Does the risk influence the adoption of alternative soil tillage technology? A compromise programming approach

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Abstract

The alternative soil tillage technology plays an important role in the development of a sustainable agriculture. The use of traditional technology gives the farmers a positive expected income. With the use of an alternative soil tillage technology, the expected income considerably rises together with the income risk.

Combinations of income and risk revealed that the use of traditional technology is an option when the objective is to lower the income risk. Nevertheless, the income risk foes not play a decisive role in the adoption of the technology, especially when the effects of production variability and available days are hidden by the agricultural policy.

Key words: Alternative soil tillage technology; agricultural policy; risk; compromise programming.

Résumé

Les technologies alternatives de labour du sol jouent un rôle un très important dans le développement d'une agriculture durable. L'emploi de la technologie traditionnelle donne aux exploitants un revenu positif. En employant les technologies alternatives, le revenu que l'agriculteur peut obtenir est considérablement supérieur, mais le risque aussi augmente.

Les combinaisons entre le risque et le revenu ont montré que l'utilisation de la technologie traditionnelle est une option possible lorsque le but ultime est de réduire le risque. Quoi qu'il en soit, le risque ne joue pas un rôle décisif dans l'adoption des technologies, surtout quand les effets da la variabilité de la production et les jours disponibles sont cachés par la politique agricole.

***Mots Clés**: Technologies alternatives de labour du sol; politique agricole; risque; programmation de compromis.*

1. Introduction

Agricultural soil degradation due to erosion processes and compaction is probably the most important problem affecting the traditional agriculture, by interesting about 157 million ha (16% of the total European surface) and, in the last 50 years, its intensification greatly contributed to accelerate the erosive processes and raise the desertification risk in vulnerable zones. Cultural systems that include ploughing before non irrigated crops cause negative externalities, especially as for soil degradation (APOSOLO, 1999).

The EU Common Agricultural Policy (CAP) clearly promoted the agriculture modernisation and intensification, but this modernisation had prejudicial effects on the environment (APOSOLO, 1999). The CAP was reformed in 1992 and this reform defined the environmental dimension of the agricultural sector as the main user of land and attempted at integrating market policy with structural and environmental policies, namely with the introduction of the accompanying measures, mainly the agro-environmental ones. The Agenda 2000 reform considers the integration of environmental objectives in the CAP and the development of the role farmers must and should play in the administration of natural resources. In this document, it is recognized that the agricultural competitiveness in rural areas, in conjunction with agricultural policies, should contribute to the economic cohesion of the European Union.

Alternative soil tillage technology plays an important role to play in developing a sustainable agriculture, from both an economic and an environmental point of view. From an environmental point of view, reducing compaction and preventing erosion promote soil conservation. From an economic point of view, they give a relevant contribution to the maintenance of equal levels of farmers' income (Martins, 1994).

The production variability of this technology, according to the state of nature, may however influence the farmers' choice, by making them opt for traditional technology. In a risky environment, the farmers' behaviour is very important when higher incomes are at the same time very variable (Klemme, 1985).

On farm, with determined production equipment, the production variability implies different production plans that may raise production costs and punish the income deriving from the application of an alternative soil tillage technology, including the farm income.

The production variability also implies income variability and then it is also an important element in the economic analysis of the alternative soil tillage technology to be applied although its effects are partially covered by an agricultural policy in which part of the subsidies is not linked to the quantity produced.

The used tillage technology implies a difference in the number of days needed to seed and, depending on the type of machinery used and on how this machinery leaves the soil, a difference in the number of days available to execute

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the cultural operations that lead to the establishment of cereal crops. On average and per state of nature, the available days are different according to the type of applied technology (considering 8 working hours/day). Finally, the available days for each technology and each state of nature vary according to the different soil types, because they are related to how the mobilised soil supports the climatic phenomena, which depends on soil type. This matter is extremely important because it has obvious implications on production costs and because the effect of the variability of available days on income variability must also be considered.

The objective of the developed model is to evaluate the decision that farmers have to make on the traction sets that should be used on farm and, consequently, the technological choice in a risky environment, in particular by assessing the variability of the main factors that can influence the decision-making process, i.e. the intra-annual production variability obtained by applying different types of technology and the available days needed to mobilise the soil with different technology and therefore traction costs to be supported by the farmer.

2. The Method applied – The mathematical programming model

Basch & Carvalho (1996) stated that farmers usually consider only variable costs in the analysis of the alternative mobilization technology. Nevertheless, this technology also affects tractors and implements number and the permanent work needed, that is to say the so called fixed costs. The technological choice of the mobilization system to be used should be therefore based on an economic evaluation of the entire farm, by considering the fixed and variable costs and the interactions existing on farm.

Mathematical programming allows comparisons of different technological options and considers the natural and economic factors that influence the technology use (Spharin & Seligman, 1983). Beside, this method allows the consideration of the system's interactions (Knipscheer *et al.*, 1983).

Kramer (1983) cites Nowak & Wagener to state that, in the framework of the soil conservation problem, risk attitudes can affect adoption behaviour and that further research on the relation between risk and the adoption of soil conservation practices would be useful in designing or implementing soil conservation policies.

