University doctoral (PhD) dissertation abstract

EVALUATION OF MAIN FACTORS DETERMINING THE PRODUCTION RISKS OF SOUR CHERRY AND PEAR

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1. INTRODUCTION, RESEARCH TARGETS AND RESEARCH HYPOTHESES

The climate of Hungary is suitable for producing good quality fruit, as the Carpathian Basin is protected, and it has relatively balanced continental climate. At the same time the winter and spring frosts, drought and hail damage could cause sporadically and occasionally heavy dropout of crop. Beside the frostbite experienced in the past few years – in the years of 2007, 2009, 2010, 2012 - the extent of drought damage and hail damage became more severe as well, and the lack of irrigation causes a growing concern for the farmers. Due to the increase of frostbite in recent years in Hungary great attention should be paid to the crop safety of fruits. As a result of extreme weather events the production risk of the sector is growing, which has to be considered by producers.

In 1998, **global fruit production** reached 435 million tons. It was increasing along with the population and of the standard of living and in 2010 it already exceeded 609 million tons, too. According to the forecasts, this growth will still continue in the next two decades.

Currently, the production of **sour cherry** in the world is around 1.1 million tons. According to the forecasts, it could even reach 1.5 million tons by 2015. 66-70 percentage of the produced sour cherry is grown in Europe. The most significant producers of sour cherry are: Turkey, Poland, Ukraine and Russia. Sour cherry is the second most important fruit after apple in our country. While in 2000 sour cherry was being grown only on 10000 hectares, by that time in 2011 we were already producing this fruit on 13,388 hectares, reaching 61,735 tons of crop.

China is the world's leading **pear** producer (67%), followed by Russia and the USA. Though our climate is suitable for producing good quality pear, even so our pear growth is slight and our arrear is also significant regarding our production standards. Regarding the regional location the Great Hungarian Plain and Northern Hungary represent outstanding ratio.

The rethinking of future of the fruit sector – beside the conditions of powerful and strong European competition – should be started with analysing the current situation and with checking the accordance between the fruit species and growing places.

In my dissertation I analyse two different fruit species (sour cherry and pear) and I draw inferences regarding the risk of growth based on several production sites (Újfehértó, Bánfapuszta, Zalasárszeg, Alsóbereczki, Siófok). Within production risk, I analyse the effects of the weather and the effects of the species affecting growth risk.

As in the northern region of the Great Hungarian Plain – in particular, in Szabolcs-Szatmár-Bereg County – sour cherry has a significant tradition regarding the production, therefore I checked the risk of sour cherry production and the risk of yield in this region. The yield risk of pear, as the other most important fruit of the Hungarian fruit industry, was analyzed in Bánfapuszta, Zalasárszeg, Alsóbereczki and Siófok.

Research aims:

- Overview of related research antecedents.
- Introduction of Hungarian sour cherry and pear production.
- Classification of risk types in fruit production.
- Estimation of sour cherry budburst and flowering using phenology models based on heat sums.
- Examination of weather indicators determining the risks of sour cherry production.
- Foundation for optimal decision making with the help of mathematical risk modelling for sour cherry and pear in different variety-production area combinations.

My research hypotheses are as follows:

Hypothesis 1: The expected climatic change – warming – will affect the timing of sour cherry phenophases.

Hypothesis 2: Not only the different fruit species but also the various fruit varieties can be produced with different yield risks in different production areas.

2. DATABASE AND APPLIED METHODS

I utilised the database of the Institute of Research and Extension Service for Fruit Growing at Újfehértó Ltd. referring to the period 1984-2010 for analysing the budbreak and start-blooming time. The following meteorological data have been registered: daily average, minimum, maximum temperatures (°C) and precipitation (mm). The data set was completed with phenology data from the same site (’Újfehértói fürtös’, ’Kántorjánosi’ and ’Debreceni bőtermő’) (Budbreak dates were available for time interval 1984-1991, only).

I aimed to build up a relatively simple model, which will be suitable to predict the date of budburst and blooming in the 3 most important sour cherry varieties grown (’Újfehértói fürtös’, ’Kántorjánosi’ and ’Debreceni bőtermő’) at Újfehértó. The error of the estimation has defined as the sum of squares of deviations expressed in days.

I determined with optimization the statistically estimated starting date of ectodormancy and from this period I accumulated the heat sum. I determined the optimal lower and upper base temperatures separately for the budbreak and full bloom starting dates by minimization such that the lowest root mean square deviation of the observed and predicted dates (standard error, days), the lowest average absolute and the lowest maximum error of predictions (both measured in days) can be achieved. From the observed data, we calculated the sum of daily mean temperatures for the three varieties taken the values above the basic temperature only, from the chosen term and cumulated them until the day of budburst for each year. In case of full bloom starting date estimation the summation began at budbreak. In a year, after the starting date, the daily averages of temperatures above the lower base temperature (maximized by the difference of the upper and lower base temperature) are accumulated. If the critical value of the respective variety is reached, the date of budburst is indicated and the accumulation for the full bloom starts. If the critical value of the respective variety is reached, the starting date of bloom is indicated. I calculated the average sum of degree days over the examined years for each variety and estimated the critical sums of degree days.

To examine the effect of climatic changes I took the RegCM3.1 (regional) climate model with 10 km resolution referring to 2021-2050 and with reference period 1961-1990. The original model was downscaled at Eötvös Loránd University, Department of Meteorology.

Expected value-variance (E-V) **efficiency criteria** – common in related scientific literature – can be applied to assess which decision alternative has higher expected value and at the same time lower variance value creation or risk. I used **expected value** (E) for characterising yield average, while I used **variance** (V) as a deviation indicator to express risk.

My aim was to determine how different fruit varieties could be characterised – what characteristics – to compare their risks. **Stochastic dominance** (SD) criterion method is suitable for determining whether such decision versions can be separated in the examined period that produce better or at least just as good results as the others. Risk assessment also reveals the personal attitude of the decision maker to risk taking, or what related literature refers to as risk aversion (r_a). In my thesis I used the first and second degree stochastic dominance criteria as well as the generalised stochastic dominance. Generalized stochastic dominance is a criterion with an assumption about risk aversion as it takes the risk attitude of the decision maker into account so it has a stronger discriminatory power than the criteria above. Generalized stochastic dominance criterion says that if we plot the function CE then the higher curve assigns the more preferable alternative for the decision maker.

