A DECISION SUPPORT SYSTEM FOR REGIONAL SUSTAINABLE DEVELOPMENT: THE FLAG MODEL

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Abstract

This paper presents a new approach to the analysis of spatial sustainability, with a particular view on agriculture. After a methodological introduction, a new tool - the so-called Flag model - is introduced in order to assess the degree of sustainability of various policy alternatives. The model is tested by means of a case study for the island of Lesvos, Greece.

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1. Introduction

In recent publications (see Van den Bergh 1996, Giaoutzi and Nijkamp 1993) the issue of **regional sustainable development** has been considered under the three broad headings of **economic**, **social** and **ecological** concerns in a demarcated geographical area. The economic aspects are related to income, production, investments, market developments, price formation etc. The social concerns refer to distributional and equity considerations, such as income distribution, access to markets, wealth and power positions of certain groups or regions etc. And the environmental dimensions are concerned with quality of life, resource scarcity, pollution and related variables. Clearly, the above mentioned three classes of variables are strongly interlinked, but they are to a certain extent also mutually conflicting. Putting more emphasis on a higher availability of the one category tends to reduce the availability or usability of either of the other ones. This may in a stylized way be depicted by means of the following Möbius triangle (see Figure 1).

Two observations are in order in relation to Figure 1. The three force fields are essentially latent variables which have to be measured (or approximated) by means of manifest, observable **indicators**. And secondly, the actual state of (un)sustainable development is never static in nature, but always in a state of flux (see Kay 1991, Norgaard 1994). Consequently, there is a need for **monitoring** actual development over time and for identifying changing conflicts of interest between actors.

In general, it would be desirable to construct a comprehensive impact model which would encapsulate the complex interacting patterns of regional development and related land use in relation to social and environmental variables. Such a modelling activity could take the form of either an econometric model (validated by empirical data on solid statistical grounds) or a simulation model (calibrated at best by plausible information). In light of the near-impossibility to construct for each individual regional development plan or project a dedicated model, in practice one often resorts to an ad hoc impact assessment, based on simple cause-effect relationships. Such a more limited approach has obviously several shortcomings, but has the advantage that it is manageable, practical and based on local expertise. In such a case, foreseeable consequences of various types of human or government intervention can be assessed by a combination of ad hoc surveys, comparative

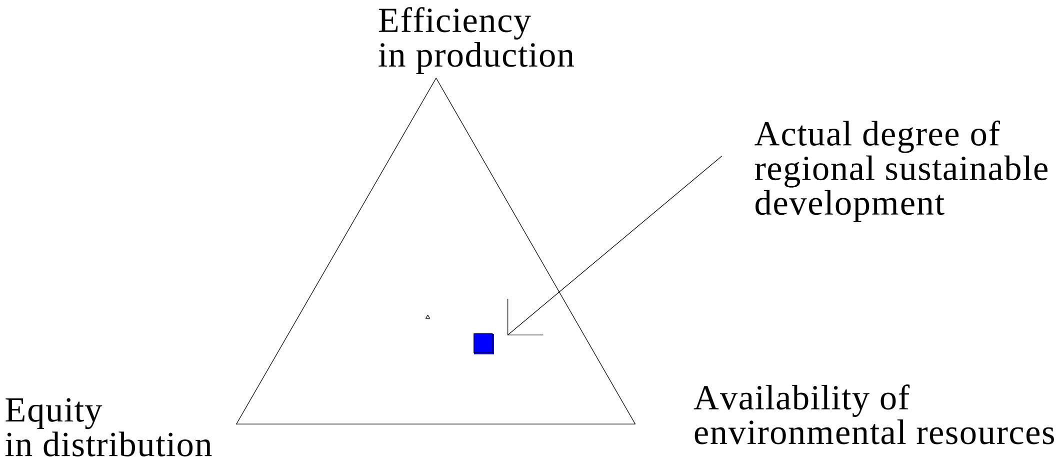

Figure 1 Möbius triangle illustrating mutual dependence of policy goals.

studies, simple correlation techniques, local experts' views and Delphi methods. The uncertainties involved may then be gauged by exercising a systematic sensitivity analysis in a broad range of uncertainty intervals around the information used.

Finally, it is noteworthy that the **spatial** scale of analysis may be handled by using geographical information systems (GIS). Such modern GIS techniques have been instrumental in developing interactive modes between quantitative modelling and spatial mapping (see Giaoutzi and Nijkamp 1993). Especially when regional development plans have a bearing on land use (e.g., in relation to agricultural policy aiming at food security, self-reliance or pesticides management), GIS may offer a powerful analytical tool for spatial sustainable development (see Douven 1997).

2. Regional Sustainable Development: A Normative Concept

In the present section we will address the normative aspects of sustainable development. The rising popularity of the notion of **sustainable development** has increasingly provoked the need for an **operational** (i.e., practical, measurable and policy-relevant) description or definition of this concept. The standard, widely-cited WCED definition of sustainable development as “a development that fulfils the needs of the present generation without endangering the future needs of future generations” is a meaningful starting point, but fails to offer manageable guidelines for sustainability strategies of (local, regional, national or international) decision-making bodies or other actors. The complementary description of sustainable development by the IUCN/UNEP/WNF emphasises from a more ecological angle the need for “improving the quality of human life while living within the carrying capacity of supporting ecosystems”. Since the beginning of the world-wide debate on sustainable development, a massive volume of literature has been published on this notion. So far, no uniformly accepted definition has been offered, although the basic intentions of the sustainability concept are clear: it aims at directing decisions of policy bodies and private actors towards a joint state of the economy (or society at large) and the ecology, such that the needs of current and future generations are fulfilled without eroding the ecological basis for a proper welfare and activity level of these generations.

A major issue in sustainability policy is the question how sustainability can be identified as a normative orientation for policy. In this context, sometimes reference is made to the need to maintain natural (or environmental) capital (see e.g. Pearce and Turner 1990). In other cases, the need to ensure an uninterrupted flow of revenues from a given capital stock in a foreseeable time horizon is emphasized. Notions of sustainability and irreversibility are at stake here (see Georgescu-Roegen 1971 and Ayres 1978). The concepts of weak and strong sustainability are also used to clarify some of the complex trade-off issues involved. In general, it seems feasible to operationalize regional sustainability by specifying a set of minimum (or critical) conditions to be fulfilled in any development initiative for a region. These conditions may relate to economic, social and environmental objectives (see Pearce et al. 1988). Such critical conditions are usually not specified via one single indicator, but require multiple criteria. As a consequence, **multiple criteria analysis** may be seen as a helpful operational instrument for regional sustainable development policy. Application of this analysis framework may also be meaningful in the context of the precautionary principle advocated by Perrings (1991). Consequently, it seems a practical approach to describe environmental considerations and concerns mainly in terms of **reference values or threshold conditions** (limits, standards, norms) on resource use and environmental degradation (or pollution). This is in agreement with popular notions like carrying capacity, maximum yield, critical loads, environmental utilization space, maximum environmental capacity use and so forth. It has - despite a variety in approaches - increasingly become clear that sustainable development is a normative development concept. We will in this article adhere to this approach by using the notion of a critical threshold value as a normative form of reference in a multiple criteria modelling context.

