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Environmental quality and sustainability in the province of Reggio Emilia (Italy): using multi-criteria analysis to assess and compare municipal performance

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Sustainability has become an increasingly significant issue, although practical implementation remains difficult. In Italy, promoting sustainability is particularly problematic at the provincial and municipal level, where the lack of resources and expertise, and the effects of uncoordinated policies make it difficult to achieve minimum requirements to make sustainable policies operational. One essential requirement is knowledge of baseline environmental conditions in each municipality. In the province of Reggio Emilia (Northern Italy) Legambiente*, an environmental association, launched an initiative called* 'Ecopaese' *aimed at gathering data on environmental conditions and stimulating local administrations to implement sustainable policies. To this end, the state of the environment in the 45 municipalities within the province has been monitored using 25 indicators. Their values have been used to rank the municipalities by multiple criteria analysis (MCA). The results of this comparative approach provide information about the level of sustainability attained in the province as a whole as well as in the single municipalities. It is hoped that it will provide the basis for direct action plans at the provincial level by identifying areas for remedial action, as recommended by Agenda 21, the declaration adopted by many countries attending the Rio Summit in 1992.*

Keywords: Agenda 21, sustainability, multicriteria analysis, non-governmental organisations, environmental policy.

Introduction

Premise

Agenda 21, the declaration adopted by many countries attending the Summit at Rio in 1992, sets out many of the policies and commitments necessary to ensure sustainability (Brady, 1992). While there are clearly problems which require supranational monitoring and regulation, Agenda 21 emphasises the role of local initiatives as pivotal elements in the transition towards sustainability (ICLEI, 1992). Local authorities are responsible for creating and maintaining economic and social infrastructures and establishing local environmental policies. As the governmental level closest to the population, they are in charge of the active implementation of national and sub-national environmental programs, and are responsible for their success or failure (ICLEI, 1997).

In this framework, contrasting evidence emerges between countries. Where local authorities have a longer history of environmental responsibility, as in the UK (Marshall, 1993; Gibbs, 1994; UK Local Government Management Board and Touche Ross

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Management Consultants, 1994; but see Tuxworth, 1996), the implementation of EU and international recommendations is facilitated, and incorporating criteria for sustainability into planning has been a relatively smooth process. In other countries, by contrast, attempts to pursue sustainability at the local scale are often hampered by the lack of an adequate regulatory framework from central authorities, resources, and necessary expertise (Bosworth, 1993; ICLEI, 1998).

Situation and problem

In Italy local policies emanate from a variety of regional, provincial and municipal authorities. To make sustainability operational these authorities should work in a co-ordinated fashion, but such integration is still in its infancy because they have different, often conflicting, priorities. The first level of integration involves the smallest administrative units, the municipalities. Co-ordinated efforts require that common goals are defined at the provincial scale, and that municipalities set up their policies accordingly. To this end it is necessary to know the state of sustainability reached by every municipality, and to use this information to highlight similarities and differences in the way the municipalities have come to grips with the challenge of sustainability. This approach may help to define reasonable thresholds and common minimum requirements so that all the municipalities can actively participate in the implementation of Agenda 21.

Sustainability is a multidimensional concept with economic, social and environmental aspects (Redclift, 1994; Walter and Wilkerson, 1994), and any attempt to define coherent sustainable policies must consider all of them. In the 45 municipalities belonging to the province of Reggio Emilia (RE) in northern Italy, attention has focused mainly on the economic and social aspects of sustainability, and detailed knowledge about environmental conditions is presently lacking. Such knowledge is essential to make sustainability operational (Parker and Hope, 1992), and RE is now facing the urgent problem of remedying this (Ministry of the Environment, 1993; ANPA, 1999).

Legambiente is a non-governmental organisation established to protect the environment and apply pressure about environmental issues at both the national and local level. In 1997 it launched an initiative, called *Ecopaese*, designed to document environmental conditions in all the municipalities.

Objectives

The initiative focused at both the provincial and municipal levels and had two main objectives. The first was to use the results of the survey to identify environmental conditions throughout the province and thus provide the basis for an environmental action plan. The second was to use the indicators to identify specific areas for remedial action at the municipal level.

General approach

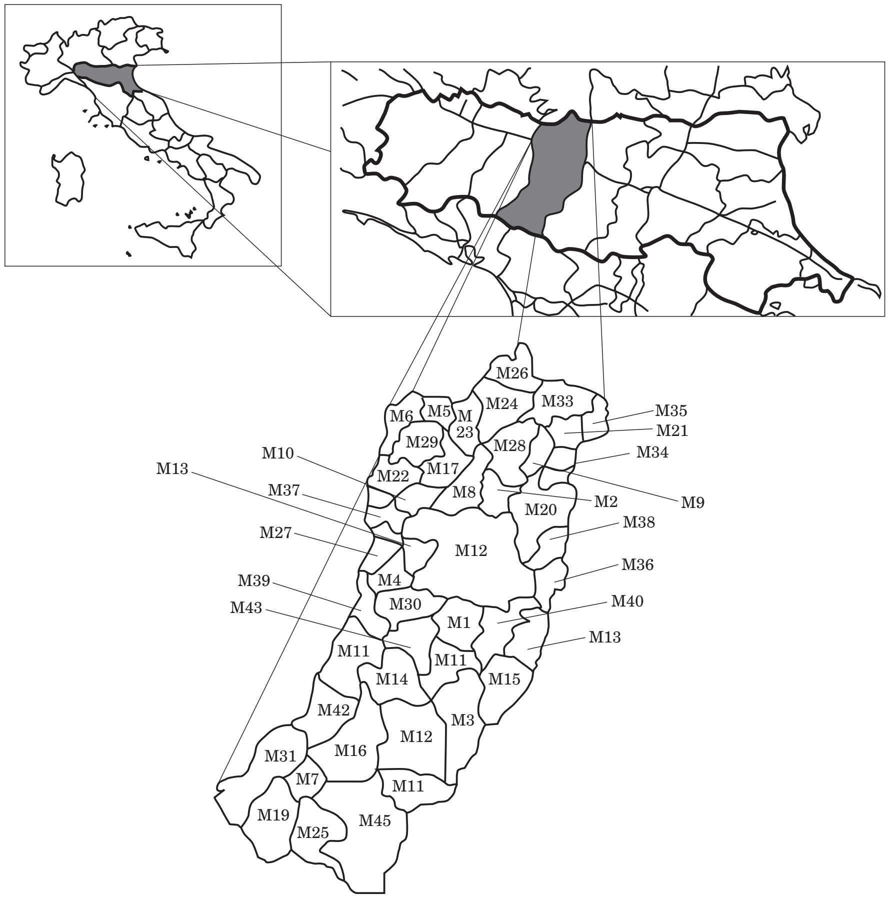
Twenty-five indicators were selected, focusing on those aspects for which sufficient data were available. A comparative approach seemed the most appropriate strategy. Differences and similarities, necessary to highlight patterns of environmental conditions at the provincial level, could emerge only through a comparison of the environmental performance of the municipalities. Also, the factors responsible for bad or good performance could be identified, suggesting areas for remedial action at the municipal level.

