EFFICIENT FARMING OPTIONS FOR GERMAN APPLE GROWERS BASED ON STOCHASTIC DOMINANCE ANALYSIS

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Abstract

Apple production is afflicted with various risks. As it is a permanent crop, apple producers are less flexible to react upon undesirable events. As a result, for a sustainable economic performance, the determination of efficient farming options, as a combination of the production system and risk management instruments (RMI), is crucial. Our investigation focuses on this choice problem utilizing stochastic dominance criteria, which apply to a wide range of risk preferences. Based on data for 134 apple producers operating in the two main production areas in Germany, we compare and determine efficient production options for the most common regional varieties. Furthermore, appropriate RMIs are identified using stochastic dominance criteria. In this context we investigate internal RMI (frost irrigation and hail nets) as well as external risk protection tools (insurance options). In Germany only a single insurance concept against hail is available, whereas insurance against late frosts is not at the apple growers' disposal. As frost insurance exists in neighboring countries, we analyze the effect of the latter based on a hypothetic frost-hail insurance policy.

Simulated net present values of a one hectare level serve as decision criterion, for which the associated cumulative probability distributions are evaluated according to first and second degree stochastic dominance criteria. In addition, we use SERF (Stochastic Efficiency with Respect to a Function) as it evaluates farming options for defined ranges of relative risk aversion and thus has a higher discriminative power.

The results indicate that Red Prince is the most efficient option 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 under rational aspects, but the tested insurance solutions are not as efficient as the common production practice under hail nets.

Keywords

crop insurance, risk perception, risk behavior, risk management, SERF, hail, frosts

1 Introduction

Open field production, fraught with risks, 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., 2012a , CATALÁ et al., 2013). Due to the high complexity, we focus on the latter two issues of farm planning for apple production.

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 by up to 50% by producer organizations (DIRKSMEYER et al., 2014: 59-60). In addition, hail insurance that protects against revenue loss is available. For hail insurance, no governmental subsidy schemes exist (BIELZA DIAZ-CANEJA et al., 2009). Even if producer organizations subsidize insurances, 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., 2012b).

Deterministic crop budgets for an economic assessment of apple production systems in Germany are available (KTBL, 2010). However, no information is provided on which risk management strategies are the most promising ones and whether new strategies, for instance combined frost-hail insurances, could provide appropriate instruments for apple growers in Germany.

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 we use stochastic dominance relations to determine appropriate farming options including variety choice and risk management strategies.

2 Literature Review

Literature on apple growers' risk behavior in industrialized countries is currently scarce. MENAPACE et al. (2014) analyzed risk perception of apple farmers in Italy in the context of climate change as province level hazards. 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, while 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 reject indications against it) (MENAPACE et al., 2012b).

CHEN et al. (2007), compare risk reduction properties of a multi-peril crop insurance with an income based one for conventional and organic apple producers in the north-west pacific area of the USA. Their analysis is based on historical prices 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, with only one variety-dependent exception, a lower welfare (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: 62-63; LIEN et al., 2011). The historical data approach (HARDAKER et al., 2004: 80-82) allows to combine historical data and subjective probability estimates to reproduce the correlation structure and therefore to account for stochastic dependencies (HARDAKER et al., 2004: 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, working with probability distributions is advised (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).

Two methods are common in the literature for discriminating efficient from less efficient farming options considering the distribution of performance indicators and risk attitudes of the decision makers. The first is stochastic dominance. For example SCHENK, et al., (2014) apply stochastic dominance criteria for assessing Australian farmers' decision making in the context of crop-choice, focusing on five arable crops and pasture, given uncertain amounts of water supply. They further use stochastic efficiency with respect to a function (SERF), which provides a better discriminatory power due to stricter assumptions on risk attitude (SCHENK, et al., 2014).

To our knowledge, 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 so far. Thus, we aim to determine the most efficient farming options by applying stochastic dominance criteria and SERF on data of net present values for investments in apple orchards.

