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"A Decision Support Model for Dairy Farms"

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Abstract

Dairy is the main sector of the Azorean economy and it is much influenced by PAC (Common Agricultural Policy).

The main objective of this paper is to estimate the objectives that limit the decision making process for the Azorean dairy farms that exist regarding the different grazing systems. Then, we apply a utility model based on multicriteria models, to develop the decision models for Azorean dairy farms. Here the farmers` behavior is not explained by gross margin maximization but by a utility function with several conflicting objectives.

The results show that the farms` objectives depend on the intensity of grazing systems. In this paper, we show that the traditional objective (income) is not very important, at least for two groups of farmers. Only in the less intensity grazing systems the income seems to be significant.

Key-words: utility function, multicriteria analysis, goal programming, dairy.

Introduction

The Azores are a Portuguese insular territory with a population of about 250000 inhabitants, where the main economic activity is dairy farming. The dairy policy depends on the CAP (Common Agricultural Policy) of the European Union, and that influences the decision making of dairy farms.

Single objective: profit maximization (estimated as a gross margin) has been the classical decision model. Nowadays, it is accepted that multiple objectives are most common where the decision is taken at the farm or regional level. We estimate the influence of the objectives in the decision process, using a multicriteria approach. This methodology permits to define a surrogate utility function for a dairy farms` typology.

The objective of this paper is to analyze Azorean farmer's decision process by developing multicriteria models that permit a simulation of the farmers' behavior.

There are two main approaches to building decision making models with regard to the farmers` priorities:

1) Multi-attribute Utility Theory (MAUT) developed by Keeney & Raifa (1976). The major difficulty associated with the formulation of MAUT models lies in the high degree of interaction with the decision maker required by this methodology. This is important in agriculture, where cultural background is often the most suitable form undertaken in such an interactive process, but is difficult to apply to agriculture decisions, because there is some interaction difficulty between the analyst and the farmer (low level of education) (Amador *et al.,* 1998).

2) Multiobjective criteria lack the theorical soundness of MAUT, but it can accommodate in a realistic manner the multiplicity of criteria inherent to most agricultural planning problems. Among the possible surrogates of MAUT, the most widely used method in agricultural field are: goal programming, multi-objective programming and compromise programming (Romero & Rehman, 1989).

As alternative of MAUT, we present a methodology propose by Sumpsi *et al.*(1996) and Amador *et al.* (1998) that permits the assessment of the farmers utility function. The proposed method does not rely an interaction with the decision maker, but it is aware of the actual behavior demonstrated by the farmers, this means to obtain a utility function consistent with the preferences revealed by the farmers themselves.

The utility models and multicriteria models had a multiple applications to agriculture. In Portugal, some references are Noéme (1989), Berbel & Barros (1993), Poeta (1994), and Silva (2001) and at international literature we can quote Lara (1993), Zamora & Berbel (1995), Herrero *et al.*, (1999), Zekri & Romero (1991), de Zekri & Albisu (1993), Niño de Zepeda *et al.* (1994), Minguez *et al,* (1988) and Rehman & Romero (1987), Berbel & Gómez-Limón (2000), Sumpsi *et al.* (1996), and Gomez-Limón & Berbel (1995). The decision was researched using the utility models by Amador *et al.* (1998), Berbel *et al.* (1999), Torrico *et al,* (1999), Gomez-Limon & Berbel (2000).

Material and Methodology

Data is based on European Union, Farm Accountancy Data Network (FADN) of the Azores over the period from 1992 to 1996, INRA (1988) to the feed requirements, Berbel & Barros (1993) to the required times for farming operations, and the information of experts in dairy, pasture, and animal nutrition.

Using FADN Silva (2001) defined a farmers typology, witch grouped three Azorean farms: I – medium intensive grazing systems (1,4 a 2,4 cows per hectare), II – low intensive grazing systems (less than 1,4 cows per hectare, and III - high intensive grazing systems (more than 2,4 cows per hectare).