Multiple criteria techniques were used. In general, these tools are used in decision-making scenarios, when a solution must be selected from a set of alternatives. In *Ecopaese* there were no real alternatives, as the idea was to compare environmental conditions; nonetheless, the values assumed by the indicators could be seen as the result of alternative approaches to environmental sustainability. From this perspective, the use of these techniques was legitimate. Also, because the indicators described different aspects of the real world, the comparison had to be conducted using a set of heterogeneous measures that differed from one another both in terms of scale and measurement. The main features and principal outcomes are presented and discussed in this paper.

Study area

RE is located in northern Italy, in Emilia Romagna (Figure 1). It extends over about 2292.9 km^2 and sustains a population of 438 500 inhabitants.

The province can be subdivided into three parts, based on topography. The southern part is mountainous (northern Apennines) and contains 10 municipalities (M7, M12, M14, M16, M19, M25, M31, M41, M42 and M45). The central part is hilly and contains nine municipalities (M1, M3, M4,



M1	Albinea
M2	Bagnolo
M3	Baiso
M4	Bibbiano
M5	Boretto
M6	Brescello
M7	Busana
M8	Cadelbosco di Sopra
M9	Campagnola
M10	Campegine
M11	Canossa
M12	Carpineti
M13	Casalgrande
M14	Casina
M15	Castellarano
M16	Castelnovo Monti
M17	Castelnovo Sotto
M18	Cavriago
M19	Collagna
M20	Correggio
M21	Fabbrico
M22	Gattatico
M23	Gualtieri
M24	Guastalla
M25	Ligonchio
M26	Luzzara
M27	Montecchio
M28	Novellara
M29	Poviglio
M30	Quattro Castella

M31	Ramiseto
M32	Reggio Emilia
M33	Reggiolo
M34	Rio Saliceto
M35	Rolo
M36	Rubiera
M37	S. Ilario d′ Enza
M38	S. Martino in Rio
M39	S. Polo d′ Enza
M40	Scandiano
M41	Toano
M42	Vetto
M43	Vezzano sul Crostolo
M44	Viano
M45	Villa Minozzo

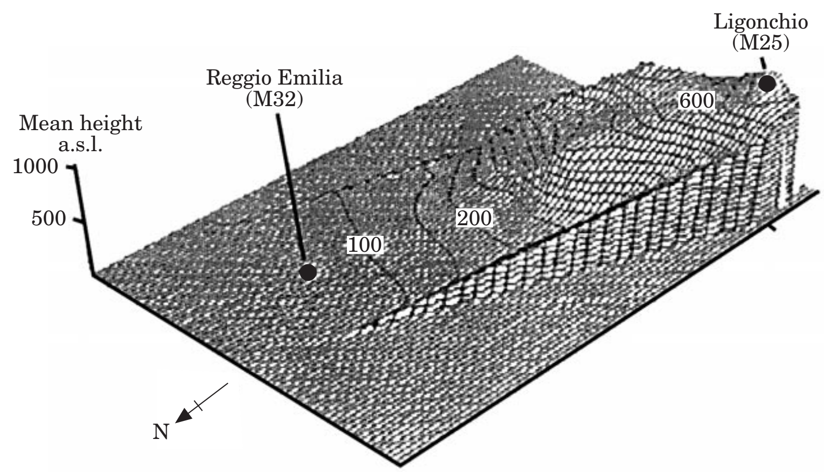


Figure 1. Study area. The province of Reggio Emilia and its 45 municipalities within the boundaries of the region Emilia Romagna. The map at the bottom shows the height gradient of the province.

M11, M15, M30, M39, M43, M44). The northern part is flat (Po river plain).

In this latter area the main economic activity is agriculture. Industrial activity is concentrated in five municipalities in the eastern part of the province: Casalgrande (M7), Castellarano (M17), Rubiera (M36), Scandiano (M40), Viano (M44). Food industry connected to agriculture employs 25 000, while mechanical industries employ around 20 000 (Anceschi, 1995).

In the south, tourism is a considerable source of income. Its wildlife attracts numerous tourists in summer, and its ski slopes are popular in winter. A regional park (Parco del Gigante) has been recently established.

Wetlands along the Po river, although of limited extent, are important because of the presence of many species of birds living in typical biotopes. There is a historical and architectural heritage, with many castles and churches.

Methods

Multiple criteria analysis (MCA, Voogd, 1983) allows comparison of alternatives on the basis of a set of criteria, measuring aspects by which the dimensions of the various possibilities under consideration can be characterised. The intrinsically multi-objective nature of environmental problems means that MCA is frequently used in this context (Janssen and Ritveld, 1990; Giaoutzi and Nijkamp, 1993; Bodini *et al*., 2000).

Four different methods of calculation made available in the same software package called DEFINITE (Janssen and van Herwijnen, 1994), were used in the study: Weighted Summation, Regime, Expected Value and Evamix. The first step of an MCA is the construction of an effect table that describes the real or potential impact that various alternatives can have on a set of criteria. A weight, or importance value, must be assigned to each criterion. Weighted Summation ranks the alternatives according to the formula

$$\underset{I=1,2,\ldots,I}{\text{maximize}} \quad \sum_{j=1}^{J} (w_j x'_{ji})$$

where w_j is the weight associated to criterion j and x'_{ji} is the standardised score that quantifies the impact that alternative i produces on criterion j. DEFINITE uses the following formula as a standardisation procedure in the Weighted Summation:

$$x'_{ji} = \frac{x_{ji} - \min\limits_{i} x_{ji}}{\max\limits_{i} x_{ji} - \min\limits_{i} x_{ji}}$$

This means that for each alternative i scores are scaled according to their relative position between the lowest and the highest value.

Evamix is designed to deal with a table of evaluation containing two subsets of qualitative and quantitative scores. Within each subset all the alternatives are evaluated in a pairwise comparison that produces a series of dominance coefficients. Since this study used only quantitative coefficients (the values of the indicators) the procedure was simplified and the dominance coefficients were calculated as

$$\beta_{ii'} = \left[\sum_{j \in Q} \{ w_j (x'_{ji} - x'_{ji'}) \}^p \right]^{\frac{1}{p}}$$

where Q identifies the set of quantitative criteria and i and $i'$are two generic alternatives. The scaling parameter p, a positive integer value that is set up according to certain rules, is taken to be equal to 1 (Voogd, 1983; Jansen and van Herwijnen, 1994). The results of all pairwise comparisons yield a matrix of dominance scores. Row totals of this matrix provide the final score for the alternatives. The same standardisation procedure used in the Weighted Summation applies here.

