doi: 10.17221/238/2015-AGRICECON

Optimal allocation of production resources under uncertainty: Application of the mulitcriteria approach

Jaka ZGAJNAR, Stane KAVCIC

University of Ljubljana, Biotechnical Faculty, Ljubljana, Slovenia

Abstract: Analysing economic efficiency of farm production always faces a problem of insufficient information. This is particularly true when the analysis is performed on the reference farm where estimates are based on the average aggregated data. The paper illustrates how the combination of different mathematical programming methods could be efficiently used to analyse the farm-production plan with the lack of the on-farm accounting data. The utilised approach shows how the holistic analysis of production planning as a multi-criteria problem could be conducted. The estimation of the missing information and the disaggregation of the endogenous farm data is enabled through different models that are based on the constrained optimisation. The developed models are linked into the spreadsheet modular tool enabling systematic analyses of the farm decision making under risky conditions. Illustration of the modular tool application is given via the analyses of three hypothetic dairy farms. The obtained results indicate that the developed approach enables holistic analyses of the production planning. The methodology applied provides also important information for the measures aimed to increase efficiency as well as to benchmarking the performance of different farm types. The results point to a discrepancy between the solutions obtained through different objective functions and shows the advantage of the multi-criteria approach.

Keywords: farm-level production planning, goal programming, mathematical programming, risk aversion, risk modelling

In the fast developing globalised and liberalised world, production conditions are continuously changing. This is particularly true in agriculture that has never been so liberalised and institutionalised in the past. For agriculture, it is also typical that decisions are taken far in advance, much earlier than the market prices for outputs are known. This is even more significant and important in terms of the market liberalisation since it manifests in more fluctuating prices (Huirne et al. 2007). Risk is becoming a significant factor in agricultural production and there are different sources of risk threatening farm businesses (Hardaker et al. 2007). Since farmers in general are supposed to be risk-averse, it is important to consider risk in the production planning. For the policy makers, farm advisers as well as for researchers, it is important to have information, what is going on at the particular farm or farm type and where are the most important triggers to improve the production efficiency, taking into account various socioeconomic and environmental conflicting objectives involved in managing agricultural systems. However, such analysis is particularly challenging, when there is a lack of reliable on-farm data.

To address this kind of problems, different approaches can be taken. One of them is the mathematical programming framework. It captures both the agricultural production theory and modelling (Buysse et al. 2007). There is a wide body of literature how the mathematical programming techniques have been successfully applied in practice to support the production planning problems. Biswas and Pal (2005) are mentioning some studies that confirm extensive studies of linear programming (LP) for the farm planning problems between 1960s and mid-1980s. Also Hardaker et al. (2007) are stressing that the analyses of production planning are most often conducted by the deterministic linear programming (LP). Namely, from the modelling point of view, the farm production planning is a typical example of the resource allocation problem, where scarce and risky resources have to be utilised in the best possible manner in order to achieve the farmer's objectives. However, most of the farm planning problems is multi-objective in the nature (Biswas and Pal 2005). The multi-criteria concept is therefore often recognised as a necessary approach in farm management analyses. Goal programming (GP) is one of the prominent tools introduced by Wheeler and Russel (Biswas and Pal 2005). Sharma et al. (2006) are also stressing that GP is one of the most widely used techniques from the field of the

doi: 10.17221/238/2015-AGRICECON

operation research that has been used in the agricultural management decision making.

The purpose of this contribution is to illustrate an innovative approach of linking different mathematical programming methods into a complex modular tool for the holistic analysis of farm production planning. Planning is addressed in a multi-criteria manner. Apart from the maximal farm income and minimal risk, other factors influencing decision making are also considered. Common to those factors is that they usually do not contribute to a more (economically) efficient production plan, but they have to be considered since they influence the decision making. Such examples could be the farmers' conservative decision making or their effort to gain a positive local reputation, as well as the pressure of public goods and goals. Any analysis ignoring such factors may result in a bias solution. The main idea is that the tool should enable a systematic analysis of the farmers' behaviour in production planning on the hypothetical case farms, for which not all necessary information is available. To be precise, Čančer and Mulej (2010) are stressing that systematic analyses are intended for decision makers in companies, non-profit organizations and government agencies as practical working tools to help them resolve complex problems.

Based on the available data for the analysed farms and the potential of different mathematical programming methods, the tool should enable the holistic analysis of production planning. In the first stage, it is necessary to estimate the farm's economic and production baseline plan, followed by the evaluation of the possible changes in the production practice that are considered through different objective functions. Based on this background, the tool should find the best compromise solution within the range of possible solutions, obtained by different objective functions.

MATERIAL AND METHODS

Multi-criteria paradigm

The multi-criteria decision making has been broadly applied in production planning (Ortuno and Vitoriano 2009). In the literature, there are numerous multi-criteria methods based on different approaches and techniques that search for compromise solutions. They could be classified into the quantitative and qualitative approaches. For the purpose of this study, quantitative methods based on the constrained optimisation are more appropriate. However, in the literature one can find also numerous examples of qualitative methods or their combination, such as the DEX and AHP (analytic hierarchy process) that are used in the field of the multiple-criteria analysis to support decision making at the farm level (Pažek et al. 2010; Pavlovic et al. 2011).

