

A model for determining efficient portfolio cropping plans in organic farming

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Abstract

This paper proposes a model that helps organic growers choose crops that better adapt to their risk profile and expectations of profit. One of the main advantages of the model is its treatment of uncertainty in this market, in which historical information regarding prices and production is unavailable. The economic approach of this work is inspired in the classic theory of portfolio selection, which assumes that profitabilities follow a beta distribution. Finally, an example of the model's use is reported, providing a viability analysis of these cultivation systems from a new point of view.

Additional key words: beta distribution, Markowitz, PERT, Roy, portfolio selection.

Resumen

Un modelo para valorar una cartera eficiente en agricultura ecológica

El objetivo de este artículo es presentar un modelo aplicable a la agricultura ecológica que permita al agricultor elegir aquellos planes que mejor se adapten a sus expectativas personales de rentabilidad y riesgo. Uno de los logros principales del modelo es el tratamiento especial de la incertidumbre en un mercado en el que no se dispone de información histórica sobre precios y producción. El planteamiento económico de este trabajo está inspirado en la teoría clásica de selección de carteras y supone que los rendimientos siguen una distribución de probabilidad tipo beta. Finalmente, se incluye una aplicación empírica del modelo con un análisis que trata de enfocar el problema de la viabilidad de este tipo de sistemas de cultivo desde un nuevo punto de vista.

Palabras clave adicionales: distribución beta, Markowitz, PERT, Roy, selección de carteras.

Introduction

Many financial models exist for the selection of cropping plans. In Spain, Romero (1976) used the Markowitz model to select among several varieties of apple in the province of Lérida (Spain). Alonso and Rodríguez (1983) used the Sharpe model to select the main rain fed crops for the river Duero area (choosing the cropping plan portfolio according to a pluviometric index). Rodríguez *et al.* (1990) used Markowitz's model to determine efficient portfolios for wine production, and

Alaejos and Cañas (1992) used Markowitz's model to select efficient cropping plans for the area of the Bembézar reservoir (Córdoba, Spain). This last paper also provided a list of similar works, including those of Alonso (1977), Caballer (1979), and Calatrava *et al.* (1981).

The work of Arias (1994) represented an important step forward since, as well as considering the constraint of area, it took into account those of cropping and soilworking frequency, comparing the quantitative techniques that employ quadratic risk treatment with those that use the linear approximation of the MOTAD method. Millán and Millán (1995) made a critical revision of the portfolio models used in cropping plan selection and set out the basic hypotheses underlying them. These same authors (1996) also used the different indices of the Sharpe model of cropping plan selection and analysed the applicability of the Simple Index Method to agriculture¹.

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¹ All these models are characterized by the availability of historical information on prices and production volumes, allowing the means and the variances of the returns of different cultivations to be estimated.

The treatment of uncertainty was introduced for the first time in the 1960s (McFarquhar, 1961; McInerney, 1967, 1969) using game theory. More recently it was used by García *et al.* (1998), in which Roy's model was used to select intensive farming portfolios for western Almería (Spain). The present paper, however, presents a quadratic programming model in which: i) agronomic and social factors are introduced (making it an interdisciplinary model), ii) models of selection typical of risk situations and uncertainty evaluation methodologies are combined, and iii) great flexibility in the selection variables is shown, when the values of either returns or risks are pre-fixed. The model has four phases: the establishment of the production possibilities frontier (PPF), determination of the most efficient cropping plan, analysis of viability of the investment, and the introduction of a feedback and control mechanism. In this work only the two basic stages of the model are considered, with special emphasis on the financial method of selection in the second phase. However the need for all four phases is justified throughout the text.

Establishment of the production possibilities frontier

The use of the model requires two basic assumptions: i) That farmers behave rationally and wish to obtain the maximum return possible but worry about the risk involved in achieving such profitability; this is logical, as farmers are, after all, investors; ii) Agricultural markets behave in the same way as financial markets; this is also logical since prices are determined by the law of supply and demand.