3 Data and Methods

For the risk ranking of farming options, we extend the deterministic budget in order to obtain cumulative distribution functions (CDFs) of the net present value (NPV) for apple orchard investments and apply stochastic dominance criteria for a ranking. In our stochastic simulation, the NPV is calculated for 16 years of full bearing for a combination of one hectare of a certain variety and the respective risk management strategies. The juvenile phase of the orchard in years one to three after establishment is considered as a deterministic component of the NPV.

We use the historical data approach for implementing stochastic dependencies between yield and price variables and subjective risk perceptions (HARDAKER et al., 2004: 80-82).

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 river 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 is a major risk.

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, we used the pyramid scheme to acquire more 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, we also obtained details on their risk attitude.

3.2 Elicitation of Subjective Probabilities

For the elicitation of probabilities, we assumed the estimation of probabilities based on experience technique to be the simplest question framework, as it only requires three values (HOAG, 2010: 212-213). However, only estimations of yield were successfully elicited with this technique, as the pretest revealed, that farmers do not feel comfortable when they are asked to assign a minimum, maximum and modal value to losses and prices. Therefore, we followed the route of MENAPACE et al. (2012a) and elicited losses and prices with the fixed value method. Thus, farmers were asked to indicate their expectations for the upcoming production years by allocating ten years to given intervals of losses and prices. Afterwards, these absolute frequencies were converted into relative ones and the midpoints of the given intervals were used for further calculations. 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. We addressed a time interval of ten years, since longer time intervals might result in a lower willingness to participate and a decline in attention during the interview.

3.3 Parameter setting of the SERF-Approach

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 the recommended behavior 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, we adopt CRRA for our analysis. Even if one might argue that we simulate at a one hectare level, which is relatively small to 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: 112).

We follow the route of LIEN et al. (2007b) and assume wealth as $W_T = W_0 + W_s$. Where W_0 is the non-stochastic wealth, equaling 45,000 € per hectare, and W_s is the stochastic wealth of apple production.

The range of risk aversion coefficients of 0 to 3.00 is set according to the results of our risk attitude analysis. We elicited risk attitude 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. Table 1 indicates the absolute frequency of the elicited coefficients.

Table 1: Elicited relative risk aversion coefficients.

Relative risk aversion coefficient	**0.155**	**0.470**	**0.815**	**1.265**	**2.000**	**n**
Absolute Frequency	25	15	14	3	8	65

3.4 Description of the model and calculation of key variables

The risk model was developed in MS EXCEL. After combining historical data with subjective probabilities, we used the Palisade add-in @Risk for Latin Hypercube simulation, an advancement of the Monte Carlo simulation, which generates probability distributions for stochastic variables of interest. We used 5000 iterations for our analysis.

Regarding the key variables of the model, we followed the route of CLANCY et al., 2012 and set those parameters as stochastic ones, which are substantial risky determinants of revenue. As reported by BRAVIN et al., (2009), yield and quality have an important impact on farm profit, whereas production costs are less important. Therefore, we 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 this stadium, yield under normal conditions is already combined with historical data. In addition, the event of fire blight (*Erwinia amylovora*) as bacterial infection is included as a stochastic variable in the simulation as a rare but severe event.