For the purpose of this study, the multi-criteria paradigm is addressed as the GP approach. It is a technique that in general minimises the undesired deviations from target values. As a special compromise method, it assumes that the farmer knows the goals' values and their relative importance. It is designed to consider many goals simultaneously by searching for a compromise solution utilising the mathematical programming optimisation potential (Martel and Aouni 1998). In the literature, one could find numerous GP derivatives. A variety of goal-programming methods is defined by the philosophy of compromise-solution searching (i) and how deviations from the target goals' values are measured (ii) (Jones and Tamiz 2010). Concerning the philosophy of measuring the distance (under/over achievement of the aspiration value), three basic variants exist: (i) weighted goal programming (WGP), (ii) lexicographic goal programming (LGP) and (iii) Chebyshev goal programming (CGP) (Jones and Tamiz 2010). For the purpose of this study, the WGP approach seems to be the most appropriate.

The WGP is based on the Archimedean achievement function that minimises the sum of weighted deviations from the target values (Equation 1). The major difference between the WGP and the LP approach is in the allowable deviations. They are measured using positive and negative deviation variables that are defined for each goal separately, and present either the over- or underachievement of the goal (b_q). The negative deviation variables (n_q) are included in the objective function for goals that are of the type 'more is better', while the positive deviation (p_q) variables are included in the objective function for goals of the type 'less is better'. Since any deviation is undesired, the relative importance of each deviation variable is determined by the relevant weight. Apart from the "valorisation" (u_q and v_q) role, reflecting the decision-maker's preferences among the goals, the "normalisation" (k_q) role is also crucial as it prevents incommensurability among the goals. The objective function is defined as the weighted sum of the deviation variables. Therefore, the objective function in the WGP model minimises the sum of weighted undesirable deviations (a) from the target goal levels

doi: 10.17221/238/2015-AGRICECON

and does not minimise or maximise the goals themselves (Ferguson et al., 2006).

$$Min\ a = \sum_{q=1}^{Q}\left(\frac{u_q n_q}{k_q} + \frac{v_q p_q}{k_q}\right) \quad s.t.$$
$$f_q(x) + n_q - p_q = b_q \qquad q = 1, \dots, Q \qquad (1)$$
$$x \in F$$
$$n_q, p_q \geq 0$$

A major issue within the WGP concerns the use of normalisation techniques to overcome incommensurability (Tamiz et al. 1998). The observed goals are mainly measured in different units of measurement. Consequently, the deviation variables cannot simply be summed up and taken as absolute deviations. To overcome this problem, all objective-function coefficients must be transformed via a mathematical process of normalisation into the same unit of measurement. In the literature, different normalisation techniques exist. For more details, see Jones and Tamiz (2010).

Within the WGP, all deviations are expressed as a ratio difference (i.e., (desired – actual)/desired) = (deviation)/desired)). In this case, any marginal change within one observed goal is of equal importance, no matter how distant it is from the target-goal value (Rehman and Romero 1987). This addresses an additional issue in analysing decision-making. Namely, larger deviations from the target level are less acceptable than the smaller ones. To keep deviations within the desired limits, and to distinguish between different levels of deviations, penalty functions (PFs) can be introduced into the WGP model (Rehman and Romero 1984). These functions enable one to define the allowable positive and negative deviation intervals separately for each goal. Sensitivity of under/over achievement of the goal is dependent on the number and size of the defined intervals and on the penalty scale utilised.

Risk modelling

Risk management can be addressed in different ways. Huirne et al. (2007) mention two groups of measures for the risk reduction. In this paper, we are concerned with a possible reduction at the farm level, particularly concerning those possibilities that the farmer has available in the field of the production planning. It is an issue of the diversification of the production plan. To model this problem, the expected value and variance (E, V) model, based on the risk-balancing hypothesis proposed by Markowitz is going to be utilised.

The method applies the mathematical concept of variance as a measure of risk. The latter is justified under the conditions of the normally distributed expected income and by the farmer's utility function expressed as a negative exponential function. Under these conditions, it could be assumed that the farmer takes a decision on the basis of the expected income and variance as a measure of risk (Hardaker et al. 2007).

From the mathematical point of view, the problem can be addressed by the quadratic programming (QP), minimising risk, or by the quadratic constrained programming (QCP) where the risk is parameterised. An optimal-production plan considering risk could be in such a manner determined by maximising the certainty equivalent (CE; Equation 2).

$$\max CE = cx - 0{,}5 r_A x' Qx,$$
$$\text{s.t.} \qquad (2)$$
$$Ax \leq b$$
$$x \geq 0$$

To find the optimal-production plan on the efficient curve, the coefficient of risk aversion (r_A) is essential (Equation 2). A variety of methods and approaches have been developed to measure the risk attitudes of agricultural producers (Antle 1987). From the literature, three different generally known aspects could be mentioned (Gomez-Limon et al. 2003). One is the direct estimation of the utility function (direct interaction with the decision maker) (Torkamani and Abdolahi 2001), the second is the 'experimental method' and the third one is the observation approach, where the models are tuned to fit the actual behaviour. The last approach is particularly beneficial for analysing the hypothetically constructed farms, since one does not have all the data necessary for such analyses, and average decision maker also does not exist (Zgajnar and Kavcic 2011). Lien (2002) provides an example of the non-parametric estimation of risk-aversion values based on imitating the actual farmers' behaviour.