The methodology used was proposed by Sumpsi *et al.* (1996) and used by Berbel *et al.* (1999). It considers four main steps:

1) To identify a set of tentative the objectives that can influence the decision

2) To determinate the “pay-off” matrix for above objectives

3) To obtain the real values of objective function

4) To obtain the set of weights that best reflect the farmers’ preference by solving the weighting goal programming approach

5) If the weight found in (4) is satisfactory, process finishes. Finally, the utility function will be estimated. In order to get a solution, Amador *et al.* (1998) propose three alternative criteria (L_1, L_∞, and a compromise between the last two criteria that permits to the estimation of Manhattan, Tchebycheff and Augmented Tchebycheff, utilities functions). To get a solution we selected L_1 criteria and the Manhattan utility function (μ). This choice was made because this criteria is widely used in most agriculture works, and the results obtained using alternative methods are similar; that means, any method can explain the preferences revealed by farmers. In this criterion the sum of negatives and positives deviational variables is

minimized. This criterion underlines the use of metric 1 and this can be formulated in terms of goal programming, as following:

$$
\begin{aligned}
& Min\sum_{i=1}^{q}\left(\frac{n_i + p_i}{f_i}\right) \\
& suject\ to \\
& n_i - p_i = f_i \\
& \sum_{i=1}^{q} W_j = 1, \quad i = 1,2,\ldots,q
\end{aligned}
$$

Where p_i and n_i are the positive and negative deviational variables respectively. From a preferential point of view, an L1 criterion is consistent with an additive and separable utility function, and permits the estimation of a standard function (Amador *et al.*, 1998). That means weights obtained from the last equation, lead to the following function:

$$
\begin{aligned}
& \mu = \mathrm{Max}\sum_{i=1}^{n} w_i \frac{f_i(x)}{K_i} \\
& suject\ to \\
& X \in F \\
& K_i = f_i^{*} - f_{i*}
\end{aligned}
$$

Where K_i is a normalized factor obtained by the difference between the maximum value, f_i^*, (ideal) and the minimal, f_{i*}, (anti-ideal) of objective i of the pay-off matrix. This allows estimating the weights, which indicate the relative importance to be attached to the objectives followed by a farmer elicited. The “best” weights are those compatible with the preferences revealed by farmers being analyzed.

The Multiobjective Model Definition

It is considered that the decision variables can assume any value of the feasible set, and this is defined by constrains of the systems (land, agronomic, feeding and labor requirements, grazing systems, risk profit, and so on).

The decision variables selected as belonging to the decision making processes of the Azorean dairy farms was: X_1 – direct pasture cultivation high area (ha); X_2 – direct pasture cultivation medium area (ha); X_3 – direct pasture cultivation medium area and silage (ha); X_4 – direct pasture cultivation medium area and hay (ha); X_5 – direct pasture cultivation low area (ha); X_6 – direct pasture cultivation low area silage (ha); X_7 – direct pasture cultivation low area hay (ha); X_8 – maize cultivation medium area (ha); X_9 – maize cultivation low area (ha); X_{10} – Annual crop winter medium area (ha); X_{11} – Annual crop winter low area (ha); X_{12} – Annual crop winter de medium area (ha); X_{13} – Annual crop winter low area (ha); X_{14} – kilos of concentrated feed (Kg); X_{15} – number of dairy animals, X_{16} – hired labor requirements (hours).

Four objectives were considered relevant ‘a priori’: 1: Profit maximization, MB (euro); 2: Risk minimization, by Minimization of Total Absolute Deviation, MOTAD, developed by Hazel (1971) and presented by Romero & Rehman (1989) (euro); 3: Labor seasonality minimization, EST, (hours) and 4: External labor minimization, MOsal (hours).

Model constrains are: 1 a 4: Total cultivation area per altitude (high, medium, low); 5 -7: Rotational and agronomic considerations, (20% of the area was improved by maize over five years); 8- 9: different labor requirements concerning 6 periods and specific activities, and the possibility of finding work in the exterior of farm; 10: Risk profit (euro) over 7 years; 11: operational constrain; 12 to 18: Feed and animal requirements of energy (UFL), protein (PDIE and PDIN), calcium (CA) and phosphor (P), and dry matter intake; 19: Intensity grazing system ; 20: No negativity constrains.