3.5 Characterization of farming scenarios

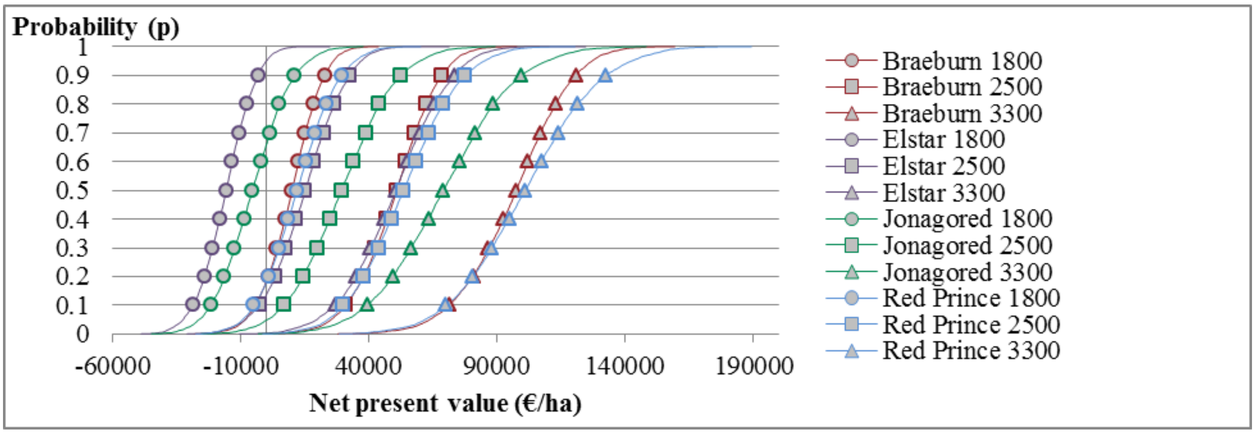
For farming scenarios, we focus on varieties which are common in the considered production areas. Our data indicate that in the north of Germany mainly the varieties of Braeburn, Elstar Jonagored, and Red Prince are produced, whereas in the south Braeburn, Elstar, Jonagold, and Gala are the predominant ones, usually propagated on M.9. These varieties provide the basis for our analysis of one hectare of certain farming options over a period of 16 years of full bearing capacity. As we are interested in the effect of already existing as well as non-established risk management tools, we compare the following scenarios for common varieties of each region. The first step of our analysis determines the optimal planting density for each variety under standard risk management strategies. In the North, frost-protection 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 we consider frost irrigation, combined with a hail insurance (HI) and for the south hail insurance is analyzed as an alternative for hail nets. The preferred options are inserted in a third and last step of the analysis, where we focus on a hypothetical set of combined frost-hail insurance (FI+HI) for both regions.

As currently available subsidies cover up to 50% of installation and insurance premium costs, we simulated step two with and without subsidy payments. For the subsidy schemes we made the following assumptions: 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 a multiplication of the sum insured with a distribution factor as laid down in the subsidy scheme of the producer organization. This distribution factor represents 1% of the 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

Four region-specific varieties under common practice are part of the first analytic step. Fig.1 displays the CDFs of NPVs (discounted at 4 percent) 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.

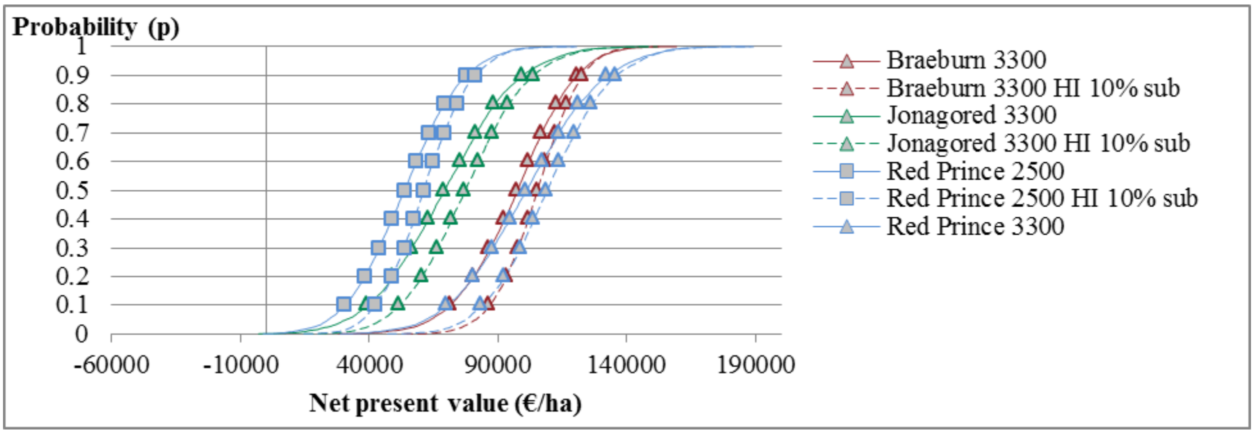
Fig 1: Common practice with frost irrigation (north).