Being a problem of income and risk, the analysis of the technological adoption within a production system is no doubt a decision-making problem and decision making is rarely neutral to risk. This means that decisions are generally influenced not only by the expected values on prices, productions or income (Anderson & Dillon, 1992) but also by the income variability induced by the variability of prices, productions or resources. The obvious conclusion is that optimal choice made by farms is not purely motivated by profit maximisation (Hope & Lingard, 1992).

Many modelling techniques have been developed to overcome the limits of linear programming in failing to account for variability in incomes of farms and in farmers' attitude to the associated risks (Hope & Lingard, 1992). The principles of decision-making under risky conditions have been reviewed by Hazell and Norton (1986) and by Anderson *et al.* (1977). The problem can be seen as including two parts: first, the analysis of the likely outcomes and their relevant risk; second, the decision-maker's attitude towards them (Hope & Lingard, 1992).

MOTAD programming (Hazell, 1971) was selected to consider the first aspect. This method is a linear alternative to quadratic programming and allows the maximization of expected income (EI) to any level of total absolute deviation (TAD). Parameterisation of TAD and the subsequent calculation of standard deviation lead to the generation of a EI - δ frontier showing the efficient set, i.e. the minimum level of standard deviation associated to a given level of expected income. The model is developed elsewhere (Martins, 2006) and can be stated as:

$$MaxZ = \sum_s P_s \left[\left(\sum_j \left(r_j f_{js}(k_{js}) - c_j k_{js} \right) x_{js} \right) - (c_t x_t) \right] \qquad (1)$$

s.t.

$$\sum_j x_{js} \leq S$$

$$\sum_j x_{js} - x_t \leq 0$$

$$x_{js} \geq 0; x_t \geq 0; k_{js} \geq 0;$$

where Z is the objective function, which represents the planning period economic result, P_S is the probability of occurrence of state of nature *s*; r_j is the profit of a product *j*; f_{js} is the continuous production function for product *j* given state *s*; k_{js} is the vector representing the amount of production factors used per unit level of short-term activity *j* given state of nature *s*; cj is the unit cost of production factors used on short-term activity *j*; c_t is the unit cost of long-term activity *t*; S is the amount of resources available on farm; x_{js} represents the units of *j* activity in state of nature *s*; and x_t is the amount of long-term activities *t*.

This model presents a group of activities representing the short-term activities, which change with the state of nature and another group of activities representing the structural decisions on the farm production structure that do not change with the state of nature, i.e. they represent the long-term decisions of the farmer. The model result maximizes the planning period economic result, considering the best long-term solution for traction equipment, permanent workers and animals, and the best short-term production solution, i.e. the most likely best production plan in each state of nature.

In order to consider the second aspect, we chose the compromise risk programming (CPR) approach of Romero *et al.* (1988), which allows the selection of the efficient plans set that best fits the farmers objectives.

A rational choice considering risk can be defined as a choice consistent with the decision makers beliefs about the uncertainty surrounding the decision and with the farmers relative preferences for the alternative possible consequences (Hardaker *et al.*, 1997). Based on the expected utility theory, it can be stated that the decision maker's beliefs are reflected and quantified in probabilities he assigns to uncertain events, while the farmer's preferences translate his attitude facing the decision's consequences, i.e. the expected utility theory shows us how both components of utility (preferences) and probabilities (individual expectations) can be integrated to make a risky choice become rational (Hardaker *et al.*, 1997).

Ballestero & Romero (1991) proposed to combine Compromise Programming (CP) with the models of risk programming (such as MOTAD), leading to the Compromise Programming with Risk (CPR). By means of this method, we limit the boundaries of the efficient set, where there exists the tangency point between the iso-utility curves and the Risk/Income efficient frontier.

With compromise programming we aim at identifying the ideal solution - the point where each objective reaches its optimal value. When there is a conflict between objectives, the ideal point is an impossible solution and is only used as reference. Compromise programming assumes that any decision seeks a solution being as closer as possible to the ideal (Zeleny's *axiom of choice*) (Ballestero & Romero, 1991).

The ideal point coordinates are given by the optimal values of the farmer's objectives. Obviously, this point is unfeasible, revealing the conflict between objectives (the maximum income and the minimum risk). To measure the proximity of an efficient point to the ideal, compromise programming uses distance functions.

Compromise Programming uses the distance concept as measure of human preferences rather than in a geometrical sense. Mathematically, the distance concept can be generalized by introducing the idea of metrics L_p, that lead to the following generalization of the Euclidian distances (Romero & Rehman, 1985):

$$L_p(K) = \left[\sum_{j=1}^{k} |x_j^a - x_j^b|^p\right]^{1/p}$$

where K is the number of objectives and p weighs the magnitude of the difference between the objective j and the ideal point, being the metric that defines the family of distance functions.

Yu (1973), cited by Romero *et al.* (1988), has proved that the metric L_1 (with p=1, the longer distance in a geometric scene) defines a boundary of the efficient set (tangency segment between iso-utility curves and the efficient frontier), while the other boundary corresponds to the metric L_∞ (with p=∞, the *Chebysev* distance).

