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Nijkamp, P.; Vindigni, G.

***published in***
Management of Environmental Quality
2003

***DOI (link to publisher)***
10.1108/14777830310460423

***document version***
Publisher's PDF, also known as Version of record

***citation for published version (APA)***
Nijkamp, P., & Vindigni, G. (2003). Impact Assessment of Qualitative Policy Scenarios; A Comparative Case Study on Land Use in Sicily. *Management of Environmental Quality*, *14*(1), 108-131. https://doi.org/10.1108/14777830310460423

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## A Comparative Case Study on Land Use in Sicily

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**Abstract**

The purpose of this paper is to offer a contribution to the study of integrated assessment procedures for evaluating the effectiveness of agri-environmental policy strategies. While in the past the studies in this context have typically concentrated on the contents of methods in isolation, there is a growing trend towards methodological perspectives that support the linking of such methods. The focus here is on the combination of discrete multicriteria approaches used for handling qualitative information in a sequence of steps: the regime method, the evamix method and rough-set analysis. The first two methods will be used to obtain a ranking of four alternative scenarios of agri-environmental policies in a selected area of study, in this case, Sicily. The results obtained are discussed and re-analysed by using the rough-set approach as a recent meta-analytical tool. Finally, the analysis findings are applied to an investigation into the potential effectiveness of agricultural policies in promoting sustainable rural development in Sicily.

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## 1. Sustainable Land Use and Agriculture

Land use has become an important policy issue in the context of (global) sustainable development. In the same vein also the notion of sustainable agriculture has become an important policy orientation in past years (see Hermanides and Nijkamp, 1998). The concern about environmentally benign modes of land use and agriculture is not only of local or regional importance, but highlights also global change issues and threats imposed by climate change, deforestation, desertification and the loss of biodiversity in general (see Meyer and Turner II, 1994).

Land use increasingly has become a battle field of conflicting interests (see Frederick and Rosenberg, 1994). Over the last centuries, a significant and progressive transformation of natural areas into areas which support agricultural, urban, or industrial functions has been observed. Apart from Europe, where both forests and grasslands show a slight expansion, the overall trend is towards a substantial loss of natural land in favour of cropland. The combined pressure of factors such as population growth, food production, wood production, and land tenure arrangements (Pearce, 1991) has influenced as much as forty per cent of the forests and grasslands of some areas. This trend will continue in the future, as the demand for space and natural resources will probably continue to rise. Irrigated land, cropland, rangeland and pasture will increase in absolute terms, but their availability per capita will also decrease. Without countermeasures, this will necessarily lead to further pressure on land, to an increasing load on the environmental, and to an impoverishment of the natural resources capital. The negative effects of land-use exploitation are manifested in soil erosion, loss of habitats, increased vulnerability of the soil, a decrease in the carrying capacity of land, landscape modification and loss of natural amenities (see Beinat and Nijkamp, 1999).

Thus, it is clear that in our modem age land use is a source of much concern, both locally and globally. External factors and the limits to growth have become a new focal point of economic research in the past few decades (with regard to both renewable and non-renewable resources). In view of the long-term threats exerted by the (apparently) inevitable and persistent changes in local and global environmental conditions, the major policy challenge is to avoid a “tragedy of the commons” (Hardin, 1968). Against this background, land use and the spatial-environmental aspects of the economy deserve more attention from economists and scientists in general. Land-use planning traditionally has been concerned with the solution of a fundamental trade-off: conservation versus economic exploitation (cf. Van Lier and Taylor, 1998). Conservation refers to the preservation of the natural resources stock (e.g. water, soil, air), of the biological stock (e.g. the conservation of the genetic pool), but also the re-creation of lost land (e.g. reforestation of fallow land) and the rehabilitation of degraded land (e.g. cleaning-up contaminated sites).

The relationship between conservation and sustainability is rather straightforward. Conservation involves the prevention of disruptive developments and the retracing of past developments in order to make environmental stock available for future generations. The economic dimension of land-use management, in contrast, refers to the relationship between sustainability and a durable socio-economic system (cf. Barbier, 1990).

Policies on sustainable development and land-use planning have increasingly moved from a global level to a meso approach (area1 level or a sector intervention). The introduction of the spatial dimension has also permitted the development of additional sustainability management concepts, such as strong and weak sustainability (see van Pelt ,1993; Pearce and Turner, 1990).

Its multi-faceted feature attributes an integral economic value to land. Consequently, the question whether some use of land leads to a sustainable outcome depends not only on external sustainability criteria of land use (e.g. land degradation versus economic growth), but it is also determined by internal sustainability criteria (e.g. agriculture versus tourism). Some of these trade-offs are of a long-range nature and lead to inter-temporal trade-offs, adding a temporal dimension to land-use choices (cf. Palmquist and Danielson, 1989).

The multi-functionality and complexity of land use is a source of much ambiguity in sustainable policies. There is no uni-dimensional denominator which can be used to assess and evaluate land-use changes and policies. Consequently, land-use planning requires an "intellectual family" of approaches (Kooten, 1993), which combine the experience and the strengths of many disciplines. In order to develop an appropriate methodology for sustainable land-use planning at a local or regional level, a set of scientific research methods and tools may be helpful. Examples are: dynamic systems analysis, impact analysis, economic and social assessment, geographic information systems, scenario analysis, and multicriteria decision support (see for details Giaoutzi and Nijkamp, 1994). The latter approach will be employed here as the major analytical tool.

Multicriteria analysis (MCA) aims to evaluate the outcome of alternatives and possibly to choose certain best alternatives based on a set of multiple criteria. A basic feature of land-use choices is that the effects and the information concerning spatial decisions are multi-dimensional in nature. In addition, effects presented in the form of monetary units, physical units, or survey measurements, must be comparable within a suitable methodology. To a large extent, multi-criteria analysis (Beinat and Nijkamp, 1998; Beinat, 1997; Nijkamp et *al.*, 1990) serves to meet these requirements, because it encapsulates an applicable analytical framework and conflicting policy objectives.

In this paper we will demonstrate the usefulness of MCA methods for sustainable land use planning. After a presentation of some MCA techniques, we will present an Italian case study.

## 2. An Analytical Framework for Sustainable Land Use Planning

In order to develop an appropriate methodology for sustainable land use policy evaluation, two general assessment methods will be concisely discussed in Subsection 2. 1., viz. impact analysis and scenario analysis. Next, in Subsection 2.2 we will introduce three multi-dimensional evaluation methods, viz. the regime method, the evamix method, and rough-set analysis. They have assumed an increasingly important role due to the importance of their practical applications in the field of operational sustainability policies. These methods, mainly applied separately until now, have resulted in a series of analyses which are worthwhile exploring and applying to a common case.

