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Rough Set Approach Applied To Environmental Labeling In Sicilian Agri-Food Sector

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Abstract:- Actually, in the agri-food sector there has been the springing up of voluntary environmental labelling systems used as instruments for environmental communication and useful to obtain a commercial feed-back of eco-sustainable management. The result is a large variety and it becomes extremely difficult and complex for the operators to choose the most effective label able to explain the values of their environmental involvement and the application of the operating modes of the chosen labelling system. This paper proposes the results of an exploratory survey, carried out through a suitable questionnaire, built up by us, on variables concerning the implementation of environmental labels in small and medium enterprises of agri-food. In order to have a survey as general as possible, this questionnaire has been proposed to some Sicilian companies of various sizes, located in the provinces of Catania and Syracuse. The aim of the analysis is to investigate what are the steps of the production cycle, mandatory and voluntary regulations in the company, type of packaging used, voluntary eco-labelling and certification applied in the considered companies, kind of end-users, category of environmental impacts during different stages of production cycles in the diverse classes of companies interviewed. The answers obtained have been elaborated through the Rough Sets approach, a method of data analysis that allows us, through an easily understandable language, to describe relations in terms of decisional rules (if…, then…), among a series of attributes relating the different managerial and organizational problems and the critical points regarding the subject discussed. Some examples of such rules are shown in this paper as tables in order to point out the most interesting results obtained.

Keywords:- agri-food sector; voluntary environmental labelling; rough sets analysis; questionnaire

I. INTRODUCTION

The sustainability of the productive processes is a factor of great competitiveness for the companies especially for those which intend to answer to the increasing request of social and environmental responsibility by the consumer. The energy theme, the climatic changes, the water consumption, the exploitation of the soil, are just some of the examples which will deeply bear on the productive processes in years to come. This trend will be more definitive for the agro food sector both for its specific exposure to some risk factors and for the importance of the relationship between the producers and the consumers about the quality and health of the agro food productions.

In the last years it has been thought about the more suitable instruments to direct the efforts of the firms towards the renewal of the productive processes to involve the environmental performance, and to give the products an objective environmental value, recognizable and saleable on the market. In this context, the use of labelling and environmental declarations should appear both functional to demonstrate the responsibilities of the companies towards the use and the management of the sustainable environmental resources and a way to communicate this commitment to the consumers and the stakeholders (Coldiretti 2011). The result is a varied survey and it becomes extremely difficult and complex for the operators to choose the more effective label which explains the values of their environmental involvement and the application of the operating modes of the chosen labelling system. Hence, it follows the need to carry out some guidelines which, considering the peculiarities of the soil, the specificness of the products, the characteristics of the supply chain, of the company operative context and of the final reference markets, give the firms a way to choose the more adequate environmental label for their agricultural and food products and which allow to bring out their communication strategies and the visibility on the market. Consumers must have access to aggregated information that takes into consideration the chemical additives, land stewardship practices, and fossil fuel consumption required to introduce any food into the market (Czarnezki 2011). and declaration programs to influence production and management practices in any industry. To achieve these purposes, we have proposed some guidelines, an innovative instrument suitable for evaluating the characteristics and the environmental impacts of a

product/service and for assisting the firms which are willing to apply an environmental label to their own outputs by choosing a communication system close to their activities through the evaluation of their objectives, choosing a communication system close to their realities through the evaluation of objective, comparable and believable information (Lo Giudice and Clasadonte 2010).

The outlined and written guidelines are the result of an exhaustive study which has highlighted the more common problems among the operators who intend to implement an environmental communication instruments into their productive chain, because the voluntary labelling system is really diversified and it makes particularly difficult and complex for the operators the choice of the most effective type of label to transmit the values of their environmental commitments. Consequently, companies have to choose a labelling system which suits the specific characteristics of their product and the distinctive features of their sector. This is particularly important in some productive contexts like the agri-food sector, where the characteristics of the products depend on the interactions among different subsystems of the productive chain, from farming to transformation processes and marketing, which bring about some impacts in water, air and soil (Girardin et al. 2000).

