The foregone risk premium: a communicative and practical method for the evaluation of risk-return profiles in agriculture

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Abstract

Risk considerations have become increasingly important in nowadays agriculture, due to a variety of reasons. Surprisingly, the practice of formalized risk management is not widespread despite the huge amount of scientific literature on this topic. This discrepancy between risk science and extension is described by many authors. This paper presents a communicative method, rooted in financial economics, to evaluate risk-return profiles in a way that is communicative for individual farmers. The method is derived from the modern portfolio theory, in which individual assets are implicitly compared to the risk-return trade-off of that asset with the highest Sharpe ratio. We use this idea to compare individual risk-return profiles to a particular benchmark. The method can be used for evaluating different risk-return profiles of different farms, different risk management instruments and different production systems. To illustrate the communicative nature of our method, it is applied to evaluate risk-return profiles of conventional versus organic cropping systems.

1. Introduction

The Neolithic revolution – the transition from hunting and gathering to agriculture – was partly a response to the riskiness of hunting and gathering for food (Hardaker et al., 1997). Yet in agriculture, risk remains an ineradicable part of life. More even, nowadays, risk becomes increasingly important. First, volatility of prices is expected to increase due to globalization, liberalisation and increased trade levels (European Commission, 2001; Eakin, 2005; Chavas and Kim, 2006; Ericksen et al., 2009; Sumner, 2009). Second, restrictions on the use of certain inputs and production techniques might increase production risks. Third, government interventions in the EU that were traditionally stabilizing income are being replaced in favour of alternative mechanisms. This means that safeguarding a stable farm-level income becomes the responsibility of the farm manager (Majewski et al., 2008). Fourth, income risks may cause financial risks and thus may jeopardize the viability of farm operations and may cause social injuries to farm families. The degree to which income risks are transferred to financial risks is expected to increase as farm businesses become more and more capital intensive, which, combined with the abundance of family farms, leads to a lower solvency ratio. Finally, the perceived riskiness of new production technologies, relative to the traditional systems as benchmarks, may impede technological and organisational change towards more sustainable production systems. (e.g., Acs et al, 2009).

Surprisingly, risk is still seldom considered in various aspects of the farm business. First, the economic comparison of production systems, for instance, is mostly focused on one or more measures of return and income, whereas risk is rarely taken into account. This is in contrast to the general perception that different production systems differ not only in return, but also in the associated risk. Second, risk considerations have yet to permeate farm consultancy and extension. Indeed, companies providing farm statements and advice most often rely on income figures and financial ratios, ignoring the past and expected future potential exposure to risk. Last, Meeuwissen et al. (2008), among others, observed that agricultural risk markets in Europe are very limitedly developed, in contrast to the USA, Canada and newly emerging agricultural powers such as Brazil and China.

Traditionally, risk management is regarded as a process of maximizing return for a given level of risk or minimizing risk for a given level of return. In practice, however, decisions at farm level and changes in external factors will cause both risk and return to shift. Then the question arises whether this alternative risk-return profile is preferable to the base profile. In some situations, this question will be easy to solve, such as situations in which return drops to an unacceptably low level or in which return increases while risk decreases, but not so in others. This paper presents a model for the evaluation of risk-return profiles. Rather than relying on already developed and demonstrably analytically sound methods, we aim to reconcile both analytical soundness and applicability at farm level, to bridge the gap between research and extension.

2. Literature review

2.1. Comparing alternative production systems

Fox et al. (1991), reviewed the comparative economics literature from North-America on different production systems such as conservation tillage, controlling soil erosion, alternative pest-control methods, conventional versus integrated versus organic production systems. Most importantly, they observed that the comparative analysis of risk

across production system was a mostly neglected dimension, regardless of some exceptions, such as Held and Zink (1982) and Klemme (1985). More recently, Roberts and Swinton (1996), focused on the methods for comparative analysis rather than on the results. Reached the same conclusion. Since then, risk has been taken into account more often such as in studies comparing organic to conventional farming (e.g., Lien et al;, 2006; Perillat et al., 2004; Langyintuo, 2005). However, also nowadays, an analysis of the comparative economics of alternative production systems very often occurs without considering the comparative risk. Example of the latter are Pimentel et al (2005), Clark et al, (1999), Delate et al, (2003), Eltun et al, (2002), Argilés and Brown (2010).