### 2.1 Assessment methods

*Impact analysis* is a scientific tool of analysis widely used to assess the results of policies or projects at different levels. It serves to analyse different types of impacts on the relevant subsystems of the sustainability objective (economic, social and environmental) and to offer a concise indication for the performance of each alternative. It is generally introduced into the planning procedure at a rather early stage, before options and alternatives are narrowed down. Its flexibility permits us to use several types of analytical methods like econometrics models, input-output models, simulation and scenario methods, goal achievement methods and qualitative decision support models.

In our study, impact analysis will be applied to examine the effects caused by EU agricultural strategies concerning a sustainable development at the local level of the area analysed. In order to examine in a more operational way the effects of different development strategies, we may construct a so-called **impact matrix (see** Table 1). On the horizontal axis we list the alternatives or the development strategies under consideration in the form of policy scenarios. On the vertical axis the relevant elements of our system represent the impacts of political strategy on any policy relevant attribute or criterion of the system. For example, entry $X_{1A}$ represents the effects of policy development strategy A on the first entry of the system.

**Table 1.** Impact matrix

| Element/Effect | Scenario A | Scenario B | | Scenario N |
|---|---|---|---|---|
| $X_1$ | $X_{1A}$ | $X_{1B}$ | | $X_{1N}$ |
| $X_2$ | $X_{2A}$ | $X_{2B}$ | | $X_{2N}$ |
| $X_3$ | $X_{3A}$ | $X_{3B}$ | | $X_{3N}$ |
| $X_n$ | $X_{nA}$ | $X_{nB}$ | | $X_{nN}$ |

In the framework of an assessment of the impacts on a system caused by a given policy decision, two levels of information may be distinguished: hard information and soft information. Hard information refers to data measured on cardinal scale, while soft information is used to denote qualitative data (ordinal or nominal scale). Often an impact analysis includes both kinds of information (i.e., mixed).

In the evaluation of sustainability problems we frequently deal with qualitative information. Essentially there are two approaches to digest qualitative information: the *direct approach* where the qualitative information is used directly in a qualitative evaluation method and the *indirect approach* in which qualitative information is first transformed into cardinal data, whereupon one of the existing quantitative methods can be used. Such a cardinalisation is particularly useful in the case of available information of a mixed type (both qualitative and quantitative).

*Scenario analysis* (Nijkamp, 1998) attempts to develop and judge a set of hypothetical policy or development alternatives for a compound and complex decision-making system, in order to generate a rational frame of reference for evaluating different alternatives. By assessing the foreseeable and expectable impacts of various selected future strategies (scenarios), we can identify a policy strategy which fulfils to a maximum the aim of a desired or sustainable policy. Scenarios can assist decision-makers in the:

- selection of proper policy solutions which produce robust results under varying conditions
- assessment of strategies to cope with threats from particular natural and socio-economic conditions
- risk assessment of various uncertain future developments.

In order to evaluate possible paths as a frame of reference for sustainable agricultural policies and to identify its impact on the future in the selected area of study, the assessment of qualitative scenarios based on the ***backcasting scenario approach*** is utilised in our study. In the context of future-oriented studies, and in particular in the study of complex sustainability problems, the ***backcasting scenario*** approach has proved to be fruitful because it is based on trends that are likely to generate solutions that would presuppose the breaking of trends desirable for achieving environmental objectives. This approach should normally consist of three parts (Nijkamp and Blaas, 1994): a) an analysis of the current situation; b) a design of a number of possible future situations;

c) a description of events that could turn the present state into future ones. Such scenarios do not necessarily need to be realistic because they are used as a kind of game - with the aim of presenting a possible impact of policy options.

## 2.2 Evaluation Methods

### 2.2.1 Introduction

*Multicriteria* ***decision support analysis*** is a method of judging different policy scenarios by means of explicitly formulated criteria. After the above steps have been followed, we evaluate the outcome of alternatives and select the best alternative on the basis of relevant criteria. Multicriteria decision support analysis appraises the effects of each hypothetical scenario on all relevant subsystems. The assumption here is that the effectiveness of agricultural policies in terms of promoting sustainable development, cannot simply be measured in terms of an unidimensional choice criterion - in other words, an overall increase in income and employment. A review of recent literature and of E.U. documents would suggest that the criteria used to judge policy success in rural areas should include three important dimensions of the agricultural sustainability problem: economic, social and environmental. Understanding the balance of the economic, social and environmental processes which shape the contemporary rural areas require, in fact, far more than a rigid agricultural sector approach. As the capacity to stimulate rural development through a sectoral agricultural policy is extremely limited, significant change can only be brought about by moving towards an adjusted, more integrated rural policy.

The advantage of utilising these methods stems from the necessity to overcame the limits of unidimensional evaluation in situations which present unavoidable ambiguity. In the debates about sustainable agricultural land-use, in fact, many choices and decisional problems involve the evaluation of impacts that are not only intangible but also incommensurable. For this reason they could not be measured with the traditional metric system. Also the potential of qualitative discrete methods has a concrete expression in analysing a finite number of alternative choices and of information appraisals, and adopts both an ordinal scale and a cardinal scale (qualitative type). At the same time it allows the use of mixed information, both qualitative and quantitative.

To assess the effectiveness of agricultural policies in sustainable development, we applied first, as instruments of multicriteria analysis, the regime method and the evamix method.

### 2.2.2 Regime Analysis

The application of the regime method allows us to prioritise each alternative with regard to the criteria inserted into the model. It involves two principal phases of work:

a) construction of the *impact matrix* for the purpose of individuating the behaviour of each alternative with respect to each criterion. A values scale of the type 1, 2, 3 is usually adopted;

b) construction of the *regime matrix* through the comparison between the alternatives on the basis of the values presumed for each of them in the matrix of impact, In the regime analysis, the sign of the differences between the impacts of the alternatives is individuated by performing a pair-wise comparison. When considering two alternatives i and i', the sign of the difference between these two alternatives according to the j criterion could be described from the symbol $r_{ii',j}$ , defined as follows:

$r_{ii',j} = 1$ if $p_{ij} > p_{i'j}$

$r_{ii',j} = -1$ if $p_{ij} < p_{i'j}$

When the two alternatives are compared according to all the criteria j= 1, J the *regime vector* $r_{ii'}$ is constructed:

$$r_{ii'} = (r_{ii',1}, r_{ii',2}, r_{ii',3} \ldots\ldots r_{ii',J})$$

The above vector reflects a certain degree of pair-wise dominance in the choice of option i with respect to option i' for the unweighted effect of all J judgement criteria. Since there are I (I-1) comparisons, we have I (I-1) regime vectors, so that this procedure leads to a *regime matrix* with a number of lines equal to the number of criteria (where the behaviour of the two alternatives regarding that criterion is indicated) as well as a number of columns equal to the number of the possible comparisons between the alternatives. The dominance of one alternative over another, regarding the analysed criteria, is indicated by a positive sign "+" or negative, "-". If the comparison does not express dominance, the sign "x" is used. In order to evaluate the attractiveness of the i alternative versus alternative i', the following indicator is generally adopted:

$$\mu_{ii'} = \sum_{j}^{J} \lambda_j r_{ii'j}$$

The indicator constitutes a linear combination of the weight vector and indicates a preference among the various criteria, and of the regime vector that corresponds to the pairs of considered alternatives.