The model was solved using “solver” algorithm in “Excel” spreadsheet.

Results:

At the second and third step of the methodology, the pay-off matrix and real value for the Azorean dairy farm typology is estimated. The definition of groups was done by using cluster analysis included in SPSS package. Three groups were selected:

In Group I, medium intensity system grazing (1,4 to 2,4 cows per hectare), the objectives of hired workers and seasonality labor were complementary. That means they have similar values (21657 euro to seasonality and 21088 euro for hired labors), it is observed in table I, that real value is similar to seasonality and hired labor minimization, and this can mean that Azorean dairy farms in their decision processes include the labor rationality. The labor constrain the dairy farms` profits, and if it was used for more than 2020 hours (for one person), it will increase the profit. The conflictive and conditioned objectives in the decision processes, in group I, were profit maximization, risk minimization and labor seasonality minimization.

In Group II, low intensity system grazing (less than1,4 cows per hectare), the risk (MOTAD) and hired labor minimization were complementary. The real value was similar to the profit maximization, and the decision making process was much influenced by profit maximization. To increase the profit more 302 hours of temporary labor are necessary. The 274 hours as a real value means the family effort is increasing. In practical terms this corresponds to the labor positive deviational variable. In group II, dairy farms decision was conditioned by three conflictive objectives: profit maximization, risk and labor seasonality minimization.

In Group III, high intensity system grazing (more than 1,4 cows per hectare) risk and hired labor minimization were complementary. The real value was similar to the labor seasonality minimization. To reach the biggest profit, these farms require more than 2628 hours (a full time worker and a temporary worker). The agricultural labor is a strong constraint of the profit.

In any group of Azorean dairy farms the decision making process seems to be influenced by three conflictive objectives: profit maximization, labor seasonality and risk minimization. The hired labor minimization was generally complementary to other objective.

The fourth step of the methodology used, formulates a goal programming, to estimate the weights, following the methodology proposed by Amador *et al.* (1998).

The weights obtained per farm typology were:

Group I: W_2 (MOTAD minimization) = 44,8 % ,W_4 (hired labor minimization)= 55,12%

Group II: W_1 (profit) =81,79%, W_3 (seasonality minimization)=17,7%

Group III: W_2 (MOTAD minimization)=24,1%, W_3 (labor seasonality minimization)= 75,4%

Groups I and III, bigger system grazing, have not a weight value for the profit maximization, but group II (less intensive grazing system) shows a big weight value to profit maximization. Group I gives more importance (55,12%) to hired labor minimization, and risk minimization (44,8%). Group II, (less intensive group) gives more importance (81,79%) to profit maximization and seasonality minimization (17,7%). Group III, (more intensive system grazing) gives more importance to (75,4%) labor seasonality minimization and risk minimization (24,1%).

The next step of the methodology, estimates utility functions per group of grazing system of Azorean dairy farms. At first the utility function was estimate by the L_1 method, the subrogated utility function. Then the final utility function was estimated using the normalized factors. In these functions the maximization objectives have a positive signal and the minimization objectives have a negative signal.

Standard utility functions of the Azorean dairy farms:

Group I - $U_1 =(1*10^{-13}\ MB_1) – 2{,}521 MOTAD_1 –15{,}36\ MOsal_1$;

Group II - $U_2 = 20{,}47\ MB_2 – 11{,}7\ SAZ_2$;

Group III - $U_3 = 3{,}77*10^{-15}\ MB_3 – 0{,}73\ MOTAD_3 – 2{,}967\ SAZ_3$

The normalized utility functions show major importance of seasonality labor and the minor importance of profit maximization in the groups I and III (more intensive system grazing). Group II shows a major importance of profit maximization.

