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Academic paper: RISK ANALYSIS AT BERRY FRUIT FARMS

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MANAGING FARM BUSINESS

RISK ANALYSIS AT BERRY FRUIT FARMS

The paper presents a risk analysis for hypothetical farms focused on berry fruit production. The main objective is to analyse risk reduction efficiency on different farms and how it changes, considering the different strategies and production conditions. A linear program was developed to prepare an optimal production plan, while quadratic risk programming served to minimize the total variance as a measure of risk. We analysed three farm types, with different areas of land. Additionally, we analysed production planning on a small family farm under three different scenarios, focusing on how different sets of production activities influence the efficiency of risk management in order to (i) reduce the risk or (ii) at the given level of risk achieve better economic results. We found that on the small family farms decreasing SD by 1 EUR costs 3.06 EUR, while for a semi-large family farm it is only a bit more expensive, and for a large business farm it is 6% more expensive. The small family farm is most efficient in reducing risk with up to 42% decrease, but due to more available resources, semi-large and large farms have more opportunity for further efficient risk reduction. In all scenarios less capital and labour intensive productions of raspberry - Willamette and blueberry - Bluecrop where the most efficient risk reduction production activities.

Key words: berry fruits, production plan, risk reduction, hypothetical farms

Introduction

Strawberry fruit production is a risky business and for efficient production planning the main risk challenges need to be identified. Besides the consequences of climate changes such as increasing frequencies of droughts in areas where they were not common, early autumn and late spring frosts, frequent hail, storms etc. there are also other risks that influence production (Turveyle and Driver, 1987; Musser and Patrick, 2001; Ramaswami, 2003).

This paper is a case study under production conditions in Bosna and Herzegovina (BiH). Taking into consideration the entire BiH agriculture sector, the most intensive development in the past was the production of fruit, especially raspberries (MAWF, 2014). The orchard area has increased by about 5,000 ha in the last ten years. There is an increasing number of family farms dealing with the production of berry fruits, especially raspberries and strawberries. They face different challenges in decision making and the purpose of this analysis is to observe how risk can be reduced on these different farms by diversification and on the other hand how much it costs. The lack of diversification of production on an increasing number of farms due to specialization presents a challenge, associated with unstable fruit prices at the local market.

In the planning of production, farmers have to choose between different alternative activities with different levels of risk. Alternatives with minimal risk usually also generate a smaller profit. Alternatives with higher risk can generate higher profits, but they may be riskier than the farmer is willing to accept. The desired and optimal choice needs to balance the potential for profit and the risk of loss (Crane et al, 2013). It is also important to determine the opportunity costs resulting from the decision, i.e., how much does it cost to lower the risk to a certain level. Numerous studies have shown that farmers are in general risk averse (e.g. Zgajnar and Kavcic, 2016, Binswanger, 1980), commonly choosing less risky activities resulting in lower profits. This opens up a number of challenges, as how to effectively organize those holdings and which activities to select to (i) reduce risk or (ii) at the given level of risk achieve better economic result (Zgajnar, 2017). Risk management can be addressed in different ways. This paper addresses the reduction of the risk at the farm level through diversification of the production.

Material and methods

The main objective of this study is to analyse risk reduction efficiency on a farm specialising in berry fruit production and to research the main production challenges in small-scale productions farms. This is a classical problem of the optimal allocation of production resources considering risk. For this purpose, a microeconomic spreadsheet model-tool has been developed. Microsoft Excel has been used as a basic platform, which enables relatively simple integration, complementarity and adjustment of the model-tool to any analysed farm

(Zgajnar, 2017). To solve the allocation problem, a mathematical programming concepts have been applied, utilising MS Excel Solver for linear and non-linear problems (Powell and Baker, 2009). Optimisation is carried out on the basis of maximizing the objective function.

The developed model-tool consists of three sub-models. The first sub model consists of 60 static simulation models (calculations) that enable calculation of different economic indicators at the level of production activities. In addition to economic indicators its main purpose is to calculate technical parameters for different production activities. Therefore, for each production activity a technology card[3] has been defined.