The **normative** nature of sustainability requires therefore, in general, a framework of analysis and of expert judgement which should be able to test actual and future states (or developments) of the economy and the ecology against a set of reference values. This requires three important components in any sustainability analysis for a region:

- ☐ identifying a set of **measurable sustainability indicators**
- ☐ establishing a set of **normative reference values** (e.g., carrying capacity or critical load)
- ☐ developing a practical **impact methodology** for assessing future developments (as a result of changes in behaviour, exogenous developments or policy orientations).

Clearly, a major problem in operationalizing the notion of sustainable development is its **lack of specificity** in concrete circumstances (e.g., particular regions or economic sectors). A sustainable development in a given region or sector is not necessarily sustainable elsewhere. Thus, sustainability is **context-specific** and hence co-determined by needs and opportunities in a particular region or sector. This observation has in the mean time led to a more flexible delineation of sustainable development by referring to **regional or sectoral sustainable development**, witness popular notions like ‘sustainable city’, ‘sustainable transport’, ‘sustainable tourism’ or ‘sustainable agriculture’.

In this framework also FAO has developed a specific definition by encapsulating the interest of agricultural activities. Sustainable development is in the FAO description “environmentally non-degrading, technical appropriate, economic viable and socially acceptable”. Later on, this broad notion was put in a more precise context by specifying the features of a sustainable development as follows: “Resource use and environmental management are combined with increased and sustained production, secure livelihoods, food security, equity, social stability, and people’s participation in the development process”. This means clearly that in the FAO view this notion refers to a balance between environmental, social and economic objectives to obtain maximum welfare (broad definition), while taking account of external factors (such as technology). Thus, this definition regards sustainability as a balanced state in a force field of three distinct motives, each with its own indigenous value. It is also clear that agriculture comprises various sectors (such as cattle breeding, food production, forestry, fishery etc.) each of which may require its own specific operational definition within the above reference definition.

Nevertheless, it seems plausible to extend the above FAO definition by describing sustainable development in a given region more precisely as **a balanced development policy for all resources in a region concerned, to such an extent that a maximum level of welfare (including quality of life) - now and in the future - is achieved through a co-evolutionary strategy focused on environmental, social and economic objectives and/or constraints, while taking into consideration the impact of exogenous circumstances on the region concernd**. Clearly, the above mentioned analytical steps, viz. **indicators, reference values** and **impact analysis**, will play a crucial role in any attempt at assessing the degree of sustainability (or at least its qualitative direction) in a relevant area.

In addition to a practical methodology for sustainability analysis for the agricultural sector, there is also a need to design a **software framework** for this approach, so that - based on operational descriptions of sustainability variables - also a user-friendly computerized set of guidelines for empirical policy experiments (e.g., scenarios) is built up. Such a self-contained sophisticated software will also be used in the empirical part of our study.

3. Towards Regional Sustainable Development Indicators

The judgement of a regional development process requires a set of relevant sustainability indicators. In a recent paper by Boisvert et al. (1996), the following considerations were formulated for the identification of practical sustainability indicators:

- ☐ they should be representative for the structure and dynamic behaviour of the system concerned
- ☐ they should be constructed on a spatial and temporal scale that is relevant to natural, economic and social phenomena
- ☐ they should be presented in a format suitable to decision-making, i.e. quantifiable, legible and transparant
- ☐ they should include distributional dimensions
- ☐ they should specify threshold values in a normative policy context
- ☐ they should be able to be used in forecasting.

It is clear that there is not an unambiguous set of environmentally sustainable development indicators, although the pressure-state-response (PSR) model developed by OECD (1993) offers an interesting operational framework.

The methodology to be developed here aims to offer a broad framework for decision support for regional sustainable development and may be useful for a wide array of applications, such as soil conservation, development of agro-industry, forest management, irrigation, watershed management, pesticides use, changes in vegetation, alternative harvest methods and so forth. For all such issues the idea is to offer a widely applicable framework for sustainable development planning, based on a systematic scoping and monitoring of sustainability opportunities and strategies. Clearly, this requires an identification of various classes of relevant indicators. Examples of environmental indicators are:

- ☐ impacts on ecosystems
- ☐ impacts on water quality and quantity
- ☐ effects on climate change and atmosphere
- ☐ use of (renewable and non-renewable) resources
- ☐ generation and disposal of waste
- ☐ changes in land use and landscape
- ☐ visual intrusion
- ☐ impacts on human health.

Such a set of classes of indicators is however not exhaustive; the ultimate choice of relevant indicators depends on the general policy field under investigation and on the specific policy issues and strategies to be envisaged (e.g., new cultivation methods, use of herbicides or pesticides, change in land ownership, changes in animal husbandry, changes in the natural resource base, new quota systems for fishery etc.).

By assessing all relevant effects, a data base has to be created which may serve to judge whether a certain regional development is sustainable or not, whether policies have been more or less successful, and whether new initiatives support sustainable development of the area. This requires in all cases some sort of an impact assessment (either ex post or ex ante), which means that the status quo (the initial conditions), the extent and type of intervention (e.g., policy), and the resulting state have to be assessed.

In order to assess the level of **economic** welfare, we usually look at GNP per capita. This is a macro-economic tool which measures production and economic growth in an aggregate and quantitative way. In principle, this measure can be further subdivided into regional or sectoral measures (including the social distribution of GNP). But average GNP does not seem to be helpful in measuring sustainable development. In this respect, the Human Development Index (HDI) advocated by UNDP (1990) seems to offer more opportunities as an alternative indicator for development, as it incorporates both social and economic indicators. This approach is based on the assumption that human development is the process of enlarging people’s choices, where the most basic rights are concerned with healthy life, education and a decent standard of living. Nevertheless, it is still difficult to include also many environmental aspects. For **social** and **environmental** values such composite indicators are even more difficult to define. In general, an indicator is a partial, representative and quantitative mapping of a compound phenomenon into a one-dimensional measure which is relevant for decision-making. Such indicators have to fulfil normally the following conditions:

- scientific basis
- measurability
- predictability
- user - and policy-relevant
- flexible space-time aggregation scale
- monitoring capability
- compatibility with available information bases.