The following step is the establishment of the crop set over which the selection criteria are applied. This crop set, which satisfies the constraints set by the reigning socioeconomic and environmental conditions, is termed the PPF.

The incorporation of environmental constraints aims to avoid non-viable selections being made for an area. In the case of conventional agriculture, this is not so important since growing can be forced using plastic greenhouses or other systems. In organic farming, however, it is clearly more important.

The incorporation of socioeconomic constraints takes into account access to markets, human resources, and the continuous access to consumables at a reasonable

price. The consideration of all these constraints allows the PPF to be identified.

Establishment of an efficient growing plan: introducing the context of uncertainty

One of the classic approaches to this kind of problem has been the use of quadratic programming models, especially the Markowitz's model (1952) —the forerunner of the portfolio selection theory. This model determines the set of assets that best satisfies the particular return and risk preferences of each investor. The concept of rationality is based on the fact that the actions of all investors are guided by two forces working in opposite directions: on one hand they wish to obtain the maximum return, but on the other they are concerned about the risk to which they are exposed if they are ever to obtain such profitability (Suárez, 1995).

In mathematical terms, the problem is represented in the following way:

$$\max \sum_{i=1}^n x_i p_i - \lambda \sum_{i=1}^n \sum_{j=1}^n x_i x_j \sigma_{ij} \quad [1]$$

where p_i is the mean of the return of asset i , and σ_{ij} the covariance of the returns of assets i and j , with the

$$\text{constraints } \sum_{i=1}^n x_i = 1, x_i \geq 0, \quad i = 1, \dots, n.$$

The solution involves finding a value for the coefficient of aversion to risk (λ), i.e., the economic agent's aversion to risk. This element is the determining factor in Markowitz's model, since it specifies the preferences of the economic agent. Hillier and Lieberman (1991) indicate that λ varies between zero and infinity, which demonstrates the trouble in reasonably determining such a coefficient and therefore the difficulty in using this method.

Despite having gone largely unnoticed, Roy's model (Roy, 1952), a contemporary of the former, supplies an original and more pragmatic approach. In the selection of investments, this model considers risk from a different point of view. The aim is to choose a portfolio reflecting the minimum return the investor expects to obtain and to determine the probability of reaching such profitability. Roy (1952) showed that the efficient frontier is then given by the following hyperbola:

$$\left[\frac{(AW^{-1}A')(BW^{-1}B') - (AW^{-1}B')^2}{BW^{-1}B'} \right] \left(\sigma^2 - \frac{1}{BW^{-1}B'} \right) = \left(m - \frac{AW^{-1}B'}{BW^{-1}B'} \right)^2 \quad [2]$$

where $A = (p_1, \dots, p_n)$, p_i is the mean of the return of asset i , $X = (x_1, \dots, x_n)$ is the matrix comprising the different combinations of products in the PPF, B is a matrix of the form $B = (1, \dots, 1)$, W is the matrix of variances-covariances, and $m = AX'$ and $\sigma^2 = XWX'$.

Therefore, if

$$T = \left[\frac{(AW^{-1}A')(BW^{-1}B') - (AW^{-1}B')^2}{BW^{-1}B'} \right] \quad [3]$$

$$U = \left(\frac{1}{BW^{-1}B'} \right), \text{ and}$$

$$V = \left(\frac{AW^{-1}B'}{BW^{-1}B'} \right)$$

expression [1] could be written in the following manner:

$$T(\sigma^2 - U) = (m - V)^2 \quad [4]$$

The optimum combination of assets would then be given by:

$$X = \mu W^{-1}(A - dB) \quad [5]$$

where μ is chosen such that $\sum_{i=1}^n X_i = 1$. Similarly, the

risk associated to the portfolio is therefore determined by:

$$R = \frac{1}{(A - dB)'W^{-1}(A - dB)} \quad [6]$$

The economic bases of both models are the same, but they concentrate on different variables: the first on risk, the second on returns. However, as indicated by Cruz *et al.* (1999), Roy's model has some advantages over the Markowitz model:

1. Risk represents the probability of not reaching the minimum pre-fixed return. In the Markowitz model, this is determined by λ and the variance. Nevertheless, this approach is clearly a little intuitive.