In this study, for the sake of identifying the obstacles found by the operators of the sector in the implementation of environmental communication system and with the aim of pointing out the areas considered to be highly critical on which to appropriately intervene to remove the critical points, a suitable questionnaire to managers of Sicilian small and middle farms was prepared. In particular, some specific studies showed that the sectors most representative are citrus chain firms, wine industries and cereal sector firms. The tool used to achieve this goal was the development of a questionnaire distributed to the companies in order to know their main features, measure the environmental impacts throughout the production process, analyze the level of dissemination of product certifications and process and measure the degree of sensitivity to environmental problems. The answers supplied by those interviewed have been elaborated, through an interesting method of data analysis, the Rough Set approach (Pawlak, 1982, 1991), based on the indiscernibility relation, which is a mathematical tool used to handle data characterized by vagueness and uncertainty. Using this kind of approach, we were able to obtain as output the most important attributes among all used in the questionnaire and some decisional rules describing in a synthetic and understandable way the main results of the study.

II. STRUCTURE OF QUESTIONNAIRE

The questionnaire consists of 84 questions, divided into three parts, in order to facilitate the company at compile time, mainly because the issues dealt with different business areas and therefore require the participation of several individuals.

The first part deals with the general analysis of the company, then its specific sector and size, its organizational structure and investment that devotes itself to R&D. Also prompted companies to make a detailed analysis of the production process and the environmental impacts that are generated in each stage of the supply chain. The second part concerns the mandatory regulations of the agri-food sector, in particular any difficulties encountered in the implementation phase.

The third part is devoted to the voluntary regulations, product or process, the degree of knowledge of these certifications by business and the possible adoption by firms, the reasons that have led companies to choose to adhere to systems labelling and / or environmental certification and what are the benefits. In this part of the questionnaire, concerning the environmental labelling issues, it was necessary to change the structure of the questions and of the answers, because the latter are more technical and specific.

Questions were formulated containing the explanation and normative reference labelling to which they relate, to facilitate the reader to quickly obtain information if he does not know the required subject matter. For the processing of data a sample of 16 companies was taken operating in the sector and belonging to various fields of the food industry and of various sizes, located in eastern Sicily (particularly in the provinces of Catania and Syracuse) .

The questionnaire due to its flexibility and adaptability has been a valuable tool to guide the choice of companies and to suggest voluntary environmental labelling more responsive to the needs and characteristics of the production processes and products.

III. ROUGH SET APPROACHES

The rough sets theory, introduced by Pawlak (1982, 1991), is an excellent mathematical tool for the analysis of a vague description of objects called actions in decision problems.

The adjective vague, referring to the quality of information, means inconsistency or ambiguity which follows from information granulation. This theory is based on the assumption that with every object of the universe U there is associated a certain amount of information (data, knowledge), expressed by means of some attributes used for object description. Objects having the same description are indiscernible with respect to the available information. The *indiscernibility relation* thus generated induces a partition of the universe into blocks of indiscernible objects, called elementary sets.

Any subset X of the universe may be expressed in terms of these blocks either precisely (as a union of elementary sets) or approximately only. In the latter case, the subset X may be characterized by two ordinary sets, called lower and upper approximations. A rough set X is defined by means of these two approximations. The lower approximation of X (denoted by $\underline{P}(X)$) is composed of all the elementary sets included in X (whose elements, therefore, certainly belong to X), while the upper approximation of X (denoted by $\overline{P}(X)$) consists of all the elementary sets which have a non-empty intersection with X (whose elements, therefore, may X belong to X). The difference between the upper and lower approximation constitutes the boundary region of the rough set X (denoted by $Bn_P(X)$), whose elements cannot be characterized with certainty as belonging or not to X, using the available information. The information about objects from the boundary region is, therefore, inconsistent or ambiguous, so it constitutes the "doubtful region" of X.

The definition of approximations of a subset $X \subseteq U$ can be extended to a classification, i.e. a partition $Y = \{Y_1, \dots, Y_n\}$ of U. Subsets Y_i are disjunctive classes of Y. By P-lower and P-upper approximations of Y we mean sets $\underline{P}Y = \{\underline{P}Y_1, \dots, \underline{P}Y_n\}$ and $\overline{P}Y = \{\overline{P}Y_1, \dots, \overline{P}Y_n\}$ respectively. The ratio $\gamma_P(Y) = \sum_{i=1}^{n} \left|\underline{P}Y_i\right| / |U|$ is called *quality of classification*. It expresses the ratio of all P-correctly classified objects to all objects in the system.

The information regarding the objects is supplied in the form of a data table, whose separate rows refer to distinct objects, and whose columns refer to different attributes considered. Each cell of this table indicates an evaluation (quantitative or qualitative) of the object placed in that row by means of the attribute in the corresponding column. An issue of great practical importance is that of "superfluous" data which can be eliminated without deteriorating the quality of information contained in the original table. A Y-*reduct* of P (denoted by $Red_Y(P)$) specifies a minimal subset P' of P which keeps the quality of classification unchanged. The set containing all the indispensable attributes of P is known as the Y-*core* which is the intersection of all the Y-reducts, formally $Core_Y(P) = \cap\, Red_Y(P)$.

