Synthetic environmental appraisal of waste management systems: an application to the Sicilian region

A. Governanti[1], M. La Gennusa[2], G. Rizzo[2] & G. Scaccianoce[2]
[1]*Department of Energy and Environmental Research (DREAM), University of Palermo, Viale delle Scienze, 90128, Palermo, Italy*
[2]*Environmental Engineer, Palermo, Italy Environmental Engineer, Palermo, Italy*

Abstract

This paper addresses the problem of synthetically evaluating the environmental performances of urban solid waste systems. This, in fact, represents a crucial point in the management process of complex systems that local administrations are called to cope with, in order to provide decisions about policy options that involve different issues characterising the quality of life of people. Suitable methods of evaluation are clearly required for this aim. This work introduces the dashboard of sustainability and the ecological footprint approaches as aggregate indicators of the performances of solid waste management systems. The methods have been selected due to their intrinsic simplicities, provided that the required data are available, although the first one can be defined as a political tool, while the second one can be defined as a technical tool. An application of both methods to the situation of Sicily is proposed here.

1 Introduction

Waste management does represent an important issue to cope with in order of achieving sustainable features in the governance of urban contexts.

With the increasing levels of lifestyle of people, in fact, enormous quantities of solid waste are currently released in industrialised as well developing countries.

A suitable approach to this problem is therefore a crucial in the aim of properly addressing the environmental performances of towns.

Waste Management and the Environment II, V. Popov, H. Itoh, C.A. Brebbia & S. Kungolos (Editors)

Unfortunately, there is presently a deep lack in the availability of methods devoted to the easy assessing of the environmental compatibility of waste management system. Generally, in fact, administrators are called to manage a great number of indicators, ranging from the quality of air to the release of quantity of solid waste, that are quite difficult to be arranged together.

What it is required is an aggregate method able to provide a simple but reliable judgement about the sustainability of the design alternatives assessed by administrators.

Recently, a new approach has been proposed, the ecological footprint method that, starting from a limited number of parameters, does allow the definition of the general impact exerted by a given system on the environment. In fact, the parameter that is taken into account for this analysis is the so called "bio-productive surface of land". This means that each anthropic activity is reported in terms of the required amount of natural capital, referring both to land and sea. Moreover, another method, the dashboard of sustainability has been released in the aim of providing a whole evaluation about the environmental, economic and institutional quality of anthropic systems.

The methods are here applied to the Sicilian region, in order of assessing the environmental suitability of the urban waste system, at a province scale.
After the definition of the present state, some alternative scenarios are contemplated, by changing typical parameters of the waste management approach, with a particular attention to the amount of the recycled materials.

All the considered alternatives are environmentally ranked by means of the application of the ecological footprint and of the dashboard of sustainability methods.

Moreover, the suitability of the methods in order of providing an useful tool for administrator is argued, especially referring to the actual availability of the required input data.

2 The Sicily waste management system

Sicily, with its 390 municipalities and 5.108.000 inhabitants, delivers yearly an average value of 2.500.000 tons of urban solid waste, that is 500 kg per inhabitant or 1.4 kg per day and per inhabitant. This remarkable amount of municipal solid waste determines an emergency situation with regard to its proper disposal.

Landfills are presently the most important way of waste treatment in Sicily: as far as 260 landfill plants are in fact in activity in the island, most of which are approximately saturated and operated in an uncontrolled regime.

As a consequence, the national Italian government has officially stated, with a decree released in 1999, the state of emergency of the solid waste situation in Sicily. The Sicilian government (Sicily is in fact an Italian region almost autonomously governed), by receipting this decree, has released a "priority document" (P.I.E.R., "Piano degli Interventi di Emergenza Rifiuti") aimed at the establishing on the regional territory of the favourable conditions for a correct management of the MSW. With this aim, the Sicilian Island has been subdivided

Waste Management and the Environment II, V. Popov, H. Itoh, C.A. Brebbia & S. Kungolos (Editors)

into 26 optimal territorial ambits (ATO, "Ambiti Territoriali Ottimali"), that will be managed by private organizations, monitored by the regional government through its “Commissariato per l’Emergenza Rifiuti" [1].