2. Roy's model uses risk as a variable in decision-making rather than returns. If the risk is fixed, the minimum return is expressed as follows:

$$d = V + \sqrt{\frac{UR}{1 - TR}} \left(T - \frac{1}{R} \right) = V - \sqrt{U \left(\frac{1}{R} - T \right)} \quad [7]$$

However, according to Cruz *et al.* (1999), it can be shown that the concept of risk presented by Roy is closely linked to the Markowitz model through the following expression:

$$R = \frac{1}{\lambda^2 \sigma^2} \quad [8]$$

Therefore, if the Markowitz model is used after fixing a value for λ , the risk associated with the return of an efficient portfolio can be obtained. Thus, the most efficient cropping plan is that set of crops which, forming part of the PPF, maximizes the return-risk relationship. To obtain this, one can:

1. Use [1] and the relationship established by [8].
2. Set the minimum percentage of return wished for, and so determine the composition of the plan using [5], and the risk using [6].
3. Set the risk and determine the return associated with the plan determined by [5] using [7].

The decision context

The use of any of the above models requires some historical information on prices or returns for each of the products in the PPF. For conventional products, such data are available from a number of publications, such as the COEXPAL yearbook². Based on this information, the means and the variances of all these products can be estimated in a relatively simple way. In this risk context, the model discussed in the above paragraph would be used. However, no historical information exists regarding the prices and profitabilities of ecological products. Therefore, from an economic point of view, the problem involves a context of uncertainty. To deal with this, the beta hypothesis, and in particular PERT methodology, needs to be incorporated (see Herreras, 1989).

The greatest criticism levelled at organic farming is its relatively low productivity, high cost, and lower profitability compared to intensive agriculture. The

² Cooperative of Exporters and Producers of Almería (Spain).

analysis of production costs and sale prices is therefore required when studying the final viability of organic cropping plans. However, the literature contains little and often contradictory information in this respect.

With respect to productivity, Viel (1979) was the first to compare organic and conventional agriculture (in the French region of Lot-et-Garonne). It was deduced that the yields obtained in biological agriculture are not always equivalent to those of its classic competitors, particularly with respect to vegetable products. However, one of the most recent studies by Tilman (1998) reports the results of an experiment in which the effects on the soil and the final profitability were measured in one intensive and two ecological agricultural systems concerned with raising corn and vegetables. Over the ten year period studied, the difference in final profitability between the products obtained was just 1%. Similarly, Gregori (1997) found no significant difference between the mean yields per hectare of both techniques; this is particularly significant since most of the products compared were fruits and fresh vegetables. In contrast, the UNCTAD (1996) reported that, in general, the yields obtained in organic farming are usually 10%-30% lower than those achieved by traditional agriculture.

Opinions also differ with respect to production costs and final viability. After comparing the results obtained by ecological and conventional techniques for single crops, Gregori (1997) concluded that production costs are usually 25% higher for ecological products, and occasionally more than 50%. Tree-borne crops showed the smallest differences while vegetables showed the greatest. Nevertheless, the final margin for the ecological products was 32% greater than that for the conventional products, mainly as a consequence of the former's higher sale price (often more than 50% higher).

