A new environmental approach in the territory assessment

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Abstract

Research on the brownfield topic has mainly been focused either on the practices of redevelopment and restoration of a single portion of territory or on the investigation of the causes of a polluted site.

In this paper we present a different approach that includes a vast territory (a region or a district) with different types of soil use. This approach allows one to evaluate the state of the territory as a whole and to investigate the pressure due to human activities. The case study is on the Province of Grosseto and it is studied by emergy analysis. This environmental accounting methodology is able to compare the value of human and natural systems on a common basis: the quantity of solar energy directly and indirectly required for a process. This quantity is called emergy and represents the memory of all the energy, matter and time that the biosphere used up to make a product available. Emergy analysis permits us to divide the territory into different districts and to highlight those with a better relationship with the environment.

In particular, one of the emergy indices, the empower density, i.e the emergy per unit time and area, gives a concrete measure of the pressure exerted on a territory. We can assess the state of the pressure associated to an activity and then manage the territory in an environmentally sound way.

Moreover this index, with the Environmental Loading Ratio (the ratio between non-renewable and renewable resource used) is able to differentiate those areas where the extractive activities have or had an impact on the territory with respect to those areas where the excavations are limited or absent. Using this environmental account methodology it is then possible to outline a photograph of the Province of Grosseto and to give indications for a sustainable development of the territory.

Keywords: emergy analysis, mining sites, sustainability.

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1 Introduction

The territory assessment can be pursued looking at the particular aspects and studying the system as a whole. The first approach gives indications of the properties of a small portion of territory (local level) and so it is proper to highlight polluted sites; the second approach regards the development of a system and tries to avoid possible future situation of pollution or stress. A territorial system is a complex system in a steady state. Its structure is based on many levels of organizations, its openings to the outside, its irreversible dynamics are peculiar features of a complex system. This system requires resources and energy to enhance internal order and to self-organize, while increasing the entropy of the surroundings. The increase in entropy exceeds the internal entropy decrease of the system, so that the second principle of thermodynamics is observed. Hence a territory behaves like a dissipative structure [1].

From a thermodynamic point of view, the dissipation of resources, such as fossil fuels, means positive entropy changes in the environment associated with greenhouse gas emissions and the co-products commonly called wastes. Humans need to decrease the speed of exploitations of resources, and aim for development compatible with the biophysical limits of the planet. The Earth is a finite system and as a consequence it has physical constraints: its resources as well as its capacity for absorption and regeneration are not infinite. The existence of constraints means that the planet has a carrying capacity, namely a capacity to sustain human and other forms of life (plants, animals...) that are interdependent: this is the basis of sustainability [2].

In this paper, we analyse the province of Grosseto, that is located in the southern part of Tuscany; its territory extends along the Tirrenic coast and it is delimited by the province of Livorno, Siena, Pisa and Viterbo. To analyse this system we have used an environmental accounting methodology, the Emergy Analysis. All the data refer to year 2000. In order to give a comprehensive assessment of the environmental sustainability of the system we have also divided the Province in five districts.

2 Emergy analysis

The methodology was developed by H.T. Odum [3,4] of the University of Florida, (USA) in the early 1980's. The solar emergy (from now on simply emergy) of a flow or storage is defined as the solar energy directly or indirectly required to generate that flow or storage. It is an extensive quantity and its units are solar emergy joules, sej. In order to convert all the flows, involved in the process, into this common base a conversion factor is used: the (solar) transformity, defined as the emergy per unit flow or unit product. It is an intensive quantity measured in sej/J. Emergy can be considered as an energy memory because it takes into account all the energy, past and present, needed to produce that product or flow. As the emergy analysis is useful to check applications of the first Daly's rule, it is recognized as an important tool to

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define the sustainability in the long run and measure the human impact on nature [5]. This environmental accounting methodology can be used to assess the complex relationships between the economic system and its supporting environment because the work of both is expressed in equivalent terms. In this way we can also consider the energy flows that are "free" and generally neglected in the traditional energy and material balances. Moreover, a set of emergy-based indicators is proposed to evaluate different scenarios comparing their emergy inputs [4]. The total emergy of the system (U) is divided into the renewable (R) and the non-renewable (N) part, and the local (L) and imported from outside inputs (F).

The environmental loading ratio (ELR) is the ratio of purchased and non-renewable indigenous emergy to renewable (free) environmental emergy:

$$ELR = \frac{N + F}{R} \tag{1}$$

A high ratio suggests a high technological level in emergy use and/or a high level of environmental stress. It is like an alarm-bell for a state of non-equilibrium which could become irreversible in the long run. Emergy use per person suggests a measure of the standard of life in a country intended as availability of resources and goods. The empower density (ED), the emergy flow per unit area and time, is a measure of spatial concentration of emergy flow within a process or system. A high empower density can be found in processes in which emergy use is large with respect to the available area. This suggests that the land is a limiting factor for the future economic growth.