In order to calculate L_1 and L_∞, the model structure presented in eq. 1 has to be modified. L_1 and L_∞ are separately calculated, as follows (Martins, 2006):

$$MinL_1 = W_1 \frac{Z^* - Z}{Z^* - Z_*} + W_2 \frac{D^* - D}{D^* - D_*} \quad (2)$$

s.t.

$$Z = \sum_s P_s\left[\left(\sum_j \left(r_j f_{js}(k_{js}) - c_j k_{js}\right) x_{js}\right) - (c_t x_t)\right]$$

$$\sum_j x_{js} \le S$$

$$\sum_j x_{js} \le 0$$

$$\left[\left(\sum_j \left(r_j f_{js}(k_{js}) - c_j k_{js}\right) x_{js}\right) - (c_t x_t)\right] - Z + D_s \ge 0$$

$$\sum_s D_s = D$$

$$x_{js} \ge 0; x_t \ge 0; k_{js} \ge 0;$$

where all the variables have the same meaning of before, Ds is the deviation of income Z_s in each state of nature *s* from average Z and D is the total absolute deviation. Z*, D*, Z_* and D_*, represent the best and worst values for expected income and total absolute deviation, respectively, and W1 and W2 represent the weight on each objective – the maximum expected income and the minimum total absolute deviation – in the objective function.

$$MinL\infty = d \quad (3)$$

s.t.

$$Z = \sum_s P_s\left[\left(\sum_j \left(r_j f_{js}(k_{js}) - c_j k_{js}\right) x_{js}\right) - (c_t x_t)\right]$$

$$W_1 \frac{Z^* - Z}{Z^* - Z_*} \le d$$

$$W_2 \frac{D^* - D}{D^* - D_*} \le d$$

$$\sum_j x_{js} \le S$$

$$x_{js} \ge 0; x_t \ge 0; k_{js} \ge 0;$$

where variables mean the same as before and d is the maximum deviation among all individual deviations.

3. Production context

Within this work, three different types of soil tillage technology were studied: direct seeding, reduced mobilisation and traditional technology.

Traditional technology includes one year of fallow, covered or not, with a primary mobilisation with a mouldboard and, during an "average" year, two secondary mobilisations with a tile mould before seeding. Reduced mobilisation has only a primary mobilisation with a scarifier and a secondary mobilisation with a vibratory scarifier before seeding. Direct seeding has no primary mobilisation and the secondary mobilisation is reduced to the seeding device working on the seeding line. The weed control is assured by the application of a pre-seeding herbicide.

These alternative types of technology allow a reduction in the traction power needed to perform the seeding operations.

Taking into account that different technologies have different machinery needs and differences in the available days necessary to carry out the seeding operations, five investment activities were considered, corresponding to the traction sets needed for each mobilisation technology (Martins, 2004).

The objective of the developed model is to evaluate the farmer's decision on the traction sets that should be used on farm and, consequently, the technological choice to be made in a risky environment, especially by evaluating the variability of the main factors that influence decision making - the intra-anual production variability obtained with different types of technology and the available days to mobilise the soil with different technology and, therefore, the traction costs to be afforded by the farmer.

In general terms, there are cereals and sunflower production activities and animal production activities - that consume land (the first ones), work and traction – permanent and eventual labour activities and sets of traction investment activities. Cereals activities and animal activities complement each other, by playing an important role in the orientation of the farm and the sets of traction needed. Cereals and sunflower products are sold, stored or given to the animals as food; animal products are sold. The only limiting resource is land, whereas all the other factors may change or do not limit production activities.

In this problem it is critical to consider each state of nature productivity for cereals and sunflower and the need to give the right size to the machinery set of the farm, given the difference in the available days necessary to carry out the cultural operations, coming from different cultural operations and different machinery used with each technology and the eventual possibility of decreasing the number and power of the tractors used in direct seeding or reduced mobilization technology.

The model considers investment activities in sets of traction, which include a tractor and all the tools needed for each technology. Each set has fixed costs – amortization – and variable costs – gas oil and oil - that depend on the working hours. The number of sets is estimated by considering that the farmer would adopt the annual production plans able to optimize his long-term decision.

On the basis of the interactions between temperature, rainfall and soil tillage technology and the important effects on the soil, soil operability, productions and states of nature, different levels of production were defined according to the seeding technology applied.

The amount of rain that occurs in winter (December, January and February) and spring (April) as well as the winter temperature have been defined by Oliveira (1955) as being the most important determinants of wheat production. Considering data collected in 27 years between 1963 and 1990, the definitions given by this author, adapted by following the opinion of experts from Évora University and National Agronomy Bureau, allow us to define a dry winter, a very dry winter, a rainy winter and a very rainy winter as shown in the following table (table 1):

Table 1 - *Definitions of Winter and Spring, as far as rainfall is concerned*

		Dry	Very dry	Rainy	Very rainy
Rainfall accumulated in December, January and February	Winter	Below the average	Below 50% of the average	Above the average	Above 150% of the average
Rainfall accumulated in April	Spring	Below the average	Below 50% of the average	Above the average	Above 150% of the average

Source: Martins, 2004

The same author (Oliveira, 1955) also defined cold, mild and hot winters by considering the temperature of winter months (December, January and February) and using the following procedure:

For each year - December and January average temperature = ϕ

Average between ϕ and February temperature = L

Global average - $(\sum L)/27 = \chi$

Hot, mild and cold winters are defined in table 2.