Only under such conditions may we expect indicators to represent a high quality and reliability, a high policy relevance and a user manageability. It is clear that in all cases policy-relevant indicators should be concerned with both **socio-economic** and **environmental** aspects of agricultural development. Examples of elements of a socio-economic profile in the agricultural sector are:

- income per capita
- skewness of income distribution
- unemployment level
- average duration of unemployment
- investments
- growth in production
- access to and use of technological knowledge and equipment
- training and eductional level
- demographic structure and growth
- cultural inertia, and so forth.

As will be suggested later on, these indicators can be subdivided into **efficiency**-oriented and **equity**-oriented indicators. Examples of environmental indicators are:

- health condition
- quality of and access to health care systems
- longevity
- infant mortality
- food supply
- nutrition level

- air pollution
- soil pollution
- noise
- landscape deterioration
- general natural resource condition
- top soil quality
- pollution abatement technologies
- distribution of pollution over various social classes or regions, and so forth.

Environmental externalities can also be subdivided into **emissions of pollutants**, and **ambient** concentrations in various areas, a distinction which runs **parallel to efficiency and equity** as level and distribution indicators. Finally, we may also separately include pollution abatement technologies for each relevant area or time period.

The above lists of indicators are only indicative and have to be operationalized for specific policy questions and geographical areas. A main problem is of course that the number of indicators always tends to grow towards unmanageable sizes. A generally useful methodology for limiting the number of indicators, while nevertheless maintaining completeness and cohesion, is to use a **hierarchical** approach, based on a tree-like composition for aggregation and disaggregation of indicators, so that a distinction between single and composite indicators can be made (see Figure 2). Such a tree-like structure can of course also be further distinguished according to relevant time scales (e.g., medium and long-term) and geographical scales (e.g., district or country). In this case, GIS may be very appropriate.

Having outlined now the most important principles for the identification of indicators, we will in the next section pay attention to the selection of reference values.

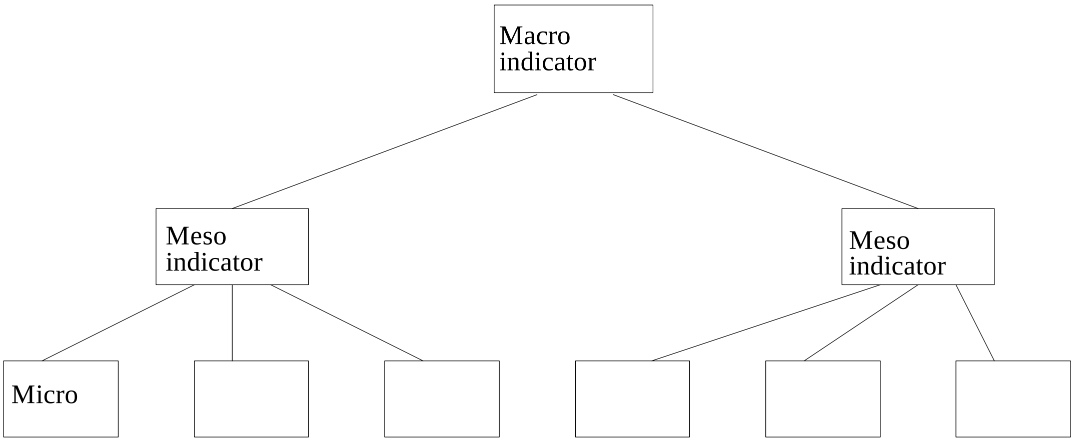

Figure 2 A hierarchical measurement scheme.

4. Selection of Reference Values for Sustainability

In the previous section the emphasis has been laid on the identification and definition of sustainability indicators. It became clear that there is no generic set of such indicators, as site-specific conditions, policy preferences and socio-economic conditions determine the relevance of each specific indicator for policy-making. The same remarks also apply to the interpretation to be given to quantitative values of such indicators. The question whether a certain socio-economic and environmental resource development is balanced - now and in the long run - is co-determined by value statements in a political context which may differ over space and time. Nevertheless, certain developments can be classified as clearly unsustainable (e.g., if they lead to soil erosion, desertification or unlimited extraction of scarce ground water). In this context, the notion of **carrying capacity** is of great importance, as it indicates the maximum environmental resource use that is still (marginally) compatible with an ecologically sustainable economic development. This means that this concept refers to a threshold value that cannot be exceeded without causing unacceptably high damage and risk to the environment. Such a carrying capacity concept is sometimes also referred to as environmental utilisation space or maximum environmental capacity use (see Weterings and Opschoor 1994). In order to emphasize the need for unambiguous quantification, we will use the notion of a **critical threshold value** (CTV) here.

Clearly, for each sustainability indicator - be it environmental or socio-economic - a CTV has to be specified, so that the entire set of CTV's may act as a reference system for judging actual states or future outcomes of scenario experiments. If a certain indicator has a cost meaning (i.e., the lower the better), then its corresponding value means that a higher level than CTV means a dangerous or threatening development which is in a strict sense unacceptable. An outcome of the sustainability indicator that is lower than the CTV is in principle desirable and more sustainable. The reverse reasoning applies to benefit indicators. We will use here in our interpretative analysis for the sake of simplicity only cost indicators, as benefit indicators can easily be transformed into cost indicators.

We may now assume - after re-scaling - the following range of values of each sustainability indicator S:

$S_{min} = 0$
$S_{max} = CTV = 100$

This can easily be depicted in the following way:

```
                              CTV
      |---------------------------------|
  0                                    100
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Figure 3. A standardized CTV representation

A major problem faced in practice is now the fact that the CTV level is not always unambiguous. In certain areas and under certain circumstances different experts and decision-makers may have different views on the precise level of an acceptable CTV. It may even happen that the CTV is sometimes fuzzy in nature. This particular case requires a different approach, as outlined in a study on fuzzy assessment (see Munda and Nijkamp 1995).

A relatively simple and manageable approach to the above uncertainty problem is to introduce a band width for the corresponding value of the CTV, defined as CTV_{min} and CTV_{max}, respectively. CTV_{min} indicates a conservative estimate of the maximum allowable threshold of the corresponding sustainability indicator (min-max condition). CTV_{max} on the other hand refers to the maximum allowable value of the sustainability indicator beyond which an alarming development will certainly start (max-max condition). This can be represented as follows (see Figure 4).

CTV_{min} CTV CTV_{max}

|-----------------------------|--------------|------------|------

0 A B 100 C D

Figure 4. A range of CTV values

The line segments can now be interpreted in the following imaginative way:

☐ section A:	**'green'** flag:	no reason for specific concern
☐ section B:	**'orange**' flag:	be very alert
☐ section C:	**'red'** flag:	reverse trends
☐ section D:	'**black**' flag:	stop further growth

The main problem is now that we have **multiple** sustainability indicators, so that the question is how to manage a complex system in case of different perceptions or views on critical loads or values. This can be illustrated by means of a situation of two indicators, denoted by superscripts 1 and 2. We assume that for both indicators a critical carrying capacity (CTV^1 and CTV^2, respectively) can be identified, but that the range of uncertainty around these threshold values is different. This is illustrated in Figure 5.By superimposing now both ranges of outcomes for the two indicators concerned, we may in principle identify six general areas reflecting different states of sustainability:

(a) entirely sustainable
(b) almost sustainable
(c) moderately sustainable
(d) moderately unsustainable
(e) almost unsustainable
(f) unsustainable

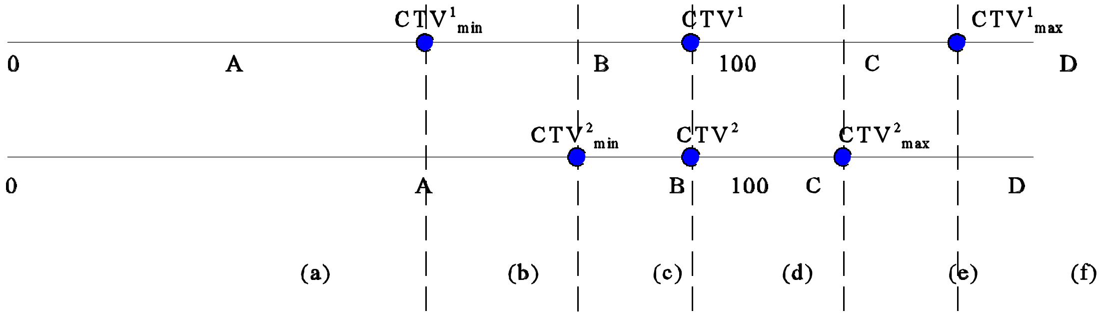

Figure 5 A situation of multiple CTV domains

Clearly, if the states of different regions (or of the same region under different development scenarios) are compared, an unambiguous conclusion may not always be inferred, as sustainability indicators may fall in entirely different domains. This is the reason why multiple criteria methods may be helpful, as these evaluation methods allow to introduce different weights for different indicators (or criteria). A further refinement can be achieved in constructing a diagram in which the indicators are put on the two respective axes. The CTV for both indicators form the origin and the CTV_{min} and CTV_{max} are also given. This divides the plain into 16 areas, each indicating a combination of sustainability for the two indicators involved (see Figure 6). In this way the combined scores for two indicators can be depicted for all scenarios involved, which facilitates an easy comparison of the scenarios.

It is evident that a generalization towards multiple sustainability indicators is straightforward. This typology - by using multiple criteria techniques - enables us to infer conclusions on the actual or predicted socio-economic and environmental achievement of a regional system, while respecting local expertise and site-specific or sector-specific conditions. It puts of course a heavy claim on the establishment of the CTV_{min} and CTV_{max} values and on criteria on (or indicator) weights, but it is hard to see how clear conclusions

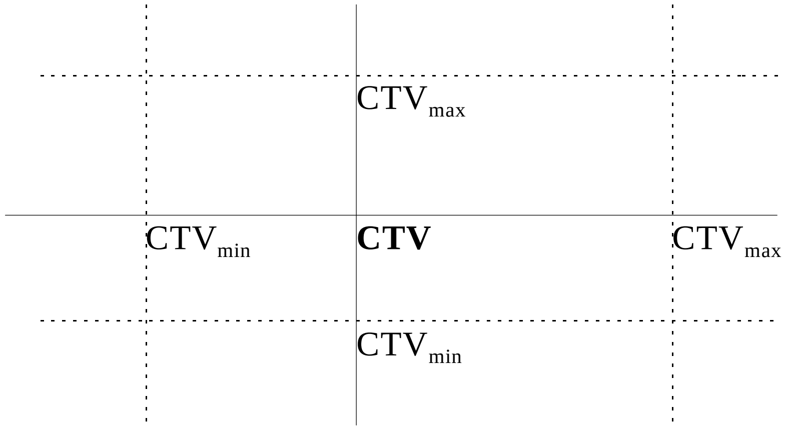

Figure 6 Multiple CTV domains in two dimensions

can be drawn on sustainability issues in a region, if no normative standards or threshold values are known.

It is of course possible to make a further subdivision of the various sustainability indicators by using the above mentioned three main categories incorporated in conventional policy analysis, viz. efficiency, equity and environmental quality (see also Figure 7). In this way also conflicts between economic, social and environmental objectives can easily be identified.

Finally, it is of course also possible to make a further distinction between various regions or districts, so that the analysis outlined above seems to be an appropriate tool for spatial sustainability analysis. This leads us also to the distinction between **internal** and **external** sustainability. Internal sustainable development in a certain area means that only within the area concerned the sustainability conditions are fulfilled; no consideration is given to impacts of regional activities on sustainability conditions in other (e.g., adjacent) areas. External sustainability incorporates also spatial interaction effects (e.g., diffusion of pesticides) on other areas and refers to overall sustainability for all relevant areas in a certain spatial system. A prerequisite for applying the above methodology is of course that (i) sustainability indicators are known in advance, (ii) a set of critical threshold conditions (and ranges therein) is known, and (iii) an assessment can be made of the consequences of various exogenous changes or policy responses in the regions concerned.

	sustainable	almost sustainable	moderately sustainable	moderately unsustainable	almost unsustainable	unsustainable
●efficiency ●equity ●environmental quality						

Figure 7. A representation of sustainability categories for three main policy dimensions

5. A Multiple Criteria Decision Support Model for Regional Sustainable Development

As mentioned above, a sustainability policy should try to optimize economic, social and environmental concerns simulaneously. Formally, this leads to the following multiple criteria (or vector optimization) problem:

$$\begin{array}{l} \max \underline{w} = (x_1, x_2 , x_3) \\ \text{with} \\ x_1 \in K_1 \; x_2 \in K_2 , \; x_3 \in K_3 \end{array} \qquad (5.1)$$

where x_1, x_2 and x_3 stand for economic, social and environmental objectives, and where K_1, K_2, K_3 represent the boundary conditions for x_1, x_2 and x_3, respectively. In a discrete multiple criteria problem x_1, x_2 and x_3 are limited by the given number of alternatives, a_1 ...,a_N, so that the problem is essentially of an integer nature which can be represented as follows:

$$\text{Max} \begin{pmatrix} x_1 \\ x_2 \\ x_3 \end{pmatrix} = \begin{array}{c} a_1 \ldots\ldots\ldots\ldots\ldots\ldots\ldots a_N \\ \begin{pmatrix} & & \\ & & \\ & & \end{pmatrix} \end{array} \begin{pmatrix} \\ \underline{\delta} \\ \\ \end{pmatrix} \qquad (5.2)$$

where $\underline{\delta}$ is a unit vector. The main problem is of course to identify which element 1 in the $\underline{\delta}$ vector leads to a maximum $\underline{w}$. This requires 2 steps:

☐ the assessment of the impact matrix at the right hand side of (5.2)

☐ the application of an appropriate multiple criteria method (including a weight vector for x_1, x_2 and x_3).

