Sustainability indicators for environmental certification of Siena province (Italy)

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Abstract

Organizations which intend to obtain environmental certification following the international standards ISO 14001 [1] and the European Emas [2] regulations are required to evaluate their environmental performance and to demonstrate its continuous improvement in accord to sustainable development principles. Thus getting and maintaining environmental certification needs the employment of methodologies to monitor systems’ environmental performance through time. Emas suggests adopting indicators to measure the evolution of the organizations’ environmental status.

Dealing with complex systems, such as Siena province, common indicators (i.e. analytical pollution measures) are not sufficient to consider all the involved environmental aspects. “Macro” indicators able to evaluate the global environmental performance of the organization are needed. Here we propose sustainability indicators given from different thermodynamic methodologies such as emergy analysis [3], CO₂ balance calculation [4] and ecological footprint [5] to monitor on a large-scale the environmental performance of Siena province. Due to their systemic character and their holistic approach, these indicators successfully fit to assess the environmental performance of such a complex system for environmental certification.

1 Introduction

Environmental certification following ISO 14001 international standard and/or Emas European regulations is a voluntary adhesion of an organization to a
program of *environmental performance* continuous improvement. Certification is based on sustainable development principles [6] and its final target is to permit future generation to survive and develop in accord to Bruntland Commission definition of sustainable development [7].

Aim of environmental certification is the environment protection and preservation through pollution reduction, and pursuing a correct use of resources, the renewable and especially the non renewable ones. Environmental certification has been already obtained by many organizations, from industrial and manufacturing to agricultural and services sector. Starting from 1999 when the first Italian Public Administration, Varese Ligure (a small city of Liguria region, north-west Italy) got both ISO 14001 and Emas certification, interest for environmental management systems has been growing among public Italian administrations. Due to enormous difficulties to manage all their environmental aspects, all the public administrations till today certified have quite small dimensions and Siena province is the first Italian large territorial system to go through this way.

Siena experience is thus particularly important and it is a fundamental step to make policy makers and administrators finally understand that their efforts are fundamental to promote and carry out a coordinate action to make our development sustainable.

## 2 Siena Province: a complex territorial system

Siena Province (252,972 inhabitants in 1999) covers an area of 3,821 km² in the region of Tuscany, centre Italy. Not far from the Tirrenian sea, Siena territory has a mild climate and a prosperous agriculture, especially for wine and oil productions; some of the most important Italian wines (such as Chianti and Brunello) are produced there. Big industries are not present in the province and among small-medium industries crystal and furniture productions are important. Plants to convert geothermal energy to electricity are present in the province and mineral extraction activity is relevant.

Tourism is one of the most relevant economic activities of the province, both for the artistic city of Siena and for its countryside where eco-tourism is very wide.

Siena economy results as a whole very rich and this is mainly due to the fact that the town is the head office of one of the most important Italian banks, Monte dei Paschi, that was born there prior to American continent discovery.

Siena province is thus a complex territorial system with a wide variety of activities and its public administration has an enormous number of tasks and services to offer the citizens all with relevant environmental potential effects.

It is sufficient to think about public transport or wastes disposal to understand how many direct and indirect environmental impacts a provincial administration may have.

Furthermore it must be highlighted how a province may influence behaviours of other hierarchically dependent public administrations in particular local governments, thus heavily influencing also their environmental impacts.
Due to complexity of the activity of a province administration, composed by many services with a wide variety of environmental impacts, direct and indirect to manage, it is a very difficult task to identify and select a set of indicators useful to measure the environmental performance of the organization in order to demonstrate its continuous improvement through time as requested by ISO 14001 and Emas certifications.

While for an industrial production or an organization with a well defined activity, indicators related to energy consumption or pollutants emissions are commonly used, for such a complex organization as Siena province these indicators, each focused on a singular environmental aspect, cannot be sufficient to measure the system environmental performance, but they need to be integrated with "Macro" indicators able to give an immediate measure of the environmental status of the system as a whole.

Thus, being environmental certification a tool to apply sustainable development principles, here we propose to use sustainability indicators to base certification on.

We choose thermodynamic indicators from emergy analysis [3], CO₂ balance calculation [4] and ecological footprint analysis [5] and calculate them for the province of Siena to evaluate its environmental performance.