Both the Regime and the Expected Value methods make use of a set of feasible weights (S). They group values that satisfy a given set of qualitative priorities obtained by ranking the criteria in order of importance. Since there may be many such values several weight vectors are applied. In Regime the vector is calculated as the expected value of the feasible set (Rietveld, 1984) and is used in a Weighted Summation approach.

The starting point of Regime is the concordance index (van Delft and Nijkamp, 1977):

$$c_{ii'} = \sum_{j \in C_{ii'}} w_j$$

where $C_{ii'}$ is the subset of criteria for which alternative i dominates i'; as before, w_j is the weight associated with criterion j. By comparing all possible pairs of alternatives a set of concordance indices is obtained. The method focuses on the difference

$$C_{ii'} - C_{i'i}$$

If it is positive, alternative i is preferred to i' and the reverse holds if the sign is negative. All the vectors in S are used to calculate the concordance indices. If the sign of the difference between two indices remains positive for all the vectors of weights, the dominance of plan i over plan i' is said to be complete, and a probability of dominance equal to 1 is assigned to alternative i. It may also happen that for a part of the set S the sign of the difference is positive and for the other part it is negative. The number of positive cases is taken as the probability of dominance of plan i over plan i'. The results are given in the form of a probability table. For each alternative an overall score is calculated as the row average of the relative success (probability) coefficients that compose the table. This method requires no score standardisation.

Results

Choice of indicators and data acquisition

When assessing environmental conditions in the framework of sustainability the choice of indicators is a crucial step (Meadows, 1999). Several countries, such as New Zealand (Ward, 1990), Canada (Environment Canada, 1991), Denmark (Holten-Andersen *et al*., 1998), The Netherlands and Canada (Alberti and Parker, 1991) have taken this approach. Local Agenda 21 (http://www.igc.org/habitat/agenda21/) and the OECD (1991, 1993) provide basic lists of indicators; however, while some regional and national indicators are found among them, most deal with global problems. Sustainability evaluated at different scales (planetary, regional, national, local) and in different environmental contexts (city, countryside, mountain or coastal areas) requires that appropriate indicators are chosen on a case by case basis.

In general, environmental indicators are selected within a few broad categories, the most common of which are air pollution, climate change, biodiversity, resource depletion, urban problems, waste production, water pollution, population, health and disease (OECD, 1991; Eurostat, 1999). These can, however, change as well as single measures within them, depending on specific conditions. For example, in the Environmental Resource Program (ERP; http://www.sph.unc.edu/erp/about.html), a collaborative program between the School of Public Health and the Carolina Environmental Program at The University of North Carolina, relevant indicators for environmental quality are chosen from the following groups: air quality, surface water quality, solid waste, toxic releases, vehicle miles travelled and commercial marine fish catch.

In the UK, Coventry (http://www.cwn.org.uk/agenda21/coventry/index.html) has developed a system of environmental indicators that includes household waste produced and recycled, wildlife habitats, domestic water consumption, electricity consumption, river and water quality, and air quality. Sustainable Seattle, an initiative that has become a prototype for this kind of project (Palmer and Conlin, 1997; Bossel, 1999), has selected waste generation and disposal, recycling, energy efficiency, material balances, ecological footprint, parks and wilderness area. In the National Plan for Sustainable Development, launched by the Italian Ministry for the Environment within the framework of Local Agenda 21, a panel of experts has been working on a system of indicators for the urban environment, and proposed the following categories: public health, air quality, water consumption, efficiency of depuration, urban waste, potential for recycling, public and private transportation, public green areas, and energy consumption (Berrini *et al*., 2000).

This framework guided the choice of indicators to be used in *Ecopaese* which are listed in Table 1; a brief explanation of their meaning is given below. Population size (inhabitants per km^2) indicates the generic pressure that is exerted on the environment. Water use (per capita m^3 of potable water), consumption of electric energy (kWh), soil consumption due to quarrying (m^3 extracted), road development (km of roads per km^2 of surface), and presence of landfill sites (capacity, in m^3) were chosen to quantify resource depletion.

Several parameters were originally included in the list of indicators concerning the quality of potable water, such as heavy metals, nitrates, chlorine, ammonia, organic compounds, pesticides, and so forth. However only those that were above the detection limit of the instruments appear in the final list: they are nitrates and chlorine, given as annual mean values (mg lt^{-1}).

Available information about air pollution did not cover the entire province, as only six municipalities had monitoring stations. The per capita number of cars and the number of industries discharging in the atmosphere were used to estimate air pollution. Also, the number of cars indicates the pressure due to congestion of traffic and reduced mobility. This form of environmental degradation does not depend solely on the number of cars but also on road development, included in Table 1 as an indicator of land consumption and alteration of landscape. The meaning of this measure seems ambiguous: it can be intended either as a cost criterion (the lower the better with respect to the objectives) or a benefit criterion (the higher the better). Because in many municipalities road development is not sufficient to avoid traffic congestion, the indicator was taken as a cost criterion. The use of public transportation appears in the list because it lowers the impact caused by traffic both in terms of air pollution and reduced mobility. It is measured as percentage of inhabitants that commonly use public means of transport.

Table 1. Indicators used in the analysis and their units

Indicator		Units
C1	Nitrates	Mean concentration (mg lt^{-1}) of nitrates
C2	Chlorides	Mean concentration (mg lt^{-1}) of chlorides
C3	Discharges in atmosphere	Number of industries discharging in the atmosphere per km^2
C4	Waste water treatment	Percentage of inhabitants served by secondary and tertiary treatment
C5	Green areas	Per capita m^2 of green
C6	Traffic	Per capita number of cars
C7	Farming	Tons of pigs and cattle per km^2
C8	Population	Inhabitants per km^2
C9	Quarrying	m^3 extracted
C10	Landfill sites	Capacity of landfill sites in m^3
C11	Energy consumption	Consumption of electricity (kWh per capita)
C12	Waste production	Per capita kg of waste
C13	Water consumption	Consumption of potable water (L. per capita)
C14	Recycling potential	Quantity of unmixed urban waste (kg per capita)
C15	Road development	Km of roads per km^2
C16	Environmental expenditure	Municipal budget for environmental initiatives ($\times$1000 Lit.)
C17	Industrial risk	Number of industries at risk of accident
C18	Environmental concern	Presence of environmental offices in the local administration
C19	Public transportation	Percentage of inhabitants using public transportation
C20	Age index	(Inhabitants aged over 65/under 14) *100
C21	Unemployment	Percentage of unemployed people
C22	Public health concern	Number of inhabitants served by every pharmacy
C23	Real estate	Per capita real estate ($\times$1000 Lit.)
C24	Taxable incomes	Per capita taxable incomes ($\times$1000 Lit.)
C25	Deposit account	Per capita deposit account (*1000 Lit.)