If in a data table the attributes of set Q are divided into *condition attributes* ($C \neq \emptyset$,) and *decision attributes* ($D \neq \emptyset$,), $C \cup D = Q$ and $C \cap D = \emptyset$, such a table is called a *decision table*. The decision attributes induce a partition of U deduced from the indiscernibility relation I_D in a way that is independent of the condition attributes, and D-elementary sets are called *decision classes*. Since the tendency is to underline the functional dependencies between condition and decision attributes, a decision table may also be seen as a set of *decision rules*, which are logical statements (implications) of the type "*if..., then...*", where the antecedent (condition part) specifies values assumed by one or more condition attributes (description of C-elementary sets) and the consequence (decision part) specifies an assignment to one or more decision classes (description of D-elementary sets).

The objects are considered as examples of decisions. An object $x \in U$ supports a decision rule if its description is matching both the condition part and the decision part of the rule. A decision rule *covers* an object *x* if it matches at least the condition part of the rule. Procedures for generation of decision rules from a decision table use an inductive learning principle. There are different possible strategies: generation of a minimal set of rules covering all objects from a decision table; generation of an exhaustive set of rules consisting of all possible rules for a decision table; generation of a set of "strong" decision rules, even partly discriminant, covering relatively many objects each but not necessarily all objects from the decision table. To select the most interesting rules the *support*, the *relative strength* and the *confidence level* for each rule are evaluated. The *support* is the number of objects supporting the rule. The *relative strength* is given by the ratio between the number of objects supporting the rule and the number of objects matching the decision part of the rule. The *confidence level* expresses the ratio between the number of objects supporting the rule and the number of all objects matching the condition part of the rule.

IV. APPLICATION OF THE MODEL

The implementation of the rough sets model based on indiscernibility, in this specific case was realised using the Rose 2 software. As regards the input data, the 16 companies interviewed represent the objects, while from the questionnaire 33 condition attributes are obtained, belonging to four different areas as well as two different decision attributes which will be considered separately; thus two decision tables are used.

The condition and decision attributes are identified by numbers preceded by the letters C and D respectively. The domain of the attributes, in this case represented by exclusively qualitative data, is also codified by numbers. The information relative to the condition attributes is specified in tables 1,2,3,and 4. The decision attributes are described in table 5.

Table 1 – General data of the companies and social structure

Condition attribute	**Domain**
C1 - Province	1=Catania 2=Caltanissetta

	3=Siracusa 4=Ragusa
C2 – Sector belonged to	1=production and commerce of food products 2=production of coffee 3=dairy 4=drinks bottling 5=sweets industry 6=production of poultry-beef 7=greengrocery 8=wine production 9=restaurant
C3 – Number of employees	1=up to 5 2=from 6 to 10 3=from 11 to 50 4=from 51 to 100 5=more than 100
C4 – Market research on quality, environment and safety	0=no 1=yes
C5 – Destination of resources to R&D	0=no 1=yes

Source: personal elaboration

Table 2 – Analysis of the production process and innovations

Condition attribute	**Domain**
C6 – Gathering or purchase of raw materials	1=gathering 2=purchase
C7 – Transport with own vehicles of raw materials	0=no 1=yes
C8 – Bottling-packing-packaging	0=no 1=yes
C9 - Transport with own vehicles of finished product	0=no 1=yes
C10 - Distribution-direct sale	0=no 1=yes
C11 – Biggest environmental impact of productive process	0=don't know 1=air 2=water 3=land
C12 – Use of compost, fertilisers, pesticides	0=no 1=yes
C13 – Organic production of raw materials	0=no 1=yes
C14 – Electric energy consumption plus other pollutants	0=no 1=yes
C15 – Processes of cooking, desiccation, sterilisation, etc. of food	0=no 1=yes
C16 - Materials used for packaging	1=wood, cardboard, glass 2=plastic, cardboard, metal 3=plastic, cardboard 4=wood, plastic, cardboard 5=cardboard, metal, glass
C17 – System of waste management and disposal	0=no 1=yes
C18 – Collection of old batteries, printer and fax toner.	0=no 1=yes
C19 – Distribution of products	1=internal transport 2=external vehicles