2.2. The inclusion of risk in the economic comparison of alternative production systems

This section presents a short overview of methods to include risk in a comparative analysis. Gloy and Baker (2001) compared different methods for the comparative analysis of risk and return. The first, expected profit maximization, is consistent with the behavior of a risk-neutral decision maker, as the different options are compared on the basis of their expected return. We have no knowledge of another application of this criterion.

The second, value-at-risk (VAR), has also not yet been applied in agriculture. However, Manfredo and Leuthold (1999) have reviewed its current use and suggest it may have application in agriculture. For a given probability and time horizon, VAR is defined as a threshold such that the probability that the loss exceeds this level, is the given probability. Thus, value-at-risk is more consistent with the notion of downside risk.

Stochastic dominance is the most often used method in the comparison of the risk-return performance. These techniques compare the outcome distribution of several alternatives, putting conditions on the risk utility functions. Depending on these restrictions, first-degree, second-degree and third-degree stochastic dominance is distinguished (Hardaker et al., 1997; 2004). Williams (1988), Mahoney et al, (2001), Mahoney et al, (2004), Smith et al, (2004), Ribera et al, (2004), Langyintuo et al, (2005), Lien et al, (2006), Flaten et al, (2008) use stochastic dominance to compare income risk differences between different cropping systems. Perillat et al. (2004) uses this technique for an analysis of different systems of backgrounding and finishing steers.

The Sharpe ratio compares risk-return configurations on the basis of their first two moments (Sharpe, 1966; 1975; 1994). It is a measure of the excess return per unit of risk. The Sharpe ratio is widely used in financial economics, we encountered only one application outside this domain. Watson and Robinson (2003) used it to compare the risk-return performance of male- and female-led SMEs.

Two other methods were found in literature. Held and Zink (1982) used a modified profit maximizing linear programming (LP) model to compare the risk-return trade-offs between cash-crop versus crop-livestock systems. Finally, some studies used Roy's safety first criterion (e.g. Wu et al., 2002; Watkins et al. , 2004). Roy's safety first criterion is consistent with maximizing expected profits. It is defined as the excess return over the minimum required return, divided by standard deviation. Hence it bears a striking resemblance to the Sharpe ratio.

2.3. The gap between risk management research and applied risk management

Most farm level agencies – both public and private – very seldom use risk notions when reporting farm statements to farmers or when giving advice. Anderson and Mapp (1996)

suggest that extension agents are often dissatisfied with the risk analysis being done by the research division of their institutions. They report that most extension workers thought there was a gap between published research on risk management and risk management practices that could be used in programs to improve producers' abilities. Castle (1993) refers to this as the communication gap. Coble and Barnett (1999) point to the fact that farmers cannot internalize the necessary expertise for all kinds of risk management and this expertise has to come from an external source. Selley and Wilson (1997), conducting a survey among risk research and extension economists, observed that extension economists use less sophisticated risk tools in their outreach efforts and that all respondents saw a need for more applied risk analysis. Brorsen and Anderson (1999) notice that research topics that are deemed relevant by extension workers and that are published by researchers match in some journals, but not in other. They also showed that extension agents are rarely able to use research directly from academic journals. Just (2003) argues that research should focus on risk at the farm level rather than continue to demonstrate points and methodology with aggregate data simply because they are available. Upadhyay and Young (2005, p. 3) summarize these findings: "*Despite considerable methodological progress in the past, there has been concern that standard risk analytical methods including expected utility/stochastic dominance have not been practical for agricultural extension use*".

3. The model

3.1. Sharpe ratio, capital allocation line and risk premium: modern portfolio theory

In financial economics, many models exist to evaluate the risk-return configuration of assets, in order to describe optimal behavior by minimizing risk for a given return, or by maximizing return for a given amount of risk. Modern portfolio theory (Markowitz, 1952; Elton et al., 2007) is such a theory of investment, aiming at deriving the optimal portfolio mix between a risky asset (or a risky market return) and the risk-free asset. In this subsection, we will describe the different concepts of the theory, in order to, in the next subsection, adapt this methodology to a method allowing individual farmers to evaluate their risk-return configuration. In modern portfolio theory, an investor can reduce portfolio risk by holding combinations of instruments that are not perfectly correlated. When there is risk-free asset – an asset that pays a risk-free return – then there is an efficient line representing all combinations of the risk-free asset and the risky asset with the highest Sharpe ratio, called the capital allocation line (CAL).