Table 2 - *Definitions of Winter and Spring, as far as temperature is concerned*

Hot	Mild	Cold
Annual temperature $\geq (\chi + 0.5° C)$	$(\chi - 0.5° C) <$ Annual temperature $> (\chi + 0.5° C)$	Annual temperature $\leq (\chi + 0.5° C)$

Source: Martins, 2004

According to these definitions, each annual winter conditions as for rainfall and temperature and spring conditions as for rainfall were defined and the various years were grouped in 6 states of nature, whose likelihood of occurrence is given by the relationship between the number of years it occurs and the twenty seven years of data, following the definitions given in table 3.

In state of nature 1, direct seeding and reduced mobilization production are under the average - on soils mobilised with these types of technology, ground water is closer to soil surface and such high precipitations in winter, leading to swampy soils, are more adverse to cereals seeded with these types of technology. The higher superficial density of these soils leads to less space between pores and the higher humidity may lead to lower gas

Table 3 - *Definitions of States of nature*

	Winter	Spring	Likelihood of occurrence
State of Nature 1	Mild but rainy	Rainy	11%
State of Nature 2	Mild or cold but dry	Rainy	14.5%
State of Nature 3	Cold and dry	Dry	14.5%
State of Nature 4	Warm and rainy or very rainy	Neglectable	22%
State of Nature 5	Temperate or cold and rainy or very rainy	Dry	19%
State of Nature 6	Mild and very dry or hot and dry	Neglectable	19%

Source: Martins, 2004

changes and anaerobic conditions, thus reducing the root development. These conditions are obviously less restrictive for reduced mobilised soils, which are less compact on the surface. Traditional mobilisation has higher productions because in very humid years, or after severe rains, the oxygen in the soil is inadequate to plant roots and the soil mobilisation has beneficial effects.

As for state of nature 2, it can be referred that soil condition in springtime manuring is influenced by the seeding mobilisation technology applied. On directly-seeded soils, in which cereals may establish a well developed root system and there are canals to drain the water, the great amount of rain falling in spring does not lead to a swampy soil and allows the plant to properly grow and to efficiently use manure and spring temperature. Traditionally mobilised soils have a tendency to become swampy and the plant development is affected by the spring rain. Thus, directly-seeded and reduced mobilised cereals have higher productions, whereas cereals seeded with traditional technology present a production close to the average.

In state of nature 3, traditional mobilisation may raise the water on the ploughed surface, which leads to grater evaporation losses under dry conditions. Besides this aspect, the total amount of water available to plants with a significant part of their roots close to the soil surface will be much lower than for those that have deeper roots uniformly distributed. Resistance to drought is higher since the soil layer explored by roots is thicker, therefore, cereals established with direct seeding are more resistant to drought. The conclusion is that in this state of nature production is lower with traditional technology than with direct seeding or reduced mobilisation.

For state of nature 4, production is under the average in all cases, because high temperatures do not allow a well established cereal but it is even lower with direct seeding and reduced mobilisation that sum up the rainfall effect to the temperature effect. For these conditions, the cereal establishment is compromised and the spring situation can be neglected.

In sate of nature 5, the effects of winter rainfall, followed by spring dry conditions do not allow a good cereal development in any case and so productions are always

Table 4 - *Variability in Cereal, forages and sunflower production per soil type, mobilization technology and state of nature*

		STATE OF NATURE 1	2	3	4	5	6	δ
	Probability of occurrence	11%	14,5%	14,5%	22%	19%	19%	
Clay Soils	Mobilization			Traditional				
	Main cereals	5,000	3,750	3,000	3,000	2,600	2,350	980
	Secondary cereals	4,000	3,000	2,800	2,800	1,750	1,750	859
	Sunflower	1,250	800	700	700	650	650	234
	Mobilization			Reduced				
	Main cereals	4,500	5,250	3,250	2,750	2,600	1,750	1,315
	Secondary cereals	3,250	5,000	2,800	1,800	1,500	1,000	1,474
	Sunflower	700	1600	700	700	650	650	377
	Mobilization			Direct seeding				
	Main cereals	4,500	5,500	3,250	2750	2600	1,750	1,390
	Secondary cereals	3,500	5,250	2,800	1800	1500	1,000	1,585
	Sunflower	-	-	-	-	-		
Sandy -loam Soils	Mobilization			Traditional				
	Main cereals							
	Wheat	2,750	2,550	2,000	2,250	1,750	2,000	380
	Triticale	2,500	1,800	1,500	1,600	1,250	1,500	440
	Secondary cereals							
	Triticale	2,500	1,600	1,350	1,500	1,000	1,250	524
	Other cereals	1,800	1,300	900	1,000	650	750	430
	Sunflower	550	475	450	450	350	350	78
	Forages							
	Type 1	2,000	1,300	850	1,000	900	900	449
	Type 2	1,750	1,200	750	1,000	800	800	386
	Mobilization			Reduced				
	Main cereals							
	Wheat	2,250	4,500	2,250	1,750	1,600	1,600	1,113
	Triticale	1,750	3,750	1,600	1,350	1,350	1,350	946
	Secondary cereals							
	Triticale	1,800	3,250	1,500	900	900	900	928
	Other cereals	1,800	3,250	1,500	900	900	900	928
	Sunflower	500	800	450	250	250	250	221
	Mobilization			Direct seeding				
	Main cereals							
	Wheat	2,250	4,750	2,250	1,750	1,500	1,400	1,252
	Triticale	1,500	4,000	1,600	1,250	1,000	1,000	1,146
	Secondary cereals							
	Triticale	1,350	3,500	1,500	900	900	1,000	1,004
	Other cereals	900	2,600	1,000	600	600	750	767
	Forages							
	Type 1	1,000	3,000	1,000	600	600	750	924
	Type 2	900	2900	1,000	500	500	500	938