C20 – Information about product use on label	0=none 1=obligatory information 2=means of use 3=obligatory and environmental information

Source: personal elaboration

Table 3 – Obligatory regulations applied to products in the agri-food sector

Condition attribute	**Domain**
C21 – Critical points regarding EC Reg. 178/02	0=none 1=traceability of lots 2=certificate of origin of the suppliers 3=information mechanisation
C22 – The information provided by the obligatory regulations on labelling is sufficient	0=no 1=yes
C23 – How much have the recent regulations influenced the choice of raw materials	0=not at all 1=little 2=a lot 3=an extreme amount

Source: personal elaboration

Table 4 – Environmental labelling and process certification

Condition attribute	**Domain**
C24 – Environmental labels adopted	0=none 1=IGP, organic 2=DOC, DOCG, IGT 3=BRC,IFS 4=organic 5=DOC 6=DOP
C25 – Reasons for adopting environmental labels	0=none 1=improvement of business image, higher quality 2=higher quality 3= improvement of business image 4=product differentiation 5=disciplinary compliance
C26 – How careful are consumers of environmental labels	0=not at all 1=little 2=a lot 3=an extreme amount
C27 – Does the company adopt or know about at least one type of environmental label	1=yes, it knows about at least one type of labelling 2=yes, it adopts at least one type of labelling 3=it does not know about any type of labelling 4=it does not adopt any type of labelling
C28 – The company has thought about adopting the European Ecolabel	1=yes, it knows about this type of labelling 2=yes, it adopts this type of labelling 3=it does not know about this type of labelling 4=it does not adopt this type of labelling
C29 – The company has adhered to DAP environmental labelling	1=yes, it knows about this type of labelling 2=yes, it adopts this type of labelling 3=it does not know about this type of labelling 4=it does not adopt this type of labelling
C30 – The company adopts the BRC standard	0=no 1=yes
C31 –Which environmental certifications will you adopt in the next 5 years	0=none 1=consumer guarantee certification 2=2nd type labelling 3=ISO 14001:2004

	4=EN 16001
C32 – Are Italian consumers as sensitive as European ones about environmental themes and labels.	0=don't know 1=more sensitive 2=less sensitive 3=just as sensitive
C33 – Are European consumers sensitive to environmental themes and labels.	0=no 1=yes

Source: personal elaboration

Table 5 – Labels and environmental impact

Decision attribute	**Domain**
D1 – Does the company use environmental labelling or does it intend to in the next 5 years	1=yes, it uses environmental labelling 2=no, but it intends to do so in the next 5 years 3=no and it does not intend to in the next 5 years
D2 – Environmental impacts of the production process	0=don't know 1=air 2=waste 3=air and waste 4=energy consumption and water 5=water

Source: personal elaboration

V. RESULTS AND DISCUSSION

The use of the ROSE software allowed us to compute, among other things, the quality of the classification, the reducts and the core of each decision table . Given the high number of condition attributes, it was decided to choose the most significant to obtain the decision rules. The choice was made by calculating the reducts for each database corresponding to the two decision attributes D1 and D2 and then taking into consideration the fifteen attributes which present the highest relative frequency. These attributes are listed in table 6 and 7.

Table 6 - Database with D1

Attribute	**Frequency %**
C32	31.69
C18	29.70
C9	25.92
C33	25.45
C7	25.18
C15	25.14
C13	24.69
C4	24.68
C6	23.63
C5	22.77
C10	21.38
C23	21.02
C14	20.85
C26	18.56
C1	18.33

Table 7 – Database with D2

Attribute	**Frequency %**
C7	30.24
C32	28.20
C4	23.87
C13	22.97
C14	22.35
C5	21.78
C29	21.68
C33	21.36
C6	20.82
C18	19.94
C9	19.15
C19	18.52
C12	18.39
C31	18.31
C26	17.57

Source: personal elaboration

The two subsets of condition attributes both guarantee a quality classification equal to 1 and present eleven elements out of fifteen in common. In the first group we have the attributes C29, C19, C12 and C31 which are not present in the second group. In the second group we have the attributes C15, C10, C23 and C1, which are not present in the first group. It can also be observed that some attributes relative to the general data about the companies (C2, C3), 7 attributes describing the production process and innovations (C8, C10, C16, C17, C20, C21, C22) and 5 relative to the environmental labels and to the certifications of process (C24, C25,