Conceptual framework of modelling

The framework of a developed spread-sheet modular tool is founded on the multi-criteria approach considering risk and utilising the group of methods based on the constrained optimisation. The main principle is that the farmer decides what to produce at the beginning of each year based on his/her expectations of returns (expressed as the income per farm and the expected gross margins per activity) at the end of the year. The expectations are based on the

doi: 10.17221/238/2015-AGRICECON

expected (average) gross margins and their variances (and co-variances), calculated on the historical data obtained for the representative model-farms[1]. Since they are not existing farms, no precise accounting data are available.

The main idea is that the developed tool should enable as much as possible the automated analyses of an annual whole-farm production plan and that missing information could be estimated endogenously. To achieve these ambitions, the spread-sheet tool is supported by seven modules that are further briefly presented (Figure 1).

The **first module** is an example of the production planning model, based on a deterministic LP approach, maximising the expected income. It searches for a production plan that yields the maximal income, considering the available resources of the analysed agricultural holding. The same principle (LP) is applied

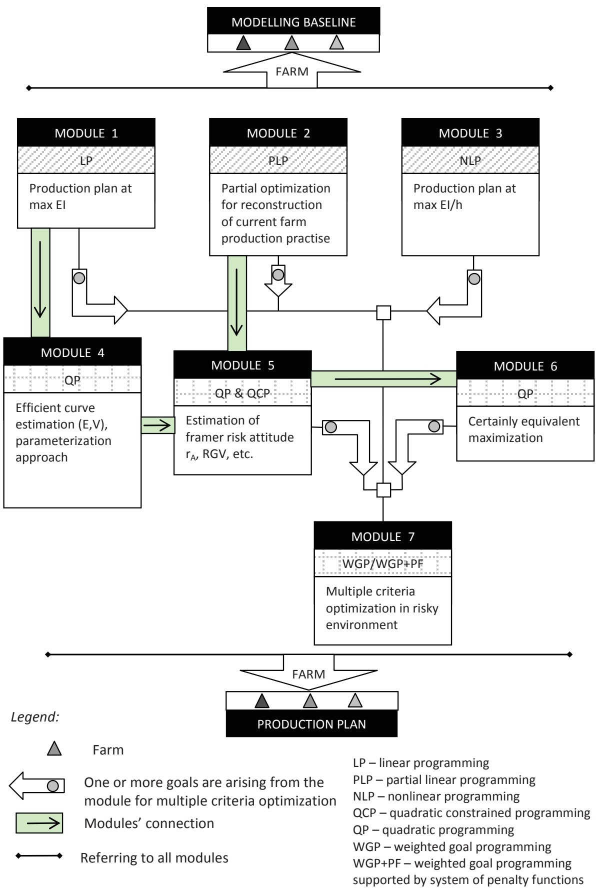

Figure 1. Scheme of the developed modular tool with the main modules' approaches assigned

Source: Own construction

in the **second module** in order to disaggregate data. Its crucial aim is not to optimise the annual production plan, but to reconstruct the economic situation and to define the baseline (current) production plan of the analysed farm. The partial term by the linear programming (PLP) denotes that only a part of the decision variables enters into optimisation, since some data are already known (e.g. the number of breeding animals, selling/purchasing activities, the maintenance of arable land) and therefore also fixed in the optimisation process, with additional constraints, added into the model. However, some data necessary for a proper holistic analysis is not known and should be estimated. The optimisation is, therefore, performed just for those activities, like the fodder-purchasing activities and activities on grassland (how much is gathered as hay, silage, pasture etc.) where only the intensity of production is known. In the reconstruction process of the PLP, the main assumption is that the 'balance' is optimally organised and that the farmer behaves rationally.

Since the efficiency of the production plan could be judged also through the achieved expected income per hour, the nonlinear **module 3** is integrated into the modular tool. It maximises the achieved income per working hour.

In the developed modular concept (Figure 1), a special focus has been put to consider risk. The main idea is to analyse how efficient a farm could be in terms of the risk reduction and what kind of attitude toward risk the analysed farm has. In the first place, **module 4** calculates the efficient frontier for the analysed farm. It is based on the Markowitz formulation of the mean-variance (E,V) approach, whereby the objective is to minimise the total variance expressed as standard deviation (SD). It is an example of a quadratic programming (QP).

