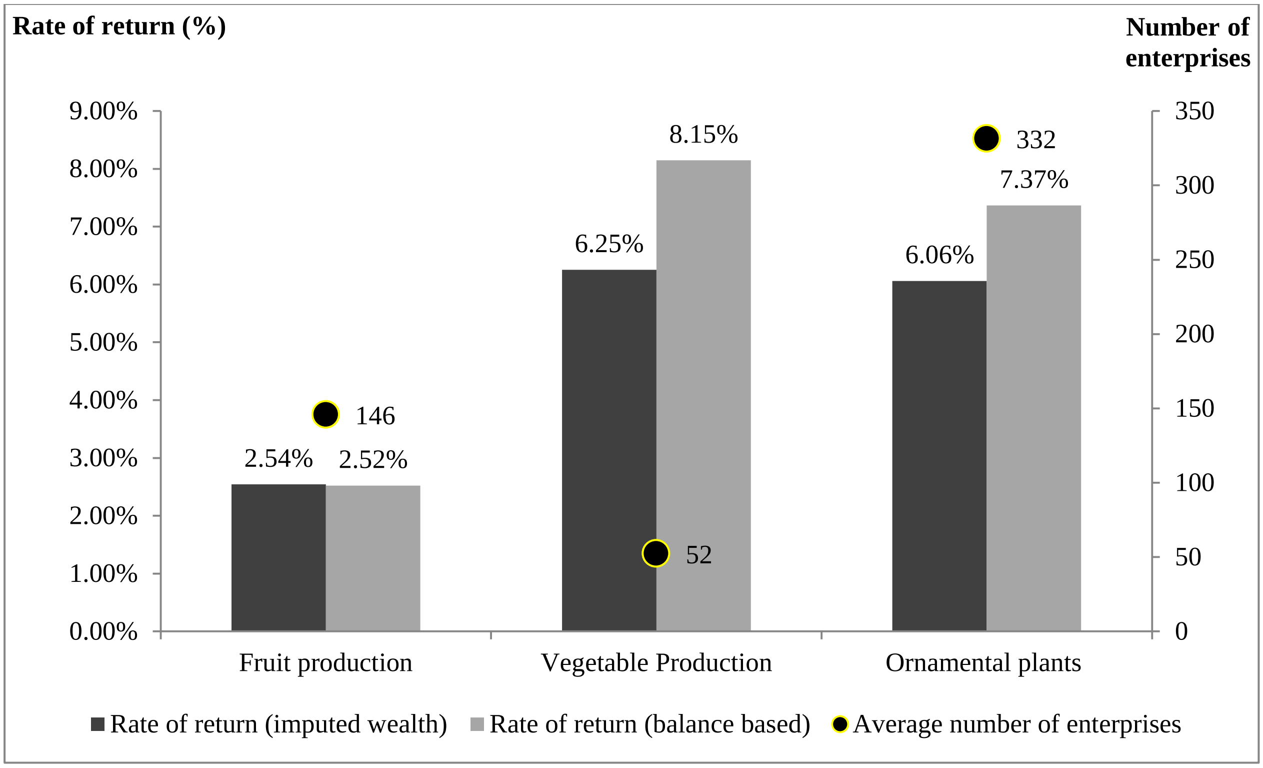

Figure 1. Average rate of returns calculated for different branches of German horticulture (Zentrum für Betriebswirtschaft im Gartenbau e. V., 2012-2017).

Besides framing and payoff effects, the results obtained indicate that HLLs might not be able to sufficiently control for background risk. Similar observations were made by Hellerstein et al. (2013) for an outcome scaled lottery. However, Menapace et al. (2015) successfully derived insights in the behavior in reality from a framed EGL. Thus, further research is needed to investigate whether probability scaled lottery tasks, accounting for framing and payoff effects, are able to control for background risks and in consequence provide insights on real world behavior.

1.2 Risk perception

The second paper refers to the determination of efficient production options in apple production, comprising choices of variety and risk management instruments (RMIs). For this purpose, subjective probability estimates of German apple growers for prices, yield and weather-related losses were elicited and combined with historical data. However, the elicitation of subjective estimates is not a trivial task as risk perception is expected to be domain specific (Meraner and Finger 2017). An appropriate technique can be find in the work of Menapace et al. (2013). To reduce the cognitive burden, they apply a fixed-value-method by asking apple growers to assign previous growing seasons to six intervals of crop value losses before being asked to state their estimates for the upcoming season (Menapace et al. 2013). As this is a reasonable design, the present work tried to follow the approach of Menapace et al. (2013) by applying the estimation of probabilities based on the experience technique, which is a simple question method as it only requires three values, i.e. minimum, maximum and modal value, to create a PERT probability distribution (Hoag, 2010, p. 212-213). However, apple growers showed reluctance to state these values for prices and losses and preferred to answer the questions based on the fixed value method design. Consequently, the fixed value method is a recommendable technique for the elicitation of farmers' subjective estimates, resulting in full-distributions for different contexts.

When comparing the results with the behavior of apple growers in reality, they adequately reflect the observed behavior, since apple growers have already implemented the most optimal risk management instruments, i.e. hail nets in the south and frost irrigation combined with hail insurance in the north. Besides the available risk management instruments, a subsidized, hypothetical multi-peril insurance covering frost and hail would lead to slightly higher net incomes in the south than observed for the subsidized hail insurance alone. Nevertheless, the production under hail nets remains the most efficient strategy as hail nets protect against total loss of harvest and thus ensure the supply of apples as well as the maintenance of trade relations. In the north, a multi-peril insurance is only recommended for very risk-averse apple growers who cultivate apples extensively.

1.3 Decision support model

The third paper combines all information to create a utility efficient, whole-farm programming model that is used to determine optimal farming strategies. The model is developed on the basis of historical price and yield data as well as the risk perception and risk attitude of apple growers, obtained from the survey, and takes technical and market restrictions into account. The simulated discounted cash flow per year serves for the calculation of the expected utility, for 100 different draws. Finally, the associated certainty equivalents per year were summed up to a total certainty equivalent, which represents the criterion to be maximized. Since risks arise over the years and the associated consequences add up over time, the cumulative values of the utility-weighted cash flows reflect the real situation better than the utility of net present values in which risk is offset by summation. As the model is formulated for a more general case based on a 15 ha farm in the south and a 20 ha farm in the north, it does not consider the liquidity risk, i.e. that the farm goes bankrupt as a result of a number of consecutive years of failure. The problem in including this aspect is to set a relevant initial liquidity buffer and make assumptions on the access to further loans. Instead, it is assumed that farmers can borrow from banks as long as the apple production is generally profitable. However, for applications to real farm cases, where the liquidity buffer is known, the liquidity risk should be included in the analysis.

In the context of political programs, there is still a need to support the expansion of existing risk management strategies and the development of advanced risk management instruments. Di Falco et al. (2014) analyzed the effect of insurance and crop diversification on revenues of farms in Italy. Their results indicate that both strategies reduce the variance of revenues and show significant positive correlations with the skewness of the revenue distribution. This implies that insurance and crop diversification reduce the risk of revenue losses. Furthermore, they observe that crop diversification may replace insurance participation, as both strategies are negatively correlated (Di Falco et al. 2014).

The results of the whole-farm programming model for German apple production reveal that the degree of diversification is low and remains stable for a wide range of risk aversion coefficients. As expected, higher discount rates lead to a reduction in variance and thus shift diversification to higher risk aversion coefficients. However, the composition of the portfolio remains almost constant. One may conclude that the production of different varieties as risk coping strategy is of minor significance, as apple growers in Germany showed to be less risk averse. When evaluating the benefits of insurance, the consideration of region-specific weather conditions is crucial. In the north of Germany, late frost is the predominant weather event causing high losses in yield. The benefit of subsidized multi-peril insurance, which secures against frosts and hail, can only be observed for low yielding varieties if risk aversion is low. Only for high risk aversion coefficients above 1.1, the proportion of the frost-hail insurance increases in the portfolio. Nevertheless, the absence of frost irrigation puts yield and therefore trade relations in jeopardy and thus subsidized frost insurance only represents an alternative for areas in which frost irrigation systems cannot be established. Combining frost irrigation with a subsidized hail insurance results in higher expected utilities, also when low risk aversion is prevalent. Therefore, subsidies and indemities payments compensate the costs of subsidized hail insurance. In the south of Germany, hail is the major source of weather-dependet risk in apple production. Therefore, the efficiency of insurance solutions and hail nets as risk management instruments were examined. Contrary to the north, the basic scenario, i.e. production under hail nets, represents the most efficient strategy. Damages related to frost and hail events are not offset by subsidized insurances. This implies, that apple producers in the south already behave in accordance to a rational pattern and that subsidized insurances only provide an advantage when the installation of hail nets cannot be realized due to legal or area-specific reasons.

There are some optimization suggestions for the further enhancement of the model. Firstly, only some of the common varieties could be considered in the model, as the data basis was not sufficient for additional varieties. Secondly, the assumption that apple growers can hire supplementary workers at any time and thus restrictions on labor requirements during peak periods are not taken into account are further simplifications. Likewise, liquidity constraints were not considered in the model, as loans are available for farms in Germany. Nevertheless at farm level it could be interesting to take debt repayment into account, but this cannot be generalized. Furthermore, the shares of the marketing channels were set as a fixed proportion, based on the data collected. In retrospect, this is certainly a too restrictive assumption and an upper limit would be more appropriate.