Agriculture is an important economic activity in RE, but it also produces severe water pollution. In *Ecopaese* non-point pollution was estimated through the number of pigs and cattle (tons km^{-2}) raised in every municipality. Non-treated waste water represents one of the most pressing problems at the urban level, and the percentage of inhabitant served by secondary or tertiary treatment plants was included to provide an estimate.

Two indicators relate to waste production: total amount produced per capita, and quantity of waste collected in separate form (paper, glass, organic material) as the result of source separation. The first indicator is a true measure of environmental pressure, whereas the second is important because Italian legislation requires every municipality to collect wastes in separate form to make recycling, an important component of sustainability, possible. Because recycling is organised and managed by companies that operate at a regional scale, efficiency of recycling at the municipal level could not be calculated; instead, what each municipality collects in separate form, a measure of recycling potential, appears in the list.

The number of industries that, according to Italian legislation (law 203/1988), are particularly at risk of accident was also included in the list as an indicator of environmental pressure. In cities and villages the presence of green areas is perceived as a value. The services they provide are in fact many: pure air, reduced levels of noise, opportunities for recreation. This survey considered only the extension of urban green areas; protected areas, located far from major conurbations, were excluded because they are not present in every municipality. Expenditure that every municipality allocates to improve environmental conditions, and the number of offices or initiatives devoted to solve environmental problems or promote public environmental awareness are important indicators of the environmental attitude of each municipality; as such they were included in *Ecopaese*.

The list also contains social and economic indicators, such as the number of inhabitants served by every pharmacy. It is well known that bad environmental conditions can have repercussions on human health. In a sustainable society pollution prevention represents the best strategy to avoid health problems, but nowadays an acceptable degree of prevention is the exception rather than the rule. Given this premise, it is important that municipalities are active at the forefront of public health surveillance and pharmacies provide a ready source of data. In RE at least one pharmacy can be found in every municipality, whereas hospitals are located only in big cities; accordingly, pharmacies operate as first-aid centres where people can receive primary care or be sent to hospital.

Although this survey was devised to describe baseline environmental conditions, the inclusion of economic indicators such as real estate, taxable income and deposit accounts seemed necessary. As municipal revenue heavily depends on taxation, an economically prosperous municipality probably provides more resources to its local government, with beneficial repercussions on environmental policies. In the framework of *Ecopaese*, economic indicators must be considered in this perspective. Two other social indicators complete the list: the percentage of unemployed people and an age index that quantifies the demographics of the population. The number of unemployed always represents a pressing problem for any municipality: when it is high, effort to create job opportunities can withdraw resources from other sectors of municipal activity and usually this occurs at the expense of environmental initiatives. The second indicator was chosen on the understanding that a population with a well balanced age structure is a prerequisite for economic prosperity; this in turn, affects environmental initiatives, as explained above.

Indicators are central to the decision-making process. Accordingly, one should always consider whether a certain list of measures is appropriate. *Ecopaese* faced difficulties in selecting the indicators because it was necessary to consider only parameters that could be measured in all the municipalities (Knut and Saebo 1993). Noise pollution, for example, could not be considered because only four municipalities had appropriate instruments to measure it.

Serious problems were encountered in measuring public health indices as related to environmental conditions. Because of the legislation protecting privacy, public institutions are not allowed to release data about disease or deaths registered in every single municipality, and only a general summary at the level of province could be made available. Gasoline and fuel consumption could not be measured despite its importance for assessing air pollution due to domestic heating and lorries. In those municipalities where only one or two gas stations exist, measuring gas consumption would readily allow everyone to calculate their earnings; this is not permitted by law. Despite these and other problems the list includes several indicators that are used often in sustainability studies (Hardi and Pinter, 1994; UK Department of the Environment, 1994).

Many indicators that have become very popular in recent years, such as deforestation or biodiversity loss, were not included. Much of the land in RE is urbanised and the agriculture is intensive. Forests, where they exist, are confined to protected areas.

The choice of indicators often generates disagreement. As a consequence, certain indicators may be replaced by others that are more directly relevant. Accordingly, there are no optimal solutions for selecting appropriate indicators.

After the list was completed, a questionnaire was mailed to the major municipal public relations offices to obtain data. These offices collect and store information relevant for their own field of activity (water, transportation, public works, waste management, and so forth) so that all the required data could be found without difficulty. However, to test the reliability of the information, and to fill some informational gaps, other agencies were contacted to provide a cross-comparison. They were the Italian Institute of Statistics (ISTAT), the Regional Environmental Protection Agency (ARPA), the Provincial Agency for Waste Management and Resource Utilization (AGAC), the Italian Association of Drivers (ACI) and the National Agency for Energy Production (ENEL).

In 1997, the first year of implementation of *Ecopaese*, several municipal offices did not send the required information. After some public pressure they decided the following year to collaborate and sent the required information. The complete series of data gathered from all 45 municipalities in 1998 has been used to perform the analysis described in this paper.

MCA applied to environmental performance

The measurable aspects (criteria) used to compare municipal environmental performance were the 25 indicators. The values collected in the survey were used to compile an effect table for MCA, presented below as Table 2. Each column identifies a given municipality and each row pertains to a given indicator. Each score in the table calibrates the performance. A negative score means a cost indicator, that is the lower its value the better it is according to the objective of a more environmentally sustainable community. All the criteria are measured on a quantitative (ratio) scale.

Table 2. Effect table for multiple criteria analysis. Columns (M) indicate the 45 municipalities to be compared by means of the 25 criteria/indicators listed in rows (C). Each coefficient in the table quantifies the performance of the municipality against the row indicator