I assessed sour cherry yield risk in Újfehértó, pear at two plantations – Zalasárszeg and Bánfapuszta – of Gyümölcskert Plc. based in Nagykanizsa, at the planatation of Pyrus-94 Ltd. in Alsóbereczki and at the plantation of Siófoki Gyümölcstermesztési Plc.

As I have not found in domestic professional literature any books yet, which introduce the **types of risks occuring in fruit production** in details, I consider it important to methodise these sources of risk in my dissertation.

I classified the types of risks occuring in fruit production into three big groups: we can differentiate **production, human** and **management risk**. **The production risk** originates from discrepancy of variability generated by random effects affecting the ecological conditions and of biological demand of the grown plants, which I demonstrate in the dissertation without attempting to be comprehensive – I intended to organise them in order of importance. Sources of production risks are the growing site, weather, the usage of species, the selected technology and the possibility of random losses. Within the production risk I manage the weather risk with high priority, as the extreme weather factors - winter and spring frost, hail, unfavourable distribution of precipitation, the high temperature in the period of rest season and growing season, more frequent thunderstorms and windstorms, just as precipitation coming in extreme frequency and period – are differentiated according to regions and they represent significant risk factor. For that very reason in the future we have to take crop failure caused by weather into account.

Preparedness and competence of the farmer making decision and the grower applying the technology determine tendencies and efficiency of the whole fruit production and sales system, therefore the **human risk** should be managed with high importance.

Having approriate level of biological, technological, technical, management and market knowledge rational decision could be developed regarding direction and size of the production, therefore the analysis of **managment risk** has also high importance.

3. MAIN CONCLUSIONS OF MY THESIS

3.1. Budbreak model

The optimal lower and upper base temperatures with the optimal starting date (called the statistically optimized end of endodormancy) for budbreak are 2.5°C, 5°C and 42nd Julian day of the year. The root mean square error (standard error), the average (absolute) error and the maximal (absolute) error are 2.75, 2.25 and 6 days for budbreak.

In *Table 1*, we can see the sum of degree-days (in °C) of the varieties accumulated until budburst. The values presented, correspond the statements come up to the data based on the physiological considerations in the literature. Among the 8 years examined, the year 1989 deserves special attention because budburst ensued at 17.5ºC, which proves that budburst may occur even at low sum of degree-day. Substantial differences are observed between 1984 and 1990 only. Budburst of the variety ’Debreceni bőtermő’ was observed at higher temperatures (32.6ºC) in 1984, whereas in 1990, variety ‘Újfehértói fürtös’ performed similarly. The differences are, however, not significant, which is comparable to the phenological comparisons of SZABÓ (2007).

Table 1: The sums of average daily temperatures and the critical averages for the varieties examined between 1984 and 1991 (°C)

Years	Varieties			Average
	’Újfehértói fürtös’	’Kántorjánosi’	’Debreceni bőtermő’	
1984	30.1	30.1	32.6	30.9
1985	36.3	36.3	36.3	36.3
1986	32.3	32.3	32.3	32.3
1987	28.2	28.2	28.2	28.2
1988	23.9	23.9	23.9	23.9
1989	17.5	17.5	17.5	17.5
1990	41.4	38.9	38.9	39.7
1991	24.6	24.6	24.6	24.6

Source: Own compilation based on the data of the Újfehértó Research Station, 2011

In *Table 2* we can see among the 8 years examined, the years 1989 and 1990 were excessive. In 1989, the differences were even 5–6 day long, i.e. budburst ensued later than signaled by the model. In 1990, the results changed in the opposite direction (–3; –4 days).

Table 2: The errors of estimates (days)

Years	Varieties			Yearly averages of absolute values
	’Újfehértói fürtös’	’Kántorjánosi’	’Debreceni bőtermő’	
1984	0	0	-1	0.33
1985	-2	-2	-2	2.00
1986	-1	-1	0	0.67
1987	1	1	1	1.00
1988	3	3	3	3.00
1989	5	5	6	5.33
1990	-4	-3	-3	3.33
1991	2	2	3	2.33
Averages of absolute values	**2.25**	**2.13**	**2.38**	**2.25**

Source: Own compilation based on the data of the Újfehértó Research Station and RegCM3.1, 2011

3.2. Start blooming model

The optimal lower and upper base temperatures for bloom start are 1.6°C and 19°C. The root mean square error (standard error), the average (absolute) error and the maximal (absolute) error of validation of the full bloom starting dates are 2.76, 2.39 and 9 days.

As we can see in *Table 3* the model indicates from 27 to 19 years maximum 3 days or lower variance. In 1990 the observed and predict data are the same for three sour cherry varieties. The biggest variance between the observed and predicted start blooming time is in 1998, because the model estimates 8 or rather 9 days earlier start for blooming time. The estimation was the most efficient for the

’Újfehértói fürtös’ variety. Although the model explains the beginning of blooming time efficiently, it seems, that the first decade (1984-1988) it estimates earlier start for blooming time than observed and from 1999 to 2006 it estimates a later. This phenomena draws attention to fact that climate change might slightly change the response of plants.

Table 3: The errors of estimates (days)

Years	Varieties			Yearly averages of absolute values
	'Újfehértói fürtös'	**'Kántor-jánosi'**	**'Debreceni bőtermő'**	
1984	-2	-3	-1	2.00
1985	-1	-1	-1	1.00
1986	-1	-1	-1	1.00
1987	-7	-8	-8	7.67
1988	-2	-2	-2	2.00
1989	1	1	2	1.33
1990	0	0	0	0.00
1991	-1	-1	0	0.67
1992	1	-1	0	0.00
1993	4	3	4	3.67
1994	1	0	-1	0.00
1995	-4	-4	-5	4.33
1996	1	1	1	1.00
1997	1	1	1	1.00
1998	-8	-9	-8	8.33
1999	0	1	1	0.67
2000	2	3	2	2.33
2001	1	2	-1	0.67
2002	4	4	4	4.00
2003	3	4	4	3.67
2004	3	3	3	3.00
2005	3	3	3	3.00
2006	2	2	3	2.33
2007	-5	-6	-5	5.33
2008	3	3	3	3.00
2009	6	6	6	6.00
2010	-1	-3	-2	2.00
Averages of absolute values	**2.29**	**2.52**	**2.38**	**2.39**