As mentioned above, for ad hoc regional development plans the economic, social and environmental effects of each alternative a_1, ..., a_N can be assessed by using available local information and local expert knowledge. The solution of the resulting multiple criteria decision method can then be found by applying an evaluation method that is suitable for the information level given in (5.2) (see for details Nijkamp et al. 1991). In many cases, it turns out that the so-called regime method offers a good potential for arriving at a comprimise solution among conflicting decision options.

In our case, two more remarks are in order. In the first place, as mentioned above, the variables x_1, x_2 and x_3 are usually latent variables which have to be approximated by measurable indicators, following e.g. the hierarchical scheme of Figure 2. This will be further illustrated in our empirical case study later on.

In the second place, our sustainability analysis may enforce us to impose on our optimization scheme the CTV's, as discussed above. This may imply the following extra conditions for (5.2):

$$x_1 \leq CTV_1$$
$$x_2 \leq CTV_2 \tag{5.3}$$
$$x_3 \leq CTV_3$$

This can of course be extended towards ranges of CTV values, as illustrated in Figures 4 to 6. In that case, a fairly complicated Decision Support System may emerge, which requires also rather cumbersome software in order to employ the above described flag model.

When conditions (5.3) are taken into account, the evaluation basically results in a two-step procedure. In the first step the alternatives are checked for sustainability, by employing (5.3). In the second step the regime method - or any other suitable multiple criteria method - is used to decide upon the best alternative from those that guarantee a sustainable development. Software programmes for MCA methods are readily available (see e.g. Janssen 1992); a computer programme executing the flag model as described in Section 4 - which essentially captures conditions (5.3) - was developed recently by the authors. We will give a concise description of its main features.

The flag model checks the sustainability conditions of scenario's or alternatives. It does so for the three dimensions identified earlier, viz. environmental, social and economic. Three main steps can be identified in applying the programme:

- ☐ assembling the input for the programme
- ☐ construction of indicators with accompanying threshold values
- ☐ examination of sustainability of scenarios.

Further, the programme can take any number of scenarios into account. Besides a straightforward evaluation of a single scenario, it offers also the option to compare the sustainability scores of two scenarios. This is not meant to replace the multicriteria evaluation method, but only to get a better insight into the relative scores of any two scenarios, and to get more insight into the structure of the data. We will now elaborate on the three steps mentioned above.

The **input** for the programme basically consists of the impact matrix (5.2). Thus, for each indicator its estimated outcome in each scenario is given. However, the number of indicators is not restricted to three (an environmental, social and economic one), but it can be any number. Indeed, the indicators of (5.3) are composite indicators, and the programme is written to facilitate the factual composition. This means that the composing elements, which we call **basic indicators,** are to be provided as input for the programme.

Consequently, two additional pieces of information are to be given as well, namely whether a specific basic indicator is related to environmental, social or economic issues (which we denote as the **class** of the indicator) and whether the basic indicator is a cost or benefit (denoted as the indicator **type**).

Finally, since each basic indicator is an indicator in its own right, CTVs have to be specified for each indicator. This serves two purposes. First, the CTVs for the composite indicators of (5.3) are usually difficult to derive, in particular given the latent variable character of x_1, x_2 and x_3. Yet, when the CTVs of the basic indicators are known, the CTVs of the composite indicators can analogously be derived. So, e.g. let y_l, $l = 1..m$, be the basic indicators of the environmental class, and let $CTV(y_l)$ be the CTV of y_l. Further, we assume that

$$x_1 = f_1(y_1,\dots,y_m), \tag{5.4}$$

then, we may postulate that

$$\mathrm{CTV}(x_1) = f_1(\mathrm{CTV}(y_1),\dots,\mathrm{CTV}(y_m)). \tag{5.5}$$

with of course similar expressions for the other two classes. We will discuss the pros and cons of this approach below. The important point here is that (5.5) requires the CTVs of the basic indicators, and therefore they have to be provided as input information.

The second reason why CTVs of basic indicators are to be given is that the programme not only works for composite indicators. Instead, there are also possibilities to evaluate scenarios on the basis of basic indicators as well. Again this requires that CTVs for these basic indicators are given, and hence are required as input.

The basic indicators are used to construct a list of indicators that are used in the evaluation part of the programme. This list of indicators is labelled the **working set of indicators** (WSI). The WSI counts at least three elements (viz. one environmental, one social and one economic indicator), while the upper limit is in principle only set by computational restrictions. Moreover, each WSI by definition contains at least one indicator of each class.

There are three ways to define an indicator of the WSI. The first is simply to directly put a basic indicator on the list. This is the most simple and direct way. Secondly, two or more basic indicators can be used to construct a new indicator, which is put on the list. This is a generalization of the idea captured in (5.4). Usually such a derived **constructed** indicator can be an element of the WSI together with the basic indicators that are used in its construction. For example, when population and crop yield are basic indicators, per capita crop yield may be computed as a constructed indicator. A user of the program may well decide however, that all three mentioned indicators are to be included in the WSI. So, the construction of indicators essentially increases the number of indicators available for the WSI. Thirdly, a number of indicators of the same class can be aggregated into one **aggregated** indicator. The method of aggregation is taking a weighted average. This is not restrictive however, since other methods of aggregation can be defined as well in computing a constructed indicator. For example, a series of data on various types of crop yields may be aggregated into one crop yield (aggregated) indicator. When a basic indicator is used for an aggregated indicator, it is not logical - though not impossible - to include both this basic indicator and the aggregated indicator for the WSI. The basic idea of aggregation is that information available in a large number of basic indicators can be meaningfully aggregated into one aggregated indicator. Therefore, it is pointless to use the information contained in a basic indicator twice, once as an indicator itself, and once as a part of the aggregated indicator. Consequently, the use of aggregated indicators reduces essentially the number of available indicators.