The information relative to the weight vector is usually ordinal and the weights are represented by means of a rank order in which hi >$\lambda_j$ implies that criterion i is regarded as more important than j. In order to treat this ordinal information, it is assumed that the ordinal weights are a representation of an *unknown* cardinal stochastic weight vectorhc with max hi = 1, hi ≥ 0.

The weight dominance of option i with respect to option i' can still be described by using the same indicator but is defined in terms of stochastic weights:

$$v_{ii'} = \sum_{j=1}^{J} r_{ii',j} \lambda_C$$

in which a positive value for $v_{ii'}$ indicates that option i is preferred to option i'.

A certain probability is then introduced in the event and an aggregate probability measure is obtained for the event that option i is on average more highly-valued than any other alternative on the basis of the pair-wise comparison. A ranking of options is determined by using the aggregate probability measure. This implies that some assumptions can be made on the probability distribution function $\lambda_C$. If no preliminary information is available, a uniform density function is chosen (Random sampling method). The regime method then allows us to individuate the pertinent subsets of the n-dimensional Simplex representing all the admissible weights by means of an appropriate algorithm.

Once the probability of occurrence of each subset is evaluated, the last step of the regime analysis gives the desired final ranking of alternatives expressed by a frequency matrix whose generic element Fik represents the probability that alternative i has rank number k for all i and k.

### 2.2.3 The Evamix Method

The evamix approach is another method designed to deal with impact matrix E with elements $e_{ij}$, where $i(i=1, \ldots, I)$ represent an alternative and j ($j=1, \ldots, J$) mixed information an evaluation criterion. The set of criteria can be divided in two subsets denoted as 0 and C, containing respectively criterion score having ordinal value and criteria that can be assessed on a cardinal measurement scale:

$O = \{j |$ j takes ordinal value$\}$
and
$C = \{j |$ j takes cardinal value$\}$

The difference between the two alternatives can be expressed by means of two dominance measures: a dominance scores $a_{ii'}$ for the ordinal criteria and $b_{ii}$ for the cardinal criteria. These scores represent the degree to which alternative $i$ dominates alternative $i'$. They have the following structure:

$a, = f(e_{ij}, e_{ij'}, w_j)$ for all $j \in O$
$b_{ii} = g(e_{ij}, e_{ij'}, w_j)$ for all $j \in C$

where $e_{ij}$ the criterion score of criterion $j$ and alternative $i$ and w, the weight attached to criterion j. The two functions $f$ and g differ because the $e_{ij}$ variables have different metric characteristics. The two dominance measures can be expressed as follows:

$$a_{ii'} = [\{w_j \text{ sign } (e_{ji} - e_{ji'})\}^c]^{1/c}, \quad c = 1,3,5$$

$$b_{ii'} = [\{w_j \text{ sign } (e_{ji} - e_{ji'})\}^c]^{1/c}, \quad c = 1,3,5$$

where

$$\operatorname{sign}(e_{ji} - e_{ji'}) = \begin{cases} +1 \text{ if } e_{ji} > e_{ji'} \\ 0 \text{ if } e_{ji} = e_{ji'} \\ -1 \text{ if } e_{ji} < e_{ji'} \end{cases}$$

The symbol c in the formula denotes an arbitrary scaling parameter, for which any positive parameter may be chosen. The larger c is , the less influence will the difference between the alternatives based on minor criteria have on the value of the qualitative dominance measure (Voogd, 1982).

The methods require quantitative weights but can be used in combination with any of the methods dealing with ordinal priority information (Janssen, 1991). As $a_{ii'}$ and $b_{ii}$ will have different measure units, a standardisation into the same unit is necessary, because otherwise no comparison can be made between the two outcomes (Nijkamp,1990). A total dominance measure is calculated as the weighted sum of the qualitative and quantitative dominance scores.

## *2.3* A Multidimensional Classification Method: Rough-set Analysis

### 2.3.1 Introduction

Rough-set theory, which was proposed by Pawlak in the early 1980s, provides a useful instrument for decision situation analysis in the presence of vagueness of a decision maker's preferences caused by the granularity of the preferential information (Pawlak, 1991).

In rough-set theory knowledge is understood as an ability to classify objects (states, events, process etc.), i.e. it is assumed that knowledge is identified as a family of various classification patterns. Objects belonging to the same class are *indiscernible* by means of knowledge provided by classification, and constitute elementary building blocks *(atoms, granules)* which are employed to define all basic concepts used in rough-set theory. The fundamental concepts of the proposed theory of knowledge are *classifications* and *categories*. Categories are features (i.e. subsets) of objects which can be expressed by using knowledge available in a given knowledge base. Certainly some categories can be definable in one knowledge base but are non-definable in another. Thus, if a category is non-definable in a given knowledge base, the problem is whether it can be defined 'approximately' in the knowledge base. The concept of *vague categories* is the central point of this approach. Through the use of rough-set methodology we can obtain the following results on preferential information:

a) evaluation of the importance of particular criteria
b) construction of a reduced subset of independent criteria having the same ability to approximate the decision as the whole set
c) intersection of the reduced subset giving a core of criteria which cannot be eliminated without disturbing the ability to approximate the decision;
d) elimination of redundant criteria from the decision table
e) generation of the sorting rules (deterministic or not) from the reduced decision table that involves only the relevant criteria; they explain a decision policy and may be used for sorting new objects.

In order to discuss rough-set theory, some basic concepts will be described.

### 2.3.2 Information System

The information system consists of a finite set of objects (U), a set of characteristics or attributes (Q) with which these data can be described, a domain (V) of these attributes, and finally, an information function which permits the classification of data and their attribute to a given domain f $(x,q)\rightarrow V$ such that $f(x,q)\in V_q$ for every $q\in Q$ and $x\in U$. Hence, an information system can be expressed as 4-tuple S= <U, Q, v, f>

The information system is represented in a finite data table in which rows correspond to objects and columns correspond to *attributes.* To each pair (object, attributes) there is assigned a value called *descriptor.* Each row of the table contains descriptors representing information about the corresponding object of a given decision situation. In general, the set of attributes is then partitioned into two subsets: *condition attributes* and *decision attributes.* The information system is also called *knowledge information system.*

### 2.3.3 Indiscernibility Relation

The observation that objects may be indiscernible in terms of descriptor is the starting point for rough-set methodology. Let S= <U, Q, V, f > and $P\subseteq Q$. Two objects x, y $\in$ U are said to be indiscernible by means of the set of attributes if and only if they have the same description. Because the set theoretical intersection of equivalence relations is also an equivalence relation, the resulting family of equivalence classes (partition) can be viewed as a P *family of elementary set* (atoms, granules).