	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10
C1	−23·8	−21·6	−1·2	−28·5	−25·1	−25·6	−2·4	−21·1	−21·7	−24·7
C2	−25·2	−25·3	−4	−72·2	−57·8	−58·2	−3·2	−25	−25·3	−59·5
C3	−0·36	−0·63	−0·11	−1·21	−0·42	−0·71	−0·07	−0·55	−1·08	−0·5
C4	0·72	0·78	0·46	0·84	0·87	0·77	0·72	0·8	0·73	0·72
C5	18·07	10·58	24·91	7·51	3·6	11·08	19·1	28·03	16·95	7·89
C6	−0·63	−0·6	−0·59	−0·59	−0·57	−0·59	−0·52	−0·59	−0·58	−0·58
C7	−52·14	−82·37	−21·25	−151·79	−26·05	−23·71	−5·4	−86·41	−80·32	−122·09
C8	−171·07	−287·89	−43·09	−264·54	−234·26	−197·5	−44·23	−162·75	−184·68	−196·45
C9	−140 000	0	0	0	−320 000	0	0	0	−440 000	0
C10	0	0	0	0	0	0	0	0	−140 000	0
C11	−4·38	−4·04	−2·17	−5·42	−6·02	−4·46	−3·24	−4·5	−3·42	−3·63
C12	−531·94	−631·81	−417·61	−516·65	−516·01	−504·78	−631·72	−556·11	−769·24	−521·63
C13	−72·37	−78·62	−83·48	−61·32	−51·84	−58·07	−59·52	−60·79	−55·9	−27·63
C14	0·11	0·22	0·08	0·11	0·13	0·09	0·11	0·16	0·22	0·19
C15	−1·82	−2·45	−3·29	−2·88	−2·74	−1·39	−1·86	−2·04	−2·8	−2·64
C16	110	140	100	240	100	310	130	0	110	130
C17	0	0	0	0	−1	−1	−1	0	0	0
C18	1	2	1	2	2	1	1	2	1	2
C19	4·45	4·39	4·3	4·89	2·83	0·95	5·95	4·76	4·92	3·79
C20	−133·13	−161·95	−177·06	−176·83	−179·37	−194·5	−303·1	−165·38	−171·64	−171·4
C21	−2·55	−3·41	−3·27	−2·74	−4·43	−4·12	−1·96	−3·53	−4·35	−3·33
C22	−3650	−7634	−3214	−3631	−4402	−2346	−670	−3493	−4496	−4129
C23	58 000	52 000	25 000	54 000	50 000	67 000	54 000	55 000	52 000	52 000
C24	28 000	22 000	19 000	21 000	22 000	22 000	18 000	21 000	21 000	20 000
C25	7415	17 000	15 000	14 000	18 000	21 000	16 000	19 000	18 000	16 000

	M11	M12	M13	M14	M15	M16	M17	M18	M19	M20
C1	−1·2	−1·1	−6·2	−1·1	−5·5	−1·2	−23·2	−26·5	−1·7	−14·7
C2	−3·9	−3·6	−120·3	−3·9	−120·3	−3·9	−62·1	−75·9	−3·7	−60·5
C3	−0·23	−0·18	−2·63	−0·13	−1·89	−0·17	−0·63	−2·29	−1·29	0
C4	0·54	0·59	0·69	0·71	0·61	0·51	0·71	0·73	0·92	0·77
C5	7·94	7·47	17·63	11·07	13·87	13·85	13·04	36·29	21·32	13·91
C6	−0·6	−0·6	−0·66	−0·56	−0·61	−0·55	−0·6	−0·61	−0·46	−0·63
C7	−23·89	−31·24	−48·95	−35·47	−16·32	−41·88	−74·69	−137·65	−0·88	−91
C8	−63·94	−46·75	−353·55	−66·33	−182·18	−104·57	−211·71	−505	−15·4	−259·92
C9	0	0	−440 000	−180 000	0	0	−83 000	−93 000	0	0
C10	0	0	−140 000	−140 000	0	0	0	0	0	0
C11	−20·31	−5·33	−20·4	−2·37	−20·03	−2·69	−5·96	−5·11	−3·59	−6·44
C12	−508·77	−498·18	−507·77	−537·67	−621·2	−525·25	−555·48	−729·42	−595·45	−733·64
C13	−92·65	−96·2	−77·21	−72·38	−63·22	−86·21	−43·98	−76·28	−138·64	−86·44
C14	0·14	0·05	0·06	0·14	0·14	0·05	0·1	0·22	0·02	0·24
C15	−1·41	−2·63	−1·22	−3·21	−1·75	−2·16	−2·75	−2·62	−1·12	−3·24
C16	110	160	90	140	180	200	170	70	270	190
C17	0	0	0	0	0	0	−1	0	0	0
C18	1	1	2	2	2	2	2	3	1	3
C19	6·43	5·82	4·71	8·74	3·44	3·27	2·5	4·55	8·14	1·92
C20	−195·84	−230·13	−115·38	−176·84	−87·61	−203·17	−163·28	−163·92	−734·09	−157·35
C21	−2·44	−3·81	−3·36	−2·62	−4·18	−2·46	−3·83	−2·73	−2·7	−2·39
C22	−3393	−4090	−4442	−4257	−4924	−3607	−3274	−4223	−1076	−4021
C23	53 000	44 000	71 000	46 000	75 000	57 000	50 000	67 000	66 000	66 000
C24	18 000	18 000	24 000	18 000	25 000	21 000	20 000	23 000	17 000	24 000
C25	18 000	16 000	23 000	17 000	13 000	17 000	28 000	19 000	19 000	23 000

	M21	M22	M23	M24	M25	M26	M27	M28	M29	M30
C1	−21·6	−21·4	−24·4	−12·1	−1·9	−6·1	−27	−19·7	−24·6	−26·4
C2	−25·7	−44·7	−54·3	−16·6	−2·8	−10·5	−28·7	−24·5	−58·5	−30·8
C3	−0·48	−0·55	−0·61	−0·68	−0·02	−0·48	−1·24	−0·71	−0·25	−0·37

Table 2. (*Continued*)

	M21	M22	M23	M24	M25	M26	M27	M28	M29	M30
C4	0·88	0·77	0·87	0·68	0·69	0·61	0·86	0·75	0·66	0·84
C5	33·5	17·45	11·89	0	53·86	12·27	12·12	9·82	10·78	23·69
C6	−0·54	−0·6	−0·58	−0·58	−0·52	−0·54	−0·61	−0·6	−0·6	−0·6
C7	−44·65	−85·95	−44·03	−81·94	−1·32	−134·72	−87·72	−162·07	−53·41	−34·09
C8	−228·09	−121·67	−168·5	−256·94	−17·97	−212·05	−333·92	−199·66	−145·27	−228·5
C9	−440 000	0	0	0	0	0	0	0	0	0
C10	−140 000	0	0	0	−80 000	0	0	0	0	0
C11	−4·54	−14·61	−4·31	−4·68	−2·28	−7·02	−5·22	−3·72	−3·21	−4·2
C12	−883·75	−707·79	−545·3	−574·23	−583·58	−525·62	−745·23	−560·79	−566·36	−526·75
C13	−61·34	−41·78	−51·3	−57·95	−181·07	−34·54	−67	−49·12	−43·21	−61·7
C14	0·31	0·27	0·14	0·2	0·13	0·06	0·24	0·14	0·17	0·1
C15	−3·23	−2·57	−2·15	−4·03	−0·95	−2·11	−2·82	−2·18	−2·75	−1·6
C16	190	260	180	140	370	130	220	120	130	180
C17	−1	0	0	0	0	0	0	0	−1	0
C18	1	3	3	1	1	2	2	2	1	2
C19	3·7	2·05	3·38	2·01	5·57	1·67	2·76	4·97	3·9	5·24
C20	−216·57	−158·35	−191·5	−166·94	−637·88	−185·58	−138·47	−174·38	−191·3	−133·69
C21	−3·8	−3·9	−2·71	−3·31	−4·14	−2·63	−3·16	−2·87	−3·85	−2·91
C22	−5149	−2524	−3030	−4491	−1146	−2710	−4120	−3784	−3183	−3373
C23	55 000	72 000	48 000	60 000	60 000	55 000	65 000	54 000	50 000	46 000
C24	23 000	21 000	22 000	23 000	18 000	21 000	24 000	21 000	21 000	24 000
C25	20 000	18 000	18 000	25 000	18 000	20 000	21 000	17 000	24 000	12 000