Source: Data adapted from Publicações da Associação Nacional de Produtores de Cereais, sobre Experimentação em Cereais de Inverno e Girassol (1988-1994), discussed with Professor Ário Lobo de Azevedo.

under the average. In state of nature 6, production is under the average with any technology, but even worse with direct seeding and reduced mobilisation because the good penetrating capacity of seeds is compromised by the extreme drought. In this state of nature, the establishment of cereals is also so influenced by winter whereas spring conditions can be neglected.

The states of nature have been defined according to their consequences on production and one crucial issue of this problem is that productions obtained by different cereals on the different states of nature are perfectly defined. The productions used for each state of nature were based on an adaptation of known data, according to what is defined in table 4 and considering, as Basch & Carvalho (1996) stated, that reduced mobilization and direct seeding have the same average production than traditional technology, although they have a higher inter-annual variability.

As for the system under study, it is also important to keep in mind that the states of nature have another fundamental implication: they imply differences in the available days to work in a field, executing the cultural operations leading to cereal establishment and development. It can be stated that there is no coincidence between states of nature with lower productivity and those with less available days, essentially because dry years have productivity problems but there are not problems relative to the available days.

To implement the model according to the resources available on farm, a farm in the Clay Soil Zone of Beja that belongs to Évora University, the Herdade Experimental da Almocreva, has been chosen as potential user. This farm is characteristic of this Clay Soil Zone because it is a big farm (437 ha) with soil characteristics typical for the Zone and it is a cereal-producing enterprise, where sheep rearing complements the cereal system.

According to the soils, restrictions on land were established considering two groups with different soils texture. The first group of soil I has soils with a clayey structure; the second group of soil II has soils with a sandy loam texture. Herdade da Almocreva has 237 ha of group I soils and 200 ha of group II soils.

This farm uses the traditional technology that is usual in this *Zone* and has traction sets with more years than the usually considered useful life, which is also usual in this *Zone*. To consider these aspects, the traditional set has been valued by half of the actual value, which means half of the amortization fixed costs.

4. Results

In this section the results from the simulations made with the mathematical programming model developed are presented, on the basis of the standard situation where we only consider the traditional technology and on the technological alternatives situation, and the principal factors that determine the results, for the different years, for which the annual production plans, the use of traction and the expected economic result for the farm are identified.

In the first simulation, we determined the production plans that optimize the farmer decision on the different states of nature, as far as vegetable activities are concerned (Martins, 2006).

The more relevant aspects of these results are the fact that technological alternatives are always chosen, the clay soils are not fully used in year type 4 in both situations; these soils are not even used in year type 5 in the technological alternatives situation and finally, for this situation, the use of almost all the sandy-loam soils, every state of nature.

The results that simulate long-term decisions, representing the structure of the farm, allow us to conclude that in the standard situation the farmer will need 3 tractors, with 120 hp, 1 combine harvester and 3 permanent workers. For the technological alternatives situation, the farmer will need 1 tractor with 80 hp, 1 tractor with 105 hp, 1 combine harvester and 2 permanent workers (Martins, 2006).

Tab. 5 - *Model result with parameterisation of Total Absolute Deviation - Total Absolute Deviation (€), expected income (€) and activities optimal level*

Solutions		Type of year	θ (A)	0.75 θ (B)	0.50 θ (C)	0,25 θ (D)	0 (E)
Total A. Deviation			99,025	74,091	49,396	24,695	0
Expected income			49,625	42,597	34,367	26,137	10,076
Ha seeded with alternative types of technology		1	286	204	271	191	53
		2	286	286	214	129	85
		3	286	201	239	256	286
		4	248	229	229	229	194
		5	244	219	219	219	239
		6	286	197	197	197	197
		Average	270	223	225	206	185
Ha seeded with traditional technology		1	0	45	0	13	106
		2	0	0	50	59	1
		3	0	85	48	30	0
		4	0	58	58	58	57
		5	0	67	67	67	47
		6	0	90	90	90	90
		Average	0	60	57	57	50
traction sets	80 hp ds		1	1	1	1	1
	105 hp rm		1	1	1	1	1
	120 hp td			1	1	1	1
Flock (TH)			403	405	405	405	405

Source: Martins, 2006

As for animals, the feeding resources available in the standard situation can maintain 416 type heads, divided in two groups with different feeding regimes. One of the groups has 329 animals with an intensive feeding regime that allows to sell animals being aged 3 months, with 25 Kg live weight. The other group has 87 animals with an extensive feeding regime, which only allows selling animals being aged 4 months, with 20 Kg of live weight. These animals are basically fed with oats and triticale straw and triticale stubbles, integrated with concentrates when necessary. In the technological alternatives situation, there is only one group with 403 animals with the extensive feeding regime. The diet is the same (Martins, 2006).