The UNCTAD (1996) indicates that in organic cropping plans, the saving made in inputs can reduce production costs by some 10-40%, but that the greater labour requirements (up to 50% greater) can cancel out this advantage. Therefore, viability is subject to the social and environmental benefits afforded by ecological practices. The care taken in protecting the environment is socially advantageous and justifies a higher price for the final products, which the farmer usually receives in the form of subsidies. Yetunde *et al.* (1997) studied the economic characteristics of several ecological farms in Canada and compared them with conventional ones of similar characteristics. Their

conclusions were in the line with those mentioned above: the production costs of the ecological cropping plans were 23% lower as a consequence of the savings made in the purchase of fodder, hormones and synthetic fertilizers, etc. In addition, income was 29% higher per hectare than that achieved by conventional holdings. However, the Economics Unit of the University of Cambridge (1992), reporting on the profitability of organic farming in England, concluded that cultivation systems using exclusively ecological techniques were unable to compete with conventional systems, showing a reduction in the margin per hectare of 44%.

Thus, it is difficult to deduce the profitability of organic farming from the literature published to date. Given the difficulty associated with the heterogeneity in this type of cropping plan [indicated by Gregori (1997)], the present paper approaches the problem from a more specific point of view. Once an efficient cropping plan for a farmer has been selected, the problem is solved by using the net present value (NPV). If the NPV is greater than the necessary maximum investment to start, the plan will not be profitable.

Use of the model: an example

The use of the beta hypothesis (in particular PERT methodology) requires three estimates of the decision variable, in this case profit: pessimistic (*a*), optimistic (*b*), and most likely (*m*). Obviously, the net profit per hectare is given by the difference between the total costs and the sale price. *A priori*, it might be considered that the simplest course is to ask an expert for different estimates of the yield per hectare for each product in the PPF. But this magnitude involves taking into account a series of inherent elements such as prices, total costs and production volumes that would considerably distort any answers given. It therefore seems better to consider each of the components of profit per hectare independently. With respect to production costs, it is here assumed that they behave entirely as a random variable. This approach assumes it is easier for the farmer to estimate the total production costs per kilogram than to distinguish between fixed and variable costs. Therefore, the net yield per hectare is the product of three random variables: production per hectare, cost per kilogram, and sale price per kilogram. It is also well known that:

1. The mathematical expectation of the product of two independent random variables is the product of their expectations³.

2. With respect to the variance of a product, taking into account that the mathematical expectation of the product of the square of two independent random variables is the product of the expectations of the squares of these random variables (Rohatgi, 1988), the following equation holds:

$$\sigma^2(AB) = \sigma^2(A)\sigma^2(B) + E(B)^2\sigma^2(A) + E(A)^2\sigma^2(B)$$

If p is the price, pr production, vc variable costs and fc fixed costs, the net yield per hectare will be:

$$r = pr - (p - vc)$$

The expected value of r will be:

$$E(r) = E(pr) - (E(p) - E(vc))$$

and the variance:

$$\sigma^2(r) = \sigma^2(pr)(\sigma^2(p) + \sigma^2(vc)) + (E(p) - E(vc))^2\sigma^2(pr) + E(pr)^2(\sigma^2(p) + \sigma^2(vc))$$

Therefore, the expert should be asked to estimate the values a , b , and m for the price per kilogram, the cost per kilogram, and the production per hectare of each of the products that compose the PPF. To obtain the means and standard deviations, several models based on the beta distribution have been described. Those used were:

1. *Classic*: the stochastic characteristics of which are:

$$\mu = \frac{a + 4m + b}{6} \quad \text{and} \quad \sigma^2 = \frac{(b - a)^2}{36}$$

2. *Constant variance*: based on the idea that the beta distribution has (like the normal distribution) a constant variance equal to $1/36$. Starting from this condition, the following cubic equation can be deduced:

$$k^3 + k^2[7 - 36(m - m^2)] - 20k - 24 = 0$$

which has only one valid solution for k when m varies between 0 and 1. Substituting the value of k in [9] and [10], the mean and the variance can be obtained.