To find the optimal solution on the efficient frontier, an indifference curve has to be plotted in the E, V space. Its slope defines a coefficient, known as the absolute risk aversion (r_A). For this purpose, a non-interactive modelling approach has been applied. The main idea of the applied approach is to observe the actual farmer's behaviour (second module) without use of questioners or other direct instruments as for example by Torkamani and Abdolahi (2001). The applied methodology has been developed by Lien (2002) and for the purpose of this study slightly adopted by

[1]Model farms have been defined by Rednak et al. (2009) and are supposed to represent Slovene agriculture. The main purpose to use them is to analyse how different exogenous factors and shocks influence different sectors within agriculture.

doi: 10.17221/238/2015-AGRICECON

Zgajnar and Kavcic (2011) in the phase of the current farm-situation estimation (partial optimisation in module 2). **Module 5** is therefore supported with QP and QCP. Namely, in order to approximate the decision maker's absolute risk-aversion coefficient proposed by Lien (2002), two points on the E, V efficient frontier have to be located. The first point is derived by minimising the variance (QP) at the observed farm total income, while the second point is calculated by maximising the expected income (QCP) with variance kept at the same level as reached by the current production plan. Since the current (reconstructed) farm situation is essential, this module is linked also with module 2.

The estimated farm-risk attitude (expressed as r_A) enters into **module 6**, based on the quadratic programming (QP) approach, maximising the certainty equivalent (CE).

The main purpose of the described six modules (except module 4) is to calculate the goals' values for the multi-criteria **module 7**. The concept of the multi-criteria decision making has been supported by the WGP. To achieve a greater accuracy of solutions, the WGP has been supported by the system of penalty functions (WGP+PF).

The modular tool has been developed as an open system, meaning that different linking and combinations of modules is enabled – not necessary the one illustrated and described in this paper. Another advantage is that the list of production activities and constraints could be further extended. Consequently also other farms could be analysed. The eventual changes in technologies and production parameters between the analysed farms are also considered. Calculations per each of the production activities are based on simple production functions and apart from calculating the technical coefficients, required for the optimisation matrix, they also give the main economic parameters per each production activity. At the level of the livestock activities, the tool is supported by an additional sub-model, developed by Žgajnar et al. (2007) that estimates the animal-nutrition requirements in terms of the technology applied, the breed and production characteristics (daily milk yield, daily weight gain, etc.).

Activities in models

The activities entering into modules can be allocated into four groups: (i) livestock activities including dairy cows (intensive/extensive), suckler cows, heifer breeding, calf production and beef fattening (different technologies); (ii) activities on arable land and grassland such as the crop or fodder-production activities: maize, wheat, barley and rapeseed, maize silage, maize-grain silage (corn cob mix), grass silage (produced on grassland or on arable land, ensilaged into silo or bales), hay (dried on meadow or using cold air drying system) and pasture; (iii) purchasing activities (concentrated feed and cereals); and (iv) transfer – endogenous activities (crop rotation on arable land, forage-conservation technologies on grassland and subsidy activities).

Constraints in models

The basic set of constraints deals with the available production resources such as the tillage area, labour and different types of capital (land, buildings, machinery, breeding herd, etc.). To achieve a higher accuracy of the tool further constraints are included. They could be divided into the following groups: land management constraints, crop-rotation constraints, constraints concerning grass-yield gathering, livestock- and nutrition-balancing constraints, infrastructure-capacity constraints and other balance constraints. Apart from these endogenous constraints, exogenous constraints such as the production quotas, environmental and market constraints are also considered.

Goals in multi criteria optimisation

In the context of the multi-criteria optimisation, the current version of the tool considers ten goals (*Gi*). The target value for the first goal (G1) is obtained by the first module and presents the maximal expected income (EI) that could be achieved under the given circumstances. Risk, acceptable by the farmer, enters as the second goal (G2). Its value is calculated with Module 4 and expressed as the standard deviation (SD). The CE is considered as the third goal (G3). Its target value is estimated with Module 6. Through the absolute risk-aversion coefficient (r_A), it is related to risk. The next three goals (G4, G5 and G6) ensure that an optimised-production plan is similar to the current production situation and in such a manner the conservative farmer's nature is considered. The fourth goal (G4) tries to ensure that the family labour available is more or less utilised. Apart from unemployment, its crucial objective is to consider issues connected with the hired labour. The target value arises from the reconstructed situation (Module 2)

doi: 10.17221/238/2015-AGRICECON

that also holds for the values of the fifth (G5) and sixth (G6) goals. With the last two goals, one ensures that one's own land is fully utilised.

The next group of goals (G7, G8 and G9) is related to the so-called public goals. Goal 7 (G7) tends towards a higher employment of one's own and off-farm labour, with up to 30% of hired labour. The same upper limit is in place for the eighth (G8) and ninth goal (G9). Apart from utilising one's own land, they favour renting an additional arable and grassland, simulating the continuous growth and development of farms. As the last goal (G10) enters the result from Module 3 concerning the efficiency of employed labour, measured as the expected income per hour.

The relative importance of all ten goals has been estimated with the AHP methodology, developed by Saaty (1980). It is based on pairwise comparisons carried out by expert judgements.