This document essentially suggests that a proper management of the solid urban wastes should be characterised by the differentiated conferring of categories of waste, by the saving of secondary materials and by the production of high quality compost and of waste derived fuel. Among the interventions foreseen by this action plan, four waste incinerators are also contemplated, that will allow the recovery of sensible amount on electric energy from the combustion process.

Table 1: Yearly average recycled materials: Italian and Sicilian figures.

Recycled materials	Italian average (kg/inh.)	Sicilian average (kg/inh.)
Paper	18,50	4,79
Cardboard	4,20	0,62
Glass	14,00	3,45
Plastic containers	2,50	0,69
Aluminium tolls	0,23	0,08
Medical waste	0,06	0,02
Exhaust batteries	0,05	0,01

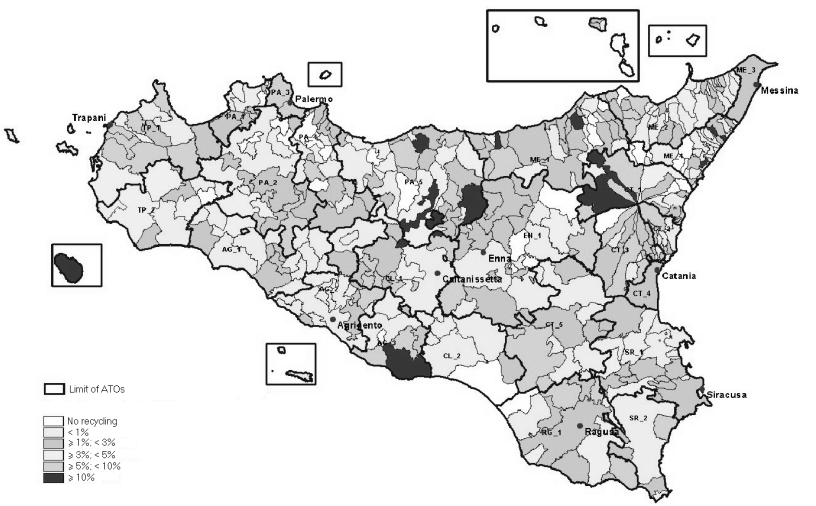

Figure 1: Performances of the Sicilian municipalities in the waste recycling (situation at year 2001).

The most relevant characteristic of the present situation that needs remarkable improvements is the poor level of recycling realised by the municipal solid waste

systems in the region. Only 1% of the urban waste is, in fact, recycled and reused [2], that represents a very low value, even in comparison with the Italian country figures, as reported in table 1.

One of the main goals of the emergency plan is then a dramatic improving of this situation, bringing to the 35% of the total waste produced the recycling percentage.

3 Environmental appraisal of complex management systems

As far the management of complex system is in question, one should have at his disposal a set of reliable and effective indicators, able to synthetically describe the environmental performances of alternative options. In the case of MSW systems, the problem becomes further complicate due to the enormous number of parameters involved in the evaluation, ranging from economic to specifically environmental issues. In the year 2002 "State of the Environment" [2] of the Sicilian Region, for example, a set of indicators have been selected in the aim of providing local administrators with useful tools for hierarchically ranking the policy options regarding the municipal solid urban waste systems. Table 2 reports these indicators, along with its territorial availability and the main environmental features that they show (response or pressure on the natural environment).

Table 2: Indicators selected by the Sicilian waste masterplan.

Indicators	Territorial availability	Environment pertinence
Percentage of differentiated materials	Region	Response
Quantity of dangerous special waste	Region	Response
Quantity of non dangerous special waste	Region	Response
Quantity of total special waste	Province	Pressure
Quantity of MSW gathered by single fractions	Region	Response
Percentage of differentiated gathering by materials	Regional	Response
Total production of MSW	Provincial	Pressure
Number of plants for the MSW treatment	Provincial	Response

Obviously these indicators need some further analysis in order of drawing from them useful information about the environmental performance of the type of management system adopted for the urban waste treatment.