3 Sustainability indicators for Siena Province

Sustainability indicators from emergy analysis [3], CO₂ balance calculation [4] and ecological footprint [5], by considering all the energy/matter inputs, outputs and flows of the territory administrated by the provincial government and by distinguishing their nature and their degree of renewability, give an overall view of the environment health and thus of the environmental performance of the province administration. The usefulness of thermodynamic emergy indicators for certification of territorial systems has been already introduced [8], but to make the environmental performance evaluation more complete they need to be integrated with other thermodynamic indicators focused on different aspects.

The methodologies here proposed produce indicators which result complementary in that emergy analysis is focused on resources use, while ecological footprint evaluates the impact of a population on the environment on the basis of its consumptions, and carbon dioxide balance deals with wastes production.

For a deeper insight of the three methodologies from which they derive, particularly of emergy and ecological footprint analyses, readers may refer to wide available scientific literature [3, 4, 5, 9, 10, 11, 12]; here the indicators proposed for environmental certification are briefly introduced, trying to underline their meanings when applied to a provincial system.

From emergy analysis the following indicators are chosen:

*Environmental Loading Ratio* (ELR): given by the non renewable energy inputs to the system (local and economic) divided by the renewable ones. The lower this ratio the lower the technology of emergy use and/or the lower the stress produced form the system on its environment. For territorial systems, with
similar technological level, the higher this value, the higher the impact on the environment.

*Emergy Density (ED)*: given by the total emergy necessary to support the system divided by its area. It is a measure of the pressure of the system on its environment: the greater the pressure the higher the value of this indicator.

*Emergy/person*: given by the total emergy supporting the province divided by its population. It is a measure of the mean life standard of a territory in terms of per capita resources availability.

*Emergy Yield Ratio (EYR)*: given by the output emergy divided by the emergy of economic inputs. The higher this value, the higher the profit per emergy unit invested.

*Emergy Investment Ratio (EIR)*: given by the emergy from economic inputs divided by the emergy provided from the natural environment inside the system. It is a measure of the province efficiency to invest to exploit its local resources.

*Emergy/Money*: given by the total emergy driving the province divided by its GNP. The lower this value the higher the profit in relation to environmental impact.

For CO₂ balance calculation are evaluated all the contributions to equivalent CO₂ emissions. All the main activities emitting greenhouse gases are considered: electric energy consumption, fossil fuels combustion and methane emissions from wastes disposal areas and from livestock. Here we propose to use as indicator for environmental certification:

The *Net CO₂ balance*: given by the quantity of equivalent CO₂ emitted inside the province, minus the CO₂ absorbed through photosynthesis by the vegetation inside the system.

The following indicators are proposed from Ecological Footprint analysis:

*Biocapacity*: it accounts the ecologically productive territories inside the province.

*Ecological Footprint*: it is the amount of productive land required to supply, in a sustainable way, all the resources used and to reabsorb, in a sustainable way, all the emissions. It is the productive territory effectively used by the province population. Thus it is a sort of reversed carrying capacity. Wherever this value exceed the system area available it means that the system territory is not sufficient to support its population and that the population has too high consumptions.

*Ecological Deficit*: given by the biocapacity minus the ecological footprint of the province. A negative value indicates that the system population has too high consumptions for the system capacity to support it.

The reference year for calculation of all the indicators is 1999.

### 4 Results and discussion

Table 1 reports for Siena province the sustainability indicators previously introduced. To make results easier to understand in the last column of the table are reported, where available, the values of the same indicators calculated for Italy [13, 14].
All the emergy quantities are expressed as sej (solar emergy joule) in that emergy of an energy flow is given by its equivalent solar energy.

Table 1: Sustainability indicators to evaluate environmental performance of Siena Province (Italy).