3. *Farnum and Stanton*: based on the idea that the estimate of the mean of the beta distribution in the PERT method is reasonable for a wide interval of

subjective modal values. Nevertheless, such an estimate fails more often as the expert situates the subjectively estimated mode further away from the interval:

$$(a + 0.13(b - a), a + 0.87(b - a))$$

To estimate the means and variances, the following options are available:

$$\text{— If } m < 0.13, \text{ one must use } \begin{cases} \mu = \frac{2m}{2m + 1} \\ \sigma^2 = \frac{m^2(1 - m)}{1 + m} \end{cases}$$

— If $0.13 < m < 0.87$, the classical PERT should be used.

$$\text{— If } m > 0.87, \text{ one must use } \begin{cases} \mu = \frac{1}{3 - 2m} \\ \sigma^2 = \frac{m(1 - m)^2}{2 - m} \end{cases}$$

4. *Expert's confidence*: this model belongs to those that gather more information from the expert in order to particularize the beta distribution to be used in the problem⁴. This model consists of asking the expert his confidence in the supplied modal value. To obtain the particularized beta value, the following cubic equation must be solved:

$$k^3 + \left[\frac{7I - 12(m - m^2)}{I} \right] k^2 + \frac{16I - 12}{I} k + \frac{12I - 12}{I} = 0$$

This provides the value for k which, when substituted into [9] and [10], allows the mean and variance to be obtained.

Table 4 shows estimates for cost per kilo, price per kilo and production, while Table 1 shows estimates for the means and variances obtained by each model. Starting with this information, different risk scenarios were simulated and an efficient portfolio cropping plan obtained using the modified Markowitz and Roy models.

Results

Table 1 shows the results provided by the Markowitz and Roy models in each case. Notice that the most conser-

³ It can be considered that price and production are independent random variables since, on an individual level, the farmer's production will have no influence on the price received for his products.

⁴ One of the main problems associated with the beta methodology is that the beta distribution is specified by four variables. It is therefore impossible to particularise this distribution with the expert's three estimates. For this reason, models with an underlying beta distribution resort either to imposing constraints on beta, as in the constant variance model, or to asking the expert for more information.

Table 1. Comparison of results obtained with the modified Markowitz and Roy models

Crops	Classic		Constant variance		Farnum-Stanton		Expert's confidence	
	Markowitz	Roy	Markowitz	Roy	Markowitz	Roy	Markowitz	Roy
Orange	26%		26%	3%	25%		22%	17%
Lemon	6%		5%	2%	6%		3%	6%
Apple	2%	2%	2%	2%	2%	2%	1%	2%
Peach	6%		5%		5%		6%	6%
Almond	6%		7%		6%		33%	18%
Grape	6%	8%	6%	8%	6%	8%	3%	5%
Strawberry	5%	10%	5%	11%	5%	10%	3%	3%
Tomatoes	6%		6%		6%		8%	11%
Cucumber ¹	3%	5%	3%	5%	3%	5%	1%	2%
Pepper	6%	13%	6%	14%	6%	14%	2%	5%
Melon	2%	3%	2%	3%	2%	3%	1%	2%
Beans	3%	7%	3%	7%	4%	7%	1%	2%
Cabbage	12%	24%	7%	14%	12%	23%	6%	6%
Lettuce	8%	18%	4%	19%	8%	18%	7%	11%
Cucumber ²	4%	10%	13%	10%	4%	10%	1%	3%
Expected return (€)	14,436.75	22,904.57	12,847.82	19,689.08	14,328.93	22,447.66	10,993.03	14,009.84
Risk	2.97%	1.91%	3.39%	2.25%	3.94%	1.94%	1.73%	1.41%

Empty cells have a value of zero. ¹ Dutch variety. ² French variety.

vative risk value never exceeds 4%. The aim is therefore to obtain a minimum profit with 96% confidence.

The expected profit value oscillates between €10,993.03 in the most conservative case, and

€22,904.57 in the most optimistic, with risk values of 1.73% and 1.91% respectively.