1.4 Implications for apple production in Germany and the applicability of the model

The results of this thesis show that apple growers in Germany are rather risk neutral than risk averse. As multi-risk insurances are available in neighboring countries, there is an ongoing debate whether comparable solutions can be offered also for German apple growers. As stated in the literature, four factors are influencing individuals in purchasing insurances, namely risk aversion, expected revenues from subsidies, moral hazard and adverse selection (Coble and Barnett 2012). Moral hazard and adverse selection can lead to insurance participation and rejection, while risk aversion and income expectations result in increased participation. Due to the results of the lottery tasks and the self-assessment in the general context, a clear risk aversion cannot be assumed. Consequently, subsidies to increase insurance participation and the associated general improvements are questionable.

It is questionable that the extension service will use the stochastic model or the whole-farm model because the amounts of data required to run the model are extensive. Strategies to simplify probability statements, as the elicitation via PERT distributions, was not applicable in reality. Furthermore, risk aversion has to be captured in form of a utility function and therefore simple self-assessments cannot be considered. Mainly large farms, which rely on apple production as their main production branch, may use the programme to support the strategic decision-making process.

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Zentrum für Betriebswirtschaft im Gartenbau e. V.. 2017. Kennzahlen für den Betriebsvergleich im Gartenbau, 60.

VI Appendix: Experimental instructions

Eckdaten Interview:

Name des Interviewführers	

Beginn des Interviews	Datum	
	Uhrzeit	
Ende des Interviews	Datum	
	Uhrzeit	

Kontaktdaten des Interviewpartners:

Name		
Adresse	Straße	
	Hausnummer	
	Postleitzahl	
Kontakt	Telefon-nummer	
	Mobil	
	E-Mail Adresse	

Betriebsnummer	Region Norden=2 Süden =1

Fragebogen

Das Zentrum für Betriebswirtschaft im Gartenbau e.V., welches an der Leibniz Universität Hannover angesiedelt ist, führt mit dem Ziel der Verbesserung der Produktionssicherheit im Kernobstbau ein vom Bundesministerium für Bildung und Forschung (BMBF) gefördertes Projekt durch. In diesem Zusammenhang erfolgt eine Befragung zum Risikomanagement auf Obstbaubetrieben. Die gewonnenen Erkenntnisse sollen dazu dienen, Handlungsempfehlungen für den Einsatz von Risikomanagementinstrumenten in der Kernobstproduktion abzuleiten.

Für die Befragung wurden Betriebe, die vorwiegend in den Regionen des alten Landes und dem Bodenseegebiet produzieren, zufällig ausgewählt.

Das Interview ist aus verschiedenen Komponenten aufgebaut: Die Ermittlung der Risikoeinstellung erfolgt in Teilbereich A anhand eines hypothetischen Experimentes und einer Selbsteinschätzung. Dadurch soll festgestellt werden, inwieweit Sie bereit sind Risiken aktiv einzugehen, bzw. diese zu vermeiden. Teilbereich B dient der Erfassung der Risikowahrnehmung. Hierbei werden Sie zunächst zu vergangenen Ereignissen befragt. Danach sind wir an Ihrer Meinung interessiert, ob und mit welcher Wahrscheinlichkeit künftig spezifische Ereignisse eintreten könnten. Anschließend möchten wir im Teilbereich C zusätzliche Auskünfte zu Ihrer Person und ihrem Betrieb erheben. Zu guter Letzt werden Aussagen zu einem weiteren, hypothetischen Experiment erfragt.

Die Teilnahme an der Befragung ist freiwillig. Die erhobenen Daten werden anonym behandelt. Dies bedeutet, dass in der Auswertung keine Zusammenhänge zwischen den gegebenen Antworten und den Daten (Name und Adresse) des Interviewpartners erstellt werden. Die Richtlinien der Datenschutzgesetzgebung werden eingehalten.

Für Ihre Teilnahme an der Befragung möchten wir Ihnen herzlich danken!

		Hannover, November 2013

Einleitende Erläuterungen

Wir werden Sie gleich bitten, Fragen unterschiedlicher Art zu beantworten. Vor jedem Teilbereich der eigentlichen Befragung möchten wir Sie gerne mit der Form der Fragestellung vertraut machen.

Generell gilt, dass es bei der Beantwortung keine richtigen oder falschen Aussagen gibt. Bitte entscheiden Sie aufgrund Ihres Empfindens.

A Risikoeinstellung

A1 Beispiel - Selbsteinschätzung

In diesem Bereich werden wir Sie fragen, wie Sie Ihr Risikoverhalten selbst einschätzen.

Bitte beschreiben Sie Ihr Risikoverhalten, indem Sie von der vorgegebenen Punkte-Skala eine Angabe wählen (1 überhaupt nicht risikoreich, 10 extrem risikoreich).

Wie würden Sie Ihre Bereitschaft Risiken einzugehen **im Allgemeinen** charakterisieren?

	1	2	3	4	5	6	7	8	9	10	
Überhaupt nicht risikobereit	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Äußerst risikobereit

Wählen Sie das Kästchen, dass am ehesten Ihre Risikoeinstellung kennzeichnet.

A1 Befragung - Selbsteinschätzung

Bitte geben Sie Ihre Bereitschaft Risiken einzugehen auf der gegebenen Skala für folgende Fragen an.

Skala

	1	2	3	4	5	6	7	8	9	10	
Überhaupt nicht risikobereit	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Äußerst risikobereit

Frage 1 (1) Wie würden Sie Ihre Bereitschaft Risiken einzugehen **im Allgemeinen** charakterisieren?

Frage 1 (2) Wie würden Sie Ihre Bereitschaft Risiken einzugehen in Bezug auf die Vermeidung **von ertrags- und qualitätsmindernden Faktoren (Krankheiten und Schädlinge ausgenommen) im Kernobstbau** charakterisieren?

Frage 1 (3) Wie würden Sie Ihre Bereitschaft Risiken einzugehen **in Bezug auf die Fremdkapitalfinanzierung** charakterisieren?

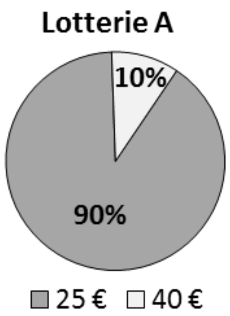
A2 Beispiele- Lotterien

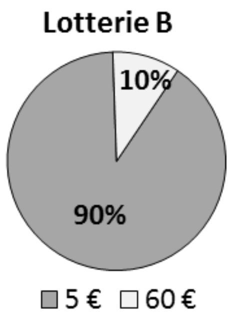
A 2.1 Lotterie mit Kleinbeträgen

Die folgende Methode soll dazu dienen, Ihre die Risikoeinstellung mit Blick auf den Kontext „Investitionen" zu ermitteln. Die Auswertung der Daten ermöglicht uns eine Einschätzung, ob Obstbauern eher probieren Risiken zu vermeiden oder sich risikofreudig verhalten. Die Lotterie basiert auf rein hypothetischen Annahmen. Wir bitten Sie sich möglichst in die Situation hineinzuversetzen und die Fragen so zu beantworten, also ob Sie vor dieser Entscheidung stünden.

Der Abschnitt besteht aus zehn verschiedenen Lotterie-Entscheidungen. Für jede der zehn Entscheidungen werden Sie gebeten, eine der zwei gegebenen Optionen (Lotterie A oder Lotterie B) zu wählen.

Welche Option würden Sie wählen?



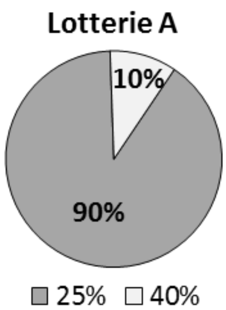


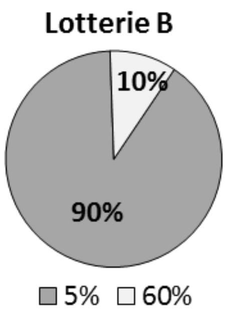
Würden Sie sich für die Lotterie A entscheiden, so hätten Sie die Chance zu 90% einen Betrag von 25 Euro zu gewinnen bzw. zu 10% einen Betrag von 40 Euro zu erhalten.

A 2.2 Lotterie mit Anteilen des Gewinns

Wie zuvor ist eine von zwei Lotterien zu wählen. Der Unterschied besteht in den Konsequenzen. Während zuvor Kleinbeträge in Euro angegeben waren, sind es nun Prozentzahlen, die den Anteil des durchschnittlichen Gewinns Ihres Unternehmens wiederspiegeln.

Welche Option würden Sie wählen?





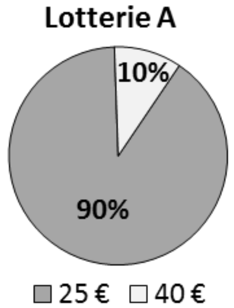
Würden Sie sich für die Lotterie A entscheiden, so würden Sie im kommenden Erntejahr mit einer Wahrscheinlichkeit von 90% einen Gewinn erzielen, der 25% des jährlich, durchschnittlichen Gewinns übersteigt und zu 10% einen, der um 40% höher ist, als der jährlich durchschnittliche Gewinn.