To ensure a better imitation of the farmer's behaviour, systems of PFs have been included. However, due to the additional complexity, we decided to support only G1, G3 and G10 for negative deviations (super control of underachievement of target values) and G2 for positive deviations (overachievements). In all four cases, a single three-phase penalty function has been applied.

Table 1. Main production characteristics of the analysed dairy farms

		Farm 1	Farm 2	Farm 3
Production resources				
Labour available	(h)	9 000	3 240	2 700
Tillage area				
Arable land	(ha)	27	8	4
Grassland	(ha)	22	9	10
Activities on arable land				
Grain maize	(ha)	7	2	0
Maize silage	(ha)	10	2	2
Grass and leguminous mixtures	(ha)	10	4	2
*No. of grass cutting**		4 (3)	3 (4)	2 (3)
Livestock				
Dairy cows				
Breed		HF	HF	SIM
Milk yield/lactation and year	(l)	7 800	6 900	5 200
Current number	(heads)	58	21	16
Pregnant heifers				
Current number	(heads)	18	7	3
Bull fattening				
Current number	(heads)	0	0	11
Depreciation cost	(€)	16 900	6 813	5 972

*The first number is related to the major part (%) of grassland and the second to the minor part; **HF stands for the Holstein–Friesian and SIM for Simmental breed

Source: Own construction based on data from Rednak et al (2009)

Analysed case farms

The modular tool has been tested on three hypothetical Slovene dairy farms (model farms), constructed on the basis of the FADN data (Rednak *et al.*, 2009). The first farm (Table 1) is an intensive dairy farm that besides dairy cows breeds also calves and heifers. With the Holstein–Friesian breed it achieves 7,800 l of milk per year. The farm is located in a low-land area and utilises 49 ha of land. The second farm is also located in a low-land region, but cultivates less land. With the same breed, it achieves 300 l less production per lactation. The third farm is an example of a small farm, located in a hilly area. Fodder is produced on 14 ha, the majority of which is grassland. This farm has less productive Simmental cows, yielding 5,200 l milk per lactation. Bull fattening contributes an important share of the farm's total income.

In Table 1, the annual labour available is presented. Since production year is divided into four quarters, effective available labour has been split into 20%, 30%, 30% and 20%, respectively. In addition, it was presumed that up to 30% of labour could be hired. A similar assumption has been made also for land – mainly due to the physical constraints of the available machinery (expressed through depreciation cost) and remoteness of the tillage area.

In the model, the CAP subsidies are considered as they were in place in the year 2011. This means that farms are entitled to regional payments (for grassland and arable land) that are included in the model as additional revenues, while the production-coupled payments in place (bulls' special premium) are included at the activity level.

RESULTS AND DISCUSSION

Since the main purpose of the paper is to illustrate the possible approach for the holistic multi-criteria analysis of production planning, only the most important results for all three analysed farms are presented. In the first part, the focus is placed on the optimal-production plans considering ten goals obtained either

doi: 10.17221/238/2015-AGRICECON

by the WGP or WGP+PF. The emphasis is put on the goals' aspiration levels and deviations. Additionally, the benefit of the penalty function system is discussed. Apart from the economic indicators and risk-aversion coefficients, also the livestock activities entering production plans are presented. In the second part, results from other modules (based on different approaches) are graphically presented in the context of expected values and standard deviations.

From Table 2, it is apparent that all ten goals have been considered. As risk indicators, both the CE and SD have been included as goals. This was based upon the intermediate analysis of the multi-criteria optimisation involving different risk parameters, which is not presented in this paper due to space limitations. The larger and more specialised agricultural holding (Farm 1) with more intensive production turned out to be less risk averse than the smaller agricultural holdings with less intensive production (Table 2). For the first farm, the calculated relative risk-aversion coefficient (r_A) is 15.64, while the coefficients for the second and the third farms are significantly higher (20.09 and 20.90, respectively[2]). However, different conclusions can be drawn from the efficiency of the risk reduction estimated through risk-gradient value (RGV) obtained. This measure, proposed by Kobzar (2006), quantifies and compares the diversification efficiency (risk-management strategies) of the individual farms.

Our results initially indicate that the larger farm is less efficient in terms of risk reduction than the smaller two farms with the less intensive production. The reduction of risk is also more expensive (–4.95 €), which is 3.4 or 13.5% more expensive than the risk reduction for the smaller second and third farm. The obtained results also show the limited diversification options in terms of combining available activities on the analysed farms. This is a consequence of the basic assumption that an agricultural holding should remain within its present farming type (due to its fixed infrastructure and relative conservative nature significant for farmers). However, in real life, this handicap may also occur due to the greater need for the specialisation and intensification in order to obtain the economies of scale.

The applied approach of GP improves the quality of the obtained results, which is mostly apparent from the economic indicators and goals' aspiration levels (Table 2). In spite of a greater complexity, the system of PFs improves the applicability of the obtained solutions, particularly in some marginal cases. By all three analysed farms, the obtained economic situation is improved due to a decrease in deviations from the first goal (EI). This is especially evident in the case of the first and the third farm. Higher EI demands also a higher exposition to risk and therefore it is expected that deviations from the third goal (CE) increase in all analysed cases. In the second and third production plan, the defined limit by the second interval of the PF is reached (25%). Consequently, it is expected that there would be a greater discrepancy between the aspiration and target levels of the CE. In the case of the first farm, it deteriorates by 4 %, while in the case of the second and the third farm, it is decreased by only 1 and 2 %, respectively.