From a methodological perspective, the model-tool is based on linear (second sub-model) and quadratic programming (third sub-model) in order to support production-planning analysis. Linear programming (LP) is used to prepare an optimal production plan maximizing the expected gross margin (EGM). This is also the starting point (value) for parametric constraints in the third sub-model that enables efficiency risk analysis. In this part, also, sensitive analysis was done by observing reduced cost and shadow price[4].

The third sub-model is based on quadratic risk programming (QRP) that considers the riskiness of activities. It enables calculating the optimal solution at a given level of risk that in a set of optimal solutions forms the E-V efficient frontier. It is the set of optimal solutions that offers the highest expected return (EGM) at given level of risk (measured as total variance at the farm level - V).

Set of activities

The model-tool includes 60 baseline production activities that could be further divided into three main production groups: raspberry, blueberry and strawberries. Within each there are different possible production activities depending mainly on the variety (different commercial names with different production technologies, yields etc.) affecting also different production

[3] A technological card is a detailed overview of the production process and all needed inputs for each production activity. It consists of information of necessary agro-technical measures, as well as time of implementation and requirements for labour and mechanization.

[4] Reduced cost represents amount by which an observed activity must be improved to be include in an optimal production plan. Shadow price on the other hand shows how much we can pay for an additional unit of scarce resource (binding constraint) not to deteriorate economic result.

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conditions and in terms of mathematical programming contain different technological coefficients.

Table 1 presents the most important activities included into the model-tool for the purpose of this case study. Within raspberry there are four varieties, within blueberries the two most frequently found in the field are included, while for the strawberries there were four varieties. All varieties of raspberries and blueberries are intensively produced, as are all varieties of strawberries except Clery, which is highly intensive. There are two systems of production for this strawberries variety, intensive and highly intensive. Highly intensive production describes growing in high tunnels, which is one of the main differences from intensive production. Clery is grown in highly intensive systems because it is early variety, and with production in tunnels, it achieves higher price as this is the first strawberry variety in the market.

Table 1: Overview of the most important production activities included into the model-tool for this case study

Production activity	**EGM (EUR/ha)**	**Variable costs (EUR)**	**Exp. Yield (kg/ha)**	**Labour input (h/ha)**
Raspberry Willamette	14,260	3,174	12,500	4,496
Raspberry Meeker	13,541	3,174	11,500	4,296
Raspberry Tulameen	13,401	3,174	12,000	4,396
Raspberry Polka	11,301	3,291	11,000	4,104
Blueberry Duke	20,033	3,936	9,000	4,554
Blueberry Bluecrop	18,341	2,965	8,000	4,151
Strawberries Clery*	21,314	13,714	24,000	4,249
Strawberries Clery	11,803	12,422	20,000	3,669
Strawberries Zenga	11,334	12,536	23,000	3,936
Strawberries Arosa	14,031	12,613	25,000	4,114
Strawberries Maja	15,739	12,727	28,000	4,380

**High intensive production system*

Analysed case farms and production conditions

Within this study, we analyse three different hypothetical farms (Table 2). The first case (Farm 1) is a small family farm with 0.5 ha of land, a farm typical for BiH[5]. It is assumed that family members provide all the labour. This farm has no possibility of hiring additional labour. We considered that it has 5,000 EUR of working capital available. The second farm (Farm 2) represents a semi-larger family farm, where the total available land is 2 ha. On this farm half

[5] BiH –Bosnia and Herzegovina

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of the labour is provided by the household members and the rest is hired. It operates with 25,000 EUR of working capital to cover running costs.

Table 2: Available production resources on analysed farms

Resources	Farm 1	Farm 2	Farm 3
Total arable area (ha)	0.5	2	20
Family labour (h)	8,800	4,400	550
Hired labour (h)	0	4,474	84,427
Available working capital (EUR)	5,000	25,000	300,000

The third farm (Farm 3) is a large commercial producer with its' own cooling facilities, and exports directly to the EU market. In this hypothetical case, it is assumed that all labour (except administrative work) is provided by hired labour. This farm has 300,000 EUR working capital available for the business. On all three farms production activities presented in Table 1 could be selected and included into the production plan.