	M31	M32	M33	M34	M35	M36	M37	M38	M39	M40
C1	−1·2	−24·7	−16·3	−20·8	−21·8	−8·9	−4·7	−12·8	−27·6	−26·4
C2	−3·7	−34·6	−22·2	−25·5	−25·5	−114·1	−115·8	−16·5	−19·8	−92·6
C3	−0·05	−0·97	−0·56	−1·65	−0·86	−2·28	−1·74	−0·85	−0·42	−1·22
C4	0·67	0·81	0·68	0·78	0·71	0·83	0·8	0·89	0·77	0·67
C5	27·13	15·04	14·53	10·87	13·91	0	24·15	17·68	23·86	25·18
C6	−0·51	−0·64	−0·57	−0·57	−0·53	−0·6	−0·56	−0·59	−0·59	−0·61
C7	−7·22	−88·14	−124·09	−74·35	−101·57	−71·4	−11·48	−67·15	−60·88	−55·78
C8	−14·97	−602·6	−190·81	−205·17	−240	−400·4	−256·52	−476·75	−150·09	−450·52
C9	0	0	−60 000	0	0	0	0	0	0	0
C10	0	0	0	0	0	0	0	0	0	0
C11	−2·05	−3·76	−5·43	−4·27	−3·54	−8·49	−10·88	−4·59	−3·92	−2·99
C12	−623·02	−669·4	−678·56	−618·65	−643·57	−587·3	−708	−646·06	−595·02	−588·18
C13	−63·47	−81·31	−45·66	−15·2	−57·28	−59·58	−64·12	−65·52	−91	−62·7
C14	0·08	0·15	0·08	0·18	0·18	0·06	0·08	0·17	0·14	0·17
C15	−1·98	−4·03	−4·03	−2·79	−4·03	−3·87	−3·17	−2·72	−2·03	−3·01
C16	150	0	240	110	140	0	170	160	130	210
C17	0	0	−1	0	0	0	0	0	0	0
C18	1	2	2	2	3	2	1	2	2	2
C19	5·25	4·2	2·8	3·33	2·62	3·84	1·9	4·16	4·24	4·05
C20	−407·4	−171·74	−116·06	−136·45	−217·28	−155·15	−144·75	−149·71	−195·23	−133·2
C21	−5·55	−3·62	−3·07	−3·35	−3·6	−2·38	−2·67	−3·51	−3·29	−2·56
C22	−1492	−4231	−4073	−4655	−3361	−4903	−5697	−3142	−4853	−5593
C23	42 000	65 000	64 000	49 000	52 000	76 000	72 000	61 000	54 000	50 000
C24	16 000	27 000	22 000	22 000	21 000	25 000	22 000	24 000	21 000	23 000
C25	17 000	25 000	19 000	17 000	19 000	30 000	30 000	18 000	16 000	18 000

	M41	M42	M43	M44	M45
C1	−1·1	−1·1	−1·2	−1·2	−1·4
C2	−2·6	−3·3	−4·2	−4	−2·2
C3	−0·22	−0·09	−0·13	−0·33	−0·04
C4	0·25	0·38	0·56	0·35	0·004
C5	19·3	15·77	9·56	6·25	20·13
C6	−0·55	−0·54	−0·57	−0·62	−0·51
C7	−42·52	−2·92	−16·53	−29·22	−8·61

(*Continued overleaf*)

Table 2. (*Continued*)

	M41	M42	M43	M44	M45
C8	−61·79	−40·21	−93·61	−64·04	−24·7
C9	−9000	−5109	−1500	−440 000	0
C10	0	0	0	0	0
C11	−6·51	−3·56	−3·42	−13·43	−2·14
C12	−453·54	−456·99	−498·9	−438·4	−484·34
C13	−84	−86·92	−68·41	−95·91	−69·53
C14	0·07	0·05	0·15	0·08	0·06
C15	−2·47	−2·4	−1·34	−1·55	−2·6
C16	120	70	150	0	260
C17	0	0	0	0	−1
C18	1	1	2	1	1
C19	6·11	3·57	7·03	4·65	5·37
C20	−187·98	−144·62	−190·45	−131·79	−327·37
C21	−2·94	−3·88	−3·69	−4·19	−6·52
C22	−1354	−2099	−1727	−2795	−2070
C23	36 000	39 000	44 000	54 000	39 000
C24	19 000	17 000	20 000	21 000	16 000
C25	32 000	16 000	10 000	17 000	13 000

MCA requires that a weight representing the value of importance or priority be attached to each criterion. Quantitative weights were assigned on the basis of qualitative statements that reflected the relative importance of the criteria. To produce such qualitative statements a panel of experts was asked to rank the criteria in order of importance according to their own perception, by using a conventional 1 to 7 (from the least to the most important) point scale (Voogd, 1983). The panel included different viewpoints; in addition to the authors, who represented the points of view of the scientific community (second author), environmental groups (third author) and environmental consultants (first author), one officer from each municipality was asked to participate. Many people drawn from the various economic sectors and other scientists were also contacted, but none accepted.

Thirty municipal officers sent their vectors of 25 values. By averaging these, one single vector representative of their point of view was obtained. This was done to have each point of view represented by a single vector of preferences, no matter how many people with the same point of view were in the panel. This vector and those proposed by the authors were further averaged to obtain a unique vector of priority values for the 25 criteria (vector of averaged preferences). The values forming this vector expressed the relative importance of the 25 criteria. To derive quantitative weights from this vector every coefficient was compared with all the others, pair by pair, and the difference that resulted from each comparison expressed on the base of the nine-point scale (Kok and Lootsma, 1985; Janssen, 1994):

1=Equally important

3=Moderately more important

5=Definitely more important

7=Much more important

9=Very much more important.