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 become part of our further analysis.

Results of the second analytic step for the north are given in Figs. 2-4.

Fig 2: Subsidized hail insurance with frost irrigation (north).



As indicated in Fig. 2, insured crops of all varieties dominate the associated common production practices in terms of SSD. This effect arises from both, insurance and subsidies, whereby the latter amount to about 850 € per hectare on average.

Fig 3: Unsubsidized hail insurance with frost irrigation (north).

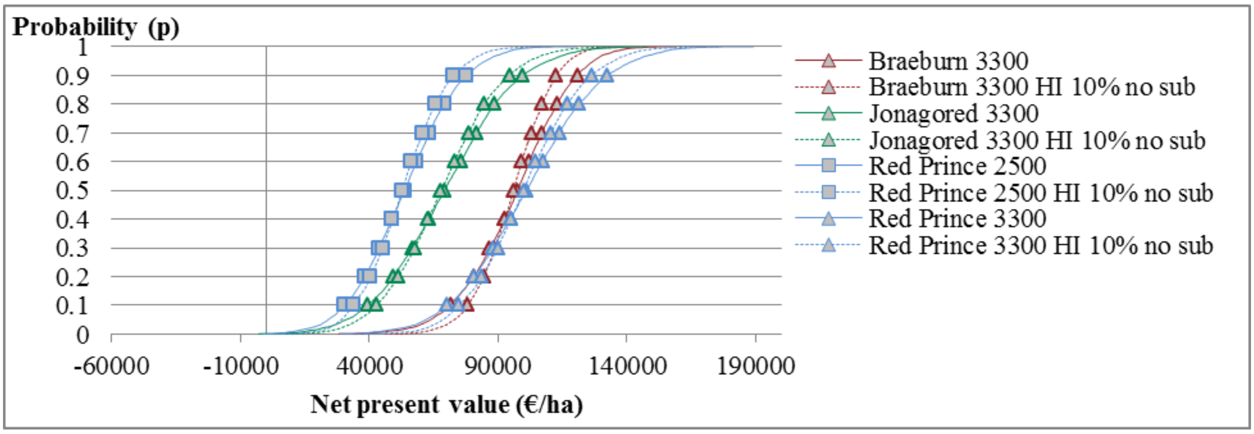
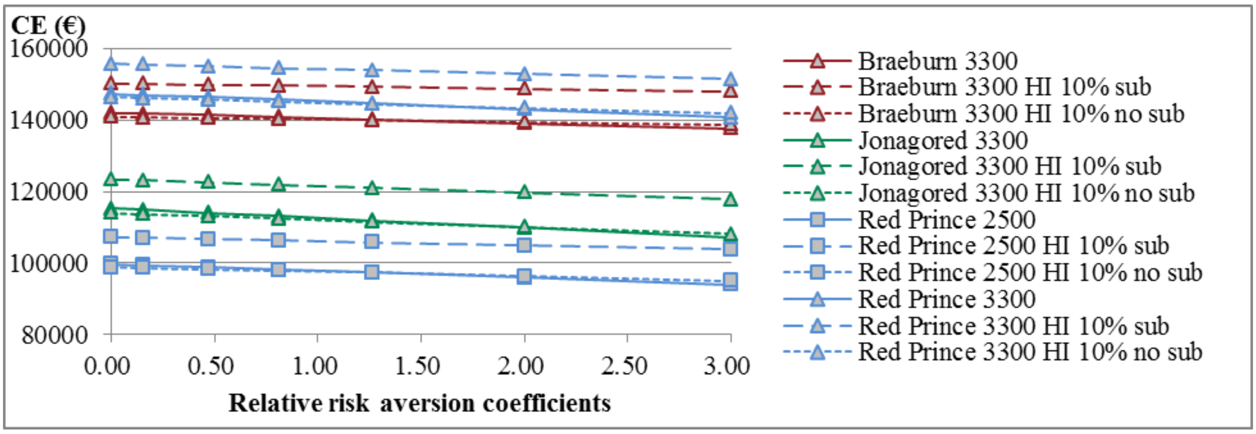