3 Case study

The Province of Grosseto has an area of 4,504 km^2, 80% of which is hilly, and the rest is equally plain and mountainous. It is one of the largest province of Italy and the first in Tuscany. It has a population of 215,594 units and a population density of 48 ab/km^2, one of the lowest in Italy (191 ab/km^2) and the lowest in Tuscany. Moreover the population density is not homogeneous and it is mainly concentrated in the coastal urban areas (Grosseto, Follonica, Monte Argentario and Orbetello). The socio-economic development of the Province is based on agriculture and tourism (mainly in the coastal areas), even if there is an important chemical industrial pole in the area of Scarlino. The territory has been divided in five areas according to economic and geographic characteristics (figure 1).

District 1 has an area of 802.83 km^2 with a population of 44,000 units. The area was known in the past for the its mining activities (pyrite at Gavorrano; silver, copper and lead at Massa Marittima; copper at Monterotondo Marittimo; silver at Montieri), and represented the main extractive pole of the Tuscany in the medieval age. In the beginning of the 1800 many industrial activities (metallurgy at Follonica, geotermy at Monterotondo, chemistry and mechanics at Scarlino) became important. These industrial sectors are partially reduced today in favor of the tertiary and tourist sector. The districts contain numerous mining sites, that need reclamation.

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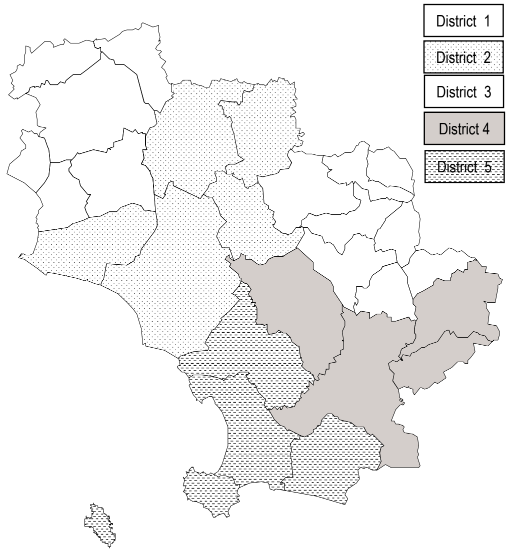

Figure 1: The five districts of the Province of Grosseto.

District 2 has an area of 706.40 km^2 with a population of 19,700 units. In the past the main activities were agriculture, sheep farming and silviculture. In the first fifty years of 1900 the mines of mercury were exploited; today the local economy is based on agriculture, on a small industrial sector (constructions and wood manufacture) and above all on the tertiary sector. The importance of this sector is easily due to the increased weight of the tourist sector.

District 3 has area of 1,322.65 km^2 with a population of 95,000 units. Historically based on agriculture and zootecnical activities, the local economy is nowadays oriented toward extra-agriculture sector, even if agriculture conserves a relevant role. The most important sector is the tertiary one while industial sector (food industry, construction industry, mechanics and wood industry and small dockyard) has low importance. Tertiary is dominated by tourism activities in the coastal towns (Punta Ala, Castiglion della Pescaia, Marina di Grosseto, Principina), the remaining public and private activities are concentrated in the main Municipality of Grosseto. District 4 has an area of 749.35 km^2 with a population of 37,700 units. The local economy was in the past based on fishing and agriculture, limited by the marshland and from the malaria epidemics. The agriculture became important with the land-reclamation during 1930s. Today agriculture conserves a significant role together with zootechny and fishing. The increase in tourism is also relevant. District 5 occupies an area of 923.10 km^2 with a population of 20,000 inhabitants. The economy is historically based on agricultural and commercial activities with the nearby regions of Lazio and Umbria. Together with agriculture activities had a relevant importance the extractive industries with the mercury, sulphur and lignite mines. Today the area has conserved the agricultural characteristics and had developed an agri-turistic sector.

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4 Results and discussion

One of the main environmental issues of the territory is the redevelopment and reclamation of past mining areas. These redevelopments require energy and resource consumptions. These consumptions cannot be accounted in the traditional emergy analysis until the redevelopments will be done. In the district 1 most of mineral sites are concentrated; for this area we decided to formulate a scenario relative to the flows of resources used in the year of analysis and one accounting for the resources that are estimated in the preliminary projects of redevelopments. We have the cost for only 4 projects of redevelopment, all of them situated in district 1, while all the reclamations should be about 20. We have applied "classical" emergy analysis in order to describe the environmental loading ratio caused by the actual development of the district and another scenario that includes the cost of the environmental loading ratio caused by the past activities. It is important to say that the data are estimations as the real cost of a redevelopment project can be quantified when all the operations are finished.