We recall that each indicator has a corresponding class attribute. For basic indicators and aggregated indicators this is clear by definition (since aggregation can only be performed on indicators of the same class). For constructed indicators, this is not immediately clear however, since it is possible to combine indicators of different classes. In the above example an economic indicator (crop yield) was combined with a social indicator (population). Consequently, the class of a constructed indicator has to be defined in the course of the analysis.

The transformations that are used to derive constructed or aggregated indicators are in the first instance also used to derive the associated CTVs. This is a straightforward generalization of (5.4) and (5.5). In addition, the user of the programme is given the option to set the CTVs by hand. This holds not only for constructed and aggregated indicators, but also for basic indicators. There are two reasons for this extra possibility. First, the input, or the transformations in case of constructed and aggregated indicators, may show unrealistic CTVs. Secondly, the predifined CTVs may be realistic, but it may be that individual users do not agree with these CTVs, or that a user may wish to perform some sort of sensitivity analysis etc.

The working set of indicators is **evaluated** in a separate module of the programme. There are essentially three approaches to this evaluation: a qualititave, a quantitative and a hybrid approach. The inclusion of three types of information is inspired by the idea that users may be in need of different levels of detail. For a quick look at the scenarios the qualitative forms are perfectly suitable. This type of analysis is comprehensive and easy to interpret. For a more precise evaluation the quantitative approach gives more detail. Its lack of comprehension makes a direct interpretation often difficult, however. The hybrid form, which combines the qualitative and quantitative aspects, provides almost full information in still manageable forms. Nevertheless, the wealth of information it provides makes it difficult to concentrate on certain aspects, and the danger of drowning into detail is clearly present. Thus, the three modes of analysis complement each other, rather than being a substitute.

The **qualitative** approach only takes into account the colours of the flags (see Section 4). This entails flag counts and cross tabulation (when two scenarios are compared), pie charts and stack bars to visualize the number of coloured flags. These summary statistics are also available for the subsets of indicators for the three classes. Obviously, the various qualitative methods do not give different outcomes, but merely represent various ways to display the same information. Hence a user can choose the type of display that suits him/her best.

For the **quantitative and hybrid** form, a transformation of the underlying outcomes of the indicators is required (except for the simple tabular presentation of the data). This transformation is necessary, since the indicators are measured on very different scales. To present the information in the data in a compact way, standardization is very useful. Fortunately, this standardization can be accomplished relatively easily and - given the present context - almost indisputably. This is achieved by rescaling the outcomes of the indicators on a scale ranging from -1 to 1, where the value of -1 is associated with CTV_{min} and 1 is associated to CTV_{max}. Furthermore, the standardized value 0 relates to CTV (we refer to Section 4 for this notation; in the case of benefit indicators the standardization alters in an obvious way). So, let x be the value of the indicator with CTV_{min}, CTV and CTV_{max} the three relevant threshold values, and s(x) the standardized value, then the appropriate formulas for this transformation are:

$$s(x) = (CTV - x) / (CTV_{min} - CTV) \qquad \text{for } x < CTV$$

$$s(x) = (x - CTV) / (CTV_{max} - CTV) \qquad \text{for } x > CTV.$$

The standardized values are in the first place used to construct a table with descriptive statistics, containing for all indicators and for each class separately the mean, standard deviation, minimum and maximum. When two scenarios are compared, also the correlation is given for each class (and overall).

Finally, the hybrid form is perhaps the most informative. It takes into account both the qualitative aspect of the flag colour and the quantitative aspect of in the intervals associated with the flags. For example, suppose that for a cost indicator CTV = 100, CTV_{max} = 120 and that for three scenarios the indicator values are 101, 119 and 121, respectively. Then the hybrid form shows that the first two indicators lead to red flags, while the third indicator is black-flagged, while it also shows that the outcomes for the second and third indicator are very close, while the score for the first is significantly better.

This is achieved by plotting the outcomes on an interval, which is distinctly divided into four sub intervals, viz. a green, orange, red and black one. Moreover, using the standardization technique described above, all indicators (for one class) can be plotted on one interval. When two scenarios are compared a plane is used, divided into 16 squares, each representing a combination of green/orange/red/black scores. Each indicator is depicted in this plane, where the scores for one scenario are measured along the horizontal axis, and the score for the second scenario on the vertical axis. In addition, in this plane the 45 degree line indicates the position for which an indicator has the same score for both intervals.

In the next section we will illustrate this decision support system for a real-world case study of the agricultural system of Lesvos, Greece.

6. Development Scenarios for the Island of Lesvos

The previous Decision Support Model will now be illustrated for a case study related to the island of Lesvos, Greece. The main goal will be to evaluate various development policy scenarios for the island, based on the above described flag model for regional sustainable development. The use of policy scenario analysis (or strategic choice analysis) enables a systematic way of scanning various uncertain future choice possibilities. In this context, a scenario is seen as a possible image of future events, in particular, a policy to be pursued. Each scenario can be mapped out by a certain set of values of sustainability indicators, gauged by means of an impact assessment approach. The case of regional sustainable development policy on the Greek island of Lesvos will now be used to test the validity and feasibility of our flag model.

The island of Lesvos is located in the Aegean Sea, just in front of the Turkish coast. Its size is approximately 1630 square kilometres. The island used to be a wealthy area in the past, but after the disruption of the linkages with Asia Minor it became a supra-peripheral area, characterized by outmigration and a declining population. The economic base of the island is partly agriculture (mainly olive production), partly tourism. Export of olive oil is a major source of revenues. In total, the primary sector accounts even for approximately 25 percent of gross regional product.

The physical geography of the island is not very favourable: Lesvos is a mountainous area and lacks sometimes even sufficient water supply, so that advanced agricultural developments are hardly feasible (see also Hermanides and Nijkamp 1997).