It is surprising that the first farm achieves a slightly higher expected income per hour when the system of PFs is not included. This is not the case for the second and the third farms, where the advanced approach improves the EI by 0.23 €/h and 1.05 €/h, respectively. Table 2 also shows that with the exception of the third farm, no major differences between both approaches appear concerning the farm's own and rented area cultivated, which are considered in the 'conservative' and 'public' goal groups (G5, G6, G8 and G9).

In all three analysed cases, it is also obvious that the system of PFs increases the total penalty and deviations from target values. Certainly these indicators somehow define the 'quality' of the obtained compromise solution, which is due to the farmers' preferences and considering the additional rules (positiveness) slightly deteriorated.

Considering the multi-criteria approach, the production plan (Table 2) compared to the current production practice (Table 1) changes in all three cases. This mainly happens due to the changes in livestock herds. On the first farm, only the dairy production is attractive, with an increasing number of dairy cows compared to the current situation. On the smaller second and third farms the opposite trend is obvious – a decrease in the number of dairy cows and an increase in the number of heifers. In addition, the number of fattened bulls increases on the third farm. A similar trend is significant when the WGP is supported with the system of PF.

Figure 2 illustrates how optimal-production plans change under different basic assumptions. The posi-

[2]The range of calculated coefficients deviates from the values reported in the literature, which Meyer and Meyer (2006) assign to different definitions of the functions' arguments (in our analysis it is approximation of the expected income).

doi: 10.17221/238/2015-AGRICECON

tion of present-production practice T3 (PLP) in both cases indicates that analysis of production planning should be articulated as a multi-criteria problem. Undoubtedly, risk is an important factor that significantly draws solutions downwards and to the left (T1). Obtained results indicate the problem of a possible

Table 2. Obtained results of multiple-criteria optimisation under risk for three analysed farms: Comparison between WGP and WGP+PF approach

GP type		Farm 1		Farm 2		Farm 3	
		WGP	WGP+PF	WGP	WGP+PF	WGP	WGP+PF
Risk attitude							
r_A/r_R		0.000156 / 15.64		0.000502 / 20.09		0.000697 / 20.90	
RGV		4.95		4.78		4.28	
Economic indicators							
EGM	(€)	158 970	165 454	53 563	53 834	33 616	35 619
Direct payments	(€)	25 242	25 242	8 146	8 146	6 115	6 115
EGM/h	(€/h)	17.7	17.5	16.5	16.8	15.4	16.5
Multiple-criteria optimisation							
Total penalty		7.75	10.55	24.69	41.60	16.54	32.41
Total deviation	(%)	101.02	109.92	128.87	131.47	167.30	177.48
Goals' aspiration levels							
EI	(€)	142 070	148 554	46 750	47 021	27 644	29 647
SD	(€)	29 513	31 555	10 150	10 257	6 256	6 770
Labour	(h)	9 000	9 447	3 240	3 207	2 178	2 156
Arable land	(ha)	27.0	27.0	8.0	8.0	4.4	5.2
Grassland	(ha)	22.0	22.0	9.0	9.0	10.0	12.0
Hired labour	(h)	9 000	9 447	3 240	3 207	2 178	2 156
Rented arable land	(ha)	27.0	27.0	8.0	8.0	4.4	5.2
Rented grassland	(ha)	22.0	22.0	9.0	9.0	10.0	12.0
CE	(€)	73 956	70 690	20 878	20 597	14 012	13 679
EI/h	(€)	15.79	15.73	14.43	14.66	12.69	13.75
Goals' deviations							
EI	(%)	−17.28	−13.50	−16.71	−16.23	−22.07	−16.42
SD	(%)	9.00	16.54	23.69	25.00	15.50	25.00
Labour	(%)	0.00	4.96	0.00	−1.03	−19.35	−20.13
Arable land	(%)	0.00	0.00	0.00	0.07	10.29	30.00
Grassland	(%)	0.00	0.00	0.00	0.00	0.00	20.11
Hired labour	(%)	−23.08	−19.26	−23.08	−23.87	−37.96	−38.56
Rented arable land	(%)	−23.08	−23.08	−23.08	−23.02	−15.16	0.00
Rented grassland	(%)	−23.08	−23.08	−23.08	−23.08	−23.08	−7.61
CE	(%)	−0.61	−5.00	−3.39	−4.69	−2.94	−5.24
EI/h	(%)	4.90	4.50	−15.85	−14.48	−20.97	−14.41
Tillage area							
Own/rented							
Arable land	(ha)	27/0	27/0	8/0	8/0.01	4/0.41	4/1.2
Grassland	(ha)	22/	22/0	9/0	9/0	10/0	10/2.01
Annual effective labour input							
Home	(h)	9 000	9 000	3 240	3 207	2 178	2 156
Hired	(h)	0	447	0	0	0	0
Activities							
Livestock							
Labour	(h)	6 320.2	6 797.7	2 290.5	2 194.2	1 347.8	1 233.0
Dairy cows	(No.)	66.5	71.6	22.9	19.7	8.2	5.8
Heifers	(No.)	0.0	0.0	15.3	27.5	29.4	35.6
Bull fattening	(No.)					14.1	17.8