The inputs to the system are transformed in the same unity, the solar emergy joule (sej) by using the transformity. That is, each resource can be weighed in order to consider the memory of the all energies necessary to make it available. The total emergy flux that supports the Province of Grosseto is 5.68×10^{21} sej/year, the main inputs are shown in figure 2.

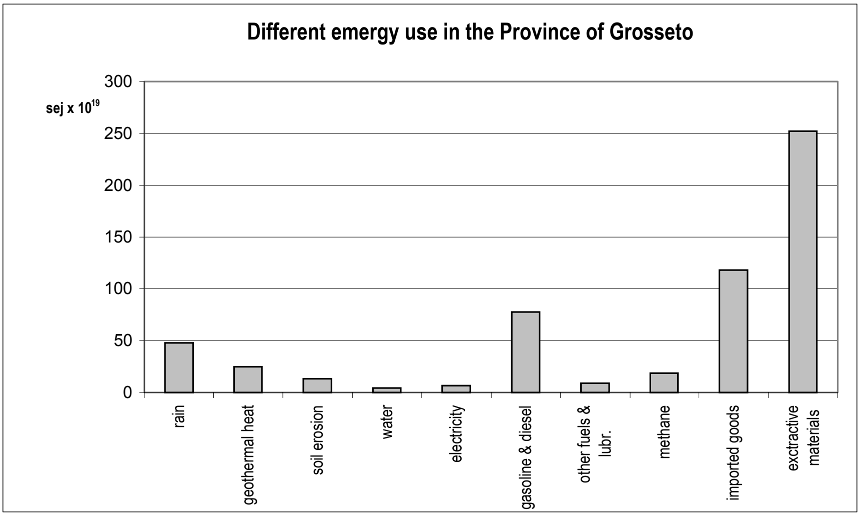

Figure 2: Emergy flows of the system.

In the figure 2 it is very easy to understand that extractive materials (as gravel and sand and not minerals whose extraction ended some years ago) have in emergy terms a very high value with respect to the rest. This depends either on

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the quantity of resources exploited or on the high transformity of this item. Extractive materials, such as fossil fuels, are non-renewable resources, and then it is necessary a care monitoring of the extractive activity, so that this sector doesn't cause a loss in natural capital. However the use of extractive materials don't produce greenhouse emissions as fossil fuel do. Imports also have a relevant emergy content although smaller than the one of extractive materials. This represents the 21% of the total emergy of the province. As far as the energy consumption is concerned the most significant input is due to diesel and gasoline. According to their use and origin, all the inputs are divided into:

- Local renewable resources (R);
- Local non renewable resouces (N);
- Imports (F=A+B)
- Imported energy (B);
- Purchased inputs (A);

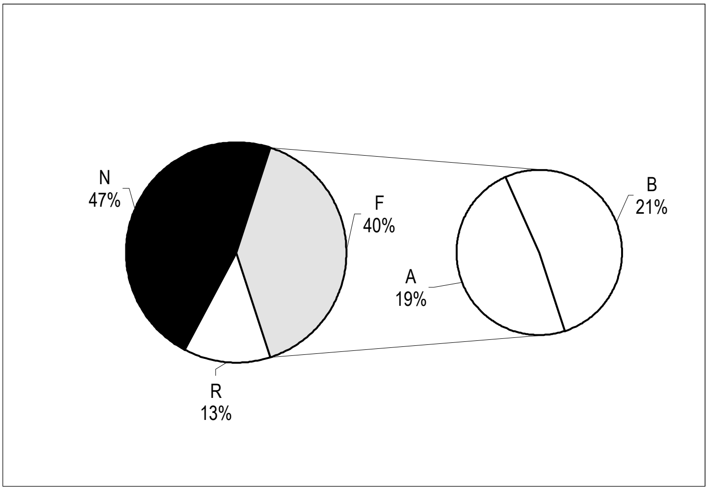

Figure 3: Composition of the emergy flows of the Province of Grosseto.

Figure 3 allows us to compare the ratio between the different type of resources. By analysing the emergy flows of the Province is possibile to say that there is an equilibrium between local and non-local resources with a supremacy of the local resources (60%). Among local resources, non-renewable resources (47%) are larger than renewable ones (13%). The total contribution to renewable resources has a low percentage in emergy terms with respect to resources used. However, the percentage of renewable resources (13%) is very high with respect to other provinces analysed by our group [6].The reason for that is mainly that the system is characterised by a low use of resources. The high percentage in the use of local non-renewable resources is due to extractive materials. The economy of the Province is centred on tourism and services rather than manufactory.