We will say that X is P-definable, if X is the union of the basic categories; otherwise X is P-indefinable. The P-definable set are those objects of the universe which can be exactly defined by knowledge base K (P-exact set), and P-indefinable set cannot be defined in this knowledge base (P-inexact or Rough).

### 2.3.4 Approximation of Sets

The indiscernibility of objects by means of condition attributes generally prevents their precise assignment of a set following from a partition generated by decision attributes. In this case the only sets which can be characterised precisely in terms of the classes of indiscernible objects are the PL *lower* and the PU *upper approximation.* These are numbers from an interval [0, 1] which define exactly how one can describe the examined set of objects using available information.

The *lower approximation* is the union of all elementary sets which are included in X, whereas the *upper approximation* is the union of all elementary sets which have a non-empty intersection. Hence, these approximations correspond, respectively, to a minimal set including objects ***surely*** belonging to X, and to a minimal set which possibly belongs to X.

The difference between the lower and the upper approximation is a ***boundary*** *set* (doubtful region of classification) consisting of all objects which cannot be classified with certainty to x or to its complements:

$BN_P(X) = PUX - PLX$

- We can imagine the indiscernibility relation (assumed here to be an equivalence relation to define a grid that we use to overlay our universe U, with each indiscernibility set (equivalence class) being displayed as a square in the grid. The grid forms our approximation space. The subset of objects $X\subseteq U$ that we want to approximate is drawn as the line that crosses the pixel boundaries and cannot be defined crispy within our approximation space.

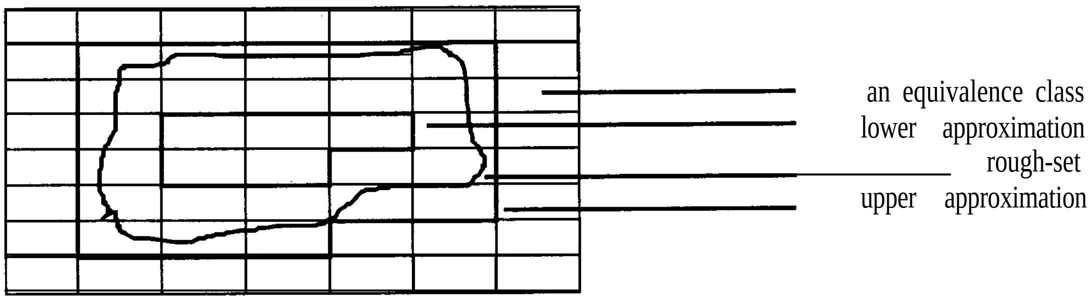

**Figure 1.** Illustration of a rough set

The inaccuracy of a set (category) is due to the existence of the borderline region. We define two measures to describe inaccuracy of approximate classifications: the ***accuracy*** and the ***quality*** of the classification.

If the borderline region of a set is greater, the accuracy of a set is lower. In order to express this idea, the accuracy coefficient can be introduced, i.e. a numerical characterisation of imprecision:

$$\alpha\ P\ (X) = \frac{cardP_L X}{cardP_U X}$$

The accuracy of the measures $\alpha_R(X)$ is intended to capture the degree of completeness of our knowledge about set X. Obviously, $0 \leq \alpha_P\ (X) \leq 1$ ; if $\alpha_P(X) = 1$, the P-borderline region is empty and the set X is P-definable; if $\alpha_P(X) < 1$ the set X has some non-empty R-borderline region and consequently is P-indefinable.

The ***accuracy coefficient*** expresses the size of the boundary of the region of the set, but says nothing about the structure of the boundary. Whereas the classification of information gives no information about the size of the boundary region, it provides us with some insight into how 'the boundary region is structured. Knowing the accuracy of a set still does not tell us its precise topological structure.

In a practical application of rough-set theory we combine two kinds of information about a borderline region: the accuracy measures and the information about the topological classification of the set under scrutiny.

### 2.3.5 Approximation of the Classifications

Let $Y = (Y_1, Y_1\ Y_2 \ldots Y_n)$ be a partition of U in S, and $P \subseteq Q$. The subset $Y_j$ ($j=1 \ldots n$) are classes of Y. The P-lower and the P-upper approximation of classification Y are respectively $P_LY = \{ P_LY_1 , P_LY_2, \ldots P_LY_n \}$ and $P_UY = \{ P_UY_1 , P_UY_2, \ldots P_UY_n \}$ . $BN_P = P_UY - P_LY$ is called P-boundary of Y. We define two measures to describe the inaccuracy of approximate classifications

- the ***accuracy*** of classification :

$$\alpha P(Y) = \frac{\sum_{j=1}^{n} card(P_L Y_j)}{\sum_{j=1}^{n} card(P_U Y_j)}$$

- the *quality* of classification:

$$\gamma Y(Y) = \frac{\sum_{j=1}^{n} card(P_L Y_j)}{card(U)}$$

that expresses the percentage of all P-correctly classified objects to all objects in the system.

### 2.3.6 Reduction of Attributes

In the reduction of knowledge, another basic role is undertaken by two fundamental concepts, a *reduct* and a *core.* A *reduct* is its essential part, which sufficiently defines all basic concepts occurring in the considered knowledge. The *reduct* is the minimal subset of knowledge that provides the same quality of classification of objects to elementary categories of knowledge. The minimal subset $R \subseteq P \subseteq Q$ such that $\gamma_R(\gamma)$ is called *y- reduct* of P (or simply *reduct).* *γ- reduct* of Q is also called minimal set or subset in S. Reducing consists of the removal of superfluous partitions (equivalence relation) and/or superfluous basic categories in the knowledge bases in such a way that the set of elementary categories in the knowledge bases is preserved. This procedure permits us to eliminate all unnecessary knowledge bases and preserve only the knowledge which is really useful.

It must be noted that knowledge can have more than one *reduct.* Knowledge with *only* one *reduct* is, in a sense, deterministic, i.e. there is only one way of using elementary categories of knowledge when classifying objects into an elementary category of knowledge. In the event of non deterministic knowledge, i.e. where there are many ***reducts***, there are generally many ways of using elementary categories when classifying objects into elementary categories. This non-determinism is particularly strong if the *core* knowledge is empty. The *core,* is in a certain sense, its most important part. The use of the concept of the *core* is twofold. Firstly, it can be used as the basis for computation of all the *reducts* and its computation is straightforward. In the second place, the core can be interpreted as the most characteristic part of the knowledge that cannot be eliminated without disturbing the ability to classify objects of elementary categories.

### 2.3.7 Decision Table

An information system can be seen as a decision table DT assuming that $Q=C\cup D$ and $C\cap D=\emptyset$, where C is a set of condition attributes and D is a set of decision attributes. Decision table DT= $< U, C\cup D\ V\ f >$ is deterministic (consistent or certain) if $C\rightarrow D$ or non-deterministic (inconsistent or possible). The deterministic table uniquely describes the decision to be made when some conditions are satisfied. In the case of a non-deterministic table, decisions are not uniquely determined by conditions.