To predict the real values we used the model presented by Amador *et al.* (1998). As observed in the figure, for any objective (profit, risk, hired and seasonality labor) the real and estimate values were similar, that means the utility functions estimated for the Azorean dairy farms revealed their preferences, and affect the decision making process.

Discussion

The low importance of profit objective maximization is unusual, because it was expected that the traditional objective would be more important. But this situation was already observed in previous works. It may be explained, in part, by the imperfect Azorean information systems, that constrain a risk aversion decision of Azorean dairy farms. The great importance of farming labor can be explained by family farms; these farms generally comprise small areas is little, and there is not alternative labor market in Azores.

The dairy farms` income can be enough to maintain the farm and family. If the economic objectives are satisfied, then the farmers can satisfy other objectives. There might be other factors (not economical ones) that constrain the decision making process.

The Azorean dairy farms` objectives can differ from the traditional objective: profit maximization; and the main objective that constrains the decision making processes may be the production cost minimization as noted by (Tauer, 1995).

Concluding remarks

There is not a perfect knowledge of the Azorean dairy farm’s decision making process, but the Azorean farmer’s decision is made with conflictive objectives. The surrogate utility function estimated seems to be consistent with the real preferences revealed by farmers.

The three groups selected differ in objective weights, and only one group defines gross margin was the main objective. This conclusion is unexpected as profit does not seems to be the priority in the Azorean farmer's decision as already observed by Amador *et al.* (1998) and Rodríguez-Ocaña (1996). In this case it we cite Amador *et al.* (1998): "Some specialists may be surprised by the assumption that the group of farms analyzed behave *as if* all have the same objective; yet, paradoxally most of the mathematical programming applications in agriculture reported in literature assume in one way or in the another that all farmers are gross margin maximizes, which does not seem to produce much surprise among the specialist!"

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Cluster I	MB	MOTAD	SAZ	MOsal	Real Value
MB	**30241**	19662	21657	21088	20814
MOTAD	21313	**12435**	13612	13263	13098
SAZ	10070	903	**319**	514	688
MOsal	10075	0	0	**0**	0

Table 1. Pay-off matrix - Group I

Group II	MB	MOTAD	SAZ	MOsal	Real Value
MB	**21792**	19238	20161	19797	21393
MOTAD	14096	**12205**	12764	12499	13826
SAZ	1945	2065	**1312**	1786	1821
MOsal	1506	0	0	**0**	1367

Table 2. Pay-off Matrix - Group II

Group III	MB	MOTAD	SAZ	MOsal	Real Value
MB	**40636**	15497	26156	15497	23438
MOTAD	24904	**8270**	14081	8340	12529
SAZ	13103	7437	**434**	6918	2115
MOsal	13108	0	0	**0**	0

Table 3. Pay-off Matrix - Group III

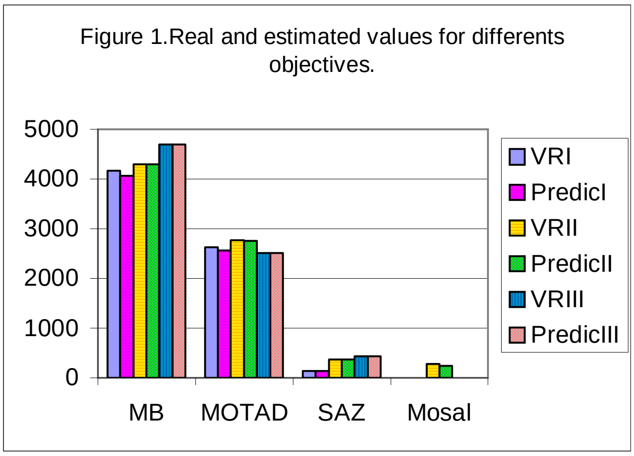
Figure 1.Real and estimated values for differents objectives.