Fig. 3 presents the results of unsubsidized hail insurance. As can be seen, insurance policies without subsidies reduce risks as the associated curves become steeper in comparison to those of the basis scenario. Again, it is not possible to judge the performance of insurance according to FSD or SSD as the crossing points are located in the lower range of the probability distributions. For a further discrimination we apply SERF.

Fig 4: SERF analysis (north).



The SERF analysis (Fig. 4) 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 marginally higher CEs. Nonetheless, a combination of frost irrigation and subsidized hail insurance provides the most efficient risk management strategy, irrespective of the variety, with Red Prince being the most efficient variety.

Fig 5: SERF analysis (south).

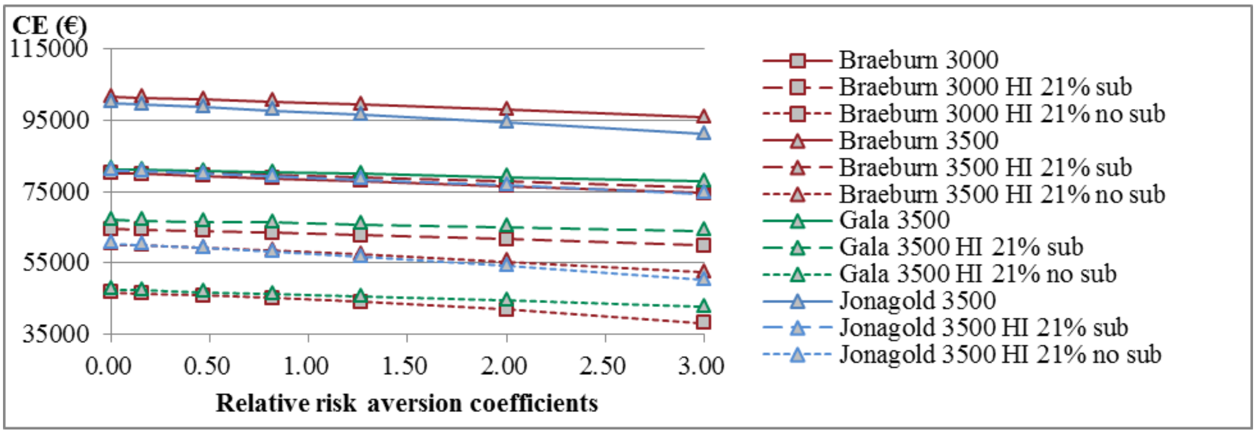
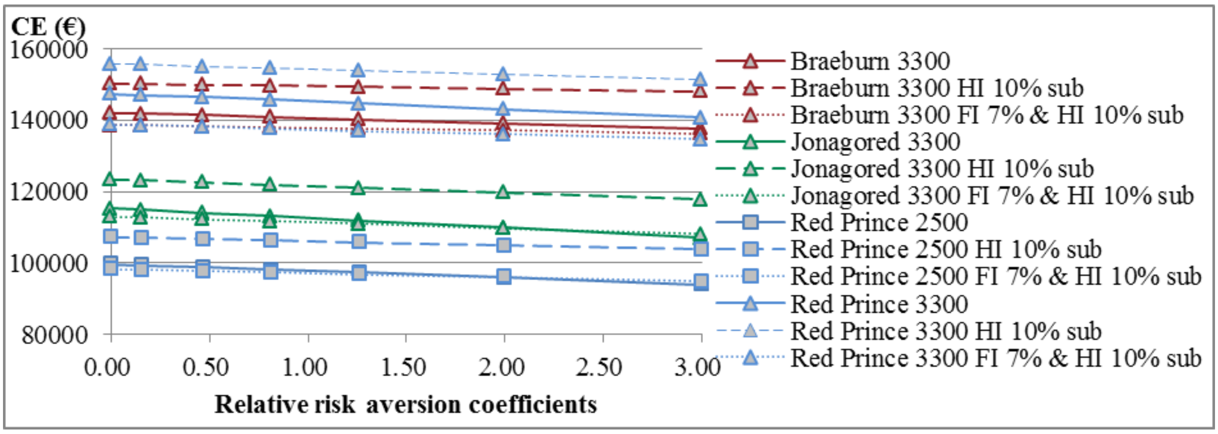