According to ASBiH (2018) small family farms present the major part of fruit farms in BiH (on average 1.8 ha of arable land). Also, they have on average relatively small amount of available capital, and usually they provide all needed labour by family members. Therefore, for Farm 1 further detailed analysis of three different scenarios has been made. We considered that in all three scenarios farm has the same available resources as Farm 1, the main assumption was that production was limited to only two groups of production activities (cultures) to be included at once into the production plan for each scenario. The first scenario (S11) considers the possibility of producing strawberries and blueberries, the second scenario (S12) the production of raspberries and strawberries, and the third scenario (S13) combines the production of blueberries and raspberries.

Prices and trends

The results obtained with the model-tool are based on the period 2008-2017. For this period, we analysed input and output price changes at an average annual level. Output and input prices have been obtained from the Agency for Statistics of BiH (ASBiH, 2018). However, since for some of the inputs there is no data in this database, an additional survey was carried out in 2017 to determine the sale prices for the berries. The value of wages was determined based

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on the farm survey and amounted to 1.92 EUR/h for 2017. The annual change in the price per working hour was calculated based on the change in average net salaries in BiH according to data obtained from ASBiH (2018). According to this, the average price for hired labour in the ten years period was 1.84 EUR/h. In further analysis estimated opportunity cost for family labour is considered and is equal to the number of utilised family labour hours multiplied by the average labour price (1.84 EUR/h). The labour cost for family members was based on what one family member earn for the similar job on another farm as a hired worker.

Results

The main results for all three hypothetical farm types are further presented. First, we present optimal production plans for all three farms maximizing EGM. This solution is obtained through LP paradigm. Further we present the efficiency of risk reduction for the observed farms obtained with the QRP method (third sub-model).

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Table 3: Optimal solutions and economic indicators for all three farms maximizing EGM

Description	Farm 1	Farm 2	Farm 3
Economic indicators (EUR)			
Revenue	15,414	55,911	547,464
Variable costs (VC)	5,000	25,000	300,000
EGM	10,414	30,911	247,464
SD of EGM	3,344	11,622	112,214
EGM/ha	20,828	15,455	12,373
EGM/h*	4.77	4.76	4.65
Share of SD in EGM (%)	32	38	45
Land Area			
Production activities included in the production plan			
Blueberry Duke (ha)	0.19	0.00	13.84
Blueberry Bluecrop (ha)	0.00	1.02	0.00
Strawberry Clery (ha)	0.31	0.98	6.16
Labour input			
Family labour (h)	2,182	3,722	550
Hired labour (h)	0	4,657	88,651
Total labour (h)	2,182	8,379	89,201
Utilized family labour (%)	24.80	84.59	100.00
Post optimal analysis			
Reduced costs (EUR)			
Raspberry Willamette	-5,670	-3,660	-5,490
Blueberry Duke	0	-700	0
Blueberry Bluecrop	-1,570	0	-620
Strawberry Maja	-5,470	-6,980	-5,670
Shadow prices (EUR)			
Arable land	19,520	0	933
Hired labour (VI month)	0	4.6	0
Working capital	0.13	0.42	0.20

*EGM/h - Expected Gross Margin per hour

It is apparent (Table 3) that for small family farms (Farm 1) the optimal production results from highly intensive strawberry production (Clery variety) on 62% of available land and blueberry Duke on the rest. In this case Farm 1 would achieve 10,414 EUR of EGM, where revenues amounted to 15,414 EUR, and total variable costs present 32%.