Source: Own calculations

doi: 10.17221/238/2015-AGRICECON

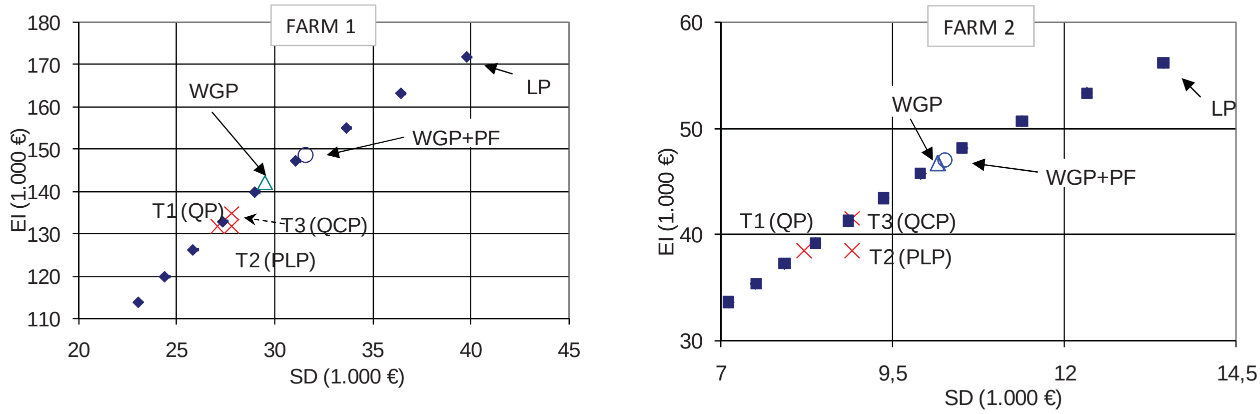

Figure 2. The obtained solutions for the first and the second farms in the context of the expected values and standard deviations

Source: Own calculations

biased solution if planning is based on the single-criteria paradigm. It proves that the maximisation of the expected income (LP) in comparison with the current situation results in a better outcome (first farm: 30.4 %, second farm: 45.8% and third farm: 49.2%). The direction of possible improvement is good; however, it is not attainable due to conflicting goals. Figure 2 also illustrates the difference between both multi-criteria approaches (WGP and WGP+PF), indicating significant benefit gained by PF utilisation. This is especially true for farm 1.

CONCLUSIONS

The approach presented in the paper seems to be applicable for the systematic holistic analyses of farm production planning. It enables studying risk issues and influences of riskiness and correlations between farming activities on the decision making in the context of multi criteria decision making. The main advantages of presented approach are: (a) it links different already applied mathematical methods for the decision analyses at the farm level; (b) it gives an idea and also enables the reconstruction of the present (reference) situation, and its comparison to other solutions; (c) it overcomes the listed problems of the poor farm-data availability and enables the analyses on the basis of the secondary data sources and therefore it could be applied for systematic studying of the hypothetical case-farms; (d) it mitigates the problem of the single-criteria optimisation based on the maximisation of the expected income that is not reachable due to the conflicting criteria considered by the farmers; (e) it shows the discrepancy between the optimal solutions based on different objective functions (f) utilising the PFs, beside the increased complexity and slight deterioration in the total deviations from the target goal values, it improves the positiveness of the obtained results and enables super control of the model's behaviour; (g) the same approach could be applied in other countries on farms with insufficient data sets. However, one of the main drawbacks of the presented modular approach is its complexity and consequentially the need of time for development. A special challenge is programming in the VBA, which enables the automation of the solution searching process. In current version of the tool there was not much attention paid to fixed costs. Therefore, the predicting power of the modular tool could be improved by a more precise consideration of fixed costs and the appraisal of potential investments. In such a manner, the current philosophy of the model, which is based on the tactical-operative planning, could also be expanded to include the strategic planning.

The main purpose of the illustrated modelling approach is not to give an exact solution, but to reconstruct the present (reference) situation on the analysed farm and to indicate the possible development trends on that farm as well as to analyse the pitfalls and challenges of risk. The idea is that the presented tool could be applied to analyse the 'model' farms derived from different data sources e.g. the FADN and to benchmark the performance of different farm types. The illustrated approach is the most suitable for the systematic analysis of the hypothetical or model-farms, where the majority of information (goal values and aggregated data) can be endogenously estimated with different models included into the spreadsheet tool itself.

doi: 10.17221/238/2015-AGRICECON

REFERENCES

Antle J.M. (1987): Econometric Estimation of Producers' Risk Attitudes. American Journal of Agricultural Economics, 69: 509–522.