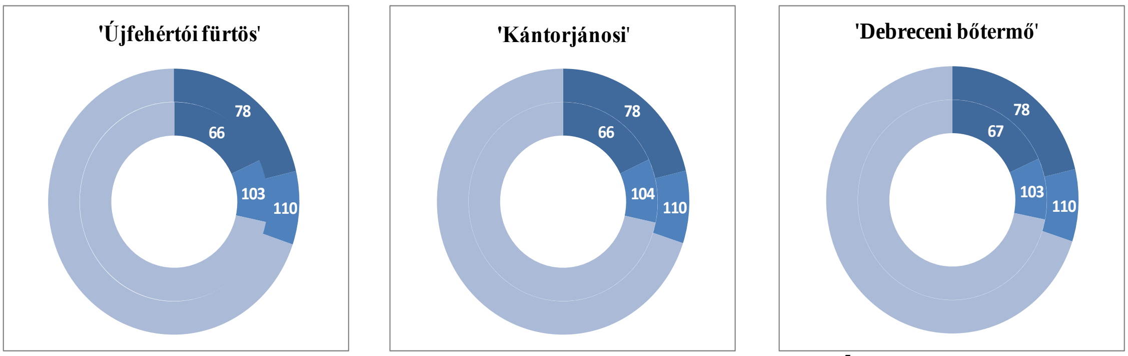
Source: Own compilation based on the data of the Újfehértó Research Station and RegCM3.1, 2011

3.3. Estimation model for budbreak and blooming time for sour cherry in the future

If the model above is run with the results of the regional scale climate model, then we can get a picture of the further expected changes of sour cherry phenological rhythm. Taking the 1984-2010 period as a reference, we calculated the length of the "**average blooming period**". I use the 110 Julianus day for the main blooming start day" and the 121 Julianus day for „the main blooming end day" between 2021 and 2050.

Figure 1 represents the budbreak and bloom start dates of the three sour cherry varieties ('Újfehértói fürtös', 'Kántorjánosi' and 'Debreceni bőtermő'). The external circle is for the observed dates (budbreak was monitored in between 1984-1991 while full bloom was recorded between 1984-2010). The internal circle is for the predicted dates (2021-2050) which were calculated based on the phenology model and RegCM3.1 data.

Figure 1: Observed (external circle) and predicted (internal circle) budbreak and start blooming time



Source: Own compilation based on the data of the Újfehértó Research Station and RegCM3.1, 2011

The RegCM3.1 model predicted that the **budbreak** dates are expected to **shift 11-12 days earlier** (2021-2050) while **blooming** may **start 6-7 days earlier** than it was observed at the end of the last century.

3.4. Indicator analysis result with the RegCM3.1 model for blooming time and 10 days prior

I compared the result of the estimation of RegCM3.1 regional climate model with the historical data (1984-2010) in Újfehértó. Assuming that the phenology model predictions of the full bloom indicate 6-7 days earlier starting dates, the indicators are calculated for the analogous bloom period which is a period shifted 7-day earlier as the base bloom period. The calculation also included 10 or 12-day earlier start as the base bloom period, because a blooming time exceeding 7 days earlier can also occur. This comparison were calculated based on the RegCM3.1 model.

The number of frosty days (days when the minimum temperature drops below the freezing point 0°C)

The mean of the frosty days was 1.1 days in 1984-2010. In 1986, 1991 and 2002 the number of frosty days was 4, while in most years the blooming period was not frosty. The result was simply: no frosty days are anticipated in 2021-2050 during the critical period of blooming and 10 days before. If the bloom occurs in approximately 7 days prior to this, the thirty-year average of two years is expected to occur in frost days during the period (a maximum of one frosty day). Blooming 10 days earlier may start for about three years, presuming a cold day (maximum one frosty day), while starting 12 days before flowering an average of 4 years, we expect average temperatures below 0°C, calculating with two days below freezing per year.

The absolute minimum

The mean of 27 years is 0.1ºC, however, significant values are also observed, as in 1996 and 2009 the values were relatively high (5ºC and 4.5ºC) as absolute minimum, whereas in 1992 and 2002, it was -4ºC or -5ºC, respectively. According to the regional climate model the absolute minimum in 2021-2050 is expected to be 6ºC on average. If the bloom occurs in approximately 7 days prior, the average will decrease to 4.3°C, 10 days prior the average will be 3.9°C and 12 days before blooming an average will be the same than between 1984 and 2010 (0.1°C).

The mean of minimum temperatures

The mean of 27 years was 6.1°C in 1984-2010. The RegCM 3.1 model predicts the average of minimum temperatures of 10.9°C in 2021-2050. Generally speaking, if the blooming occurs earlier, the average of minimum temperatures will be lower and lower. If blooming occurs in approximately 7 days earlier, the average of minimum temperature will be 10°C, 10 days earlier the average will be 9.6°C and 12 days before blooming an average will be 9.4°C.

The number of days with warmer than 10ºC as average temperatures

Results show that during the observed 27-year-long period (1984-2010) the number of days with means above 10ºC did not increase significantly. The mean of the 27 years was 15.7 days. In 2009 there were 23 days with mean temperatures above 10ºC in the observed period, while in 1986 there were only 11 such days. Between 2021 and 2050 there will be 16 days. It is expected that the number of days with average above 10°C will increase slightly, but with strong fluctuation. When the blooming starts 7, 10 or 12 days earlier, the average will decrease slightly (14.2 day, 13.4 day or 12.7 day).

The average of maximum temperatures

The observed average of the 27 years was 18.6ºC. The yearly fluctuation was noticeable. In 1985, 1991, 2001, 2002, 2008 and 2010, it was 16ºC only, whereas in 1987, it reached 27ºC, which is 8°C more than the average of the 27 years. The expected average of maximum temperatures is 13.2°C in 2021-2050 for the 10 day pre-blooming plus blooming period. If the blooming occurs earlier, the average of maximum temperature will decrease. When I analysed the average of maximum temperature I got the lowest standard deviation values (between 13% and 16%).