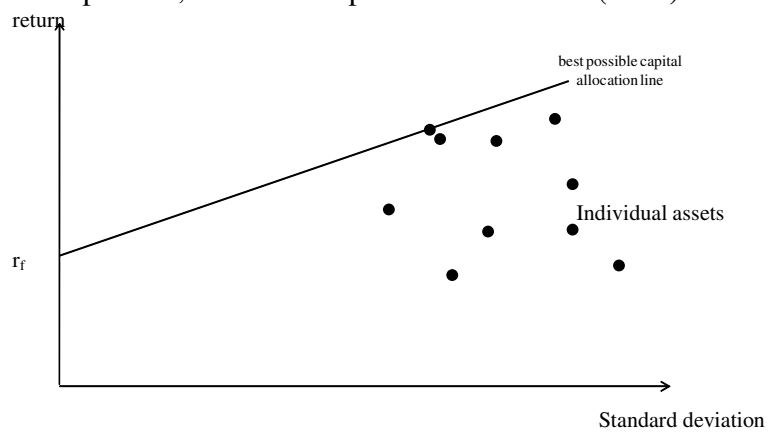

Figure 1. Capital allocation line, risk-return profiles

At the intercept of this line, the return (r_f) represents the risk-free return, this means that 100% of the portfolio is the risk-free asset. Optimal behavior is to invest in a combination of a risky asset and the risk-free asset that lies on the best possible capital allocation line. This best possible CAL is formed by this risky asset with the highest Sharpe ratio i.e. the highest return-to-variability ratio (Sharpe, 1966; 1994). The Sharpe-ratio is a risk-adjusted performance measure. It actually measures the achieved risk premium per unit of risk. Another capital allocation line is the capital market line, which is formed by a risky market return. One can consider this capital market line as the capital allocation line of the aggregate financial market. This capital market line thus represents the aggregate risk premium per unit of risk that is achieved by the aggregate market.

This model is, in financial economics, used to derive the optimal mix between risky assets or the optimal mix between risky assets and the risk-free asset. The best possible capital allocation line and the capital market line represent two potential benchmarks against which the relative risk-return performance of all other assets may be benchmarked.

3.2. The basic concepts of an agricultural risk-return benchmarking system

Benchmarking – or comparative analysis as it was called in the past – was described by Barnard and Nix (1979) as an approach that emphasizes the integrated nature of the farm business and its essence lies in calculating various efficiency factors or indices to compare with standard (such as average or best practice) obtained from other, similar farms. Inspired by this view, we believe that a benchmarking tool, comparing risk-return profiles to a standard, is a valid and communicative tool for risk management.

Let a denote a state of a farm at time t and b at time t+1. Note that the methodological derivation below also holds when a and b are two distinct farms at the same time t. In situation a, the risk-return configuration is (R_a,r_a) and in situation b (R_b,r_b). It is clear that in situation b, both risk and return have increased, the question is whether return has increased enough to compensate for the increased risk. Think for instance of a particular decision that the farmer is considering to take; when the return does not increase enough, than the advise would be not to take this particular decision, unless he is able to increase return, or to lower risk using one or more risk management strategies.

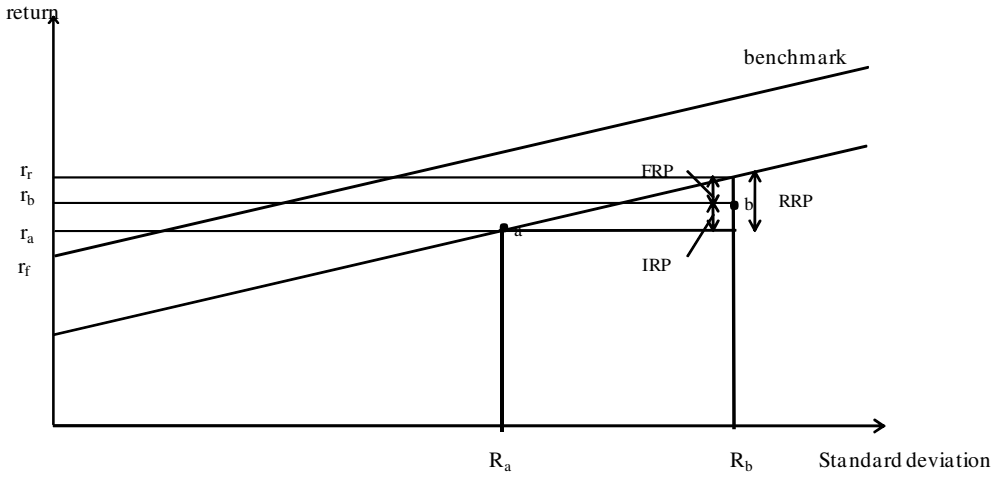

Figure 2. A framework for defining foregone risk premium (FRP), required risk premium (RRP) and insufficient risk premium (IRP)