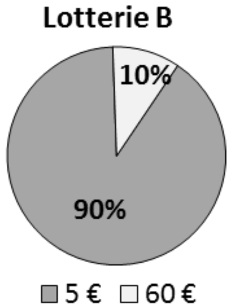
A2 Befragung- Lotterien

A 2.1 Hypothetische Lotterie mit Kleinbeträgen

Bitte wählen Sie für die zehn Entscheidungsrunden die bevorzugte Lotterie A oder B:

(1)





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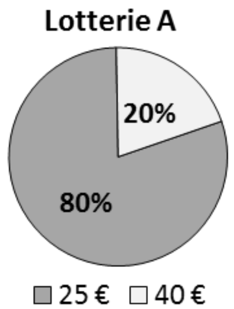

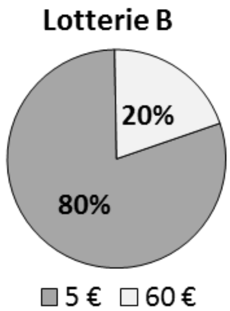

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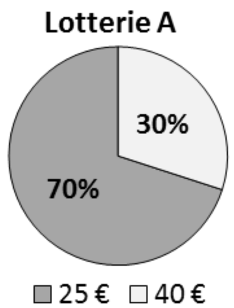
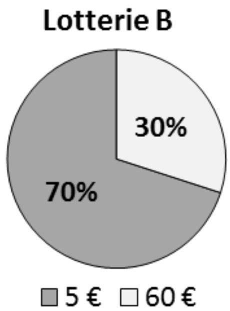
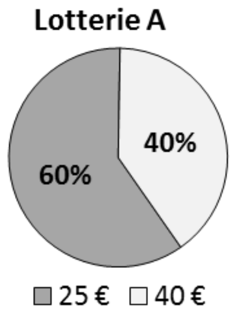
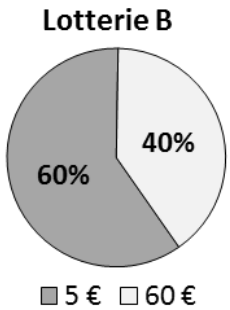




(4)





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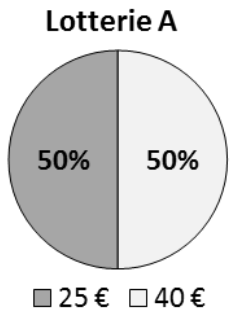

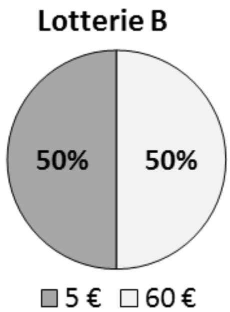

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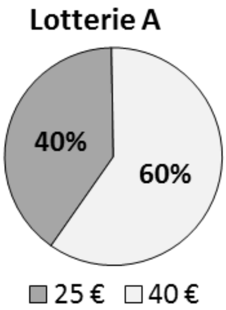
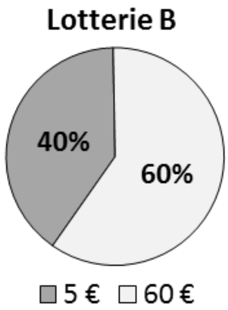
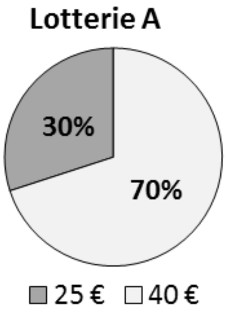
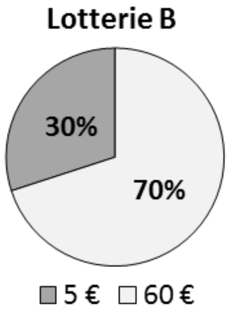

Lotterie A
40%
60%
25 €
40 €

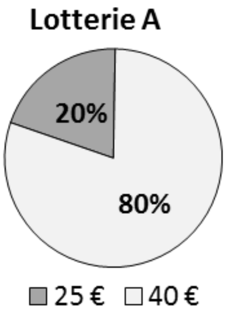

Lotterie B
40%
60%
5 €
60 €

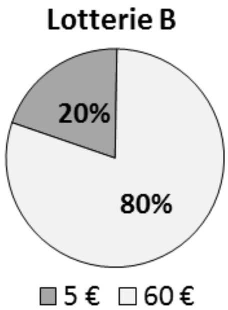
(7)


Lotterie A
30%
70%
25 €
40 €

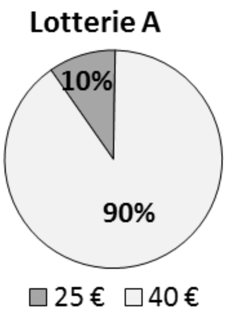

Lotterie B
30%
70%
5 €
60 €

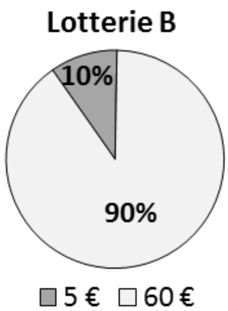
(8)


Lotterie A
20%
80%
25 €
40 €

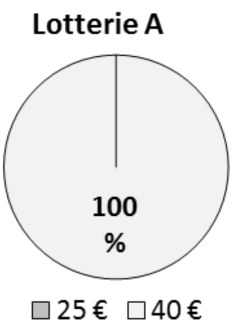

Lotterie B
20%
80%
5 €
60 €

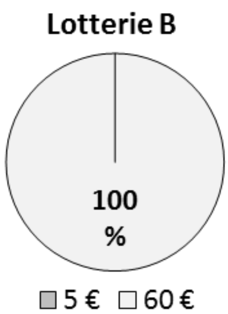
(9)


Lotterie A
10%
90%
25 €
40 €


Lotterie B
10%
90%
5 €
60 €

(10)

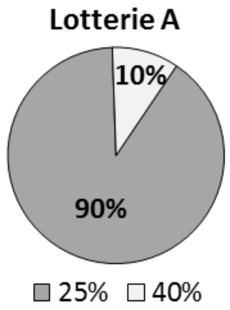

Lotterie A
100
%
25 €
40 €

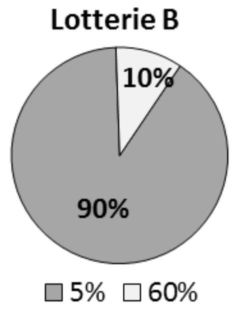

Lotterie B
100
%
5 €
60 €

A 2.2 Hypothetische Lotterie mit Anteilen des Gewinns

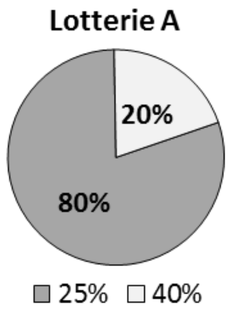
Bitte beachten Sie, dass die Konsequenzen **<u>nun nicht mehr Kleinbeträge, sondern Anteile des durchschnittlich erzielten Gewinns</u>** Ihres Unternehmens darstellen.

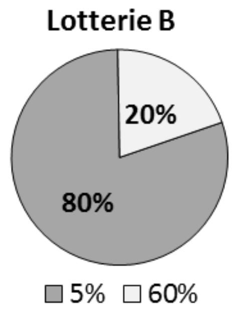
(1)



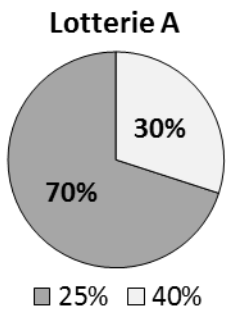


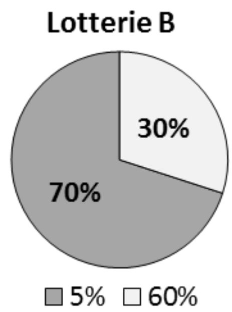
(2)





(3)





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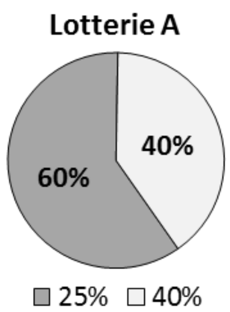

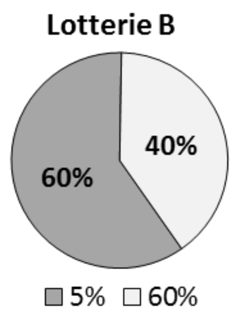

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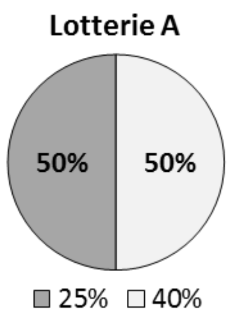