The number of days without precipitation

During the pre-blooming and blooming period the average number of days without precipitation was 13.6, but a drastic decline was observed. During the 80’s the value of the trend was 14 days, and it was only 13 days. The average number of days without precipitation during the pre-blooming and blooming period is expected to be 12.1 in the future according to RegCM3.1 estimate for 2021-2050. I did not detect significant deviation from this among the examined versions in any single earlier blooming start assumptions, so no significant changes can be expected in the number of precipitation-free days even if earlier blooming occurs.

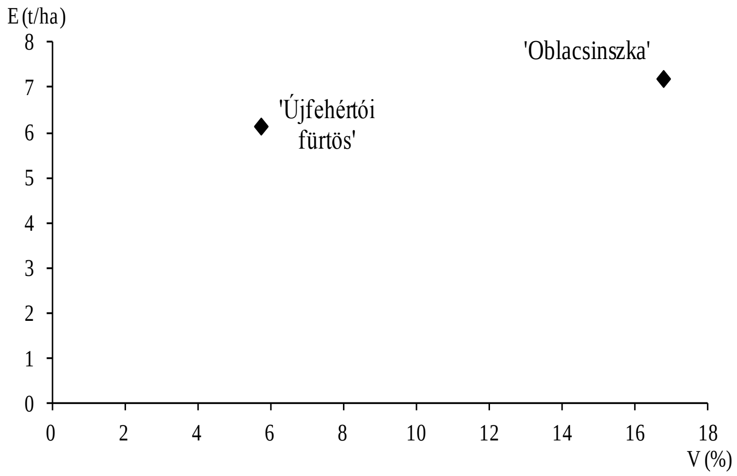
Number of days with precipitation above 5 mm

During and 10 days the blooming period, between 1984 and 2010, the average number of days with precipitation above 5 mm was 2.2. The average number of rainy days (with more than 5 mm precipitation) during the pre-blooming and blooming period is expected to be around 3 in the future according to RegCM 3.1 estimate for 2021-2050. According the climate model, the number of days with precipitation above 5 mm will not change, if the bloom occurs earlier.

3.5. Comparisons of production of sour cherry varieties regarding risk aversion

I used the E-V efficiency criterion to compare the yield risk of two sour cherries varieties (’Újfehértói fürtös’ and ’Oblacsinszka’) in Újfehértó. I analysed the yield with the **E-V efficiency criterion method** (*Figure 2*) and represented the expected value in the function of variance. The efficient set contains the points of the alternatives in the north-west quadrant, which is empty. The efficient set contains both sour cherry varieties, because in the north-west quadrant there are not any varieties, so we could not determine the ranking of alternatives. Since from the examined alternatives only some of these may be placed in any determinable order, I calculated the first and second degree stochastic dominances.

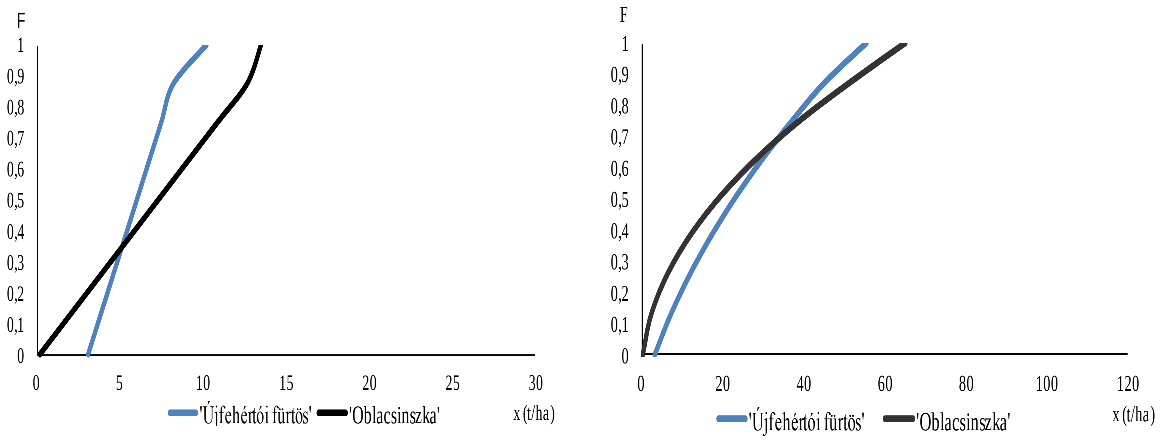
Figure 2: Az E-V efficiency for two sour cherry varieties (’Újfehértói fürtös’ and ’Oblacsinszka’) in Újfehértó



Source: Own compilation based on the data of the Újfehértó Research Station, 2013

In *Figure 3*, we can see the results of the first (*left panel*) and second (*right panel*) degree stochastic dominance. Both the distribution functions and their integral funcions cross each other, so we cannot define the most preferable alternative. We could not say that people could produce the ’Újfehértói fürtös’ or ’Oblacsinszka’ sour cherry varieties with less risk. Therefore, the general stochastic dominance method was required (*Figure 4*).

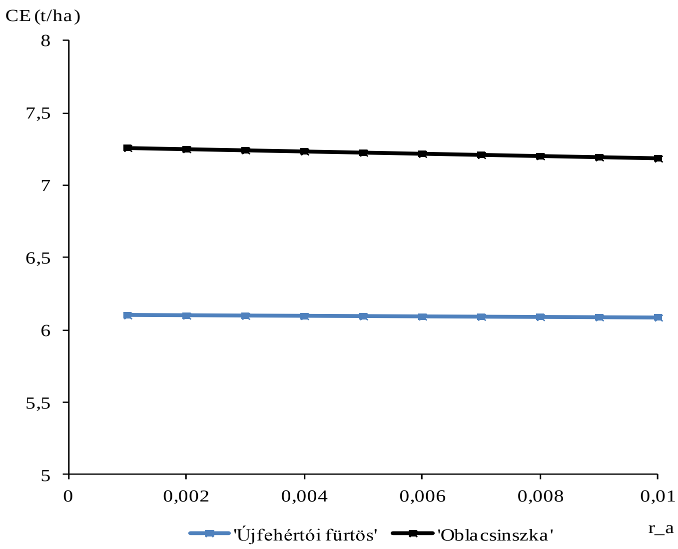
Figure 3: First (left panel) and second (right panel) degree stochastic dominance



Source: Own compilation based on the data of the Újfehértó Research Station, 2013

By the **general stochastic dominance** method I took the risk aversion of the decision maker into consideration, which can be seen in *Figure 4*. By illustrating the CE values in the function of absolute risk aversion it can be seen that the higher curve means the better version, so this is the alternative with less risk. The variety 'Oblacsinszka' from Újfehértó is the better alternative for the decision maker.