The analysis of costs and profits structure of this farm in both situations gives us some interesting points to complement our discussion.

First of all, on this farm, with a cereal-based system, cereals and sunflower are the main products contributing to the total income.

Nevertheless, there is a point that must be underlined – subsidies, paid on an ha bases, according to cereals reference productions, account for 44 to 55% (with an average of 51%) of total income, depending on the state of nature in the base situation, and for 41 to 59% of total income (with an average of 52%) of total income, also depending on the state of nature, in the alternative technology situation.

As a second point, the difference between the two situations essentially lies on the costs with the use of traction and with permanent labour.

In the standard situation, the fixed costs with traction are lower and there is a minor need for extra traction hours, which means an average gain of 5,385 €, but in the technological alternatives situation the traction variable costs are lower and the permanent costs with labour are also more reduced. This means a difference of 24460 € between the two situations, due to these aspects, favourable to the technological alternatives situation, which explains almost all the expected income difference between the two situations.

The third key point is that results show that the expected income is positive in both situations, although with technological alternatives it is 21,673 € higher; being always positive, in both situations, the expected income is lower than expected in 60% of years, that represent 3 states of nature.

5. Risk evaluation

In the technological alternatives situation, a higher expected income is matched with a higher total absolute deviation.

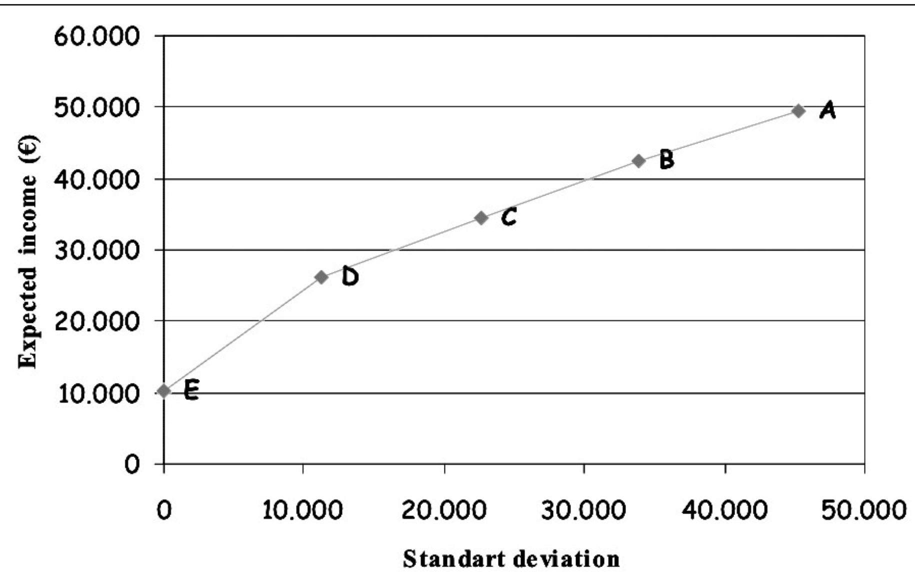
The risk evaluation of efficient production plans, given the states of nature likelihood to occur, allows the determination of the admissible plans' set that guarantee the highest income for each level of standard deviation.

With the objective of determining this set, the restriction that refers to the sum of total absolute deviations on 25% classes has been parameterized.

The obtained results, as well as the optimal levels for the activities per state of nature that are expected in each solution are presented in table 5.

What are the consequences for the system of a decreasing risk? Which should be the farmer's choice if he wants a less risky income?

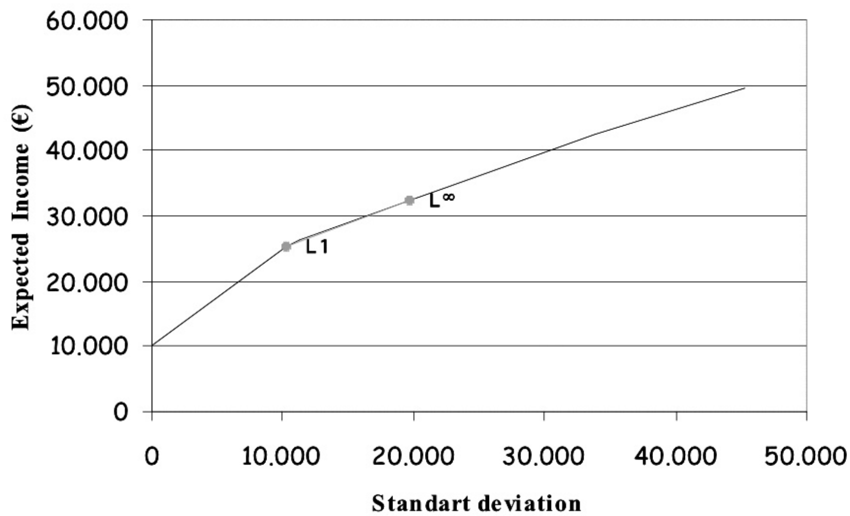
Figure 1 - *Risk* - *Expected Income frontier.*



Source: Martins, 2006

With a reduction of the Total Absolute Deviation by 25%, the traditional technology set of traction immediately enters the solution. This result is directly linked with the variability in the technology production. Relatively to a model with the same variability but only with alternative types of technology, the use of traditional technology, with a lower variability, allows the farmer to reduce the area seeded by using alternative technology during those years that are above the average and to raise the total seeded area. Thus, this gives the farmer the opportunity of increasing the amount of sold cereals, sunflower and straw together with the amount of

Figure 2 - *Risk -Expected Income frontier and Compromise set.*



Source: Martins, 2006

subsidies the farmer gets and it lowers the amount of animal feeds bought.