In such a case total variance measured as a standard deviation (SD), is 3,344 EUR, which is 32% of the EGM and shows a relatively high variability. Since this family farm utilises only family labour, the cost of labour is not included in the variable costs. Further analysis shows that such a farm achieves 20,828 EUR/ha of EGM, which is 4.77 EUR/h. However, due to the

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seasonal work, only 25% of available family labour is utilised which at the end worsens the productivity result by 74%.

The post-optimal analysis on this farm (Farm 1) shows that blueberry Bluecrop, as less productive activity, is the next closest alternative to optimal plan for this farm. However optimal EGM at farm level would be reduced for 1,570 EUR per each additional ha included in production plan instead strawberry Clery or blueberry Duke. Due to relatively intensive production on such a family farm shadow price for arable land is 19,520 EUR, which means that for each additional unit of arable land, under this circumstance, EGM would theoretically increase by 19,520 EUR.

The semi-large family farm (Farm 2) has a total EGM of 30,911 EUR (Table 3), and the associated risk measured as SD is 11,622 EUR, which is 38% of EGM. This shows that such a production plan is even more risky than for the smaller farm, which is mainly due to hired labour. All hired labour is utilised from May to August. In these months the needs for labour are higher and could not be covered with family labour. Total costs for hired labour amounts in this case to 36% of total variable costs. Due to hired labour this percentage is expectedly higher than on small family farm (Farm 1). The EGM per hectare is therefore 26% lower than on Farm 1 (15,455 EUR). Per hour of labour utilised EGM amounts to 4.76 EUR. However, in this case EGM per working hour falls if also non-utilised family labour is considered (3.42 EUR/h), which is due to equal availability throughout the year and not only in the production seasons.

For this farm the optimal production plan is utilising 49% of land for highly intensive strawberry (Clery) and 51% of the land for producing blueberry (Bluecrop). Even though blueberry Duke has higher EGM per ha (20,033 EUR), blueberry Bluecrop is the optimal option (EGM 18,341). The reason is the limited availability of working capital, which is the main bottleneck for this farm. The capital requirements for Bluecrop (2,965 EUR/ha) are less than for variety Duke (3,936 EUR/ha). In this way there will be more utilized land area, what results with higher total EGM.

Farm 3 has much larger business scope compared to the previous two family farms. The maximum EGM is 247,464 EUR. The optimal production plan comprises blueberry Duke (69%) and highly intensive strawberry Clery (31%). These are options with the highest

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EGM/ha. However, for this farm type, such an optimal production plan is the most risky, compared to the other two (Farm 1 and Farm 2). Namely, the total SD is 45 % of EGM. Costs for hired labour present 56% of the variable costs. The realized EGM is 12,373 EUR/ha or 4.65 EUR/h.

We analysed also how efficient the three farms are in reducing risk or achieving at the same level of risk higher EGM (Table 4). Regarding the risk reduction efficiency considering diversification of production plan, the most efficient is the small family farm (Farm 1). This holds down to 42% of risk reduction, where Farm 2 and Farm 3 become more efficient. On average decreasing SD by 1 EUR cost 3.06 EUR on the small family farm (Farm 1), for the semi-large farm (Farm 2) that cost was 3.09 EUR. The largest cost was for the large business farm (Farm 3) where that cost amounted to 3.25 EUR.

Table 4: Cost to reduce risk by 1 EUR

Description	**Farm 1**	**Farm 2**	**Farm 3**
Cost to reduce risk (EUR)	3.06	3.09	3.25

On Figure 1, we present three different scenarios on the small family farm (Farm 1) with a total arable land of 0.5 ha, with household members providing all the labour. The difference between three scenarios (Figure 2, 3 and 4) is in the choice of production activities in the optimal production plan. Generally, in BiH, berry farms grow maximum two varieties so we modelled what happens with risk reduction strategy and efficiency if this is a case.