Biswas A., Pal B.B. (2005): Application of fuzzy goal programming technique to land use planning in agricultural system. Omega, 33: 391–398.

Buysse J., Huylenbroeck G.V., Lauwers L. (2007): Normative, positive and econometric mathematical programming as tools for incorporation of multifunctionality in agricultural policy modelling. Agriculture, Ecosystems & Environment, 120: 70–81.

Čančer V., Mulej M. (2010): The dialectical systems theory's capacity for multi-criteria decision-making. Systems Research and Behavioral Science, 27: 285–300.

Ferguson E.L., Darmon N., Fahmida U., Fitriyanti S., Harper T.B., Premachandra I.M. (2006): Design of optimal food-based complementary feeding recommendations and identification of key »problem nutrients« using goal programming. The Journal of Nutrition, 136: 2399–2404.

Gomez-Limon J.A., Arriaza M., Riesgo L. (2003): An MCDM analysis of agricultural risk aversion. European Journal of Operational Research, 151: 569–585.

Hardaker J.B., Huirne R.B.M., Anderson J.R., Lien G. (2007): Coping with Risk in Agriculture. 2nd ed. CABI Publishing, Oxfordshire.

Huirne R., Meuwissen M., Van Asseldonk M. (2007): Importance of whole-farm risk management in agriculture. In: Handbook of Operations Research in Natural Resources. Weintraub A., Romero C., Bjorndal T., Epstein R. (Eds.). New York, Springer Science & Business Media: 3–15.

Jones D., Tamiz M. (2010): Practical Goal Programming. International Series in Operations Research and Management Science. New York, Springer.

Kobzar O.A. (2006): Whole-farm risk management in arable farming: portfolio methods for farm-specific business analysis and planning. [PhD thesis.] Wageningen University Wageningen.

Lien G. (2002): Non-parametric estimation of decision makers' risk aversion. Agricultural Economics, 27: 75–83.

Martel J.M., Aouni B. (1998): Diverse imprecise goal programming model formulations. Journal of Global Optimization, 12: 127–138.

Meyer D.J., Meyer J. (2006): Measuring Risk Aversion. Foundations and Trends in Microeconomics, 2: 107–203.

Ortuno M.T., Vitoriano B. (2011): A goal programming approach for farm planning with resources dimensionality. Annals of Operations Research, 190: 181–199.

Pavlovic M., Cerenak A., Pavlovic V., Rozman C., Pazek K., Bohanc M. (2011): Development of DEX-HOP multi-attribute decision model for preliminary hop hybrids assessment. Computer and Electronics in Agriculture, 75: 181–189.

Pažek K., Rozman Č., Bavec F., Borec A., Bavec M. (2010): A multi-criteria decision analysis framework tool for the selection of farm business models on organic mountain farms. Journal of Sustainable Agriculture, 34: 778–799.

Rednak M., Erjavec E., Volk T., Zagorac B., Mojk B., Kavčič S., Kožar M., Turk J., Rozman Č., Vučko I. (2009): Analysis of the effects of agricultural policy with the model of typical agricultural holdings. Zaključno poročilo CRP projketa V4-0361. Kmetijski Inštitut Slovenije, Ljubljana, (in Slovene).

Rehman T., Romero C. (1984): Multiple-criteria decision-making techniques and their role in livestock ration formulation. Agricultural Systems, 15: 23–49.

Rehman T., Romero C. (1987): Goal programming with penalty functions and livestock ration formulation. Agricultural Systems, 23: 117–132.

Saaty T.L. (1980): The Analytic Hierarchy Process. Mc Graw, New York.

Sharma D.K., Ghosh D., Alade J.A. (2006): A fuzzy goal programming approach for regional rural development planning. Applied Mathematics and Computation, 176: 141–149.

Tamiz M., Jones D., Romero C. (1998): Goal programming for decision making: An overview of the current state-of-the-art. European Journal of Operational Research, 111: 569–581.

Torkamani J., Abdolahi M. (2001): Empirical comparison of direct techniques for measuring attitudes toward risk. Journal of Agricultural Science and Technology, 3: 163–170.

Zgajnar J., Kavcic S. (2011): Indirect estimation of farm's risk aversion; mathematical programming approach. Bulgarian Journal of Agricultural Science, 17: 218–231.

Žgajnar J., Kermauner A., Kavčič S. (2007): Model for assessing the nutritional needs of ruminants and optimization of feed rations. In: Kavčič S. (ed.): 4. konferenca DAES. Slovensko kmetijstvo in podeželje v Evropi, ki se širi in spreminja, Moravske Toplice, 8–9 Nov. 2007, Ljubljana: 279–288 (in Slovene).

Received: 5th August 2015
Accepted: 8th October 2015

Contact address:

Jaka Zgajnar, University of Ljubljana, Biotechnical Faculty, Jamnikarjeva ulica 101, 1000 Ljubljana, Slovenia
e-mail: jaka.zgajnar@bf.uni-lj.si