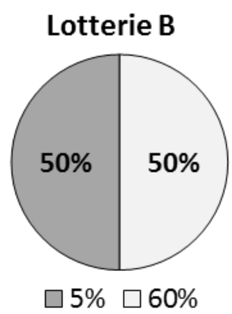

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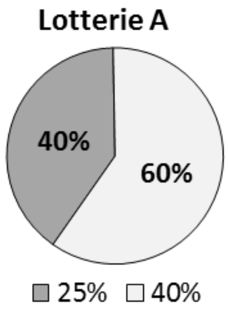
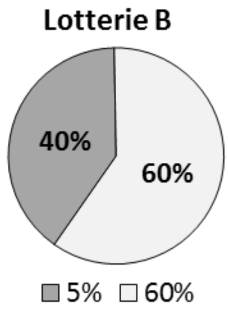
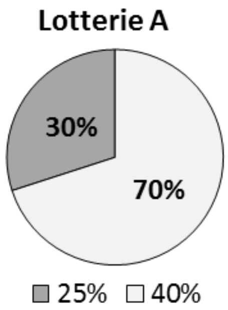
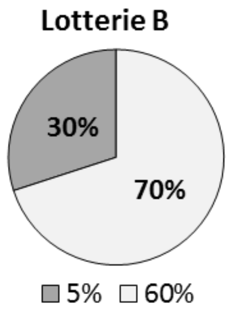

Lotterie A
40%
60%
25% 40%

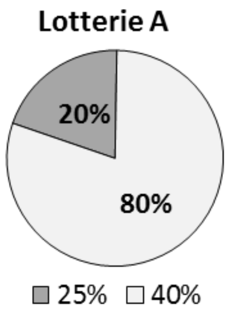

Lotterie B
40%
60%
5% 60%

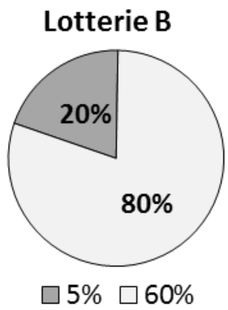
(7)


Lotterie A
30%
70%
25% 40%

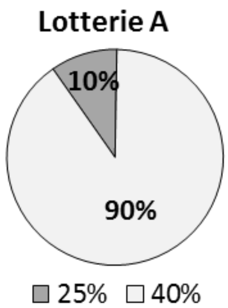

Lotterie B
30%
70%
5% 60%

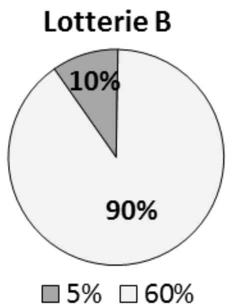
(8)


Lotterie A
20%
80%
25% 40%

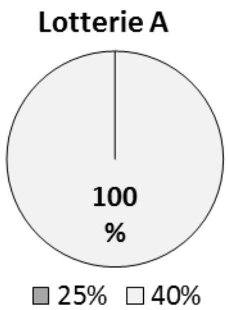

Lotterie B
20%
80%
5% 60%

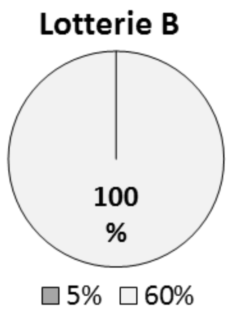
(9)


Lotterie A
10%
90%
25% 40%


Lotterie B
10%
90%
5% 60%

(10)


Lotterie A
100
%
25% 40%


Lotterie B
100
%
5% 60%

B Befragung-Risikowahrnehmung

B1 Allgemeine Angaben zur Anbaustrategie

Geben Sie uns bitte zunächst Daten für Ihre Apfel- Anlagen/Standorte.

Anzahl:____________

Gesamtfläche : ___________ha.

Gesamtfläche Junganlagen (1.- 3. Jahr): ___________ha.

Gesamtfläche Anlagen im Vollertrag (ab Jahr 4): ___________ha.

Bitte machen Sie Angaben, wie weit die zwei entferntesten Standorte vom Betrieb entfernt sind. Bitte geben Sie auch die Entfernung zwischen diesen Standorten an.

Standort 1 – Entfernung zum Betriebs-Hauptgebäude (km):_________

Standort 2 – Entfernung zum Betriebs-Hauptgebäude (km):_________

Standort 1 – Entfernung zu Standort 2 (km):_________

Bitte geben Sie an, ob Sie sich im Folgenden auf Brutto- oder Nettoflächen beziehen.

Bitte machen Sie zusätzliche Angaben zu den Standorten 1 und 2.

	Standort 1	Standort 2
Fläche (ha)		
Fläche Junganlagen (1-3 Jahre)		
Fläche Vollertrag (ab 4 Jahren)		
Durchschnittsalter der Anlage		
Flächenbesitz % Eigentum		
Dauer des Pachtvertrages (absolut, Jahre)		
Dauer des Pachtvertrages (verbleibende Jahre)		
Pachtkosten (€/ha)		
Bewässerung		
Ökologisch/- biologischer Anbau		
Hagelschutznetz		
Farbe Hagelschutznetz		
Zeitpunkt der Hagelschutznetz-Installation … installiert vor ___ Jahren		
Frostschutzberegnung		
Zeitpunkt der Frostschutz-Installation … installiert vor ___ Jahren		
Andere Schutzmaßnahmen (bitte angeben)		
Zeitpunkt der Installation … installiert vor ___ Jahren		

Bitte machen Sie zusätzliche Angaben zu den Flächen aller Standorte, die im Vollertrag (ab 4 Jahren) stehen. Bitte beginnen Sie mit den Standorten 1 und 2.

Standort	Sorte	Fläche (ha)	Unterlage	Bäume/ha	Alter der Bäume einer Sorte auf der Anlage	Erziehungssystem
1						
1						
…						
2						
2						
…						

Bitte geben Sie die drei bedeutendsten Sorten der Standorte 1 und 2 an. Falls Sie eine Sorte auf beiden Standorten produzieren, wählen Sie die der größten Fläche (ha).

Apfelsorte 1:___________________

Apfelsorte 2: ___________________

Apfelsorte 3: ___________________

Es folgen spezifische Fragen, die für die bedeutendsten Sorten der Standorte 1 und 2 beantwortet werden sollten

B2-B5 Beispiel Risikowahrnehmung

In diesem Abschnitt des Interviews bitten wir Sie zunächst um Ihre Angabe, wie häufig bestimmte Ereignisse in der Vergangenheit eingetreten sind.

Beispiel: Bitte beachten Sie, dass die Erntemengen durch Buchstaben (A,B,C…) ersetzt wurden, damit Ihre Einschätzungen unbeeinflusst bleiben.

Unter Betrachtung **der letzten zehn Jahre**: Wie hoch fiel der **Apfelertrag vor der Einlagerung, unter gewöhnlichen Anbaubedingungen (d.h. ohne die Einwirkung schwerwiegender Wettereinflüsse) aus?**

Bitte geben Sie die **betrieblichen, sortenspezifischen Erträge in Dezitonnen pro Hektar (dt/ha) für jede der 3 wichtigsten Sorten** an, indem Sie **für die letzten zehn Erntejahre** die minimale, häufigste und maximale Menge nennen.

Erträge dt/ha Sorte	Minimal	Modal (am häufigsten)	Maximal
Roter Gravensteiner	B	A	C

In diesem Fall hat der Obstbauer Erfahrung mit der Sorte „Roter Gravensteiner". Ernteerträge für diese Sorte betrugen meist A dt/ha. In den letzten zehn Jahren wurden als Extreme aber auch Erträge von B dt/ha als Minimum und C dt/ha als Maximum erzielt.

Ihre persönliche Einschätzung für **die nächsten zehn Jahre**: Wie hoch wird nach Ihrer Meinung der **Apfelertrag vor der Einlagerung, unter gewöhnlichen Anbaubedingungen (d.h. ohne die Einwirkung schwerwiegender Wettereinflüsse)** ausfallen?

Bitte geben Sie ihre Vermutung für die **betrieblichen, sortenspezifischen Erträge in Dezitonnen pro Hektar (dt/ha) für jede der 3 wichtigsten Sorten an**, indem Sie **für die kommenden zehn Erntejahre** die minimale, häufigste und maximale Menge angeben.

Erträge dt/ha Sorte	Minimal	Modal (am häufigsten)	Maximal
Roter Gravensteiner	E	D	F

In diesem Beispiel hat der Obstbauer mit Erfahrung zur Sorte „Roter Gravensteiner“ folgende Prognosen für die nächsten zehn Jahre abgegeben. Ernteerträge für diese Sorte werden meist D dt/ha betragen. Als Extreme können Erträge von E dt/ha als Minimum und dt/ha als Maximum erzielt werden.

Weiterhin erfragen wir Ihre Einschätzung für **die nächsten zehn Jahre** wie folgt: Wie häufig wird **Hagel** eine Qualitätsminderung der **Tafelobstware (betrifft Qualitätskategorien Extra, Handelsklasse 1 und 2, bzw. unsortiert)** hervorrufen, sodass das Obst **lediglich als Mostobst** vermarktet werden kann? Bitte geben Sie zuvor die Information, ob Ihre Einschätzung auf der Verwendung von Hagelschutznetzen oder auf der Annahme des ungeschützten Anbaus beruht. Bitte ordnen Sie die zehn Jahre den jeweiligen Verlustspannen zu.