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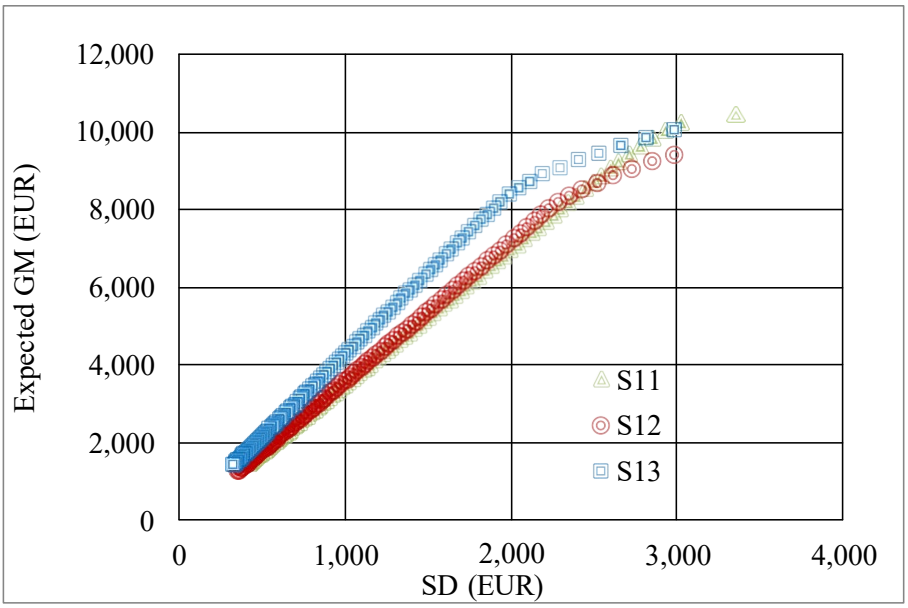

Figure 1: E-V efficient frontiers for different scenarios on small family farm

The first scenario (S11), a combined cultivation of blueberries and strawberries (Figure 2), produces the maximum EGM with highly intensive production of strawberry Clery on an area of 0.31 ha and blueberry Duke on an area of 0.19 ha. This result is the same as in the baseline case for Farm 1 (Table 2). Further analysis shows that with a slight reduction in total EGM the farm would achieve a significant (9.64% – 19.21%) reduction of risk (SD). Including blueberry Bluecrop in the plan (up to 70.51% of arable land) and strawberries on the rest, the EGM decreases by only 2%, however SD decreases by 9.64%.To reduce the risk for 1 EUR, it is necessary to sacrifice only 0.64 EUR of EGM. With further risk reduction, less risky but also less productive blueberry Bluecrop enters optimal production plan, replacing more intensive blueberry Duke. This variety is less risky because it needs less capital and labour.

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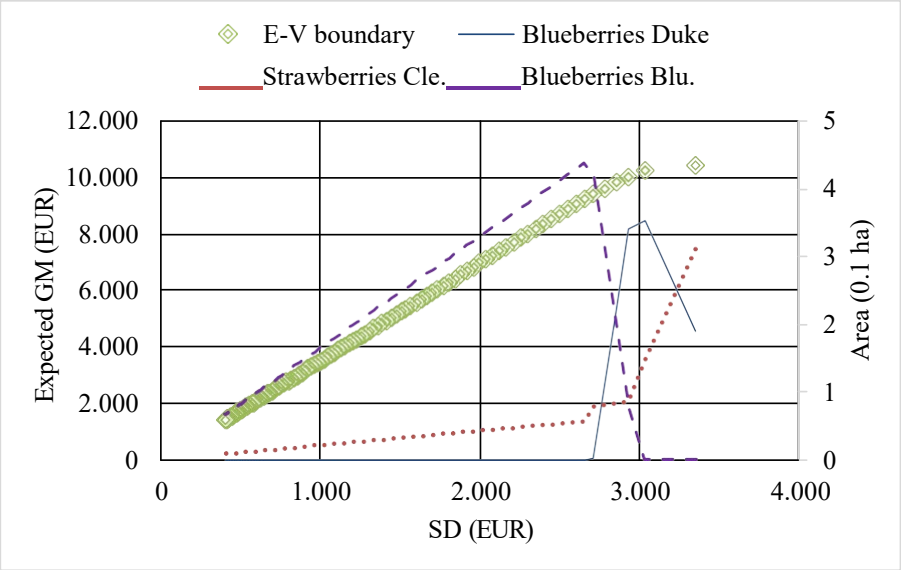