By diminishing the total absolute deviation to 50% of its initial value, the farmer can maintain the total area, with the subsidies this implies, changing the areas used with each technology. This change brings a lower variability but also a lower income. For even lower values, the seeded area becomes much smaller and the production variability has a more reduced influence on the income variability. If the total absolute deviation is only 25% of the initial value, the area affected by the alternative technology becomes much smaller and a total absolute deviation equal to 0 is only achieved with a clear reduction in seeded areas.

Nevertheless, it is important to notice that even in this last simulation the solution proposes the seeding of 235 ha, which clearly shows the great importance of subsidies.

The frontier representing the efficient set of production plans, for which the risk is minimum given the level of expected income, is shown in figure 1. The points with letters correspond to those identified in table 5. In this figure, the income is measured by expected income and the risk is measured by the standard deviation of that income.

In order to evaluate how the farmer behaviour influences its decision on which type of technology to use, the Compromise Risk Programming method has been applied to the studied model.

From table 5, ideal and anti-ideal vectors can be obtained. The ideal vector includes the highest expected value equal to 49,675 € and the minimum total absolute deviation equal to 0 €. The anti-ideal vector includes the lower expected value equal to 10,076 € and the maximum total absolute deviation equal to 99,025 €.

Assuming the farmer evaluates both objectives (to get the highest income and the minimum total absolute deviation) in the same way, the point L_1 has an Expected Income of 25,354 € and a Total Absolute Deviation of 22,356 €. The point $L_{\text{¥}}$ has an Expected Income of 22,297 € and a Total Absolute Deviation of 43,186 € (Martins, 2006).

Graphically, these results correspond to what is presented in figure 2.

According to the presented results, it can be stated that a farmer who evaluates both these objectives in the same way will mainly use alternative soil tillage technology, but he will also use traditional technology. On average, the farmer will mobilize 211 ha of his farm with alternative technology and only 57 ha with traditional technology.

In these results, the assumed evaluation of traction sets is surely sensible. Hence, it is fundamental to know which would be the farmer's choice if the evaluation was equivalent for all the traction sets, i.e. if we considered for the traditional set the total actual value – the question posed here is whether the farmer decides to abandon or not the traditional technology when he needs to renew the traction sets of his farm.

In this situation, the expected incomes and the negative deviations to each average year would be the ones shown in table 6.

Table 6 - *Expected income, Total Absolute Deviation and negative deviations in each type of year, for the standard and the technological alternative situations.*

Unit: €

Sate of nature	1	2	3	4	5	6
	Standard situation					
Negative deviation in each type of year	-	-	-	17,977	21,648	15,907
Expected income	16,640					
Total absolute deviation	55,665					
	Technological alternatives situation					
Negative deviation in each type of year	-	-	-	27,753	31,260	39,774
Expected income	49,675					
Total absolute deviation	99,025					

Source: Model results

Looking at these results, it is evident that the standard situation has two states of nature (4 and 5), which represent 41% of the years with a negative result. This means that there will be years during which the farmer will have to find short-term strategies allowing him to bypass this situation.

The parameterisation of the total absolute deviation gives the results shown in table 7.

Table 7 - Model result with parameterisation of the Total Absolute Deviation - Total Absolute Deviation ( ), expected nincome ( ) and activities optimal level.

Solutions	Total Abs. Deviation (€)	Expected income (€)	Ha seeded with alternative technology							Traction sets (n°)		Flock (TH)
State of nature			1	2	3	4	5	6	Average	80 hp d s	105 hp r m	
θ (A)	99,025	49,675	286	286	286	248	244	286	270	1	1	403
0.75 θ (B)	74,091	41,330	205	269	266	248	244	286	255	1	1	405
0.50 θ (C)	49,396	33,100	185	209	206	248	244	286	236	1	1	405
0,25 θ (D)	24,695	24,865	169	160	201	248	244	286	226	1	1	405
0 (E)	0	9,796	156	81	141	232	217	186	196	1	1	405

Source: Model results

In this situation, the possibility of using alternative technology would inhibit the use of the traditional technology. The farmer's option to reduce the total absolute deviation of his production plan would be to reduce the seeded area and to use only two traction sets, both for the alternative technology.

For the same levels of total absolute deviation as before, the expected income is always lower, which means that the farmer faces now a higher degree of income risk.

6. Conclusions

The results make us firstly conclude that traditional technology allows the farmer to pay the consumed raw materials, the labour and the fixed and variable costs with traction, but that the use of this technology puts the farmer under the significant risk of not getting the expected income.

Admitting the possibility of using alternative soil tillage technology, the results do not include anymore the traditional technology and the expected income substantially rises. Although the total absolute deviation rises as well, it is relevant that the use of alternative technology allows a substantial reduction in the costs of the farm and, therefore, the current income is only lower than with traditional technology in one state of nature (that represents 11% of cases).