Verluste (%)	0%	1-9%	10-19%	20-29%	30-39%	40-49%	50-59%	60-69%	70-79%	80-89%	90-100%
Allgemein											

B2-B5 Befragung Risikowahrnehmung

B2 Erträge und Qualitäten unter gewöhnlichen Produktionsbedingungen

Einschätzung (1): Unter Betrachtung **der letzten zehn Jahre**: Wie hoch fiel der **Ertrag von Tafelobstware vor der Einlagerung, unter gewöhnlichen Anbaubedingungen (d.h. ohne die Einwirkung schwerwiegender Wettereinflüsse)** aus?

Bitte geben Sie die **betrieblichen, sortenspezifischen Erträge in Dezitonnen pro Hektar (dt/ha) für jede der 3 wichtigsten Sorten** an, indem Sie **für die letzten zehn Erntejahre** die minimale, häufigste und maximale Menge nennen.

Erträge (dt/ha) / Sorte	Minimal	Modal (am häufigsten)	Maximal

Ihre persönliche Einschätzung für **die nächsten zehn Jahre**: Wie hoch wird nach Ihrer Meinung der **Ertrag von Tafelobstware vor der Einlagerung, unter gewöhnlichen Anbaubedingungen (d.h. ohne die Einwirkung schwerwiegender Wettereinflüsse)** ausfallen?

Bitte geben Sie ihre Vermutung für die **betrieblichen, sortenspezifischen Erträge in Dezitonnen pro Hektar (dt/ha) für jede der 3 wichtigsten Sorten an**, indem Sie **für die kommenden zehn Erntejahre** die minimale, häufigste und maximale Menge angeben.

Erträge (dt/ha) / Sorte	Minimal	Modal (am häufigsten)	Maximal

Einschätzung (2):

Unter Betrachtung **der letzten drei Jahre**: Wie hoch war die Qualität der Ernte **unter gewöhnlichen Anbaubedingungen (d.h. ohne die Einwirkung schwerwiegender Wettereinflüsse)**? Bitte geben Sie den minimalen, den häufigsten und den maximalen Anteil (in %) für die Kategorie „Qualität war besser als Mostobst" (d.h. zugehörig zu Handelsklasse Extra, Handelsklasse 1 oder Handelsklasse 2/unsortiert) **für jede der 3 wichtigsten Sorten** an.

Qualität besser als Mostobst / Sorte	0-9%	10-19%	20-29%	30-39%	40-49%	50-59%	60-69%	70-79%	80-89%	90-94%	95-100%

Bitte spezifizieren Sie unter Betrachtung **der letzten drei Jahre: Wie hoch war der Anteil (in %) der Handelsklassen 1 und Extra** an der Tafelobstqualität.

Qualität von mind. Handelskl. 1 (%) / Sorte	0-29%	30-39%	40-49%	50-54%	55-59%	60-64%	65-69%	70-74%	75-79%	80-89%	90-99%	100%

Ihre persönliche Einschätzung für **die nächsten drei Jahre**: Welche Qualität wird das Obst **unter gewöhnlichen Anbaubedingungen (d.h. ohne die Einwirkung schwerwiegender Wettereinflüsse)** haben? Bitte geben Sie den Anteil (in %) für die Kategorie „Qualität wird besser als Mostobst sein“ (d.h. zugehörig zu Handelsklasse Extra, Handelsklasse 1 oder Handelsklasse 2/unsortiert **für jede der 3 wichtigsten Sorten** an. Bitte ordnen Sie für jede Sorte die vergangenen zehn Jahre in die folgenden, vorgegebenen Intervalle für die von Ihnen angebauten Sorten ein.

Qualität besser als Mostobst / Sorte	0-9%	10-19%	20-29%	30-39%	40-49%	50-59%	60-69%	70-79%	80-89%	90-94%	95-100%

Bitte spezifizieren Sie unter Betrachtung **der nächsten drei Jahre: Wie hoch wird der Anteil (in %) der Handelsklassen 1 und Extra** an der Tafelobstqualität sein.

Qualität von mind. Handelskl. 1 (%) / Sorte	0-29%	30-39%	40-49%	50-54%	55-59%	60-64%	65-69%	70-74%	75-79%	80-89%	90-99%	100%

B3 Wetterbedingte Verluste und Qualitätsminderung des Obstes

Einschätzung (3):

In den letzten zehn Jahren - in wie vielen Jahren hat Hagel nach Ihrer Erfahrung zur Ertragsminderung geführt?

_______ Jahre

Ihre persönliche Einschätzung für **die nächsten zehn Jahre**: Wie häufig wird Hagel zu Ertragseinbußen in folgenden, vorgegebenen Verlust-Spannen (%) führen? Bitte geben Sie zuvor an, ob Ihre Prognose auf der Verwendung von Hagelschutznetzen oder ohne Hagelschutz beruht und ordnen Sie für jeden Standort die zehn Jahre den jeweiligen Verlustspannen zu.

Verluste (%) / Standort	0%	1-4%	5-9%	10-19%	20-29%	30-39%	40-49%	50-59%	60-69%	70-79%	80-89%	90-100%

Falls Ihre Einschätzungen auf der Verwendung eines Hagelnetzes beruhen, wie hoch wären die Verluste ohne Hagelnetz?

Verluste (%) / Standort	0%	1-4%	5-9%	10-19%	20-29%	30-39%	40-49%	50-59%	60-69%	70-79%	80-89%	90-100%

Einschätzung (4):

In den letzten zehn Jahren - in wie vielen Jahren hat Frost nach Ihrer Erfahrung zur Ertragsminderung geführt?

_______ Jahre

Ihre persönliche Einschätzung für **die nächsten zehn Jahre**: Wie häufig wird Frost zu Ertragseinbußen in folgenden, vorgegebenen Verlust-Spannen (%) führen? Bitte geben Sie zuvor die Information, ob Ihre Einschätzung auf der Verwendung der Frostschutzberegung beruht und ordnen Sie für jeden Standort die zehn Jahre den jeweiligen Verlustspannen zu.

Verluste (%) / Standort	0%	1-4%	5-9%	10-19%	20-29%	30-39%	40-49%	50-59%	60-69%	70-79%	80-89%	90-100%
Standort 1												
Standort 2												

Falls Ihre Einschätzungen auf der Verwendung der Frostschutzberegnung beruhen, wie hoch wären die Verluste ohne Frostschutzanlage?

Verluste (%) / Standort	0%	1-4%	5-9%	10-19%	20-29%	30-39%	40-49%	50-59%	60-69%	70-79%	80-89%	90-100%
Standort 1												
Standort 2												

Einschätzung (5):

In den letzten zehn Jahren - in wie vielen Jahren hat Hagel nach Ihrer Erfahrung zur Qualitätsminderung geführt?

_______ Jahre

Ihre persönliche Einschätzung für **die nächsten zehn Jahre**: Wie häufig wird **Hagel** eine Qualitätsminderung der **Tafelobstware (betrifft Qualitätskategorien Extra, Handelsklasse 1 und 2, bzw. unsortiert)** hervorrufen, sodass das Obst **lediglich als Mostobst** vermarktet werden kann? Bitte geben Sie zuvor die Information, ob Ihre Einschätzung auf der Verwendung von Hagelschutznetzen oder auf der Annahme des ungeschützten Anbaus beruht. Bitte ordnen Sie die zehn Jahre den jeweiligen Verlustspannen zu.

Verluste (%)	0%	1-9%	10-19%	20-29%	30-39%	40-49%	50-59%	60-69%	70-79%	80-89%	90-100%
Allgemein											

Falls Ihre Einschätzungen auf der Verwendung eines Hagelnetzes beruhen, wie hoch wären die **Verlustanteile (%) der Tafelobstware** ohne Hagelnetz?

Verluste (%)	0%	1-9%	10-19%	20-29%	30-39%	40-49%	50-59%	60-69%	70-79%	80-89%	90-100%
Allgemein											

Einschätzung (6):

In den letzten zehn Jahren - in wie vielen Jahren hat Sonnenbrand nach Ihrer Erfahrung zur Qualitätsminderung geführt?

_______ Jahre

Ihre persönliche Einschätzung für **die nächsten zehn Jahre**: Wie häufig wird **Sonnenbrand** eine Qualitätsminderung der **Tafelobstware (betrifft Qualitätskategorien Extra, Handelsklasse 1 und 2, bzw. unsortiert)** hervorrufen, sodass das Obst **lediglich als Mostobst** vermarktet werden kann? Bitte geben Sie zuvor die Information, ob Ihre Einschätzung auf der Verwendung von Hagelschutznetzen/Frostschutz oder auf der Annahme des ungeschützten Anbaus beruht. Bitte ordnen Sie für jede Sorte die zehn Jahre den jeweiligen Verlustspannen zu.

Verluste (%) / Sorte	0%	1-9%	10-19%	20-29%	30-39%	40-49%	50-59%	60-69%	70-79%	80-89%	90-100%

Falls Ihre Einschätzungen auf der Verwendung einer Frostschutzberegnung beruhen, wie hoch wären die **Verlustanteile (%) der Tafelobstware** ohne Frostschutz?

Verluste (%) / Sorte	0%	1-9%	10-19%	20-29%	30-39%	40-49%	50-59%	60-69%	70-79%	80-89%	90-100%

B4 Angaben zu Feuerbrand

Einschätzung (7):

In den letzten zehn Jahren - in wie vielen Jahren hat Feuerbrand nach Ihrer Erfahrung zur Ertragsminderung geführt?