3.1 The Dashboard of Sustainability

An aggregate method has been recently proposed in the attempt of transferring the gross domestic product (GDP) parameter into a suitable synthetic index that

Waste Management and the Environment II, V. Popov, H. Itoh, C.A. Brebbia & S. Kungolos (Editors)

also would take into account environmental and social issues. This index is called "Dashboard of Sustainability" [3].

The main characteristic of the method refers to the easy visual perceiving of the whole environmental performances of a given system, by means of the movement of a speed arrow toward the green side (more sustainability) or the red side of the graph (less sustainability). For this reason it is currently adopted within the Strategic Environmental Assessment of master plans, as required by the European Unit [4, 5, 6].

An application of the Dashboard index to the Sicilian environmental performances of the ATOs with respect to the MSW management has been introduced by some of the present authors [7]. For the present application, we have chosen a more aggregate territorial context, by joining ATOs among them in order of exactly covering the administrative pertinence of the nine Sicilian provinces.

The indicators selected for applying the Dashboard method were quite similar to those reported in table 2, with a deeper emphasis on the types of materials differentially collected.

Figure 2 reports a typical printout of the Dashboard method: it specifically refers to the province situation of Palermo (that encompasses four ATOs). In this graph, along with the colour scale that visually depicts the level of sustainability of the system, is reported on the right side the rank of the nine Sicilian provinces, as hierarchised by the output of the method.

The interpretation of the province abbreviations appearing in figure 2 is the following: AG=Agrigento, CL=Caltanissetta, CT=Catania, EN=Enna, ME=Messina, PA=Palermo, RG=Ragusa, SR=Siracusa, TP=Trapani.

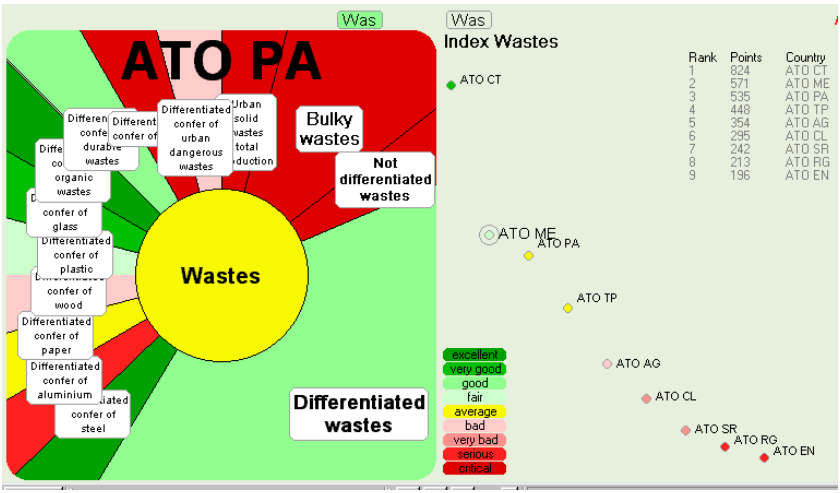

Figure 2: Printout of the Dashboard method: ATOs of the province of Palermo along with the rank of the nine provinces.

Apart the absolute value referring to the performance of each single ATO (here the ATOs belonging to the province of Palermo are depicted with a colour yellow, that signals a non excellence situation), is relevant to note that the method is able to release a relative quality classification of the nine provinces.

Clearly the general meaning of this rank does deserve some further investigation, in order of establishing the feasibility of the method in assessing the environmental quality of the waste provincial management systems.

3.2 The ecological footprint

The Task Force on Planning Healthy and Sustainable Communities [8] has developed a new method that uses the area of bio-productive land as its measurement unit. It is called the "Ecological Footprint".

It essentially converts energy and material flows into the corresponding land/water area needed to sustain them. At the basis of the methodology there is the determination of the bio-productive earth share per person, to be compared with the present availability. The main ambits of human consumption are translated into areas of productive land required to provide resources and waste products.