The analysis of costs and profits structure translates the differences in the short-term strategies that optimize the current result of farmers each year, considering the productions variability and the available days' variability and considering that the farmer equipment is sized accordingly with the traction needs of the various types of technology.

From this analysis, we can firstly conclude that a farmer who uses traditional technology may obtain more profits on average, but the use of the alternative technology permits such a reduction of costs, according to the number and type of tractors needed, that the greater variability of income these technology leads to looses importance. Nevertheless, if the farmer has on his farm operating traditional technology equipment, he can still pay for his fixed and variable costs using traditional technology, then previewing a gradual substitution of the equipments.

The points on the Risk: Income frontier that limits the compromise set revealed that the use of traditional technology in some parts of the farm is an option when the aim is the reduction of the income risk faced by the farmer.

The results obtained with compromise programming make us conclude that a farmer who wants to reach both his objectives – to obtain the best expected income and to have the lowest total absolute deviation - will use both the alternative soil tillage technology and the traditional one. This can mean that, having traditional machinery on his farm, the farmer will use the traditional technology at least in part of his farm.

Admitting the farmer would have to renew his farm's sets of traction, it has been demonstrated that the expected income remains positive, even when the farmer only uses traditional technology, but its value is always higher if he uses alternative technology. We can therefore conclude that the farmer will always choose the alternative technology, since the Risk: Expected Income frontier has no longer solutions with traditional technology.

It can be thought that farmers will let their equipments be fully paid off and only it is necessary to replace them they will adopt alternative tillage technology. This result makes us believe that in a difficult economic situation, that imposes the farmers some investment restrictions, the substitution and adoption of alternative technology will be even more gradual.

The conclusion that must be drawn is clear: it is not the income risk, coming from the production and the available days risks, that influences the farmer's adoption of the technology. The choice is determined by the difference in costs between traditional and alternative technology that is clearly in favour of the latter.

References

Anderson, J., Dillon, J. & Hardaker, B., 1977 *Agricul-*

tural decision analysis. The Iowa State University Press, Ames, USA.

Anderson, J. & Dillon, J., 1992 *Risk analysis in dryland farming systems*. Farm Systems Management Series, n.º 2, F.A.O., Roma.

APOSOLO – Associação portuguesa de Mobilização de Conservação do Solo, 1999 *Agricultura de Conservação na Europa: Aspectos Ambientais, Económicos e Políticos da UE*. Edited by Life Project nº 96-E-308.

Ballestero, E. & Romero, C., 1991. *A Theorem Connecting Utility Function Optimization and Compromisse Programming*. Operational Research Letters, 10, 421-427.

Basch, G. & Carvalho, M., 1996 *Interactions Between Soil Tillage and Water Logging*. Proceedings of the EC-WORKSHOP - III - Ivora, 1-2 April.

Hardaker, J. B., Huirne, R. B. M. & Anderson, J. R., 1997. *Coping with Risk in Agriculture*. CAB International, United Kingdom.

Hazell, P., 1971. *A Linear Alternative to Quadratic and Semivariance Programming for Farm Planning under Uncertainty*. American Journal of Agricultural Economics, 53, 53-62.

Hazell, P. & Norton, R., 1986. *Mathematical Programming for Economic Analysis in Agriculture*. MacMillan Publishing Company, New York.

Hope, J. & Lingard, J., 1992. *The Influence of Risk Aversion on the Uptake of Set-Aside: A Motad and CRP Approach*. Journal of Agricultural Economics, 43-3, 401-411.

Klemme, R. M., 1985. *A Stochastic Dominance Comparison of Reduced Tillage Systems in Corn and Soybean Production under Risk*. American Journal of Agricultural Economics, 67, 550-557.

Knipscheer, H. C., Menz, K. M. & Verinumbe, I., 1983. *The Evaluation of Preliminary Farming Systems Technologies: Zero-Tillage Systems in West Africa*. Agricultural Systems 11, 95-103.

Kramer, R. A., William T. McSweeny & Robert W. Stavros, 1983. *Soil Conservation with Uncertain Revenues and Input Supplies*. American Journal of Agricultural Economics, 65-4 694-702.

Martins, M. B., 2004. *Avaliação Económica de tecnologias alternativas de mobilização do solo em situação de risco*. PhD Thesis, Universidade de Évora, Évora.

Martins, M. B. & Marques, C. 2006. *Methodological Aspects of a Mathematical Programming Model to Evaluate Soil Tillage Technologies in a Risky Environment.* European Journal of Operational Research, 177-1, 556-571.

Oliveira, J. S., 1955. *Determinantes Meteorológicos da Produção Unitária do Trigo*. Separata da Lavoura Portuguesa, Lisbona.

Romero, C. & Rehman, T., 1985 *Goal Programming and Multiple Criteria Decision-Making in Farm Planning: Some Extensions*. Journal of Agricultural Economics, 39-2, 171-185.

Romero C., Rehman, T. & Domingo, J., 1988. *Compromise-Risk Programming for Agricultural Resource Allocation Problems: An Illustration*. Journal of Agricultural Economics, 39-2, 271-276.

Thorton, P. K., 1985. *Treatment of Risk in a Crop Protection Information System*. Journal of Agricultural Economics, 36-2, 201-209.