_______ Jahre

Ihre persönliche Einschätzung für **die nächsten zehn Jahre**: Wie häufig wird Feuerbrand zu Ertragseinbußen in folgenden, vorgegebenen Verlust-Spannen (%) führen? Bitte geben Sie zuvor die Information, ob Ihre Einschätzung auf der Durchführung von Schnittmaßnahmen beruht und ordnen Sie für jeden Standort die zehn Jahre den jeweiligen Verlustspannen zu.

Verluste (%)	Regelmäßige Kontrollen und Schnittmaßnahmen (ja/nein)	0%	1-4%	5-9%	10-19%	20-29%	30-39%	40-49%	50-59%	60-69%	70-79%	80-89%	90-100%
Standort 1													
Standort 2													

Falls Ihre Einschätzungen auf der regelmäßigen Durchführung von Kontroll- und Schnittmaßnahmen beruht, wie hoch wären die die Verluste ohne diese Maßnahmen?

Verluste (%)	Regelmäßige Kontrollen und Schnittmaßnahmen (ja/nein)	0%	1-4%	5-9%	10-19%	20-29%	30-39%	40-49%	50-59%	60-69%	70-79%	80-89%	90-100%
Standort 1													
Standort 2													

B5 Angaben zu Preisen

Einschätzung (8):

Unter Betrachtung **der letzten zehn Jahre**: Welche **durchschnittlichen Markt-Preise** wurden jeweils für die von Ihnen angebauten Sorten in den gegebenen **Handelsklassen-Gruppierungen (1. Extra, HK1=Handelsklasse 1, sowie 2. HK2=Handelsklasse 2, unsortiert und 3. Mostobst)** gezahlt? Teilen Sie uns bitte für jede Gruppe **den häufigsten Preis in (€ /100 kg) mit.**

Preis(€/100 kg) Sorte	Handelsklasse	Modal (am häufigsten)
	Extra,HK1	
	HK2, unsortiert	
	Mostobst	
	Extra,HK1	
	HK2, unsortiert	
	Mostobst	
	Extra,HK1	
	HK2, unsortiert	
	Mostobst	

Ihre persönliche Einschätzung für **die nächsten zehn Jahre**: Welche **durchschnittlichen Markt-Preise (€/100kg)** werden nach Ihrer Einschätzung künftig für die gegebenen Handelsklassen (Extra, HK1=Handelsklasse 1, HK2=Handelsklasse 2) gezahlt? Bitte ordnen Sie die zehn Jahre den folgenden, vorgegebenen Preisspannen für die von Ihnen angebauten Sorten zu.

Preis / Sorte	Handels-klasse	weniger als 20 €	20-24 €	25-29 €	30-34 €	35-39 €	40-44 €	45-49 €	50-54 €	55-59 €	60-69 €	70-79 €	80-89 €	90-99 €	100-120 €	mehr als 120 €
	Extra, HK1															
	Extra, HK1															
	Extra, HK1															

Preis / Sorte	Handelsklasse	weniger als 10 €	10-14 €	15-19 €	20-24 €	25-29 €	30-34 €	35-39 €	40-44 €	45-49 €	50-54 €	55-59 €	60-69 €	70-79 €	80-90 €	mehr als 90 €
	HK2, unsortiert															
	HK2, unsortiert															
	HK2, unsortiert															

Preis / Sorte	Handelsklasse	Weniger als 5 €	5-9 €	10-14 €	15-19 €	20-24 €	25-29 €	30-34 €	35-40 €	mehr als 40 €
	Most									
	Most									
	Most									

Einschätzung (9):

Unter Betrachtung **der letzten zehn Jahre**: Welche **durchschnittlichen Preise im Vertragsanbau** wurden jeweils für die von Ihnen angebauten Sorten in den gegebenen **Handelsklassen-Gruppierungen (1. Extra, HK1=Handelsklasse 1, sowie 2. HK2=Handelsklasse 2, unsortiert und 3. Mostobst)** gezahlt? Teilen Sie uns bitte für jede Gruppe **den häufigsten Preis in (€ /100 kg) mit.**

Preis(€/100 kg) Sorte	Handelsklasse	Modal (am häufigsten)
	Extra,HK1	
	HK2, unsortiert	
	Mostobst	
	Extra,HK1	
	HK2, unsortiert	
	Mostobst	
	Extra,HK1	
	HK2, unsortiert	
	Mostobst	

Ihre persönliche Einschätzung für **die nächsten zehn Jahre**: Welche **Preise im Vertragsanbau (€/100kg)** werden nach Ihrer Einschätzung künftig für die gegebenen Handelsklassen (Extra, HK1=Handelsklasse 1, HK2=Handelsklasse 2) gezahlt? Bitte ordnen Sie die zehn Jahre den folgenden, vorgegebenen Preisspannen für die von Ihnen angebauten Sorten zu.

Preis / Sorte	Handels-klasse	weniger als 20 €	20-24 €	25-29 €	30-34 €	35-39 €	40-44 €	45-49 €	50-54 €	55-59 €	60-69 €	70-79 €	80-89 €	90-99 €	100-120 €	mehr als 120 €
	Extra, HK1															
	Extra, HK1															
	Extra, HK1															

Preis / Sorte	Handelsklasse	weniger als 10 €	10-14 €	15-19 €	20-24 €	25-29 €	30-34 €	35-39 €	40-44 €	45-49 €	50-54 €	55-59 €	60-69 €	70-79 €	80-90 €	mehr als 90 €
	HK2, unsortiert															
	HK2, unsortiert															
	HK2, unsortiert															

Preis / Sorte	Handelsklasse	Weniger als 5 €	5-9 €	10-14 €	15-19 €	20-24 €	25-29 €	30-34 €	35-40 €	mehr als 40 €
	Most									
	Most									
	Most									

Einschätzung (10):

Unter Betrachtung **der letzten zehn Jahre**: Welche **Preise im Direktabsatz** wurden jeweils für die von Ihnen angebauten Sorten in den gegebenen **Handelsklassen-Gruppierungen (1. Extra, HK1=Handelsklasse 1, sowie 2. HK2=Handelsklasse 2, unsortiert und 3. Mostobst)** gezahlt? Teilen Sie uns bitte jeweils **den häufigsten Preis in (€ /100 kg) mit.**

Preis(€/100 kg) Sorte	Handelsklasse	Modal (am häufigsten)
	Extra,HK1	
	HK2, unsortiert	
	Mostobst	
	Extra,HK1	
	HK2, unsortiert	
	Mostobst	
	Extra,HK1	
	HK2, unsortiert	
	Mostobst	

Ihre persönliche Einschätzung für **die nächsten zehn Jahre**: Welche **Preise im Direktabsatz (€/100kg)** werden nach Ihrer Einschätzung künftig für die gegebenen Handelsklassen (Extra, HK1=Handelsklasse 1, HK2=Handelsklasse 2) gezahlt? Bitte ordnen Sie die zehn Jahre den folgenden, vorgegebenen Preisspannen für die von Ihnen angebauten Sorten zu.

Preis / Sorte	Handels-klasse	weniger als 80 €	80-89 €	90-99 €	100-109 €	110-119 €	120-129 €	130-139 €	140-149 €	150-159 €	160-169 €	170-179 €	180-189 €	190-199 €	200-210 €	mehr als 210 €
	Extra, HK1															
	Extra, HK1															
	Extra, HK1															

Preis / Sorte	Handelsklasse	weniger als 10 €	10-14 €	15-19 €	20-24 €	25-29 €	30-39 €	40-49 €	50-59 €	60-69 €	70-79 €	80-89 €	90-99 €	100-109 €	110-130 €	mehr als 130 €
	HK2, unsortiert															
	HK2, unsortiert															
	HK2, unsortiert															

Preis / Sorte	Handelsklasse	Weniger als 5 €	5-9 €	10-14 €	15-19 €	20-24 €	25-29 €	30-34 €	35-40 €	mehr als 40 €
	Most									
	Most									
	Most									

C-Persönliche und betriebliche Informationen

Anschließend werden wir Ihnen noch ein paar Fragen zu persönlichen und betrieblichen Charakteristika stellen.

C1 Persönliche Informationen

Frage 1: Ich bin …?

1 ☐…ein Mann 2 ☐…eine Frau

Frage 2: In welchem Jahr sind Sie geboren?

____ Jahr

Frage 3: Haben Sie Kinder, falls ja, wie viele?

_____ Anzahl

Frage 4: Sind Sie verheiratet?

1 ☐ Ja

0 ☐ Nein

Frage 5: Was ist Ihr höchster Ausbildungsabschluss?

1 ☐ Volks-/ Hauptschulabschluss

2 ☐ Mittlere Reife/ Realschulabschluss

3 ☐ Abitur oder vergleichbares

4 ☐ Meister/ Techniker/ Fachschulabschluss

5 ☐ Fachhochschul-/ Hochschulabschluss

0 ☐ Ohne Abschluss

☐ Sonstiges und zwar _________________

Frage 6: Wie viele Jahre Berufserfahrung haben Sie im Bereich der Kernobstproduktion?