Figure 2: E-V efficient frontiers for combined cultivation of blueberries and strawberries (S11) on small family farm (Farm 1) and changes in optimal production plan

The second possible combination (Figure 3) is the production of raspberries and strawberries (scenario S12). The optimal solution is 0.32 ha of strawberry Clery and 0.18 ha of raspberry Willamette. This scenario provides an EGM of 9,414 EUR, which is 7.24% lower than in S11, but the risk is lower for 10.93%, making scenario (S12) less risky than the first scenario (S11). The reduced cost for raspberry Meeker amounts to -718 EUR/ha, and for raspberry Tulameen -858 EUR/ha. Therefore they don't enter an optimal solution. The shadow price for capital was high and it amounts to 0.67 EUR. With the reduction of riskiness of the production plan, the share of the labour and capital less intensive raspberry Willamette production significantly increases. The efficiency of the risk reduction is somewhat lower than in the case S11.

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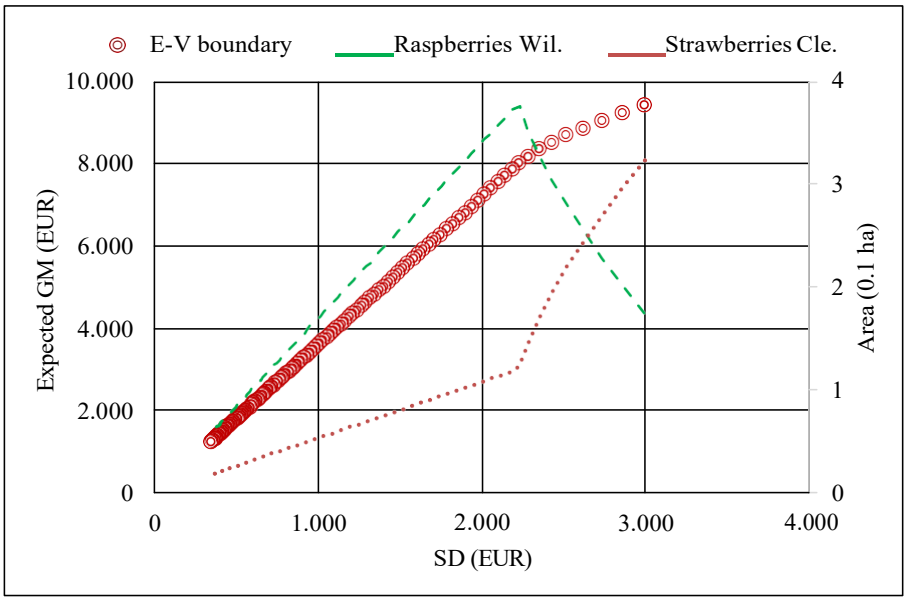

Figure 3: E-V efficient frontiers for combined cultivation of raspberries and strawberries (S12) on small family farm (Farm 1) and changes in optimal production plan

In the last scenario (S13), raspberries and blueberries activities could enter the optimal production (Figure 4). An optimal solution is cultivation of the blueberry variety (Duke) on the area of 0.5 ha. In such a case (S13) EGM is 10,016 EUR, which is 3.81% lower than in baseline scenario (Farm 1) and S11, but still higher (for 6.40%) than in S12. However, on the other hand the riskiness of such production is lower (2,993 EUR) than in S11 and S12. As is apparent from Figure 4, with reducing riskiness of the production plan (left side on Figure 4), there are less blueberry Duke included and larger share of the intensive production of raspberry Willamette enter optimal solution. The reasons are lower variable costs and lower prices variability on the market. For an even larger decrease of variability (36.36%) optimal solutions enters less demanding and less risky blueberries Bluecrop and raspberry Willamette.