Roy's model diversifies the portfolio less, which makes it more useful in this case since it is impossible

Table 2. Cropping plan selection for $\lambda = 0.0000012$

Crops	Classic	Constant variance	Farnum-Stanton	Confidence
	Markowitz	Markowitz	Markowitz	Markowitz
Orange				3%
Lemon				3%
Apple				4%
Peach				
Almond				1%
Grape				6%
Strawberry	10%	25%	11%	5%
Tomatoes				2%
Cucumber ¹	3%	8%	2%	9%
Pepper	13%	21%	13%	13%
Melon				5%
Beans	7%	13%	2%	10%
Cabbage	42%		45%	6%
Lettuce				6%
Cucumber ²	26%	32%	27%	28%
Min. return (€)	25,160.89	23,216.15	24,837.07	19,389.31
Exp. return (€)	28,535.86	27,674.47	28,324.01	29,197.13
Risk	98.93%	74.89%	95.76%	34.04%

Empty cells have a value of zero. ¹ Dutch variety. ² French variety.

Table 3. Expected value and variance (€) of cash-flow

Year	Variance cash-flow	Expectation cash-flow
1	668,543,147.60	
2	606,388,342.49	
3	550,012,102.03	
4	498,877,190.05	22,904.57
5	452,496,317.51	
6	410,427,498.87	
7	372,269,840.24	

to plant more than a certain number of crops in a single hectare. However, this result is a consequence of excessively conservative risk values. If a value of $\lambda = 0.0000012$ is selected, the results change considerably (Table 2). Table 2 shows an increase of the expected profit and a considerable increase in risk, from 34.04% (confidence Markowitz) to 98.93% (classic Markowitz). The Farnum and Stanton model provides the best scenario. Although the expected minimum return is the second highest, the risk is lower than in the maximum profit case. In addition, the portfolio is much less diversified.

One of the more conservative cases was selected to perform the investment viability analysis, using classic PERT methodology and the Roy model. This suggested a return of €22,904.57. The assumptions were: 1) a period of recovery of 7 years and a discount rate of 5% corresponding to the capital costs of an investment of

this type, and 2) that the expected return would be the same (only subject to inflation) during the recovery period.

The problem was approached in terms of the maximum outlay so that the investment was profitable. Since

$$P(E(VC) - k\sigma(VC) \leq VC \leq E(VC) + k\sigma(VC)) \geq 1 - \frac{1}{k^2}$$

if k is conveniently chosen, confidence intervals can be obtained for the capital value at every level of significance. This will determine the decision made. If only positive values are returned, the decision will be to invest; if some negative values are returned, it becomes necessary to pay attention to other criteria or to diminish the level of confidence and, hence, to assume more risk.

Starting from the data in Table 3, the expectation of the capital value is €132,534.72 and the standard deviation €4,624.94. The capital value will be in the interval (€111,851.35-153,218.10) at the 95% confidence level.

Once the capital value of the investment has been obtained, the following step is to compare it with the initial outlay necessary to put the cropping plan into operation. In this case, the work of Pérez Mesa *et al.* (2003) shows how an approximation can be performed. Indeed, this paper provides an estimation of the cost

Table 4. Estimates of cost (€) per kilo (ECK), price (€) per kilo (EPK) and production (kg) (EP)