Fig. 5 summarizes the results for the south in terms of CEs. Evidently, the basic scenarios of Braeburn and Jonagold at 3500 trees per hectare offer the most efficient alternatives, whereas slightly to very risk averse farmers should prefer Braeburn. For risk neutral apple growers, subsidized insurance 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. 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. Furthermore, the results indicate that subsidies are assumed to be a certain and non-negligible source of revenue, as all unsubsidized insurance concepts do not provide an alternative to hail nets.

As mentioned before, risk management instruments for apple growers against weather related risks are rare. Thus, we are interested in the effect of frost-hail insurance as a (so far) hypothetical alternative. As an extension of our analysis we therefore plot CEs of a subsidized frost-hail insurance together with subsidized hail insurance and the basis scenario.

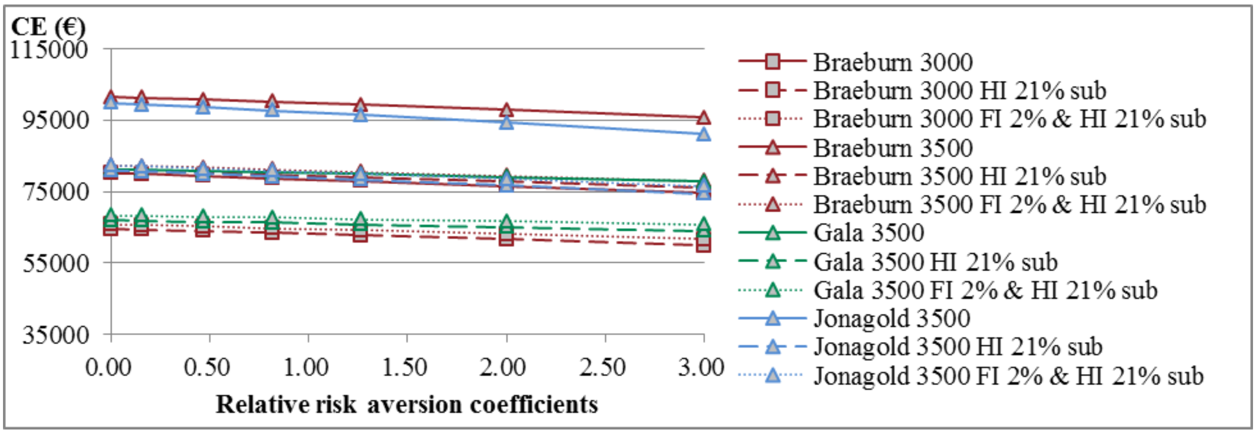
Figs. 6 and 7 present the results for the north at a 7% insurance premium level and the south with a 2% insurance premium. These insurance premiums were obtained by a comparison of average premium costs and indemnity payments.

Fig 6: SERF analysis with combined frost-hail insurance (north).



In the north, frost-hail insurance would not necessarily provide an efficient alternative to frost irrigation. Only persons with an extremely high risk aversion would obtain slightly higher CEs compared to the base scenario of Red Prince at 2500 trees per hectare and Jonagored at 3300 trees per hectare. However, as can be seen for Braeburn and Red Prince at 3300 trees per hectare, this effect depends on the planting density as well as on the variety.

Fig 7: SERF analysis with combined frost-hail insurance (south).