Figure 4: Certainty equivalent curves as functions of the absolute risk aversion (r_a) for the yield of sour cherry varieties *'Újfehértói fürtös'* and *'Oblacsinszka'* produced in Újfehértó

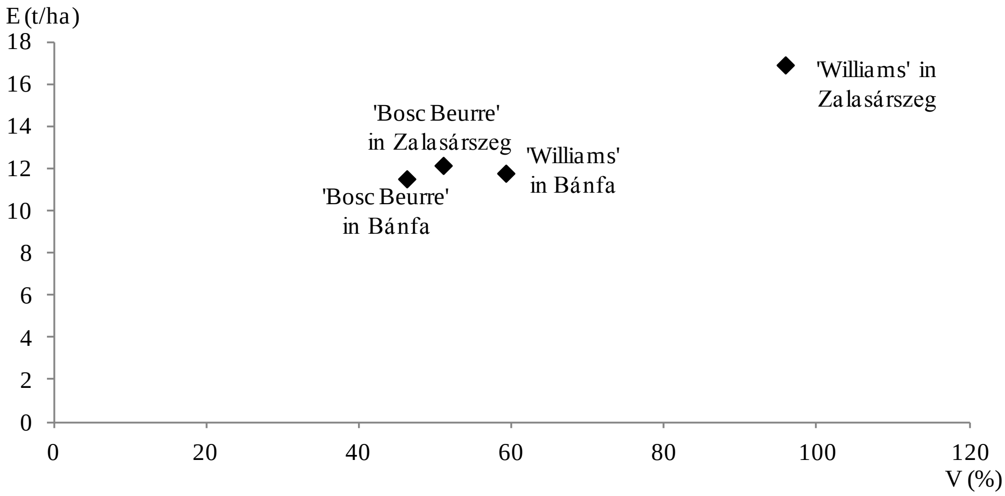


Source: Own compilation based on the data of the Újfehértó Research Station, 2013

3.6. *Comparisons of production of pear varieties regarding risk aversion*

I used this analysis to compare the yield risk of two different plantations (Bánfapuszta and Zalasárszeg) and two pear varieties ('Bosc Beurre' and 'Williams'). On the basis of E-V efficiency we can find out that variety 'Williams' cultivated in Bánfa did not make it into the efficient set, I could not compile a total set (*Figure 5*).

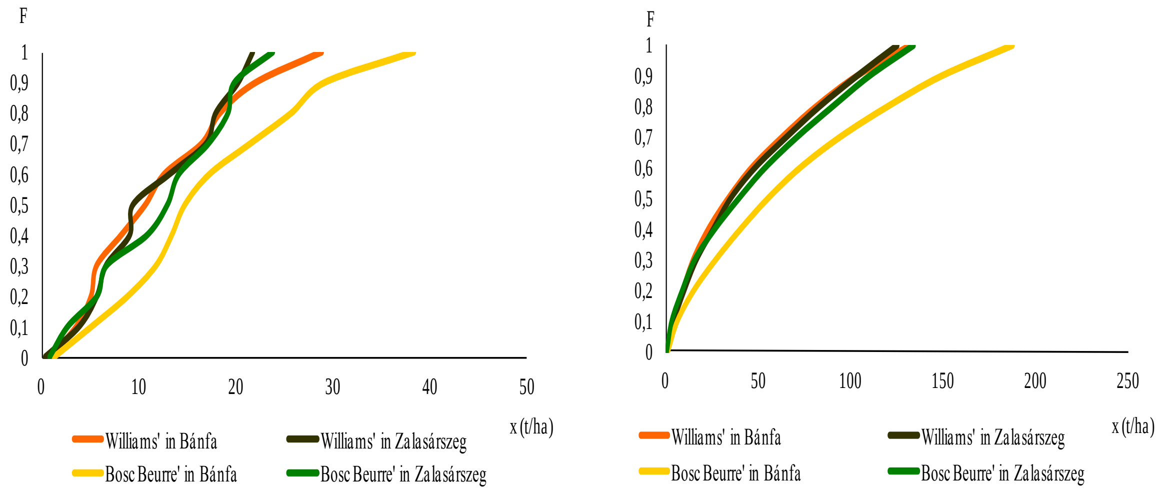
Figure 5: E-V efficiency of the yield of pear varieties produced in Bánfa and Zalasárszeg



Source: Own compilation based on the data of Gyümölcskert Plc., 2011

Since the distribution functions cross each other, the first degree stochastic dominance does not exactly define the alternative(s) with the less yield risk. As we can see in the *Figure 6.* (*right*), the variety ’Bosc Beurre’ of Bánfa seems to be the most preferable alternative since its distribution function as well as the integral of its distribution function lie everywhere below and to the right of the other curves.

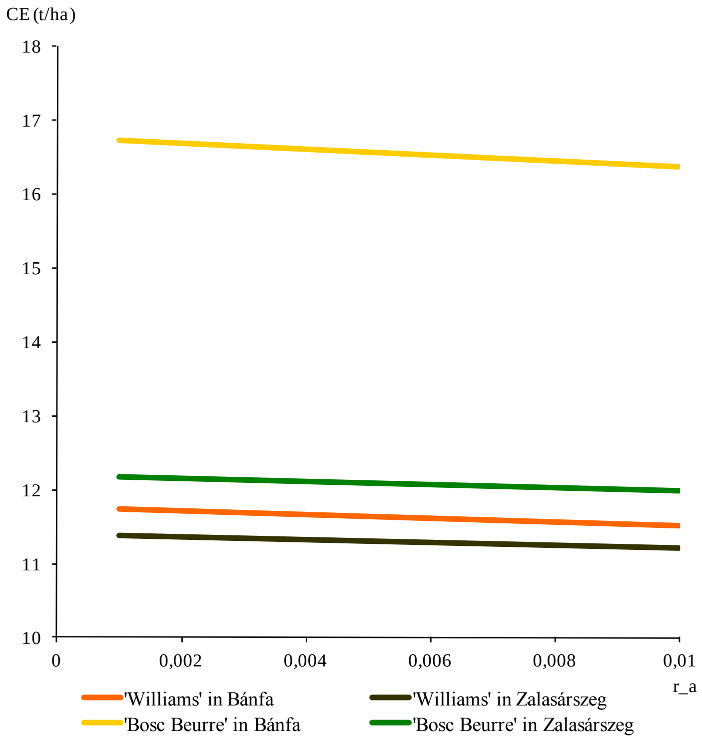
Figure 6: First (left panel) and second (right panel) degree stochastic dominance