It is interesting that intensive production of strawberries was not an interesting alternative for any of the observed farms.

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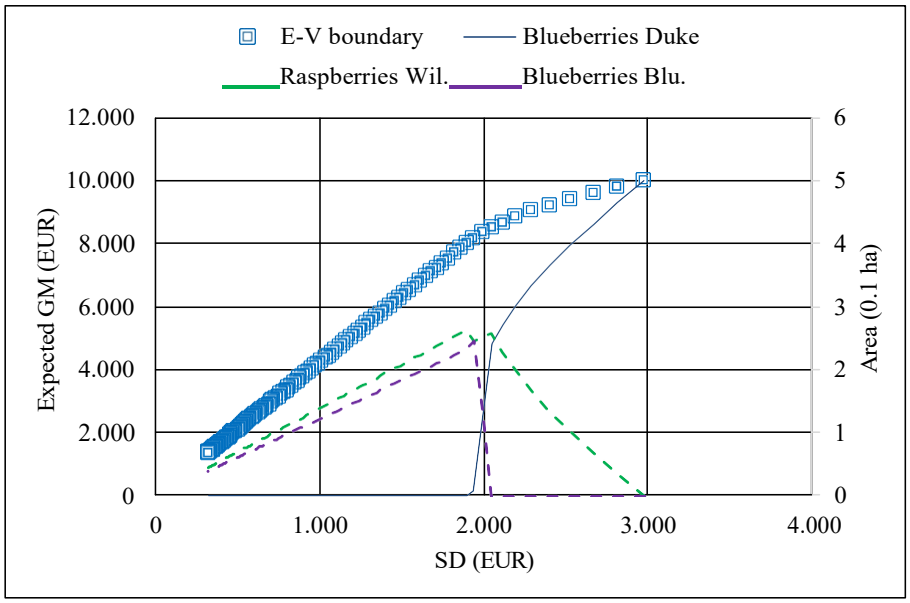

Figure 4: E-V efficient frontiers for combined cultivation of blueberries and raspberries (S13) on small family farm (Farm 1) and changes in optimal production plan

Conclusion

Results show that small farms are the most efficient in risk reduction with up to a 42% decrease, but for further theoretical reductions semi-large and large farms have more opportunity for efficient risk reduction. However, on the other side, decreasing SD by one EUR on small family farms cost 3.06 EUR, for semi-large farm it is 3.09 EUR, while for the large business farms it is 3.25 EUR. Also, small family farms have the best productivity per ha and per utilized labour unit, but because of the seasonal character of berry production activities, they have a significant unutilized family labour (75.20%). This worsens the result per available labour unit on small farms by 74%. Optimal option for maximal EGM on such a small family farm (Farm 1) is highly intensive strawberry Clery on 62% of land and blueberry Duke on the rest. On semi-large farm (Farm 2) optimal combination is 51% blueberry Bluecrop and 49% highly intensive strawberry Clery, while for a large commercial farm highest share has blueberry Duke with 69% in combination with of highly intensive strawberry Clery (31%). Results show that working capital is the most significant bottleneck at the small family farms. Shadow price for capital ranges between 0.13 – 0.67 EUR for the small farm, 0.42 EUR for semi-large and 0.20 EUR for large berry fruit farms.

Further analyses of small family farms show that the most productive combination of activities (strawberry Clery and blueberry Duke) is also the riskiest one. With higher share of strawberry Clery (62%), also EGM (10,414 EUR) and SD (3,352 EUR) are significantly higher. If the optimal production includes blueberry Duke at up to 70.51% of land and strawberries on the rest, the EGM decreases by 2%, however riskiness measured as SD decreases for 9.64%. In all scenarios, the less capital and less labour intensive productions of raspberry Willamette and blueberry Bluecrop are less risky and therefore very competitive. These activities are less productive, but still appropriate to be part of a less risky solution. The intensive production of strawberries was not an interesting alternative for any of the observed farms only highly intensive production of Clery.

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