From a decision table, a set of decision rules can be derived. If $U \mid IND(C)$ is a family of C-elementary set called condition classes in DT denoted by $X_i$ ( $i=1 \ldots, k$) and $U \mid IND(D)$ a family of all D-elementary sets called decision classes in DT denoted $Y_j$ ($j=1 \ldots, n$), $Des_C(X_I) \Rightarrow Des_D(Y_j)$ is called (C,D) decision rule. The rules are logical statements (if.. .then) which represent the relationship between the description of objects and their assignment to particular classes. The set of decision rules for all decision classes is called a decision algorithm.

The algorithm may also be used for classification of new objects. It must be noted that not all decision rules are equally important or reliable. Some rules are built by using information about a greater number of objects. This difference in importance in derived rules can be described by an additional parameter for each rule. This parameter, called ‘strength’ of the rule, is expressed by the numbers of objects in the information system supporting the considered decision rule and has a particular interpretation for non-deterministic rules. In these rules, decisions are not uniquely determined by conditions, so that parameters describe each possible assignment.

When classifying a new object it may be that there is no decision rule consistent with the description of the classified object by the condition attributes. In this case the concept of ‘nearest’ rules can be employed. The nearest rules are rules that are close to the descriptions of the considered objects.

## 2. A Case Study on Land Use in Sicily

The application of an integrated assessment methodology is verified in evaluating alternative scenarios of EU agro-environmental policy in an area of particular interest from an agricultural and environmental point of view (Nebrodi Park) situated in Sicily.

The area of the park is subdivided into four specific zones with different levels of protection according to the degree of the ecosystem’s anthrophisation, the modality of management and the admitted activity. Zone A (integral reserve) has a total of 24,540 hectare (28,7 % of the total area delimited); zone B (general reserve) is 44,870 hectare (52,4%) and is comprised of meaningful woodland systems, the pastures inside or near the woods, wetlands, and relevant mountains. Zones C and D (protection and control), respectively 578 hectare (0,7%) and 1349 hectare ( 15,8%) present a high degree of anthropisation, but at the same time they are also suitable for economic activity that contributes to a balanced socio-economic development, and have a remarkably high nature value.

The Nebrodi area is characterised by infertile land, which is mainly used for livestock farming, low productivity of the natural environment, which generates economic results below the national average, and a low population density, or even a tendency towards a dwindling population, predominantly dependent on agricultural activity.

The dominant form of production is cattle farming in the mountain and medium-high hilly areas. The other major agricultural activity is the cultivation of hazel, which has particular importance from an environmental and productive point of view.

In the Nebrodi Park, farm activities are essentially performed by the family work force, rather than paid workers. Employment is characterised as multi-activity, since both structural weakness and limited opportunities resulting from a traditional family-based production system, oblige farmers to rely on alternative sources of income.

Following the 'Agricultural Strategy Paper" (E.U. Commission, 1997), the range of hypothetical options for an integrated agricultural policy can fall into four main categories:

*S1 - Business as usual:* this is a scenario based on the maintenance of existing agricultural production methods. This option rationalises agrarian structures as much as possible to allow for an increase in agricultural productivity and a rise in agricultural income. It is based on EC Reg.2328/91 regarding the improvement of agricultural structures. Even if little attention is given towards ecological value or landscape patterns, this regulation does finance farm investments designed to protect the natural environment. EC Reg.2328/91 incorporates the regime of compensatory allowances for farmers in less favoured areas, established by Directive 75/268 EC. This regime covers mountain areas, areas with a risk of depopulation where it is necessary to ensure the maintenance of natural space and areas of small size where the continuation of agricultural activities is necessary to preserve the environment. This scenario, which ensures continuation of farming and encourages the maintenance of a cultivated landscape, may have beneficial effects on the environment.

s 2 - *Opportunity seeking:* this scenario emphasises the environmental dimension of agriculture, so that it is oriented towards a 'farming system' which is environmentally friendly rather than specifically aimed at defined wildlife conservation objectives. This means that a number of requirements compatible with the environment are outlined. The conservation objectives are subsumed under the agricultural systems specified in management prescriptions that set a minimum qualification standard. Therefore, most important are the agricultural production methods which are designed to reduce the negative effects on the environment and simultaneously ensure an adequate income. Following the logic of the 1992 Mac Sharry reform, this scenario will implement the so-called Accompanying measures based on the principle of *decoupling.* This involves the separation between market price, which would move towards the international market, and income support, through the compensation of directly supporting farm incomes. It is applied mainly through EC Regulation 2078/92, which provides compensation for farmers who make a commitment – generally five years – to practise more environmental-friendly agricultural production methods and less intensive agriculture. The objective of the regulation is twofold: a) to combine beneficial effects on the environment with a reduction of surplus production, and b) to compensate the farmers directly for income loss and/or high costs triggered by the adoption of environmentally sensitive production methods. The core of the agri-environmental regulation is an aid scheme consisting of a list of undertakings which farmers can make in return for annual payments. These include: reduction in use of fertiliser and pesticides, extending or converting to organic production methods, traditional extensive system and rare breeds, countryside management, including the management of abandoned farmland and woodland, long term training and advisory per-vices.

**S** 3 - *Ecological:* this is a scenario in which strong limitations are placed on the agrarian structure in order to promote and enhance wildlife conservation interests. A special feature of this scenario is the preservation of original vegetation. Highly polluting forms of agricultural are therefore to be avoided. There are significant possibilities for linking various forms of direct regulation to environmentally sensitive land management practices such as zoning, standards and licensing. Protection of landscape and wildlife perceived to be threatened by either farming or neglect arising from weak economic conditions of the local farming system, are prioritised. Given that uplands and marginal grazing lands are vulnerable to erosion and habitat, this scenario provides a means of simultaneously achieving economic viability for small farms and conserving sensitive land areas.

*S 4 - Market oriented:* this is a scenario oriented towards the liberalisation of the agricultural market. It could be seen as a consequence of the latest agriculture agreement of the GATT-WTO. This implies a reduction of price support and compensation for farmers, where necessary, by direct payments. It would involve the reduction of the price support to world market levels, income compensation (partial or total through direct payments), abolition of quotas, supply management measures and payments for environmental services mainly on a national basis. Compensatory payments are meant to compensate farmers for significant price support cuts. This would lead to a clear distinction between market policy and income support. It could be less distorting from an economic vantage point, by increasing the market orientation of the productive sectors, and help make them more competitive. This strategy towards more open markets and competition separates market policy and income support, thus reducing the gap between its internal price level and world market prices for a number of key products. It could be a useful way to integrate agricultural market policies. Where internal price levels are above world market prices, the risk of stimulating the production of surplus and the consequences for the environment are higher.

## 4. Results of the Regime and the Evamix Methods

### 4.1 Introduction

The starting point of the evaluation analysis is the creation of the *effect table* which shows for all agricultural policy alternatives the foreseeable effects on a set of relevant policy criteria. Thus, we have used a two-stage evaluation procedure. In a first step a set of latent variable has been identified in order to characterise the three important aspects related to the economic, social and environmental dimension of the sustainable policies. Next, for each latent variable a set of observable indicators has been specified.