Source: Own compilation based on the data of Gyümölcskert Plc., 2011

Strictly speaking however, total arrangement can not be identified, so we should use the certainty equivalent curves. The curve of variety ’Bosc Beurre’ from Bánfa lies the highest, so this alternative has the lowest yield risk. This alternative is followed by ’Bosc Beurre’ from Zalasárszeg (*Figure 7*).

Figure 7: Certainty equivalent curves as functions of the absolute risk aversion (r_a) for the yield of pear varieties *‘Bosc Beurre’* and *‘Williams’*

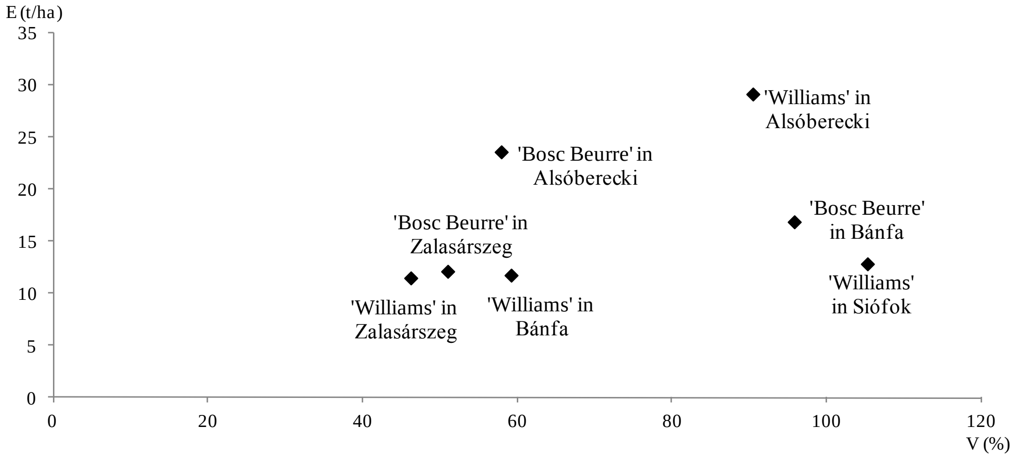


Source: Own compilation based on the data of Gyümölcskert Plc., 2011

3.7. *Comparisons of production of pear varieties for four different plantations regarding risk aversion*

I also assessed data for two south-west Hungarian, one southern Transdanubian and one north Hungarian production sites as well, which are decisive from the aspect of pear production. From among the examinded variations, the ’Williams’ and ’Bosc Beurre’ varieties cultivated in Bánfa, as well as the ’Williams’ cultivated in Siófok, do not belong to the efficient set (*Figure 8*).

Figure 8: E-V efficiency for four different plantations

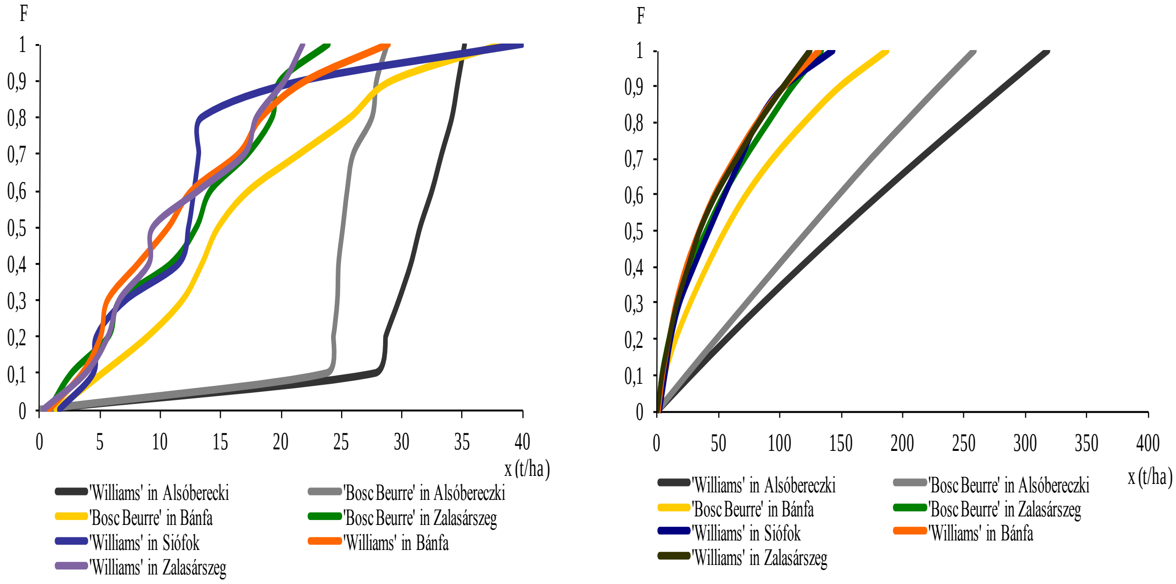


Source: Own compilation based on the data of Gyümölcskert Plc., Gyümölcstermesztési Plc. in Siófok and Pyrus-94 Ltd., 2011

In *Figure 9* (*left side*), we can see the results of the first stochastic dominance. The distribution functions cross each other, so again only partial dominance can be proved between alternatives with this method. We cannot define the alternative(s) with the less yield risk exactly; however, we can see that the distribution functions of Alsóberecki alternatives are located to the right of the other distribution functions on almost the whole domain, which indicates higher expected values with lower variances and therefore relatively lower risks.