The Ecological Footprint of a given human settlement (or of a technological system) on Earth is given by the total area needed to its continuous existence. Therefore the Ecological Footprint model represents "the total carrying capacity amount of whom a certain population takes (directly and indirectly) possession" [9].

Land and sea areas are divided into four basic types: bio-productive land, bio-productive sea, energy land, and built land. A fifth land type, that is the bio-diversity land, is the computed land share, needed to preserve bio-diversity.

The application to the waste system of the ecological footprint is here made by utilising the so called "component" method.

Within this frame, the application of the procedure to waste system allows the evaluation of the effects, in terms of ecological footprint (and, in turn, of environmental impact), of changes in the releasing of urban solid waste or in the treatment procedures. A specific attention is then paid to the recycling, since an improvement of this amount would determine a less environmental impact and a benefit to the whole performance of the system.

The relevant components here chosen for the recycling are: paper, cardboard, aluminium, metals, glass and plastic.

For each component, land for energy, forest land and built-up surface are computed, that are the bio-productive surfaces of the Earth that applies in this case.

The expression utilised for computing the land for energy is the following:

$$\textit{Land for energy} = \textit{quantity} \times \textit{energy intensity} \times \textit{carbon intensity}_{oil} \times \textit{1/absorbing rate of carbon} \times 0.69 \times \textit{equivalence factor} \times (1 - \%\ \textit{of recycling} \times \%\ \textit{saving energy})$$

The last term of the previous equation determines a reduction of the ecological footprint proportional to the amount of recycled materials.

Waste Management and the Environment II, V. Popov, H. Itoh, C.A. Brebbia & S. Kungolos (Editors)

The percentage of saved energy is different for each kind of the involved materials (as reported in Table 3).

The forest land referring to waste is here obtained by applying the following equation:

$$\textit{Forest land} = \textit{quantity} \times \textit{timber footprint intensity}/600 \times 1.65 \times (1\text{-}\%\ \textit{recycling} \times 0.8) \times 0.0001$$

where the timber footprint intensity is 6469 m^2/m^3; 1.65 is the weight ratio between the wood and the quantity of paper obtainable from it.

Table 3: Percentage of saved energy from the recycling of waste materials.

Materials recycled	Percentage of saved energy (%)
Paper and cardboard	45
Aluminium	95
Other metals	15
Glass	30
Plastic	70

The built land associated with the releasing of solid waste is computed in the same way adopted for the goods. That is:

$$\textit{Component of footprint}_{(ha/pro\ capite)} = (\textit{Apparent energy consumption} + \textit{Import rate})/\textit{Average global efficiency})/\textit{Population}$$

where the apparent energy consumption is given by the summation of the yearly production and the import rate, minus the export rate.

Table 4: Ecological footprint of the Sicilian provinces by land categories.

Province	Forest	Built-up surface	Land for energy	Total Ecological footprint
PA	0.330	0.00003	0.102	0.432
EN	0.474	0.00	0.132	0.605
CL	0.547	0.00	0.153	0.700
AG	0.547	0.00	0.183	0.730
TP	0.561	0.00	0.183	0.744
RG	0.610	0.00	0.196	0.806
ME	0.654	0.00	0.204	0.858
SR	0.656	0.00	0.208	0.864
CT	0.787	0.00	0.251	1.038

Waste Management and the Environment II, V. Popov, H. Itoh, C.A. Brebbia & S. Kungolos (Editors)

In this application the yearly production, by each province and by each material category, is usefully provided by the Sicilian waste masterplan ("Piano di Gestione dei Rifiuti in Sicilia" [1]) for the year 2001.

After all the previous computations take place, we are able to evaluate the ecological footprint of the Sicilian ATOs, aggregated by province, as reported in table 4, where territorial contexts are ranked by their environmental performances.

4 Comparison between the methods and conclusion remarks

Once both the methods are applied to the waste management system of the Sicilian region, it's obvious to try to compare their relative results. Table 5 illustrates the ranks provided by each method, in terms of environmental performances, as provided within their relative frames. It's surprising, in this aim, to observe the level of the differences between the results: it seems that results of two method are totally uncorrelated. Only a few province, in fact, maintains a similar rank in both evaluation tools.