<table>
<thead>
<tr>
<th>Indicators</th>
<th>Unit</th>
<th>Siena</th>
<th>Italy</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Emergy Indicators</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Environmental Loading Ratio (ELR)</td>
<td>-</td>
<td>10.65</td>
<td>9.47</td>
</tr>
<tr>
<td>Emergy density (ED)</td>
<td>sej/m²/yr</td>
<td>2.53 × 10¹²</td>
<td>4.20 × 10¹²</td>
</tr>
<tr>
<td>Emergy/person</td>
<td>sej/person/yr</td>
<td>3.83 × 10¹⁶</td>
<td>2.20 × 10¹⁶</td>
</tr>
<tr>
<td>Emergy Yield Ratio (EYR)</td>
<td>-</td>
<td>3.38</td>
<td>1.61</td>
</tr>
<tr>
<td>Emergy Investment Ratio (EIR)</td>
<td>-</td>
<td>0.42</td>
<td>1.65</td>
</tr>
<tr>
<td>Emergy/Money</td>
<td>sej/€/yr</td>
<td>1.59 × 10¹²</td>
<td>1.40 × 10¹²</td>
</tr>
<tr>
<td><strong>CO₂ Balance indicators</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Net CO₂ Balance</td>
<td>Gg/yr</td>
<td>772</td>
<td>-</td>
</tr>
<tr>
<td><strong>Ecological Footprint Indicators</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ecological footprint</td>
<td>ha/person</td>
<td>5.80</td>
<td>5.51</td>
</tr>
<tr>
<td>Biocapacity</td>
<td>ha/person</td>
<td>5.74</td>
<td>1.92</td>
</tr>
<tr>
<td>Ecological deficit</td>
<td>ha/person</td>
<td>-0.06</td>
<td>-3.59</td>
</tr>
</tbody>
</table>

All the three ecological footprint indicators are expressed as equivalent hectares (productive territories) per person: procapita values are more immediate to be understood.

All the calculated indicators show that Siena province has good sustainability. ELR (10.65) only slightly higher than the national value (9.47) shows a low environmental stress for Siena in consideration of the relevant presence of "green" and non urban areas in the national territory. Furthermore by comparing
Siena ELR with the values calculated for other Italian provinces, it always results the lowest, in some cases over 2 or 3 times smaller than the other values [15]. ED (2.53x10^{12} \text{ sej/m}^2/\text{yr}) value that is almost 2/3 than that for Italy (4.20x10^{12} \text{ sej/m}^2/\text{yr}) confirms a low pressure of the system on its environment. Pro capita resources availability, energy/person (3.83x10^{16} \text{ sej/person/yr}) higher than for Italy (2.20x10^{16} \text{ sej/person/yr}) means that the province has a great internal natural capital.

EYR (3.38) about two times the Italian value (1.61) shows a good investment efficiency while the EIR (0.42) almost 1/4 than for Italy (1.65) shows a very good efficiency of the province in investing to exploit local resources. Emergy/money ratio (1.59x10^{12} \text{ sej/€/yr}) is slightly higher than the Italian value (1.40x10^{12} \text{ sej/€/yr}) although the high GNP of the province. In comparison with other Italian provinces, Siena presents anyway the lowest value of this ratio and this means that for a given resources exploitation, Siena system is more wealthy than the others [16].

Emergy indicators altogether show that the province of Siena is very rich in natural capital and with a proportioned economic growth.

CO\text{2} net balance, although Siena province results a low environmental stress producing system, shows that it has a too high rate of greenhouse gases emissions. Thus the first improvement action could be to carry out policies to reduce energy consumption.

Biocapacity (5.74 eq.ha/person) covers the 99% of the use of natural services by provincial population, leaving a low ecological deficit (1%). This means that the environmental balance of the province is substantially level.

This is due not to a low ecological footprint (5.80 eq. ha/person), but to a high biocapacity (5.74 eq. ha/person), that is a high presence in the provincial territories of natural areas or dedicated to agriculture, pasture lands and forests. Population of the province makes a too high use of natural services: ecological footprint results higher than national mean, and much higher than the planetary mean available ecological space (2.18 eq. ha/person) [14].

The set of indicators here proposed shows a very positive environmental balance for Siena province, especially in comparison with national standard. The province government has a good management system both for the direct and for the indirect environmental aspects but efforts to improve environmental performance as requested by environmental certification could be made.

In particular non renewable resources use should be reduced, starting from energy consumption, in order to reduce equivalent CO\text{2} emissions and improve the system environmental sustainability.

5 Conclusions

The sustainability indicators here proposed demonstrated powerful to assess the environmental performance of a complex territorial system such as Siena province. The province showed high sustainability and a good environmental condition.
These indicators could be thus useful to monitor environmental performance of complex territorial systems for environmental certification. They may be used as “Macro” indicators integrating classical environmental indicators focused on singular environmental aspects such as analytical pollution measures to give a complete view of the environmental status of a complex territorial system.

Monitoring their evolution through years could ensure that environmental programs developed for environmental certification are respected and meet sustainable development guidelines. Furthermore they could help to point out future environmental programs and in policy decision making.

References