In order to determine the ranking of alternatives, one must employ the second degree stochastic dominance method (*Figure 9, right side*). It can be seen that 'Williams' has the smallest yield risk in Alsóberecki, since the integral of its disribution function lies everywhere below and to the right of other curves. It is followed by the 'Bosc Beurre' in Alsóberecki and by the 'Bosc Beurre' in Bánfapuszta. However with the help of the second degree stochastic dominance we cannot compile a total set as some curves still cross each other. Nevertheless, the general stochastic dominance method is applied not only for the total set but also for considering the risk aversion of the decision maker.

Figure 9: First (left panel) and second (right panel) degree stochastic dominance

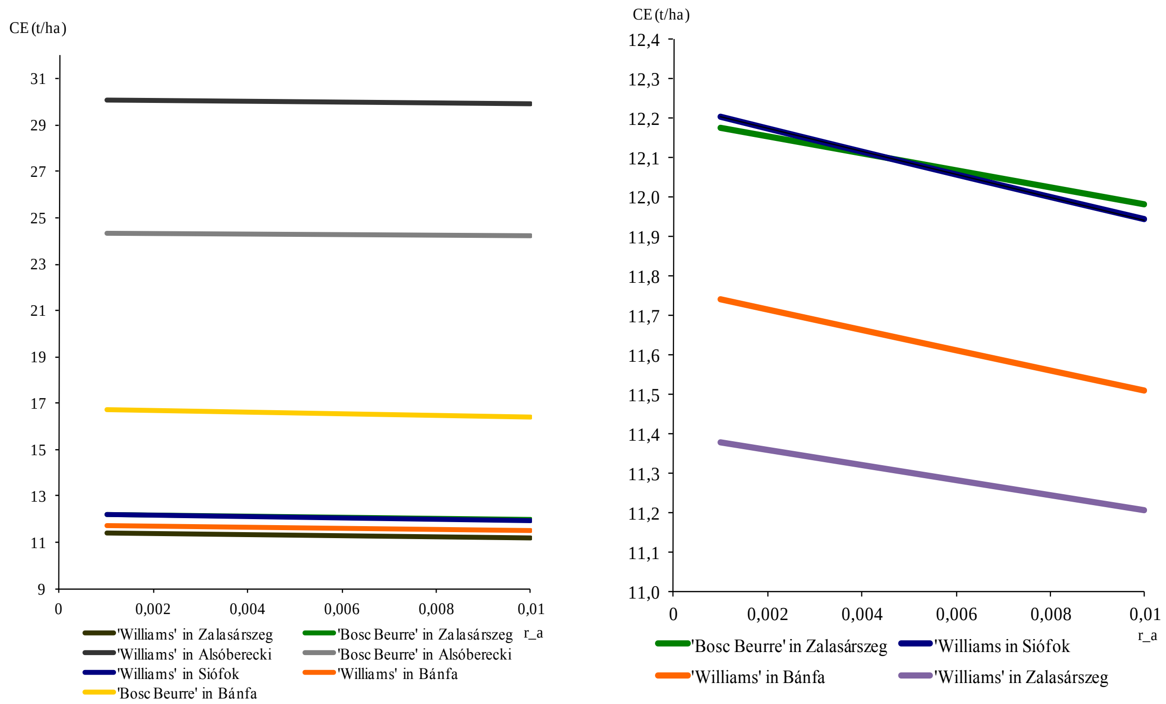


Source: Own compilation based on the data of Gyümölcskert Plc., Gyümölcstermesztési Plc. in Siófok and Pyrus-94 Ltd., 2011

If we represent the certainty equivalent (CE) curves with the help of the general stochasic dominance method, we can compare the four different plantations and the two pear varieties, according to their yield risk. As can be seen in *Figure 10, on the left*, the CE curve of variety 'Williams' from Alsóberecki lies the highest, so this alternative has the lowest yield risk. This alternative is followed by 'Bosc Beurre' from Alsóberecki.

The enlarged CE curves of variety 'Williams' from Siófok, Bánfapuszta and Zalasárszeg and variety 'Bosc Beurre' from Zala are displayed in *Figure 10, on the right*. As it can be seen in this figure, if the risk aversion is low ($r_a < 0.005$), the better alternative is 'Williams' from Siófok, while in case the risk aversion is higher ($r_a > 0.005$), 'Bosc Beurre' from Zalasárszeg is the better alternative for the decision maker.

Figure 10: Certainty equivalent curves as functions of the absolute risk aversion (r_a) for four different plantation for pear yield



Source: Own compilation based on the data of Gyümölcskert Plc., Gyümölcstermesztési Plc. in Siófok and Pyrus-94 Ltd., 2011

For considering the risk aversion of the decision maker, the CE curve of variety **'Williams' from Alsóberecki** has the lowest yield risk, this alternative is followed by 'Bosc Beurre' from Alsóberecki. The 'Williams' from Zalasárszeg has the highest yield risk.

4. NEW RESULTS OF THE THESIS

1. I applied regional climate models in the central European regions to express and assess risks for sour cherry in figures.

2. I compared the production risks of various sour cherry varieties with models aimed at minimising production risk based on mathematical-statistical and decision theory tools.

3. I compared the production risks of various pear variety-growing site combinations with models aimed at minimising production risk based on mathematical-statistical and decision theory tools.

5. THEORETICAL AND PRACTICAL APPLICATION OF RESULTS

Climate change determines the climatic nature of plant vegetation period from many aspects. Change can manifest in the modification of temperature and precipitation distribution, as well as in the intensification of severity. Changes in climatic nature during the critical period of flowering can induce a series of other changes for producers and as a result expected changes for this period constitute an important issue for a dominant production region. Examining the flowering period is not enough however, as early budburst and flowering are also phenomena experienced in connection with climate change.

In the thesis I illustrated on the one hand how climate change can induce an early start for sour cherry phenology sequence and on the other hand how the climatic nature of flowering could change somewhat considering the phenology shift. According to the RegCM3.1 climate model – scaled for Újfehértó – a decreasing risk of frost and increase of absolute minimum temperatures is expected. No significant change is expected regarding the number of precipitation free days and days with precipitation that can be utilised by plants when the estimated 30-year average is compared with the historic 27-year average.

The model is suitable for validation in other regions or even other fruit species with appropriate phenological and meteorological observations. New information regarding the plant and region could arise during optimisation and the subsequent comparison.