The evaluation scores of each CAP scenario on each indicator selected are presented in Table 2. A qualitative ordinal scale, indicating the degree of impact in the four scenarios selected (going from a high sensitivity 1 to a very low sensitivity 5).

The table shows also that the number of economic indicators is higher in respect to the social and environmental indicators, so we made an attempt to reduce the economic data set to a limited but representative subset. In this context the application of the regime method has proven to be a helpful tool of analysis. As the first step we then carried out a regime analysis for each individual main criterion of the economic level. Next we repeated this procedure for all the criteria together in order to obtain the final ranking of the four scenarios for all 12 criteria (Table 3). The intermediate results of all pair-wise comparisons of the alternatives are shown in Table 4. The scores in this table indicate the probability that - given the initial ordinal information - the alternative concerned is a dominant one. Table 5 shows on the left the ordinal weights and on the right the ranking scores of the alternative. In order to verify if the same results are obtained adopting different method of evaluation weight, the pair-wise comparison was adopted (Table 7). This method, also known as

Analytical Hierarchy Process (AHP), allows to select the most important of each pair of criteria and subsequently to determine to what extent the first criterion is more important than the other . The method converts this comparison of all pairs of criteria to quantitative weights for all criteria.

In order to test the results obtained from the regime method, we adopted the **evamix** method and as it requires quantitative weights, we determined them again. The pair-ware comparison (Table 9) and Expected value method (Table 10) were applied.

**Table 2. Ordinal impact matrix for CAP scenarios**

| *Indicators selected* | Alternatives | | | |
|---|---|---|---|---|
| | Business as Usual | Opportunity Seeking | Ecological | Market Oriented |
| **A. ECONOMIC**: | | | | |
| **1.General & structural**: | | | | |
| a) Average income of agricultural activity | 3 | 2 | 4 | 3 |
| b) Number of farms | 3 | 3 | 4 | 4 |
| c) Farm size | 3 | 2 | 2 | 2 |
| **2Type of tenure (tenant)**: | | | | |
| d) Number of market-based farms | 3 | 3 | 3 | 2 |
| e) Number of family farms (employing family labour) | 3 | 4 | 4 | 4 |
| **3Production increase** | | | | |
| f) Production of cereal | 3 | 4 | 4 | 5 |
| g) Production of meat | 2 | 4 | 4 | 5 |
| h) Production of permanent crop | 2 | 2 | 3 | 3 |
| **4Agricultural Area in Use (AA)** | | | | |
| i) Permanent pasture and meadows | 3 | 2 | 3 | 4 |
| l)12 arable land | 3 | 2 | 4 | 3 |
| m) Permanent crops | 3 | 2 | 4 | 3 |
| **B. SOCIAL**: | | | | |
| 5. Total population | 3 | 3 | 3 | 4 |
| 6. Employment in primary sector as % of total employees | 4 | 4 | 5 | 5 |
| 7. Increase in labour requirement | 3 | 1 | 1 | 3 |
| 8. Access to the amenities | 2 | 2 | 1 | 3 |
| **C. ENVIRONMENTAL**: | | | | |
| 9. Management of abandoned areas | 4 | 2 | 3 | 5 |
| 10. Forest area | 3 | 2 | 1 | 3 |
| 11. Wetland | 3 | 2 | 1 | 4 |
| 12. Flora and fauna | 3 | 3 | 1 | 4 |

**Table 3.** Reduced impact matrix using the regime method for the economic indicators

| *Indicators selected* | Alternatives | | | |
|---|---|---|---|---|
| | Business As Usual | Opportunity Seeking | Ecological | Market oriented |
| A. ECONOMIC | | | | |
| 1. General & structural: | 0.667 | 1.000 | 0.333 | 0.000 |
| 2. Type of tenure (tenant): | 0.667 | 0.167 | 0.167 | 1.000 |
| 3. Production increase | 1.000 | 0.667 | 0.333 | 0.000 |
| 4. Agricultural Area in Use (AA) | 0.667 | 1.000 | 0.056 | 0.667 |
| B. SOCIAL: | | | | |
| 5. Total population | 3 | 3 | 3 | 4 |
| 6. Employment in primary sector as % of tot. employees | 4 | 4 | 5 | 5 |
| 7. Increase in labour requirement | 3 | 1 | 1 | 3 |
| 8. Access to the amenities | 2 | 2 | 1 | 3 |
| C. ENVIRONMENTAL: | | | | |
| 9. Management of abandoned areas | 4 | 2 | 3 | 5 |
| 10. Forest area | 3 | 2 | 1 | 3 |
| 11. Wetland | 3 | 2 | 1 | 4 |
| 12. Flora and fauna | 3 | 3 | 1 | 4 |

**Table** 4. Probabilities resulting from regime methods (rank order)

| | Business as usual | Opportunity Seeking | Ecological | Market Oriented |
|---|---|---|---|---|
| Business as Usual | 0.00 | 0.00 | 1.00 | 1.00 |
| Opportunity seeking | 1.00 | 0.00 | 1.00 | 1.00 |
| Ecological | 0.00 | 0.00 | 0.00 | 1.00 |
| Market Oriented | 0.00 | 0.00 | 0.00 | 0.00 |

**Table** 5. Regime method with rank orders

| Weights | Ranking |
|---|---|
| Ranking<br>1. General & structural:<br>2. Type of tenure (tenant):<br>3. Production increase<br>4. Agricultural Area in Use (AA)<br>5. Total population<br>6. Employment in primary sector as % of total employees<br>7. Increase in labour requirement<br>8. Access to the amenities<br>9. Management of abandoned areas<br>10. Forest area<br>11. Wetland<br>12. Flora and fauna | Ranking probabilities<br>1. Opportunity seeking 1.00<br>2. Business as usual 0.67<br>3. Ecological 0.33<br>4. Market oriented 0.00 |

**Table** 6. Probabilities resulting from regime methods (pairware comparison)

| | Business as Usual | Opportunity Seeking | Ecological | Market Oriented |
|---|---|---|---|---|
| Business as usual | 0.00 | 0.00 | 1.00 | 1.00 |
| Opportunity seeking | 1.00 | 0.00 | 1.00 | 1.00 |
| Ecological | 0.00 | 0.00 | 0.00 | 1.00 |
| Market oriented | 0.00 | 0.00 | 0.00 | 0.00 |

**Table 7. Regime method with pairware comparison**

| Weights | Ranking | |
|---|---|---|
| Ranking | | |
| 1. General & structural: | Ranking | probabilities |
| 2. Employment in primary sector as % of total employees | 1. Opportunity seeking | 1.00 |
| 3. Agricultural Area in Use (AA) | 2. Business as usual | 0.67 |
| 4. Production increase | 3. Ecological | 0.33 |
| 5. Total population | 4. Market oriented | 0.00 |
| 6. Forest area | | |
| 7. Management of abandoned areas | | |
| 8. Type of tenure (tenant) | | |
| 9. Increase in labour requirement | | |
| 10. Access to the amenities | | |
| 11. Flora and fauna | | |
| 12. Wetland | | |