1 ☐ Weniger als 5 Jahre

2 ☐ 5-10 Jahre

3 ☐ 10-20 Jahre

4 ☐ Mehr als 20 Jahre

C2 Betriebliche Merkmale

Frage 7: Verfügt der Haushalt über weitere Einkommensquellen? Falls ja, welche Quellen sind dies? (Mehrfachnennung möglich)

☐ Mieteinkünfte

☐ Ferienwohnung/Pension

☐ Selbstständige Tätigkeit

☐ Angestellt/Beamtentätigkeit

☐ Sonstiges und zwar ________________________________

Frage 8: Wie groß ist die Landfläche (ha), die Sie bewirtschaften?

Betriebsfläche gesamt ________ha,

davon ________ ha Eigentum ________ ha Pachtfläche.

Frage 9: Wie hoch sind die durchschnittlichen, jährlichen Pachtkosten pro ha Pachtfläche?

____________€/ ha Pachtfläche

Frage 10: Wie viele externe Arbeitskräfte beschäftigen Sie?

Anzahl der Arbeitskräfte die permanent beschäftigt sind _____________

Anzahl der Arbeitskräfte die saisonal beschäftigt sind _____________

Frage 11: Bitte geben Sie an, ob Mitglieder Ihres Haushaltes Tätigkeiten auf dem eigenen Betrieb ausführen.

1 ☐ Ja => weiter mit Frage 12

0 ☐ Nein => weiter mit Frage 13

Frage 12: Machen Sie bitte genauere Angaben, ob es sich um eine permanente oder eine saisonale Tätigkeit zur Unterstützung handelt.

Anzahl der Familienmitglieder die permanent beschäftigt sind _____________

Anzahl der Familienmitglieder die saisonal beschäftigt sind _____________

Frage 13: Aus welchen typischen Produktionsbereichen setzt sich Ihr Unternehmen zusammen? Welchen prozentualen Anteil am gesamtbetrieblichen Erlös haben die Aktivitäten? (Mehrfachnennung möglich)

☐ Kernobst	______%
☐ Weitere acker- und gartenbauliche Kulturen (=> Genaueres in Frage 14)	______%
☐ Tierische Produkte (Milch- und Fleischproduktion)	______%
☐ Sonstiges und zwar __________________________	______%

Frage 14: Bitte machen Sie Angaben zu Ihrer Produktion hinsichtlich aller zusätzlich zum Kernobst angebauten Kulturen.

Angebaute Kultur (Auswahl- weiteres bitte angeben)		Kultivierte Fläche (ha) gesamt
Birnen	Gerste	
Beerenobst	Triticale	
Kirsche	Mais	
Pflaume	Zuckerrüben	
Pfirsich	Kartoffeln	
Aprikose	Ackerbohnen	
Weizen	Erbsen	
Roggen	Soja	
Hafer	Lupinen	

C3 Informationen über den sortenspezifischen Arbeitsaufwand

Frage 15: Bitte geben Sie uns Informationen zum sortenspezifischen Arbeitsaufwand in Arbeitskraftstunden pro Hektar (Akh/ha). Teilen Sie uns bitte für jede Sorte **den minimalen, den häufigsten und den maximalen Arbeitsaufwand in Akh/ha für die Arbeitsvorgänge Schnitt, Ausdünnen (mechanisch und chemisch) und Ernte mit.**

Arbeitsaufwand (Akh/ha) / Sorte		Minimal	Modal (am häufigsten)	Maximal
	Schnitt			
	Ausdünnung			
	Ernte			
	Schnitt			
	Ausdünnung			
	Ernte			
	Schnitt			
	Ausdünnung			
	Ernte			

C4 Informationen über die Vermarktung

Frage 16: Sind Sie an eine Erzeugerorganisation angeschlossen?

1 ☐ Ja

0 ☐ Nein

Frage 17.1: Wie hoch sind für gewöhnlich die Warenanteile in Prozent (%), die Sie unabhängig von der Handelsklasse über den Markt- und über die Direktvermarktung absetzen? Falls Sie vertraglich festgelegte Mengen absetzen, geben Sie uns bitte für gegebene Handelsklassen die gewöhnlichen Mengen in dt an.

		Minimal	Modal (am häufigsten)	Maximal
Markt (%)				
Direktvermarktung (%)				
Vertragsanbau (dt)	Extra,HK1			
	HK2, unsortiert			
	Most			

Frage 17.2: Müssen Sie evtl. Ware zukaufen, wenn Sie die vertraglich festgesetzten Mengen aufgrund von Ertragsausfällen oder Qualitätsmängeln nicht bereitstellen können?

1 ☐ Ja, die gesamte Menge muss bereitgestellt werden

0 ☐ Nein

Weitere Angaben

____

C5 Informationen über vergangene Schadensereignisse (10 jähr.)

Frage 18: Bitte machen Sie Angaben, mit welchen Risiken Sie am häufigsten konfrontiert sind. Bitte ordnen Sie hierzu die Risiken beginnend mit dem **bedeutendsten**.

1 ☐ Preisrisiken (Preisschwankungen)

2 ☐ Produktionsrisiken (Wettereinflüsse, Schädlinge)

3 ☐ Institutionelle Risiken (Politische Verordnungen, Gesetze)

4 ☐ Persönliche, humane Risiken (Krankheit, Tod, Qualitätsminderung durch Erntehelfer)

5 ☐ Kreditrisiken

6 ☐ Umsatzeinbrüche und Zinssteigerungen des Fremdkapitals

Frage 19: Waren Sie in den letzten 10 Jahren durch Negativ-Einflüsse betroffen, welche das Betriebsergebnis nennenswert beeinträchtigt haben? Bitte ordnen Sie ihre Antworten hierbei nach Schweregrad.

	Negativ-Einflüsse	0 ohne Einfluss	1 geringer Einfluss	2 mittlerer Einfluss	3 starker Einfluss	4 sehr starker Einfluss
19.1	Sturm					
19.2	Frost					
19.3	Starkregen/ Überflutungen					
19.4	Hagel					
19.5	Trockenheit					
19.6	Schädlingsbefall und Pflanzenkrankheiten					
19.7	Steigende Kosten für Produktionsfaktoren					
19.8	Sinkende Marktpreise					
19.9	Ausfall eines Familienmitgliedes oder Mitarbeiters z.B. durch Krankheit					
19.10	Nachbarschaftsstreitigkeiten					
19.11	Nicht-Einhaltung von Lieferverträgen über Produktionsmittel					
19.12	Nicht-Einhaltung von Lieferverträgen über Äpfel					
19.13	Absatzprobleme aufgrund wetterbedingter qualitativer Mängel					
19.14	Absatzprobleme aufgrund qualitativer Mängel verursacht durch Schädlinge/ Krankheiten während der Wachstums-periode					
19.15	Lagerverluste auf dem eigenen Betrieb durch Schädlinge bzw. durch Lageratmosphäre/Temperatur-Gegebenheiten					

C6 Informationen über Risikomanagement-Maßnahmen

Frage 20: Sind zur Kompensation eines genannten Schadensereignisses zurzeit noch betriebliche Einschränkungen erforderlich? Bitte wählen Sie:

1 ☐ Ja
0 ☐ Nein

Frage 21: Welche Risikomanagement-Maßnahmen haben Sie angewandt, um die in der Frage 19 angegebenen Situationen zu begegnen? Es ist möglich für jede Kategorie mehrere Maßnahmen auszuwählen (Mehrfachauswahl möglich).

<u>Verkauf</u>

☐ Verkauf von Land
☐ Verkauf von Maschinen
☐ Verkauf von Tieren

<u>Ökonomische Aktivitäten</u>

☐ Aufnahme von Fremdkapital
☐ Versicherungsanspruch geltend gemacht
☐ Verwendung von Ersparnissen/Privateinlagen

<u>Pflanzenbauliche Aktivitäten</u>

☐ Frostschutzberegnung
☐ Hagelschutznetze
☐ Anpassung der Sortenwahl
☐ Einsparung von Produktionsfaktoren (Dünger, Pflanzenschutzmitteln etc.)
☐ Flächenmäßige Erweiterung der bereits vorhandenen Kulturen
☐ Ersatz unrentabler Kulturen durch andere
☐ Verlagerung der Produktion bzw. Streuung auf andere Standorte

Frage 22: Beziehen Sie zusätzliche Informationen? Falls dies zutrifft, welche der gegebenen Möglichkeiten nutzen Sie? (Mehrfachauswahl möglich)

☐ Fachzeitschrift

☐ Fortbildung/Tagungen

☐ Internetangebote

☐ Beratungsangebot der Landwirtschaftskammer

☐ Informationen seitens der Anbauverbände

Frage 23: Haben Sie eine Versicherung für wetterbedingte Schäden der Obstplantage abgeschlossen?

1 ☐ Ja => weiter mit Fragen 24, 25,26, 28

0 ☐ Nein => weiter mit Fragen 27, 28

Frage 24: Falls Sie eine Versicherung der Ernte abgeschlossen haben, wie hoch sind die Versicherungssumme und die Versicherungsprämie? Alternativ nennen Sie uns bitte die Versicherungsprämie pro Hektar.

Versicherungsprämie _____ € (Alternativ Versicherungsprämie pro Hektar _____ €/ha)

Versicherungssumme _____ €

Frage 25: Falls Sie eine Versicherung der Ernte abgeschlossen haben, viel Prozent des Ertrags sind versichert? _______ %

Frage 26: Schätzen Sie die Absicherung durch die Versicherung als ausreichend ein?