If we want to compare the risk-return configuration of situation b with situation a, we transfer the benchmark parallel up to point a. Given this benchmark, we can define a required risk premium (RRP) for it to be allowed to take the risk associated with situation b when coming from a: RRP = $r_r - r_a$. This framework can be used to introduce two other novel concepts. The first one is an insufficient risk premium (IRP), referring to the situation where there is a risk premium but one that is too low given the benchmark. In figure 3: IRP = $r_b - r_a$ .The second concept, foregone risk premium (FRP) refers to the amount of risk premium that is foregone. In figure 3: FRP = $r_r - r_b$. Note that the three concepts are related by the following equation: RRP = IRP + FRP

3.3. Mathematical procedures for deriving FRP, RRP and IRP

In order to make the concepts operational and of practical use, we need to mathematically program the calculation procedures that, starting from measures for return, risk and a plausible benchmark, derive the evaluation measures. The mathematical procedures to determine FRP, IRP and RRP, starting from the base situation, are explained below (figure 4).
Let $(R_0,r_{0)}$ be the risk-return configuration of the base situation. For the mathematical procedures, we shift the original benchmark B parallel up to the point where it intersects the base situation. This shifted benchmark is called B' and the distance between both benchmarks is D. Let (R_i,r_i) be the risk-return profile of the alternative situation, then $r_{iB'}$ is the required return for the risk level of the alternative situation as prescribed by benchmark B'. The FRP, RRP and IRP are then defined as:

RRP = $r_{iB'} - r_0$
IRP = $r_i - r_0$
FRP = $r_{iB'} - r_i$

In these formula, $r_{iB'}$ is the return that the shifted benchmark should realize at the risk level of the alternative situation. The benchmarks B and B' are described by the following equations:

B: $r = \varphi R + r_f$
B': $r = \varphi R + r_f - D$

Note that φ is the slope of the benchmark, which represents the benchmark exchange of return for risk. The risk-free return, r_f, is the return of a risk-free asset and D is the distance between the original and the shifted benchmark, which equals the return that the benchmark B would realize at the risk level of the base situation minus the return of the base situation:

$D = r_{0B} - r_0$

Given the benchmark equations and the equation for the distance D, the three risk-return benchmarking concepts are mathematically calculated by the following formula:

RRP = $\varphi R_i - \varphi R_0$
IRP = $r_i - r_0$
FRP = $\varphi R_i - \varphi R_0 + r_0 - r_i$