According to Table 3 the indicator which received the highest value in the vector of

Table 3. Weights assigned to the 25 indicators. Numbers in parenthesis are average values of preference calculated using values provided by experts and expressed on a 1 –7 point scale (see text for details)

C1=0·115(7)	C2=0·113(6·5)	C3=0·113(6·5)	C4=0·102(6)
C5=0·068(5·5)	C6=0·066(5·3)	C7=0·038(4·7)	C8=0·035(4·6)
C9=0·034(4·5)	C10=0·034(4·5)	C11=0·034(4·5)	C12=0·034(4·5)
C13=0·034(4·5)	C14=0·034(4·5)	C15=0·034(4·5)	C16=0·016(2·5)
C17=0·016(2·5)	C18=0·016(2·5)	C19=0·015(2·3)	C20=0·014(2)
C21=0·008(1·6)	C22=0·007(1·5)	C23=0·007(1·5)	C24=0·007(1·5)
C25=0·007(1·5)			

averaged preferences, was C1, mean concentration of nitrates, whereas four indicators shared the last position in terms of preference—C22, C23, C24 and C25, index of public health concern, real estates, per capita taxable income and per capita deposit account, respectively. The comparison between C1 and the least important ones yielded the highest possible difference among all possible pairs, so that C1 was classified as very much more important than C22, C23, C24 and C25, and the highest value (9) assigned these differences. Because the same value of preference characterised C22, C23, C24 and C25 they were classified as equally important with respect to each other and the minimum value (1) quantified their differences.

In the vector of averaged preferences C2 and C3 followed immediately after C1 (see Table 3). This means that the difference in importance between C1 and C2 and C3 was the minimum possible among all pairs of criteria. Accordingly, C1 had to be judged as moderately more important than the other two, and the value corresponding to this judgement (3) assigned these differences. Since C1 was very much more important than C22, C23, C24 and C25 and moderately more important than C2 and C3, the latter two criteria needed to be classified as much more important than the least important indicators, to guarantee the consistency of judgements (Saaty, 1990).

This procedure allowed the construction of a matrix (A) whose coefficients quantified the difference in importance between the row and the column indicator, as deduced by their values in the vector of the averaged preferences. The coefficients of the eigenvector associated to the largest eigenvalue of matrix A were used as weights in the MCA (Dyer, 1990; Saaty, 1990). Table 3 shows the vector of weights and the values of averaged preferences used in *Ecopaese*.

The programme generated the different sets of weights needed in the Regime and the Expected Value methods, but the starting point was the vector of averaged preferences. Each vector of weights became part of the so called feasible set (S, see Methods) only if its values fulfilled the relative priorities expressed in the vector of the averaged preferences. The four methods of calculation produced different rankings that were evaluated by a simple Spearman's correlation analysis. The results of this procedure are summarised in Table 4.

Table 4. Summary & results of Spearman's correlation analysis applied to the rankings produced in the multiple criteria evaluation by different algorithms

	Correlation Matrix Results			
	A:	B:	C:	D:
A:	1·0000	0·8970	1·0000	0·9907
B:	0·8970	1·0000	0·8970	0·8963
C:	1·0000	0·8970	1·0000	0·9907
D:	0·9907	0·8963	0·9907	1·0000

Each correlation coefficient (r) is calculated independently, without considering the other variables.
A: Weighted summation B: Regime C: Expected value D: Evamix

A very good agreement can be observed, although the ranking produced by Regime slightly differs from the others. Its correlation coefficients never exceed 0.9, whereas in all the other cases the correlation lies between 0.9 and 1. In particular, Weighted Summation and Expected Value produced exactly the same rankings. This high positive correlation between the four methods allowed us to calculate an overall ranking without introducing much uncertainty. This overall ranking is the result of a procedure that assigns one alternative a better position in a pairwise comparison if it scores better than another for more than 70% of the methods applied (Janssen and van Herwijnen, 1994). The overall ranking is given in Table 5.

Table 5. Final ranking for the 45 municipalities

Rank	Code	Name	Rank	Code	Name
1	M7	Busana	24	M28	Novellara
2	M14	Casina	25	M5	Boretto
3	M3	Baiso	26	M37	San Ilario
4	M43	Vezzano	27	M45	Villa Minozzo
5	M30	Quattro Castella	28	M44	Viano
6	M25	Ligonchio	29	M38	San Martino
7	M41	Toano	30	M6	Brescello
8	M1	Albinea	31	M4	Bibbiano
9	M22	Gattatico	32	M2	Bagnolo
10	M15	Cast. Monti	33	M40	Scandiano
11	M19	Collagna	34	M9	Campagnola
12	M42	Vetto	35	M27	Montecchio
13	M31	Ramiseto	36	M35	Rolo
14	M23	Guastalla	37	M12	Carpineti
15	M11	Canossa	38	M21	Fabbrico
16	M8	Cadelbosco	39	M24	Gualtieri
17	M26	Luzzara	40	M20	Correggio
18	M34	Rio Saliceto	41	M36	Rubiera
19	M39	San Polo	42	M17	Castellarano
20	M10	Campegine	43	M18	Cavriago
21	M33	Reggiolo	44	M32	Reggio Emilia
22	M29	Poviglio			
23	M16	Castelnuovo Sotto	45	M13	Casalgrande

Discussion

The first evidence that emerges from the final ranking is a subdivision of the municipalities in two groups. Plotting their position against mean height above the sea level (meters) and population density (Figure 2) a quite clear distinction between municipalities located in the mountainous and hilly areas and those that are in the lowlands can be observed. With only a few exceptions all the municipalities in the former category occupy the first 15 positions of the ranking. Only two municipalities from the Po river plain are in this group: M22 and M24, Gattatico and Guastalla, in 9th and 14th position, respectively.

The remarkable variation shown by certain indicators seems responsible for the observed pattern. For example, nitrates and chlorides in potable water increase more than twenty times passing from mountain to lowland areas; so does the index of non-point (agriculture) pollution. Also, environmental quality is inversely related to population density, as Figure 2 emphasises. This reflects the fact that the number of cars, road development, waste production and resource consumption always increase in line with population density. Since the lowland municipalities are also those more densely populated, this is reflected by the position they occupy in the final ranking.