Table 5: Comparison of the province ranks provided by Dashboard and by Ecological Footprint.

Rank position	Ecological footprint	Dashboard of Sustainability
1	PA	CT
2	EN	ME
3	CL	PA
4	AG	TP
5	TP	AG
6	RG	CL
7	ME	SR
8	SR	RG
9	CT	EN

Actually, a couple of good reasons can be raised in order of explicate these differences.

First of all, it must be observed that two methods adopt similar indicators, but not exactly the same: in the case of the dashboard method, in fact, the quantities of several kinds of differentially conferred materials are accounted for, while in the ecological footprint method, only the global amount of recycled materials are taken into account.

Secondary, two methods are essentially characterised by a different structural approach. The Ecological Footprint, on one hand, determines an unique indicator, the hectares of bio-productive land sequestrated by a given human activity: in this sense this tool can be considered as a "technical" evaluating tool. The dashboard of sustainability, on the other hand, provides a general assessment of the whole performance offered by the given system, by taking into account

Waste Management and the Environment II, V. Popov, H. Itoh, C.A. Brebbia & S. Kungolos (Editors)

both environmental and economic issues. In this sense, the dashboard can be considered as a "political" evaluating tool.

These reasons could partially justify the differences among the environmental ranks provided by two methods of appraisal. Nevertheless, some further investigations are needed in the aim of better explaining the causes of such huge difference between the respective results.

After all, the judgement about the quality of a waste management system should not depend on the method utilised for its appraisal. But this problem does apply to the more general attempt of synthetically evaluating complex systems, particularly with respect to their environmental performances: the solution to this problem is of course still question.

References

[1] http://www.regione.sicilia.it/presidenza/ucomrifiuti/. Official web site of Regione Siciliana. Visited in march 2004.

[2] Relazione sullo stato dell'ambiente in Sicilia 2002. (*In Italian*) Regione Siciliana, Assessorato Territorio e Ambiente, Palermo, November 2003.

[3] J. Jesinghaus. Indicators for Decision Making. European Commission, JRC/ISIS/MIA, TP 361, I-21020 Ispra (VA) 12/12/1999.

[4] European Parliament and Council Directive 2001/42/EC. Assessment of the Effects of Certain Plans and Programmes on the Environment, (2001).

[5] SEA and Integration of the Environment into Strategic Decision-Making. Final Report, May 2001. CEC Contract No. B4-3040/99/136634/MAR/B4.

[6] M. La Gennusa, G. Rizzo, G. Scaccianoce, M. Traverso. Strategic environmental analysis (SEA) of the building sector: an annotated list of indicators and a simple methodology. Proceedings of the: PLEA 2003 – Passive and Low Energy Architecture. The 20th International Conference, Santiago – CHILE. W. Bustamante and E. Collados Editors.

[7] M. La Gennusa, G. Lascari, G. Rizzo, G. Scaccianoce. Un metodo per la valutazione delle prestazioni ambientali dei sistemi integrati di gestione dei rifiuti: applicazione agli ATO della Regione Siciliana (*In Italian*). In. Ambiente & Territorio – I quaderni di Ecomondo. A cura di Luciano Morselli. ISBN 88.387.3104.7. Maggioli Editore, 2003.

[8] M. Wackernagel, W. Rees. Our Ecological Footprint. Reducing Human Impact on the Earth. New Society Publishers, Gabriola Island, B.C. – Canada (1996).

[9] M. La Gennusa, G. Rizzo, G. Scaccianoce, M. Traverso. Assessing the Ecological Footprint of an Urban Transportation System. Proceedings (on CD) of the 19th International Conference with Exhibition "Science and Motor Vehicles 2003 - Automotive Engineering for Intelligent Vehicle Systems", Belgrade, Serbia & Montenegro, 26-28 May, 2003. YU – 03062. ISBN 86-80941-29-8.

Waste Management and the Environment II, V. Popov, H. Itoh, C.A. Brebbia & S. Kungolos (Editors)