In the south, the basic (and most commonly found) farming options remain the most efficient ones when compared to subsidized insurance solutions. The CEs of the combined frost-hail insurance are close to those of single hail insurance, although the associated values always lie above due to the assumption of higher subsidy payments. Compared to the single hail insurance, these payments lead to a 4.17% increase of the net present value and to about 178€ additional income per hectare.

5 Discussion

Risk management in open field production is a frequently discussed topic. Nevertheless, studies addressing apple growers' risk behavior and their adoption of risk management strategies are rare. In order to close this gap, we developed a stochastic budgeting model which considers weather-extremes as well as price risks.

Apparently, apple growers in the north achieve higher revenues. A comparison of the estimates obtained shows that 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. These results 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 of 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 farmer to consumer prices up to 40 € per dt have presumably a higher influence on revenue.

Results obtained for the basic scenarios 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 low yield of Elstar orchards may in part be explained by its high tendency for alternate bearing, to which other cultivars of our analysis are known to be less sensitive (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.

SERF-analysis of the north further reveals that in the basis scenario with frost irrigation, Red Prince provides the most efficient option in the north over a wide range of relative risk aversion coefficients ($0 \leq r_r \leq 3$). 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 of 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. With respect to direct costs, the high yield-level of Jonagored as well as of Red Prince result in higher direct costs, as storage costs are increased.

Results of the SERF analysis for apple production under hail nets in the south indicate, that Braeburn is the most efficient variety due to its higher price level. However, the average yield of Braeburn lies below the one 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.

The SERF analysis for the north reveals that rational apple growers should combine frost irrigation with subsidized hail insurance. However, our data shows that 30% of the apple growers who are already members in a producer organization, do not participate in hail insurance. Taking a prospect theoretical view, 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 persons to combine frost irrigation with unsubsidized hail insurance.

Generally, a 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 base scenario, if the apple grower is risk neutral to slightly risk averse and chooses varieties which are characterized by a high yield, or an elevated price level. Without subsidies, hail insurance would be clearly dominated by common practice with hail nets and thus provides no reasonable alternative.

The results further suggest that subsidized, combined frost-hail insurance in the north is only appropriate for very risk averse decision makers, even though the effect is variety-specific and depends on the planting density. In the south, a combined frost-hail insurance 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. Thus, the added value of a frost-hail insurance is low. In spite of this, commercial multi-peril insurance is available for apple production in the Netherlands covering frost and hail damages in combination with other weather-related risks such as drought and storm. This insurance receives a government subsidy at 60% of the insurance premium (VEREINIGTE HAGEL, 2012b: 12).

Finally, we address a potential criticism regarding the use of the net present value as the stochastic investment criterion our analysis. Using the NPV means we evaluate the total of 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), we assume that each variety on a 1 ha basis only represents a rather small percentage of farming activities and farmers' wealth, whose failure would not necessarily lead to insolvency of the enterprise.

6 Conclusions

Results of the present study indicate that the choice of variety as well as the adoption of RMI influences the riskiness of production and sale of apples.

In the north, Red Prince appears as the most efficient variety. Furthermore, subsidized hail insurance would provide benefits for risk averse persons 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 relying on the same variety and planting density. Our results are consistent with observed behavior, as apple growers have implemented the optimal available RMI in their production systems out of those considered in our analysis. 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 very risk averse individuals. However, in reality, where apple growers depend on direct marketing to consumers, consumer's preferences on a wide assortment of products have to be met. Thus, a certain mix of favored apple varieties has to be offered, which precludes the specialization on a single variety. In consequence, future work should focus on whole farm-risk programming which also allows for the implementation of additional requirements, such as pollination management, and farm-specific restrictions.

With respect to the subsidized hypothetical frost-hail insurance, we obtain variety specific results for the north, which also depend on the planting density. For high-yielding varieties in high density plantings this insurance concept seems to be inappropriate, whereas it may lead to a slight increase of efficiency when compared to frost irrigation as the only RMI and considering very risk averse apple growers, who use less intensive production systems. 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. The production of high yielding varieties catching good prices in high density plantations under hail nets still remains the most efficient option.

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