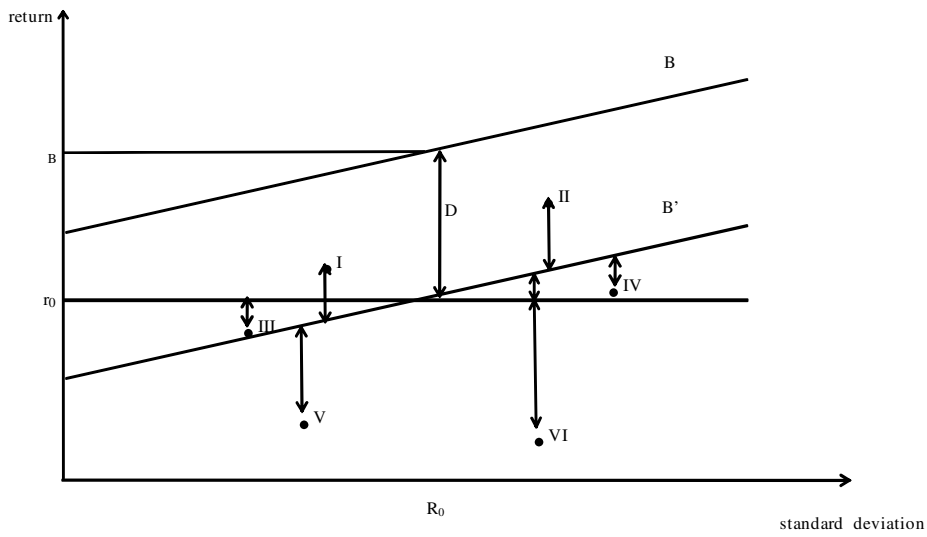

Figure 3. Risk-return benchmarking

Given the information (R_0,r_0), (R_i,r_i) and a plausible benchmark equation, the three equations above are sufficient to perform a risk-return benchmarking, using three communicative concepts. A particular decision may result in (or alternatively another farm may be in) six possible zones, relative to the base situation:

$I = \{(R_i, r_i) | R_i \leq R_0 \text{ AND } r_i > r_0\}$
$II = \{(R_i, r_i) | R_i > R_0 \text{ AND } r_i > r_{iB} - D\}$
$III = \{(R_i, r_i) | R_i \leq R_0 \text{ AND } r_i \leq r_0 \text{ AND } r_i > r_B - D\}$
$IR = \{(R_i, r_i) | R_i > R_0 \text{ AND } r_i > r_0 \text{ AND } r_i \leq r_B - D\}$
$R = \{(R_i, r_i) | R_i \leq R_0 \text{ AND } r_i \leq r_0\}$
$RI = \{(R_i, r_i) | R_i > R_0 \text{AND } r_i \leq r_0\}$

In zone I, the (R_i, r_i) outcomes are efficient with respect to the (R_0, r_0) reference: return is higher with less risk, which is reflected in a negative FRP measure. In zone II, risk increases, but so does return. Since the return is above the B' benchmark, risk is sufficiently remunerated, reflected in a negative FRP, meaning that risk is more remunerated than prescribed by the benchmark. In zone III, return falls below the conventional return, but is still above the B' benchmark. In this case, the FRP is negative, meaning that this risk-return profiles sufficiently remunerates risk. The inverse happens in zone IV, both risk and return increase but the increase of the latter is not sufficient to reach the benchmark B'. This is the first zone where the FRP and the IRP are positive. Zone V faces a drop in return, but part of it is compensated by a lower risk level. Finally, zone VI represents the worst case: both risk is increased and return is decreased. FRP is then the entire gap between the conventional return and the B' benchmark.

3.4. From concepts and mathematical procedures to a communicative and easy-to-use practical application

As the aim of this method is to be an easy-to-use tool that produces communicative results, the model is programmed in @Risk, such that with a minimum of input data, the user immediately obtains the output in an appealing format. The risk-return evaluation is

performed in terms of the FRP, which is normally expressed as a ratio figure, i.e., the income of a production factor related to the total value of this production factor. However, using some simple mathematics, this figure can be expressed in monetary terms at farm level. This highly improves the communicative nature of this indicator, and provides an immediate indication of the severity of the problem. Further, the model also allows for visual evaluation, enabling the farmer to see the risk-return position of his farm compared to the benchmark and other farms.

4. Application: the conversion to organic agriculture

This application compares the relative risk-return performance of conventional and organic arable cropping. As input, data about yield, prices, costs etc. is provided in order for the program to determine the expected return and risk of that return. Return on capital employed, ROCE, is calculated as follows

$$ROCE = (p * Q - VC - DP - FC - LC - TC) * \frac{100}{CE}$$

where p is price of output; Q is output; VC is variable costs; DP is depreciations; FC is fixed costs; LC is labour costs; TC is tenancy costs; and CE is capital employed. Returns have been simulated for both conventional and organic crops. In each Monte Carlo simulation, values for p, Q and VC were generated independently. Five iteration have been performed and for each iteration, 2000 Monte Carlo simulations have been done.

Before applying to the agricultural sector, a benchmark from the financial world has been elaborated from literature and experts' inquiries. Data from literature were pooled with the experts' outcomes for a regression analysis which yielded the following function: $ROCE = 4.38 + 0.36 * SD_{ROCE}$. The slope is this benchmark, 0.36, corresponds to φ in our mathematical equations.

Sensitivity towards institutional market failure, defined in terms of probability that the organic market is not functioning well, was tested. It is modeled in @RISK as a function RiskDiscrete {(0;1);(1-p_{mf};p_{mf})} with p_{mf} the probability of market failure. The RiskTriang function for price is then made conditional on the outcome of the function that is modeling market failure.