C27, C28, C39,) do not appear in any of the preceding subsets, so they can be considered quite marginal for the objectives of the survey carried out. By elaborating the data of the two new decision tables, constructed with the chosen condition attributes, the decision rules are determined and the most significant are taken into consideration, which are defined as those supported by at least three objects, with a relative force of at least 50% and with a confidence level equal to 1. Some of the rules thus obtained, for each decision attribute, are listed below (in the square brackets are represented respectively support, relative force, and level of confidence):

Decision attribute D1

1. (C4 = 1) & (C13 = 1) => (D1 = 2); [3, 50.00%, 1.0]
2. (C4 = 0) & (C32 = 3) => (D1 = 2); [3, 50.00%, 1.0]
3. (C26 = 2) & (C32 = 2) => (D1 = 2); [3, 50.00%, 1.0]
4. (C32 = 0) => (D1 = 3); [2, 100.00%, 1.0]
5. (C4 = 0) & (C13 = 0) & (C26 = 1) => (D1 = 3); [3, 50.00%, 1.0]

No rules of the type D1=1 was taken into consideration because only one company was found to use environmental labelling and so these rules would not be significant.

Decision attribute D2

1. (C4 = 0) & (C10 = 0) => (D2 = 0); [3, 75.00%, 1.0]
2. (C4 = 0) & (C23 = 0) => (D2 = 0); [3, 75.00%, 1.0]
3. (C6 = 2) & (C10 = 0) => (D2 = 0); [3, 75.00%, 1.0]
4. (C10 = 2) & (C14 = 0) => (D2 = 0); [3, 75.00%, 1.0]
5. (C23 = 1) & (C26 = 2 => (D2 = 1); [3, 75.00%, 1.0]
6. (C4 = 0) & (C5 = 0) & (C6 = 1) => (D2 = 2); [3, 75.00%, 1.0]

7 (C4 = 0) & (C10 = 1) & (C18 = 0) => (D2 = 2); [3, 75.00%, 1.0]

8 (C23 = 2) => (D2 = 1 o 0); [3, 75.00%, 1.0].

As an example of how these rules would be read in natural language, the decision rules for N1 relative to decision attributes 1 and 2 are as follows:

1.1 If market research is carried out on quality, environment and safety and the raw materials are organically produced, then the company does not use environmental labelling but thinks it will in the next five years.

1.2 If market research is not carried out on quality, environment and safety nor is the distribution-sales direct, then the company does not know what the environmental impacts of its production process are.

Among the main comments to the rules 2,3 and 4 of the decision attribute D1, it must be underlined how the "sensitivity" of Italian consumers (cond. attr. 32) plays a notable role in influencing the decision of whether to be adopt labelling or not. The answer "don't know" (C32=0) is on its own sufficient to push companies to not adopt labelling (reg. 4), while a higher or lower degree of sensitivity shown (C32=2, 3), together with another condition pushes the companies to use labelling in the next five years

Among the main comments to rules 1, 3, and 7 of the decision attribute D2, it must be underlined how the absence (C10=0) or the presence (C10=1) of direct sales notable influences the awareness of their company's environmental impact.

VI. CONCLUSIONS

From the analysis carried out with the innovative procedure adopted the result is that, since most of the Sicilian citrus farms are small-sized and broken up in terms of supply, the greatest obstacle to the implementation of the traceability system appears to be the integration of a computer system in the farm, whereas, independently of the size, most of the people interviewed see the company costs with greater difficulty.The results of the responses to the questionnaire show an overview on the environmental impacts generated during the entire production cycle for each sector, on what types of certification companies have already implemented, what benefits it has drawn from it and how it might wish to adopt Environmental Labelling systems. This work is structured as a good starting point to identify the critical factors of the environmental production process and the identification of a system of Environmental Labelling most appropriate to each of the companies analysed.Without this investigative tool, being able to determine which type of Environmental Labelling is closest to the needs of the company becomes very complex, because you do not know enough about the impact or environmental impacts on which to intervene and the market needs of individual sectors.The sensitivity attribute of Italian consumers, with a very high frequency in the two reducts corresponding to D1 and D2, does not appear in any rule in D1 and only in 4 of D2, always with a value of 2, that is "Italians less sensitive...". Almost all except 1) the decision rules D1 have as a consequence D1=3, that is "does not think they will adopt labelling ...". The decision rules of D2 have as a conclusion D2 = 0 (except for 4, D2 = 2), that is the declaration of not knowing the environmental impacts of their own production system (only

4 talk about "waste"). These are very disheartening results which underline how many of the firms interviewed do not even pose themselves the problem of the environment throughout their production processes.

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