Growers are compelled to increase the yields in order to compensate for the increasing costs of production as well as for the irrationally low producer’s prices. These efforts are jeopardised by the warming climate, decline of precipitation, increased frequency and intensity of weather anomalies. Conscientious of these predictions, strategies of adaptation should be developed.

6. PUBLICATIONS RELATED TO THE TOPIC OF THE THESIS

LIST OF PUBLICATIONS THAT CAN BE CONSIDERED ACCORDING TO THE REGULATION

1. LADÁNYI M. – **PERSELY SZ.** – SZABÓ T. – SOLTÉSZ M. – NYÉKI J. – SZABÓ Z. (2009): The application of A HEAT SUM MODEL for the budburst of sour cherry varieties grown at Újfehértó. International Journal of Horticultural Science. 15(4):105-112. pp.

2. **SÜTŐ SZ.** – ERTSEY I. (2009): A biztosítások szerepe a gyümölcsültetvények kárenyhítésében. Klíma-21 Füzetek. 57:91-106 pp.

3. LADÁNYI M. **– PERSELY SZ.** – SZABÓ T. – SOLTÉSZ M. – NYÉKI J. – SZABÓ Z. (2010): Climatic indicator analysis of blooming time for sour cherries. International Journal of Horticultural Science. 16(1):11-16. pp.

4. LADÁNYI M. – **PERSELY SZ.** – NYÉKI J. – SZABÓ Z. – SZABÓ T. – SOLTÉSZ M. – ERTSEY I. (2011): Két meggyfajta hozamkockázatának vizsgálata különböző módszerekkel. Klíma-21 Füzetek. 64:69-77. pp.

5. **PERSELY SZ.** – LADÁNYI M. – ERTSEY I. (2012): Comparative yield risk calculations of sour cherry and pear varieties regarding risk aversion. Apstract. Applied Studies in Agribusiness and Commerce. 6(3-4):111-116. pp.

LIST OF OTHER RELATED PUBLICATIONS

Hungarian language scientific journal with foreign language summary:

ERTSEY I. – **SÜTŐ SZ.** – NYÉKI J. – SOLTÉSZ M. – SZABÓ Z. (2009): Az alma, a körte és a meggy termelési kockázatának összehasonlító vizsgálata. Klíma-21 Füzetek. 58:82-93 pp.

SÜTŐ SZ. – ERTSEY I. – NYÉKI J. – SOLTÉSZ M. – SZABÓ Z. (2009): Az őszibarack-termelés kockázatának jellemzői Magyarországon. Klíma-21 Füzetek. 58:93-100 pp.

PERSELY SZ. – LADÁNYI M. –– SZABÓ T. – NYÉKI J. – SZABÓ Z. (2010): A meggy virágzási idejére vonatkozó klimatikus indikátorok elemzése. Kertgazdaság. 42(1):18-26. pp.

PERSELY SZ. – LADÁNYI M. – NYÉKI J. – ERTSEY I. – KONRÁD-NÉMETH C. – SOLTÉSZ M. – SZABÓ Z. (2011): A ’Bosc kobak’ és ’Vilmos’ körtefajták hozamkockázatának összehasonlítása két termőhelyen. Klíma-21 Füzetek. 64:32-37. pp.

PERSELY SZ. – LADÁNYI M. – SZABÓ T. – ERTSEY I. – NYÉKI J. – SZABÓ Z. (2011): Fenológiai modellen alapuló indikátoranalízis a meggy virágzási idejére. Kertgazdaság. 42(3-4):34-44. pp.

Foreign language scientific journal:

LADÁNYI M. – **PERSELY SZ.** – NYÉKI J. – SZABÓ T. – SOLTÉSZ M. – SZABÓ Z. (2010): Climatic indicators regarding the rest period of sour cherry. International Journal of Horticultural Science. 16(4):49-52. pp.

LADÁNYI M. – **PERSELY SZ.** – NYÉKI J. – SZABÓ Z. (2010): From phenology models to risk indicator analysis. Agrárinformatika Folyóirat. 1(2):8-16. pp.

PERSELY SZ. – LADÁNYI M. –– NYÉKI J. – SZABÓ Z. – SOLTÉSZ M. – ERTSEY I. (2010): Comparison of pear production areas from yield risk aspect. International Journal of Horticultural Science. 16(4):25-28. pp.

PERSELY SZ. – LADÁNYI M. – NYÉKI J. – SZABÓ Z. – SZABÓ T. – SOLTÉSZ M. – ERTSEY I. (2013): Climate dependence of cherry flowering. Acta Horticulturae.

PERSELY SZ. – LADÁNYI M. – SZABÓ T. (2013): Budbreak date of cherry and temperature sums: a model approach. Acta Horticulturae.

Complete foreign language presentation published in Hungary:

ERTSEY I. – **SÜTŐ SZ.** (2009): Comparative analysis of the production risk of major fruit species. International Congress on the Aspects and Visions of Applied Economics and Informatics. Debrecen 26th – 27th March 2009. 1339-1350 pp.

SÜTŐ SZ. (2009): The role of agricultural insurances in the damage mitigation. International Congress on the Aspects and Visions of Applied Economics and Informatics. Debrecen 26th – 27th March 2009. 1364-1375 pp.

Foreign language summary published abroad:

PERSELY SZ. – LADÁNYI M. – NYÉKI J. – SZABÓ Z. – SZABÓ T. – SOLTÉSZ M. – ERTSEY I. (2009): Climate dependence of cherry flowering. VI. International Cherry Symposium, Renaca, Vina Del Mar, Chile, 2009. november 15-19., 30. p.

PERSELY SZ. – LADÁNYI M. – SZABÓ T. (2009): Budbreak date of cherry and temperature sums: a model approach. VI. International Cherry Symposium, Renaca, Vina Del Mar, Chile, 2009. november 15-19., 173. p.

Hungarian language lecture with foreign language summary:

PERSELY SZ. – LADÁNYI M. — SZABÓ T. – NYÉKI J. – SOLTÉSZ M. – SZABÓ Z. (2010): Klimatikus indikátorok elemzése a meggy nyugalmi időszakában. IX. Wellmann Oszkár Nemzetközi Tudományos Konferencia, Hódmezővásárhely, 2010. április 22., 649-655. pp.