0 ☐ nein

1 ☐ ja

Frage 27: Falls Sie keine Versicherung der Ernte abgeschlossen haben, sind folgende Aussagen zutreffend?

0 ☐ Hagelschutznetze sind aufgrund geringer Schadereignisse nicht erforderlich
1 ☐ Es ist keine Versicherung der Ernte nötig
2 ☐ Eine Versicherung der Ernte ist zu teuer
3 ☐ Es steht keine adäquate Ernte-Versicherung zur Verfügung
4 ☐ Es ist erforderlich, dass die gesamte Produktionsfläche versichert wird
☐ Weitere Gründe, um Angabe wird gebeten: ________________________

Frage 28: Verwenden Sie Hagelschutznetze? (Ersichtlich aus Risikowahrnehmungsabfrage)

1 ☐ Ja => weiter mit Frage 29,31
0 ☐ Nein => weiter mit Frage 30,31

Frage 29: Falls Sie Hagelschutznetze verwenden, um Ihre Ernte zu sichern, wurden diese von bestimmten Institutionen bzw. von der Genossenschaft bezuschusst? Falls dies zutrifft, welche Institution hat das Geld für Ihren Betrieb zur Verfügung gestellt?

____

Frage 30: Falls Sie keine Hagelschutznetze verwenden, sind folgende Aussagen zutreffend?

0 ☐ Hagelschutznetze sind aufgrund geringer Schadereignisse nicht erforderlich
1 ☐ Hagelschutznetze sind zu teuer
2 ☐ Hagelschutznetze bieten keinen guten Schutz
3 ☐ Die geringere Lichtdurchlässigkeit der Netze hat negative Auswirkungen auf die Fruchtfarbe und die Knospenbildung
☐ Weitere Gründe, um Angabe wird gebeten: ________________________

C7 Informationen über die Einlagerung von Äpfeln

Frage 31: Wer entscheidet über die Einlagerung?

1 ☐ Ich selbst entscheide welche Mengen eingelagert werden => weiter mit Frage 32-35

2 ☐ Die Erzeugerorganisation entscheidet über die Einlagerungsmenge => weiter mit Frage 36

Frage 32: Wie hoch ist die Lagerkapazität in Dezitonnen? Wie viel Prozent der Gesamterntemenge entspricht dies?

Lagerkapazität	_______________ dt
Entspricht Anteil der Gesamterntemenge	_______________ %

Frage 33: Reichen die Lagerkapazitäten generell aus, oder würden Sie in manchen Jahren gerne mehr einlagern können?

1 ☐ Ja, die Lagerkapazitäten reichen generell aus

0 ☐ Nein, die Lagerkapazitäten sind zu gering

Frage 34: Welche Lagerform wird von Ihnen genutzt (Mehrfachantwort möglich) und wie viel Prozent der Ware wird mit dem jeweiligen System gelagert?

☐ Kontrollierte Atmosphäre (=CA-Lager)	______%
☐ Ultra low oxygen (=ULO-Lager)	______%
☐ 1-MCP mit dem Ethylen-Hemmstoff 1-MCP (Smart Fresh)	______%
☐ Dynamisches CA Lager mit Anpassung der Sauerstoffkonzentration	______%
☐ Anderes Verfahren ________________________	______%

Frage 35: Bitte geben Sie eine an, wie viel Prozent der jährlichen Ernte durchschnittlich eingelagert wird (in %) und wie hoch die Lagerverluste (in %) sind.

Sorte		Minimal	Modal (am häufigsten)	Maximal
	Einlagerung (%)			
	Verluste (%)			
	Einlagerung (%)			
	Verluste (%)			
	Einlagerung (%)			
	Verluste (%)			

Frage 36: Welche Faktoren könnten zukünftig für den Betrieb Probleme darstellen?

Frage 37: Welche Perspektive hat der Betrieb?

Frage 38: Welche Maßnahmen seitens der Politik oder der Verbände wären nach Ihrer Meinung wünschenswert?

VII List of publications

Papers:

Röhrig, M.B.K., Hardeweg, B. and Lentz, W. (2018): Efficient farming options for German apple growers under risk - a stochastic dominance approach, International Food and Agribusiness Management Review, Vol. 21 (1), p. 101-120 (published).

Röhrig, M.B.K., Hardeweg, B. and Lentz, W. (2018): Rationalizing apple growers' decision making in Germany - a utility based whole farm programming approach (in press).

Röhrig, M.B.K., Hardeweg, B. and Lentz, W. (2018): Testing context-specific and general framing in risk-preference elicitation tasks – an empirical approach (submitted).

Röhrig, M.B.K. and Hardeweg, B. (2016): Efficient Farming Options for German Apple Growers Based on Stochastic Dominance Analysis. Proceedings "Schriften der Gesellschaft für Wirtschafts- und Sozialwissenschaften des Landbaues e.V.", 51, 311-312 (published).

Röhrig, M. and Hardeweg, B. (2015): Risk preference and risk perception of apple producers in Germany – development of a measurement concept. Acta Horticulturae 1103, 261-266 (published).

Working paper:

Röhrig, M. and Hardeweg, B. (2014): Risk attitude and risk perception of apple producers in Germany: Development of a measurement concept, DGG-Proceedings, Vol. 4 (11), p. 1-5.

Conferences:

Röhrig, M. and Hardeweg, B. (2015): Efficient Farming Options for German Apple Growers Based on Stochastic Dominance Analysis, 55. GEWISOLA-Tagung, Perspektiven für die Agrar- und Ernährungswirtschaft nach der Liberalisierung, 24.09.2015, Gießen, Germany.

Röhrig, M. and Hardeweg, B. (2015): Strategisches Risikomanagement für Gartenbauunternehmen am Beispiel des Obstbaus, 53. Betriebswirtschaftliche Fachtagung, Strategische Entwicklung von Einzelhandelsgärtnereien und -baumschulen, 08.09.2015, Grünberg, Germany.

Röhrig, M. and Hardeweg, B. (2015): Assessing efficient farming options for German apple growers based on stochastic dominance, 50. Gartenbauwissenschaftlichen Jahrestagung und Internationalem WeGa-Symposium, Urbaner Gartenbau / Urban Horticulture und Horticultural Production – Safety and Predictability, 27.02.2015, Freising-Weihenstephan, Germany.

Röhrig, M. and Hardeweg, B. (2014): Risikoeinstellung und Risikowahrnehmung bei Unternehmern im Kernobstbau - Entwicklung eines Messkonzeptes, 49. Gartenbauwissenschaftliche Jahrestagung, Nachhaltigkeit, 5.3.2014, Dresden, Germany.

Röhrig, M. and Hardeweg, B. (2014): Risk Preference and Risk Perception of Apple Producers in Germany – Development of a Measurement Concept, 29th International Horticultural Congress, Sustaining Lives, Livelihoods and Landscapes,19.8.2014, Brisbane, Australia.

Röhrig, M. and Hardeweg, B. (2014): Messung des Risikoverhaltens von Kernobst-Produzenten in Deutschland, GEWISOLA-Jahrestagung, Neuere Theorien und Methoden in den Wirtschafts- und Sozialwissenschaften des Landbaus,18.09.2014, Göttingen, Germany.

Röhrig, M. (2014): Risikoeinstellung und Risikowahrnehmung bei Unternehmern im Kernobstbau Ergebnisse zur Risikoeinstellung, Fachkommissionssitzung des ZBG, 06.11.2014, Hanover, Germany.

Röhrig, M. (2013): Risikomanagement im Kernobstbau, Fachkommissionssitzung des ZBG, 17.10.2013, Hanover, Germany.

VIII Curriculum Vitae

Persönliche Daten

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08/2017 – 07/2018	**OBI Corporate Center GmbH, Wermelskirchen** **Junior Product Range Manager**
05/2016 – 07/2017	**OBI Corporate Center GmbH, Wermelskirchen** **Trainee Category Management**
02/2016 – 05/2016	**OBI Corporate Center GmbH, Wermelskirchen** **Praktikantin**
11/2012 – 01/2016	**Zentrum für Betriebswirtschaft im Gartenbau e.V., Hannover** **Wissenschaftliche Mitarbeiterin**
04/2011 - 09/2012	**ThyssenKrupp Steel Europe, Duisburg** **Werkstudentin**

Studium und Schulbildung

08/2018	**Gottfried Wilhelm Leibniz Universität Hannover** Promotion - Gartenbauökonomie (Dr. rer hort.)
11/2012 –08/2018	**Gottfried Wilhelm Leibniz Universität Hannover** Promotionsstudentin
10/2010 – 09/2012	**Rheinische Friedrich-Wilhelms-Universität Bonn** Studium M.Sc. Agrarwissenschaften
10/2007 – 08/2010	**Rheinische Friedrich-Wilhelms-Universität Bonn** Studium B.Sc. Agrarwissenschaften
08/2004 – 06/2007	**Abtei-Gymnasium Brauweiler, Pulheim** Erlangung der Allgemeinen Hochschulreife
08/1998 – 07/2004	**Gymnasium der Stadt Frechen, Frechen**

Auszeichnung

2013	Jahrgangsbeste des Master-Studienganges Agrarwissenschaften