The island presents a typical example of a regional sustainable development problem, as the abandonment and neglect of agricultural areas, and of olive groves in particular, causes a major sustainability problem as a result of erosion and desertification. The lack of maintenance of the terrace cultivation on the island leads to serious soil erosion. Frequent forestry fires have even aggravated this problem. The question is now which development options can be envisaged and how these contribute to regional sustainable development on the island. An important issue is also the role played by EU agricultural policies (see for a general overview also Folmer and Thijssen 1996).

We will briefly describe here three development scenarios for Lesvos (see for more details Hermanides and Nijkamp 1997).

- **Force** scenario. This scenario takes for granted a continuation of current trends based on the Structural Support for Socio-economic Similarity laid down in a Council Regulation of the European Union. This policy scenario aims also at alleviating regional income differences. Consequently, traditional agricultural production is supported as a strategy for overcoming socio-economic decline.
- **Green** scenario. This scenario is based on environmental care in agriculture, so that farmers have a dual role: agricultural producers and guardians of the countryside. Landscape and soil management are important ingredients of this scenario. Consequently, polluting agricultural activities have to be avoided, an upkeep of abandoned farmland and woodlands is favoured, environmental education and training is furthered, and natural resources are preserved.
- **Market** scenario. This scenario takes for granted a liberalisation of agricultural markets and trade in agricultural products. In this context, a better market access, a reduction in domestic support and export competition (by eliminating export subsidies) are of preponderant importance. This scenario has two variants:

- **Market I: Scaling up**. A gradual transformation to large-scale agricultural practices, which would allow more advanced farming methods and a rise in production efficiency, with the necessary consequence that small-scale farming will disappear.
- **Market II: Cooperation**. In this scenario the small landowners would cooperate (e.g., by sharing sophisticated modern agricultural equipment, by joint marketing efforts etc.). In this case, also more advanced farming methods would be possible and feasible (as a result of lower overheads).

These three scenarios will now be analyzed in the framework of a Decision Support System based on our flag model. We will present here the estimates of the indicators related to x_1, x_2 and x_3 for each of these scenarios. These estimates are based on consultation interviews with local experts on the island of Lesvos. They represent some average common opinion on the question what would plausibly happen if one of the scenarios described above would come into being. This is clearly an ad hoc assessment method, but there appeared to be quite a consensus after some consultation rounds. The results are presented in Table 1.

	Force	Green	Market I	Market II
ECONOMIC				
General & structural				
1. GDP of the primary sector as a percentage of total GDP	+	+/-	--	--
2. Average income out of farming activities as a percentage of annual household expenditures	+	+/-	+/-	-
3. Number of farms	+	+/-	-	+/-
4. Farm size	+/-	+/-	+	+/-
Livestock numbers				
5. Number of goats	+/-	-	--	--
6. Number of sheep	+/-	-	--	--
7. Number of cattle	+	-	--	--
Production figures				
8. Production of olives	+	+	+/-	-
9. Production of meat	+	-	--	--
10. Production of milk	+	-	--	--
Land use				
11. Total agricultural area in use	+/-	-	--	-
12. Total area in field and pasture	+/-	-	--	-
13. Surface area planted with olive trees	+/-	+/-	--	-
SOCIAL				
14. Total population	+/-	+/-	-	-
15. Economically active in primary sector	+	+/-	-	-
16. Employment in the primary sector as a percentage of total employment	+	+/-	--	-
ENVIRONMENTAL				
17. Number of olive trees	+/-	+/-	--	--
18. Olive yield per hectare	+/-	-	+	+/-
19. Area of abandoned olive groves as a percentage of total area of olive groves	-	-	++	+
20. Number of sheep and goats per hectare of pasture land	+/-	-	--	--

Table 1 Qualitative impact matrix for four scenarios for agricultural development of Lesvos

Legend: ++ = substantial increase
\+ = slight increase
+/- = neither increase, nor decrease
\- = slight decrease
-- = substantial decrease

7. Results of Decision Support Experiments for Regional Sustainable Development of Lesvos

After the impact assessment of the data, we need now to gauge the CTVs for each of the sustainability indicators, in order to be able to apply the flag model. Also in this case we had to resort to expert opinions. A structured interview procedure led to quite a high degree of agreement on the critical values of most of the indicators in our sustainability analysis. These results are found in Table 2.

	Low CTV	CTV
ECONOMIC		
General & structural		
1. GDP of the primary sector as a percentage of total GDP		25
2. Average income out of farming activities as a percentage of annual household expenditures		20
3. Number of farms		20,000
4. Farm size (in ha)		1
Livestock numbers		
5. Number of goats		40,000
6. Number of sheep		200,000
7. Number of cattle		9,000
Production figures		
8. Production of olives (tons per year)		90,000
9. Production of meat (tons per year)		4,300
10. Production of milk (tons per year)		30,000
Land use		
11. Total agricultural area in use (in ha)		60,000
12. Total area in field and pasture (in ha)		60,000
13. Surface area planted with olive trees (in ha)		46,500
SOCIAL		
14. Total population		90,000
15. Economically active in primary sector	8,000	9,000
16. Employment in the primary sector as a percentage of total employment		30
ENVIRONMENTAL		
17. Number of olive trees		11,000,000
18. Olive yield per hectare (in kg/ha)	1,500	2,000
19. Area of abandoned olive groves as a percentage of total area of olive groves		20
20. Number of sheep and goats per hectare of pasture land		1.4

Table 2. Critical Threshold Values for Lesvian agriculture

It appears from Table 2 that the information on CTVs is not so detailed that a numerical four-flag representation per indicator can be made. On the other hand, the clear consensus about sustainability levels reduces the need to work with uncertainty intervals for the unsustainability levels, so that the qualitative information replaces the construction of CTV_{min} and CTV_{max} . Hence, the present data allow to analyse the four development scenarios for Lesvos in a more determinate fashion, by distinguishing between a sustainable and an unsustainable outcome for all but two indicators. For indicators 15 and 18 two CTVs are defined, which gives three levels of sustainability: unsustainable, ambiguous and sustainable.

A further complication for the application of the Flag Model arises from the fact that many scenario outcomes coincide with CTVs. For quantitative information this is not much of a problem, but a certain arbitrariness may enter the analysis for qualitative forms. In the case of Levos this can conveniently be solved. When one CTV is given, we define three levels of sustainability depending on the value x for the indicator (assuming a cost indicator):

if $x < CTV$ sustainable
if $x = CTV$ ambiguous
if $x > CTV$ unsustainable.