Crops	<i>a</i>			<i>b</i>			<i>m</i>			<i>s</i>			<i>I</i>		
	ECK	EPK	EP	ECK	EPK	EP	ECK	EPK	EP	ECK	EPK	EP	ECK	EPK	EP
Orange	0.05	0.18	25,000	0.08	0.36	67,000	0.05	0.24	35,000	0.05	0.23	36,000	0.51	0.54	90
Lemon	0.12	0.21	25,000	0.19	0.54	80,000	0.18	0.30	50,000	0.15	0.33	45,000	0.54	0.48	90
Apple	0.12	0.18	15,000	0.19	0.90	90,000	0.18	0.30	55,000	0.15	0.39	60,000	0.54	0.54	75
Peach	0.27	0.33	15,000	0.51	0.90	35,000	0.33	0.48	25,000	0.33	0.48	25,000	0.60	0.54	99
Almond	0.84	3.01	500	2.10	6.61	2,400	1.80	4.81	1,500	1.65	4.51	1,200	0.48	0.54	80
Grape	0.24	0.69	10,000	0.45	2.10	24,000	0.39	1.05	15,000	0.36	1.08	14,000	0.48	0.45	75
Strawberry	0.84	1.68	15,000	1.80	2.40	40,000	1.20	2.10	30,000	1.20	2.10	30,000	0.60	0.60	99
Tomatoes	0.04	0.12	25,000	0.12	0.30	80,000	0.09	0.15	70,000	0.08	0.15	70,000	0.60	0.57	99
Cucumber ¹	0.08	0.23	60,000	0.29	0.72	140,000	0.26	0.47	100,000	0.25	0.45	100,000	0.48	0.48	80
Pepper	0.25	0.70	40,000	0.46	1.15	90,000	0.44	0.78	55,000	0.50	0.90	55,000	0.54	0.54	70
Melon	0.05	0.16	30,000	0.35	0.87	80,000	0.26	0.47	55,000	0.30	0.54	55,000	0.45	0.48	60
Beans	0.30	0.86	22,000	0.88	2.16	50,000	0.87	1.56	30,000	0.76	1.35	30,000	0.51	0.48	60
Cabbage	0.08	0.22	80,000	0.22	0.39	160,000	0.11	0.36	120,000	0.20	0.36	120,000	0.48	0.42	80
Lettuce	0.08	0.23	60,000	0.17	0.43	100,000	0.16	0.31	90,000	0.15	0.27	90,000	0.48	0.48	90
Cucumber ²	0.08	0.23	120,000	0.17	0.43	300,000	0.16	0.31	200,000	0.15	0.27	220,000	0.42	0.48	60

All the information included in this section was supplied by Francisco Montoya Martínez, Manager of ANDALUCÍA EXPORTACIONES, S.C.A., one of the most important companies in organic produce trading in the south of Spain. ¹ Dutch variety. ² French variety.

for bringing 1 ha in the province of Almería (Spain) into operation-about €125,300.

Since the present portfolio contains a high percentage of cropping under plastic, this approximation appears to be rather conservative, since the data supplied in Table 4 are not for intensive cultivation. Considering the portfolio composition to be reasonable, it can be observed that the initial outlay lies within the confidence interval, i.e., it is less than the expected capital value. Moreover, taking into account that some elements have a considerably longer useful life than the amortization period, then the investment will be clearly profitable.

Conclusions

Despite the common use of models based on the portfolio theory in the agricultural context, they are most frequently used in particular geographical areas and for conventional agricultural systems. This work therefore represents three important advances. Firstly, the consideration of agronomic and social factors makes the model more universal in its potential uses. Taking these features into account is the first step in determining whether it is feasible to use the model in a pre-selected area. Secondly, a more extensive analysis of the treatment of the risk is allowed [introduced by García *et al.* (1997)] with the revision of the new beta-based models. Finally, greater flexibility is allowed in the choice of variables incorporated, while a more intuitive concept of them is developed, especially with reference to the concept of risk. In practical terms, an analysis of viability is supplied.

The results obtained with the proposed model show that if the initial outlay (fitting-out costs, purchase of land, expenses of starting the project) is less than €111,851.35, the investment is likely to be profitable with a high level of confidence. Considering that the project will only be rejected at the 95% confidence when the initial payment exceeds €153,218.10, it is clear that the investment will be viable in most situations.

It is not necessary to carry out a precise evaluation of the initial outlay since the amount required to start a hectare of ecological crops is not known with certainty. The inclusion of the analysis of viability provides a point of reference to those who better understand the questions relating to the expenses entailed in setting up holdings of this kind.

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