Model structure

$$\text{Objective (1)}: \text{MAX MB} = \text{MAX}\sum_{\text{i}=1}^{16}\text{X}_\text{i}\text{MB}_\text{i}$$

$$\text{Objective (2)}: \text{MIN MOTAD} = \text{MIN}\sum_{\text{k}=1}^{7}\text{N}_\text{k}$$

$$\text{Objective (3)}: \text{MIN EST} = \text{MIN}\sum_{\text{j}=1}^{6}\text{n}_\text{j} + \text{p}_\text{j}$$

$$\text{Objective (4)}: \text{MIN MOSAL} = \text{MIN X}_{16}$$

$$\text{Constrain (1)}: \text{X}_1 \le \text{S}_\text{A}$$

$$\text{Constrain (2)}: \text{X}_2 + \text{X}_3 + \text{X}_4 + \frac{1}{2}\text{X}_8 + \frac{1}{4}\left(\text{X}_{10} + \text{X}_{12}\right) \le \text{S}_\text{M}$$

$$\text{Constrain (3)}: \text{X}_5 + \text{X}_6 + \text{X}_7 + \frac{1}{2}\text{X}_9 + \frac{1}{4}\left(\text{X}_{11} + \text{X}_{13}\right) \le \text{S}_\text{B}$$

$$\text{Constrain (4)}: S_A + S_M + S_B \le S_T$$

$$\text{Constrain (5)}: X_8 + X_9 \le 0{,}2\left(S_M + S_B\right)$$

$$\text{Constrain (6)}: X_{10} + X_{11} \le X_8$$

$$\text{Constrain(7)}: X_{11} + X_{13} \le X_9$$

$$\text{Constrain (8)}: \sum_{i=1}^{15}\left(MO_j X_i\right) + n_j - p_j = \overline{MO_{dj}},\ \ j = 1,\ldots,6$$

$$\text{Constrain (9)}: \sum_{i=1}^{15}\left(MO_j X_i\right) = MO_{dj} + X_{16j},\ \ j = 1,\ldots,6$$

$$\text{Constrain (10)}: \sum_{i=1}^{16}\left(MB_{ik} X_i - \overline{MB_{ik}}\right) + N_k - P_k = 0,\ \ k = 1,\ldots,7$$

$$\text{Constrain(11)}: \sum_{i=1}^{16} MB_i X_i \ge 3107$$

$$\text{Constrain(12)}: \sum_{j=1}^{6}\sum_{i=1}^{14}\text{UFL}_\text{ij} MS_{ij} X_i \ge \sum_{j=1}^{6} UFL_{15j} X_{15}$$

$$\text{Constrain (13)}: \sum_{j=1}^{6}\sum_{i=1}^{14}\text{PDIE}_\text{ij} MS_{ij} X_i \ge \sum_{j=1}^{6} PDIE_{15j} X_{15}$$

$$\text{Constrain (14)}: \sum_{j=1}^{6}\sum_{i=1}^{14}\text{PDIN}_\text{ij} MS_{ij} X_i \ge \sum_{j=1}^{6} PDIN_{15j} X_{15}$$

$$\text{Constrain(15)}: \sum_{j=1}^{6}\sum_{i=1}^{14}\text{CA}_\text{ij} MS_{ij} X_i \ge \sum_{j=1}^{6} CA_{15j} X_{15}$$

$$\text{Constrain (16)}: \sum_{j=1}^{6}\sum_{i=1}^{14}\text{P}_\text{ij} MS_{ij} X_i \ge \sum_{j=1}^{6} P_{15j} X_{15}$$

$$\text{Constrain(17)}: \sum_{\text{i}=1}^{14}\text{MS}_\text{i}\text{X}_\text{i} \ge MS_{15} X_{15}$$

$$\text{Constrain (18)}: \text{X}_{14} - 547{,}7 X_{15} = 0$$

$$\text{Constrain (19)}: \text{X}_{15} - 1{,}4\sum_{\text{i}=1}^{13}\text{X}_\text{i} \le 0$$

$$\text{Constrain(20)}: \ \text{X}_\text{i} \ge 0, \qquad \text{i} = 1,2,\ldots,16$$