Similarly, for the two indicators (nrs 15 and 18) for which two CTVs are given, also three sustainability levels are defined:

if $x < CTV_{min}$ sustainable;
if $CTV_{min} \leq x \leq CTV_{max}$ ambiguous
if $x > CTV_{max}$ unsustainable.

In this way, for all indicators three sustainability levels are defined.

In the computer programme this is achieved by setting the CTVs manually. When one CTV is given, we set:

$CTV_{min}(cp) = CTV(ex) - \varepsilon$
$CTV(cp) = CTV(ex) + \varepsilon$
$CTV_{max}(cp) = 100 * CTV(ex)$

where CTV(cp) stands for the CTV used in the computer programme and CTV(ex) for the CTV as given by the experts, see Table 2, and ε is an arbitrary small number. $CTV_{max}(cp)$ is set at an arbitrarily high level, so that no scenario outcome exceeds this threshold.

Similarly, for the case where experts gave two CTVs, we set:

$CTV_{min}(cp) = CTV_{min}(ex) - \varepsilon$
$CTV(cp) = CTV_{max}(ex) + \varepsilon$
$CTV_{max}(cp) = 100 * CTV_{max}(ex)$

Essentially, this implies that the Flag model only works with green, orange and red flags, which are interpreted as sustainable, ambiguous and unsustainable. Notice that these simplifications make the use of quantitative and hybrid forms of analysis less meaningful.

Tables 3 - 9 present in a comprehensive way all (qualitative) information that can be extracted from the data from Lesvos. Table 3 shows the flag count for each scenario: the number of red (R), orange (O) and green (G) flags, also subdivided by class (economic, social, environmental). Tables 4-9 present the cross tabulations for all pairs of scenarios, where the cell entries represent the frequencies of combinations of flag colours.

	All Flags			Economic			Social			Environment		
	G	O	R	G	O	R	G	O	R	G	O	R
FORCE	10	10	0	7	6	0	2	1	0	1	3	0
GREEN	3	9	8	1	5	7	0	3	0	2	1	1
MARKET I (Scaling up)	3	2	15	1	2	10	0	0	3	2	0	2
MARKET II (Cooperation)	1	3	16	0	2	11	0	0	3	1	1	2

Table 3 Flag count for all scenarios, overall and by class.

		GREEN		
		G	O	R
FORCE	G	2	5	3
	O	1	4	5
	R	0	0	0

Table 4 Cross tabulation of flag counts for scenarios Force and Green

		MARKET I		
		G	O	R
FORCE	G	0	2	8
	O	3	0	7
	R	0	0	0

Table 5 Cross tabulation of flag counts for scenarios Force and Market I

		MARKET II		
		G	O	R
FORCE	G	0	1	9
	O	1	2	7
	R	0	0	0

Table 6 Cross tabulation of flag counts for scenarios Force and Market II

		MARKET I		
		G	O	R
GREEN	G	1	1	1
	O	1	1	7
	R	1	0	7

Table 7 Cross tabulation of flag counts for scenarios Green and Market I

		MARKET II		
		G	O	R
GREEN	G	1	0	2
	O	0	2	7
	R	0	1	7

Table 8 Cross tabulation of flag counts for scenarios Green and Market II

		MARKET II		
		G	O	R
MARKET I	G	1	2	0
	O	0	0	2
	R	0	1	14

Table 9 Cross tabulation of flag counts for scenarios Market I and Market II

From these tables a clear picture arises about the sustainability of the four scenarios. First, it becomes clear from Table 3 that the two MARKET scenarios are unsustainable. Not only do they give rise to a large number of Red flags, but also these flags appear in all three areas: Economic, Social and Environmental. Strictly speaking, these scenarios can be left out of consideration for further analysis as being unsustainable.

For the GREEN scenario the picture is somewhat more diffuse. Again a significant number of Red flags are found, but it appears that almost all these flags are for economic indicators. In the social and environmental areas the GREEN scenario seems reasonably sustainable. Again strictly speaking, a scenario with such a significant number of Red flags should not be favoured, but in the light of the above observations, and the difficulties in deriving the CTVs, it would be unwise to eliminate this scenario from further analysis at this stage.

Finally, it is clear that the FORCE scenario passes without doubt this sustainability test. Not a single Red flag is found, while a convincing number of Green flags, quite equally distributed over the three areas suggests that this scenario is truly sustainable.

When we compare the scenarios, some interesting observations emerge. Firstly, although the overall score of FORCE is the best, it achieves its superiority in particular in the economic area. The GREEN scenario is only marginally less sustainable in the social area, and comparably sustainable for the environmental indicators. In this perspective, it is noteworthy that even the two MARKET scenarios are just slightly less sustainable, as far as the environment is involved.

Secondly, from Table 4 we find that there is only one indicator for which the GREEN scenario obtains a (qualitatively) better score than the FORCE scenario. Remarkably, even the MARKET I scenario obtains for three indicators a better score than FORCE. The cross tables further show that FORCE is at least as sustainable as GREEN for almost all indicators, but that MARKET I has a better sustainability score for a small share of the indicators.

Thirdly, GREEN and MARKET I give a somewhat diffuse pattern, but MARKET II is clearly outperformed by GREEN. Finally, MARKET II is even more unsustainable in comparison to MARKET I.

8. Conclusions

Sustainable Development is a qualitative policy concept, which needs a quantitative operationalization. Sustainability is also a multidimensional concept, which requires a multidimensional evaluation technique. Finally, sustainability is to a significant extent a discrete concept (a situation is sustainable or not), which demands some type of discrete assessment method.

All these aspects of sustainability are dealt with in this paper. We have discussed how the three main dimensions of sustainability (environment, economic, social) can be analysed simultaneously by means of multicriteria analysis (e.g. the Regime method). Also the compound nature of the three dimensions was extensively treated. The preferable operationalization is the use of indicators in combination with critical threshold values, addressing the all-or-nothing character of sustainability. Nevertheless, we recognized that such a yes-or-no approach has to be relaxed in real-world problems, and therefore we introduced the concept of a range of critical threshold values, bounded by a maximum value (above which a scenario becomes truly unsustainable in case of a cost indicator), and a minimum value (below which a scenario is sustainable). Further, for an empirical assessment of the sustainability issue, we presented our Flag Model and showed its application for the case of various agricultural policies for the island of Lesvos, Greece.

We have shown that the Flag Model is a helpful tool in assessing the sustainability of various scenarios in offering an indicative, quantitative comparison of the scenarios. For a more exact comparison, multi-criteria techniques must be applied. Therefore, the main purpose of the Flag Model is to possibly limit the number of feasible (in a sustainability sense) alternatives. The Lesvian example also showed the flexibility of the Flag Model, as we applied it to data, which did not exactly fit the required format.

We would advocate a further experimentation with the Flag Model, so that experience about its performance is gained and the model can be improved. In particular, we think the Flag model becomes more useful when larger numbers of indicators are involved, and visual inspection of impact matrices is not possible. Also, an application of the Flag Model for cases in which there is less expert or policy consensus, may improve the robustness of the model use.

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