Table 8. Total dominance resulting from evamix method with pairware comparison

| | Business as usual | Opportunity Seeking | Ecological | Market oriented |
|---|---|---|---|---|
| Business as Usual | 0.00 | - 0.07 | 0.04 | 0.09 |
| Opportunity Seeking | 0.07 | 0.00 | 0.10 | 0.14 |
| Ecological | - 0.04 | -0.10 | 0.00 | 0.03 |
| Market oriented | - 0.09 | -0.14 | - 0.03 | 0.00 |

Table 9. Evamix method with pairware comparison

| Weights | Scores | Ranking | |
|---|---|---|---|
| Ranking | | | |
| 1. General & structural: | 0.264 | ranking | probabilities |
| 2. Employment in primary sector as % of total employees | 0.142 | -1. Opportunity seeking | 0.32 |
| 3. Agricultural Area in Use (AA) | 0.124 | 2. Business as usual | 0.06 |
| 4. Production increase | 0.122 | 3. Ecological | -0.11 |
| 5. Total population | 0.111 | 4. Market oriented | - 0.26 |
| 6. Forest area | 0.064 | | |
| 7. Management of abandoned areas | 0.048 | | |
| 8. Type of tenure (tenant) | 0.048 | | |
| 9. Increase in labour requirement | 0.034 | | |
| 10. Access to the amenities | 0.015 | | |
| 11. Flora and fauna | 0.014 | | |
| 12. Wetland | 0.012 | | |

Table 10. Evamix method with expected value method

| Weights | Scores | Ranking | |
|---|---|---|---|
| ranking | | | |
| 1. General & structural: | 0.259 | ranking | probabilities |
| 2. Employment in primary sector as % of total employees | 0.175 | 1. Opportunity seeking | 0.31 |
| 3. Agricultural Area in Use (AA) | 0.134 | 2. Business as usual | 0.08 |
| 4. Production increase | 0.106 | 3. Ecological | - 0.12 |
| 5. Total population | 0.085 | 4. Market oriented | - 0.28 |
| 6. Forest area | 0.068 | | |
| 7. Management of abandoned areas | 0.054 | | |
| 8. Type of tenure (tenant) | 0.043 | | |
| 9. Increase in labour requirement | 0.032 | | |
| 10. Access to the amenities | 0.023 | | |
| 11. Flora and fauna | 0.015 | | |
| 12. Wetland | 0.007 | | |

**Table 11. Comparison of the rank between the two methods**

| | **Business as Usual** | Opportunity seeking | **Ecological** | **Market Oriented** |
|---|---|---|---|---|
| **Regime** | **2.00** | **1.00** | **3.00** | **4.00** |
| Evamix | **2.00** | **1.00** | **3.00** | **4.00** |

### 4.2 **Ranking**

From the analysis of the results, it is possible to observe that the comparison between the probabilities of the ranking of the alternatives using two different MCA and different techniques of assignments of weights, cannot be considered as significant.

As shown in Table 11, the *opportunity seeking* option has a high ranking. This option certainly has the advantage that it would favour a continuation of the policy begun with the 1992 Mac Sharry reform, which introduced the so-called accompanying measures. These results also seem coherent with the main orientation of the EU document 'Agricultural Strategy Paper' that suggests a 'Developing 1992 approach. The results also match the suggestions contained in the recent GATT-WTO agreement of Marrakesh where the environmental support measures are included in the *green box*.

The high performance of this scenario is furthermore linked to the uncertain nature of the measures foreseen in the 2078/92 E.U. regulation on which it is based. On one hand, the *premium* in favour of the farmers who adopted this incentive scheme is in relation to the loss of income derived from the adoption of environmentally friendly methods. On the other hand, the level of compensation is established on the situation productive standard, and identified on a regional basis instead of specific production situations. Since the loss of income can be different from case to case, entrants can be overcompensated, in that they may enter the scheme at a lower payment level. Recent studies on the effect of the compensation regime, as introduced in the 1992 PAC reforms, showed it can increase the income of the farmers in relation to the structure of the cost and the productive strategies adopted on the farms. The adhesion to the compensation scheme in relation to the change of the production methods can be an advantage for the areas characterised by extensive agricultural production. In particular, through flat standard compensations, farmers who already use extensive farming methods can obtain payments for the maintenance of the condition of production. In this case the standard compensation can be an additional payment for the farmers who adopt extensive farming techniques compatible with the requirements of the environment in the absence of regulatory measures.

The *business as usual* scenario is a less attractive scenario for our case study. The results show some weaknesses and an internal inconsistency of the EU structural policy. One weakness is due to the presence of several schemes that operate in the same area (LFA, 5b programs the LEADER program). If the schemes overwhelm and mitigate the effects of the dominant market policies rather than of territorial bases, they could in some cases be complementary between the programs, but in other cases could generate a duplication, thus causing complexity and confusion. Not only may modernisation actions increase production but they may also encourage the extension of farming into fragile areas in a manner which is capital intensive and environmentally damaging. The structural development policies, especially the investment aids in line with the objective to improve productivity and raise living standards, can threaten the environment when they occur in environmentally fragile areas.

The *environmental* scenario does not appear to be a plausible choice for this area. The low probability emergent from the results indicates a policy strategy mainly based on protection and conservation of habitat, and landscape could be inadequate. Where the objective of this policy is less demanding in terms of a decrease in agricultural production and maintaining good levels of employment, the conservational efficiency of the environmental instruments may be more acceptable.

Although current pressure towards more liberal trade policy is prevalent, a *market oriented* scenario does not seem to be a good choice in this context. Despite some authors who argue that free trade is favourable to economic growth, and that it will increase incomes and hence the demand for protection and enhancement of the environment, our results show that this option could compete with sustainable development in poorer areas and put pressure on natural resources. As a small area with an economy largely based upon local resources, it is likely that the actors within this context will continue to favour a supported agricultural policy. Without compensation for the reduced revenue from a liberal trade policy, it can be supposed that direct agricultural employment will decrease.

## 4.3 The Application of Rough-set Analysis

The results of the regime analysis presented above show some plausible impacts of the selected scenarios in our area of study. Now we are interested to know how these results can be transferred to other situations. Rough-set theory allows us to individuate some characteristics that are not always easy to find, particularly when we are coping with a qualitative technique of analysis which is characterised by the absence of precise information. The implementation of rough-set analysis has proceeded in three successive steps:

- a choice of the information contained in Table 3, which has been analysed
- a classification of this original information: all objects (in this case, the scenarios) subdivided into separate classes, according to the results obtained from the regime analysis
- an investigation of the obtained information system by calculating *reducts* of attributes and applying the minimal decision algorithm.