The simulations have been done for 8 crops (table 1), but the results for potatoes for processing will be treated more in detail. With 4000 euro/ha average capital employed (CE), 27 hours work at 14 euro/hour, 4 euro FC per hour worked, 640 euro/ha DP and 200 euro/ha TC we obtain a ROCE of -0.03 % (st.dev. = 27.2) for conventional farming. For organic farming ROCE is 16.0 % (st.dev. = 36.4). For the other crops, similar simulations are done (table 2).

Table 1. Return on capital employed (ROCE) and its volatility of eight major arable crops, on conventional and organic farming systems, CE is most likely value from table 1 and probability of market failure is 0.

	Conventional farming		Organic farming	
	ROCE	Volatility	ROCE	Volatility
Early potatoes	19.3	30.1	46.8	34.2
Potatoes for fresh market	64.4	36.8	95.8	55.5
Potatoes for processing	-0.03	27.2	16.0	36.4
Winter wheat	-5.2	17.7	38.2	25.0
Summer wheat	-24.2	19.8	26.4	36.7
Winter barley	-22.0	12.6	89.4	32.1
Leek	72.7	355.7	102.6	400.4
Onions	18.0	22.4	10.5	57.8

The forgone risk premium for potatoes for processing can now be expressed in euro per ha for the various assumptions in market failure. With "no institutional market failure", all crops except one face sufficiently remunerating risk premiums (table 2). The vegetable crops are highly vulnerable to institutional market failure, cereals are rather insensitive. This is because the organic price premium in the latter is relatively small. The potato crops show an intermediate sensitivity.

Table 2. Changes in FRP due to increased institutional market failure

Crop	FRP, in euro/ha, when institutional market failure equals				
	0%	15%	30%	45%	60%
Early potatoes	0	0	20	748	1394
Potatoes for fresh market	0	0	389	969	1484
Potatoes for processing	0	0	164	488	765
Winter wheat	0	0	0	81	217
Summer wheat	0	0	0	68	204
Winter barley	0	0	0	0	0
Leek	0	2253	4233	6599	8555
Onions	1216	1948	2629	3255	3832

5. Discussion and conclusion

This paper presents a method to evaluate risk-return profiles of farms. Risk-return evaluation is a necessary tool for farmers to perform appropriate risk management, however, due to various reasons current methods do not seem to provide expected results. Our method uses concepts from financial economics to develop a benchmarking method that reconciles analytical soundness with communicativeness and practical use. An application at crop level is performed to illustrate its communicative qualities.

Individual risk aversion is not taken into account in this method. Rather the method evaluates on the basis of the achieved versus the required risk premium given the benchmark. Thus, the method implicitly assumes that all decision takers should be equally risk averse than the average industry. One would expect that a decision maker who is more risk averse requires a higher risk premium than prescribed by the market and that a decision maker who is less risk averse than the market should require a lower risk premium. However, some controversy still surrounds the use of risk aversion to derive optimal behaviour. One might question the realism of the behavioural assumption upon which a certain utility function depends, or the ability of decision makers to provide consistent answers to the questioning procedures usually applied to derive such functions (Binswanger, 1982; Robison 1982; Schoemaker 1991; Kahneman and Tversky, 1979). One might also wonder whether there exists one degree of risk aversion for each individual, or whether individuals are more likely to exhibit different degrees of risk aversion according to the type, frequency and severity of the risks involved (Pennings and Garcia, 2001). Further, whereas knowledge of the degree of risk aversion is useful for describing decision behaviour, it is probably less needed when trying to prescribe optimal behaviour, as is the case in extension work.

The first challenge of our tool is that is depends upon the availability of a relevant benchmark. The proposed method does not depend on the benchmark. In future we aim to build-in a representative number of farm level figures. Using this, the user can decide whether he will use a best frontier, a financial markets or an average agricultural benchmark, or still other. The choice of a benchmark depends on the goal of the evaluation and on the relevance of the available data. The second critical point of the current model is that it depends on the reliability of figures for prices, costs and yields.

These two success factors represent the main opportunities for future research. First, we aim to extend the model with a module that is able to let the user calculate and choose between a range of possible benchmarks. Depending on the goal of risk-return evaluation, different benchmarks may be appropriate. Second, we aim to develop a whole-farm calculation module, that is able to calculate risk-return figures, taking into account the correlations between different activities.

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