A plan for sustainability at the provincial level would require action to be taken first within each group. In fact, reaching the same level of environmental quality seems easier if municipalities show similar performances, because smaller changes are needed. Lowland municipalities, in their efforts toward sustainability, will have to devote much more attention to their environment. The good performance shown by two of them (M22 and M24) suggests that improving environmental conditions in these municipalities is possible, although structural characteristics exist that can hamper the implementation of initiatives: higher population density, intensive agriculture, industrial activity. In these municipalities, although the worst performance in comparison with highland municipalities concerns non-point pollution, quality of potable water and number of industries discharging in the atmosphere, it seems that improving environmental quality can be done by acting on sectors for which fewer economic constraints exist. In fact, any reduction in

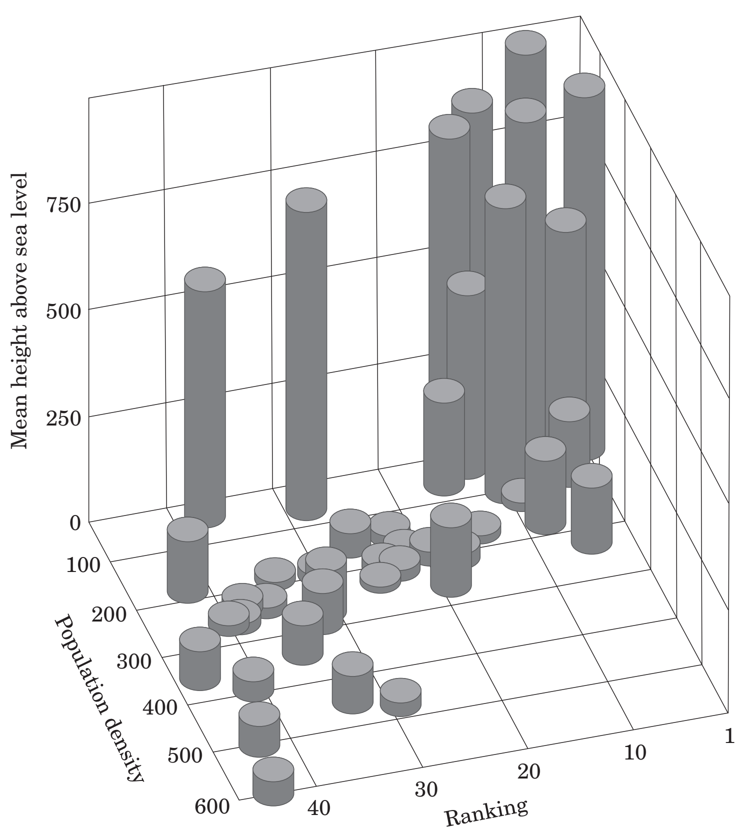


Figure 2. Multicriteria analysis plotted against mean height above the sea level (meters) and population density.

the activity of economically important sectors such as farming or industry will cause inevitably conflicts not easy to solve.

In general, municipalities in the highlands show better environmental performance, although the final ranking indicates that there are exceptions. To render environmental quality more homogeneous, municipalities that perform in an anomalous way compared with the others must take action. For example, M45, Villa Minozzo, ranks 27th, whereas all the others are in the first 15 positions. Waste water treatment (worst in the province), the presence of industries at risk (it is one of the few cities that host this kind of activity), the age index (highest in the province) and a high unemployment coefficient are responsible for its poor performance.

Among the municipalities located in the hillier areas, Castellarano (M17) and Carpineti (M12) rank very low in comparison with the others. Castellarano belongs to the core of the industrial area of the province. Although its economy thrives, discharges into the atmosphere are very high, green areas are not abundant and the quality of potable water is very low. Yet, the per capita number of cars competes with that of the lowland municipalities. Carpineti has positive characteristics that are typical of these towns, such as good quality of potable water and low discharges into the atmosphere. Its performance is lowered by the index of depuration, although other municipalities, better placed in the final ranking (i.e. Villa Minozzo), score worse in this respect. Carpineti also shows very high energy and water consumption: only two other towns in RE consume more water. Green areas are few and of limited extension, and the age index tells that its population is unbalanced in favour of the elderly. Another aspect that deserves particular attention is the low index of public health concern. Finally, the last three criteria indicate that the economy of Carpineti is not as developed as those of Casalgrande and Castellarano, although they are all located in the industrial area in which porcelain stoneware is produced.

Two further anomalies among hill cities are Viano (M44) and Bibbiano (M4). The former shows the highest coefficient of water consumption, landfill sites are present on its territory and the per-capita number of cars is rather high. This municipality is governed by one of the four administrations that do not include environmental actions in their plans for expenditure. Also, unemployment has become an urgent problem. Bibbiano is characterised by high water pollution (high concentration of nitrates and chlorine in potable water), high discharges into the atmosphere, limited extension of green areas and intensive agriculture.

The ranking reveals which municipalities are performing worse, and this should stimulate local administrators to take action to improve environmental conditions. Priorities for action are suggested by those criteria that score badly and receive high importance, but interventions cannot be conceived simply on the base of values assumed by the indicators. First, processes responsible for poor performance must identified and understood: they can vary from one situation to another and thus require different solutions. Second, specific boundary conditions, economic as well as social, have to be carefully considered to develop a feasible strategy. It is for these reasons that the results of this study should not be seen as being prescriptive. Nonetheless, the outcome of *Ecopaese* could be used as a starting point to define municipality targets, reference values, ranges, thresholds or direction of trends.

Conclusions

In the transition toward sustainability in Reggio Emilia, the contribution of *Ecopaese* can be summarised as follows. Information about baseline environmental conditions for all 45 municipalities of the province is now systematically organised in a database which, although preliminary, and as such incomplete, represents a significant contribution to helping to reduce the informational gap that has hampered the implementation of sustainable policies in this area.

MCA was applied to identify patterns of environmental conditions. According to the results, RE seems characterised by two rather distinct patches within which environmental conditions are more or less similar. They correspond to the upper part (mountain and hill municipalities) and the lower part (Po river plain) of the province. In the former, environmental quality is better than in the latter, where social and economic constraints often hamper the implementation of initiatives to promote sustainability. By taking into account such constraints, essential elements of an overall plan to improve the environment should include an increased use of public transportation (people do not use it much although these systems are more developed than in other parts of the province), a reduced consumption of water and energy and a reduction of waste production as well as an increased recycling effort. These interventions should minimise the conflicts that usually emerge when the main economic drivers, industry and agriculture, are requested to limit their activities to improve the state of the environment.

The MCA has also shown that the same environmental performance is not shared by all the municipalities within a particular area. In the mountainous area a few perform much worse than the others; in these cases specific areas for remedial actions are suggested. In the lowlands, by contrast, two municipalities have very good environmental conditions: their performance should encourage the others.

Since a threshold of acceptability for most of the indicators used does not exist, a hypothetical ideal environmental performance for all the municipalities could not be defined. Bearing this in mind, the construction of a ranking of environmental sustainability has provided municipalities with a guide to what they have done and what they have to do to improve the quality of their environment.

Full participation, as demonstrated by the Seattle experience (Palmer and Conlin, 1997) is essential. In this respect, the MCA technique seems particularly appropriate because it explicitly requires that values of importance be assigned. In doing so, perceptions can be included in the evaluation process, giving further momentum to participatory democracy, as recommended by Agenda 21.

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