The following table shows the information that is known about the area of study we have considered.

**Table 14.** Condition attributes **(1-12) and** decision attributes (d)

| | **Attributes** | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Objects | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | d |
| 1 | 3 | 3 | 2 | 3 | 3 | 4 | 3 | 2 | 4 | 3 | 3 | 3 | 2 |
| 2 | 2 | 4 | 3 | 2 | 3 | 4 | 1 | 2 | 2 | 2 | 2 | 3 | 1 |
| 3 | 2 | 4 | 4 | 4 | 3 | 5 | 1 | 1 | 3 | 1 | 1 | 1 | 3 |
| 4 | 5 | 2 | 5 | 4 | 4 | 5 | 3 | 3 | 5 | 3 | 4 | 4 | 4 |

The question now is whether all information contained in the Table is necessary for a consistent decision algorithm. In rough-set analysis a decision algorithm can be reduced without decreasing its degree of consistency. A decision algorithm which does not contain redundant information is called a *minimal decision algorithm.* The results obtained using rough-set analysis, and in particular, the reduction attributes and the decision algorithm, have great practical importance for our case study. The decision algorithm in fact shows the importance of using a minimum number of decision rules and/or attributes appearing in all decision rules so that the decision algorithm is more readable than the original information system. In addition, these results represent knowledge gained by the decision-maker in all cases from his experience recorded in the information system.

The method has been implemented in a computer program RoughDAS by Slowinsky and Stefanowsky (1990) that performs all main steps of the rough-set approach. This software has been used to identify the *reducts* of the condition attributes and to derive minimal decision algorithms.

**Table 16.** Lower and upper approximation of the classification

| | |
|---|---|
| Class 1 lower approximation: 1 object<br>Objects: 2<br>upper approximation: 1 object<br>objects: 2<br>accuracy: 1.0000 | Class 2 lower approximation: 1 object<br>objects: 1<br>upper approximation: 1 object<br>objects: 1<br>accuracy: 1.0000 |
| Class 3 lower approximation: 1 object<br>Objects: 3<br>upper approximation: 1 object<br>objects: 3<br>accuracy: 1.0000 | Class 4 lower approximation: 1 object<br>objects: 4<br>upper approximation: 1 object<br>objects: 4<br>accuracy: 1.0000 |
| Accuracy of the classification: 1.000<br>Quality of the classification: 1.000 | |

The reduction mentioned in the lower part of Table 16 reveals that there is some redundant information, because there are 21 different *reducts* of condition attributes. Each *reduct* forms the basis for a consistent decision algorithm. The relatively large number is plausible, however, as the number of condition attributes is rather high compared to the number of objects. The Table also shows that some condition attributes are more important than others.

**Table 16.** *Reducts* of condition attributes and frequency of attributes in reducts

| Attributes | Reducts of condition attributes |
|---|---|
| 1. General and structural | {11},{10,12},{9},{7,12},{4,12},{3},{2,12},{1},{8,10},{6,10}, {5,10},{4,10},{2,10},{7,8},{4,8},{2,8},{6,7},{4,7},{4,5},{2,6},{2,4}. |
| 2. Type of tenure | |
| 3. Production increase | |
| 4. Agricultural area in use | |
| 5. Total population | |
| 6. Employment in primary sector | |
| 7. Increase in labour requirement | |
| 8. Access to amenities | |
| 9. Management of abandoned areas | |
| 10. Forest area | |
| 11. Wetland | |
| 12. Flora and fauna | |

We have focused on the decision algorithms that are able to generate statements about the classification of the selected scenarios. This means that we have to identify decision algorithms in the form of logical statements of an 'if-then' nature. So from the 21 *reducts* we have selected *reducts* that can be used to predict an unknown classification of the scenarios. It should be noted that almost all the *reducts* containing the attribute 'Forest area', 'Type of tenure' and 'Agricultural area in use' have the higher score. The presence of *reducts* constituted by two variables means that it is impossible to design a consistent decision algorithm in which one attribute is considered without including the other one. Consequently, a subset of *reducts* has been isolated in order to consider the attributes that present the higher frequency. It should also be noted that the sorting rules of all these decision algorithms are deterministic and contain the attributes with the highest frequency.

*Decision algorithm I*
rule # 1: if a10 = 2 then d = 1
rule # 2 : if a8 = 2 and a10 = 3 then d = 2
rule # 3 : if a8 = 5 then d =3
rule # 4 : if a8 = 3 then d = 4

*Decision algorithm 2*
rule # 1: if a4 = 2then d=1
rule # 2: if a4 = 3 and a5 =3 then d =2
rule # 3: if a4 = 4 then d = 3
rule # 4: if a5 = 4 then d = 4scenario

*Decision algorithm 3*
rule # 1: if a10 = 2, then d = 1
rule # 2: if a6 = 4 and a10 = 3, then d = 2
rule # 3: if a10=1 then d = 3
rule # 4: if a6 =5 and a10 = 3 then d = 4

The application of the rough-set approach shows how knowledge about the impact of agricultural policy scenarios can be analysed and reduced. The main problems were to reduce the original knowledge in such a way that the decision (the scenario suitable for the case study) can be made using a minimal set of condition attributes. All the *reducts* selected have generated deterministic rules.

By analysing, for example, the *reduct* which forms the basis for the *minimal decision algorithm* 2, we see that it contains the attributes ‘Agricultural area in use’ and ‘Total population’. According to the decision rules, we can suppose that if in a protected area the ‘Agricultural area in use’ has a high score, the scenario ‘business as usual’ has an high probability for being suitable because it offers good opportunity for the improvement of agricultural structures. If ‘Employment in primary sector’ and ‘Forest area’ are considered together and they have intermediate scores, then the scenario ‘opportunity seeking’ is likely to be more appropriate, because it is based on a compensation system for lost income derived from adopting environmentally friendly methods. If we consider in the decision algorithm only the attribute ‘Forest area’ with a high score, then we can select the environmental scenario since it has conservation objectives. Finally, if the attribute ‘Employment in primary sector’ has a very low score and is associated with ‘Forest area’, and has an intermediate score, we can suppose that the scenario falls into ‘market oriented’, since it competes with the sustainable -development of poor areas especially from a social point of view.

## 5. Conclusions

In this paper a methodology is presented to evaluate the effectiveness of agricultural policies in promoting sustainable rural development in a representative area of study in the south of Italy.

The tools of analysis described above have shown themselves to be suitable for predicting the effects of agricultural policies and for anticipating the consequences of the different policies by considering a multilevel strategy.

The integrated methodology presented has permitted us to develop a procedure for exploring the data obtained in a ***primary analysis,*** to evaluate the ranking of the alternatives selected, and in a ***secondary analysis,*** that is a re-analysis of data that has already been used and has been conducted, to reaffirm answers to the question raised in the regime analysis as well as to attempt to answer possible new questions. In particular, rough-set theory in this contest has been considered as a tool to support knowledge accumulation and to improve the efficiency of the research.

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