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Hence, it imports low quantity of raw materials and means of production (B). The demand of electricity in the Province is quite low and it is completely satisfied by the local production through geothermal resources. This fact contributes to the low resource use of the Province as the transformity of the electricity produced by geothermal resources is lower than that produced by fossil fuel. The emergy used in the five areas is shown in figure 4 while in figure 5 is reported the emergy flows of the five different areas subdivided in R, N and F. From the analysis of these figures is possible to see that the total emergy used in the Province of Grosseto is mainly located in areas 1 and 2. The highest percentage of local non renewable resources used is in District 4 and the lowest in 5 one. Districts 1 and 2 have high use of imports (F) and local non-renewable resources. The use of renewable resource is highest in district 5 and 3.

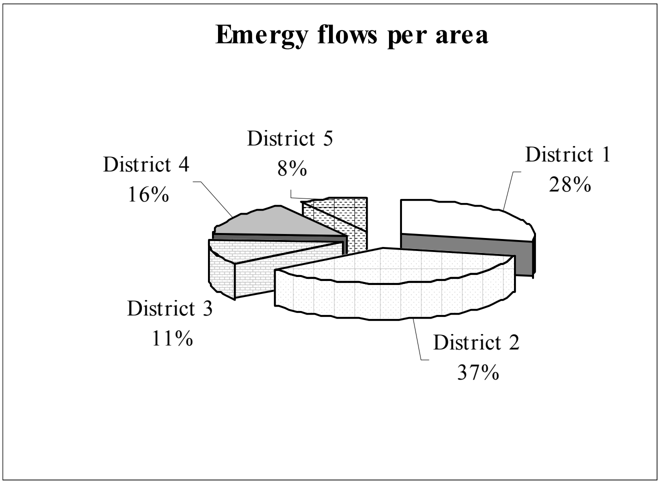

Figure 3: Emergy used in the five districts.

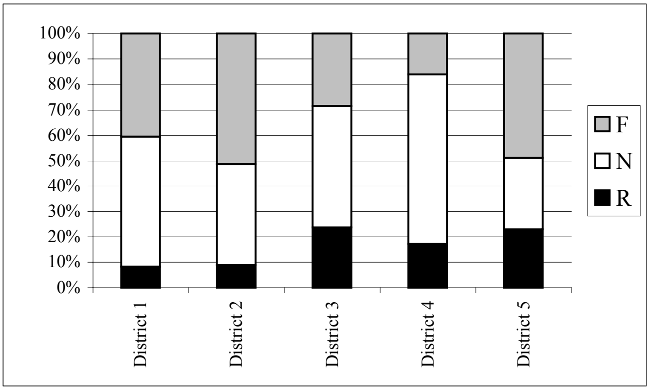

Figure 4: Composition of the emergy flows of the 5 districts.

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All the information coming from the emergy analysis are synthesized by emergy indices reported in table 2. The analysis of emergy per person should be done, considering the renewability of the resources. The emergy of a single citizen can have two different meaning. In the case of a mainly non-renewable emergy flow an high emergy per person shows a resource consumption, in the case of a mainly renewable emergy flow the resource use is constant in time and shows a resource availability. The results identify the area with higher human pressure and the area developed in a virtuous relationship with the environment. The indicators used to do this are emergy density and environmental loading ratio. The higher emergy per person is calculated in District 4 and 1 which are the areas with the numerous extractive sites. As materials are not completely used in the district where they are extracted, in analysing the various areas we recalculate emergy indicators excluding this emergy flow.

Table 2: Emergy indices of the Province of Grosseto and of the five districts.

System	Empower density (sej/m^2)	ELR	Emergy per person (sej·person^{-1}·year^{-1})
Province of Grosseto	1.27×10^{12}	6.69	2.63×10^{16}
District 1	1.99×10^{12}	10.94	3.60×10^{16}
District 2	1.59×10^{12}	10.22	2.17×10^{16}
District 3	1.37×10^{11}	3.23	3.11×10^{16}
District 4	9.96×10^{11}	4.77	4.57×10^{16}
District 5	6.12×10^{11}	3.10	1.20×10^{16}

The analysis of emergy density gives an indication about pressures exerted per unit of territory and identifies District 1 and District 2 as districts where the emergy flow per unit of territory is higher than in the other areas, where a great number of activities is localized and where there is a big concentration of population. In the District 1, as just pointed out in the analysis of emergy per person, it is possible to find high values due to tourists and productive activities specially in Scarlino municipality. Instead the emergy pressure in the District 2 is due to the presence of the main municipality.

Before going into the analysis of Environmental Loading Ratio, it is necessary to remember that environmental loading ratio values obtained are quite low. Moreover, it is important to show that these values suffer, more than the other two indicators, from high value of mining activity which deal with non renewable resources. In fact, if we include extractive resources, district 1 is that one which has the greatest environmental loading and district 5 shows the lowest value. Excluding extractive materials the highest environmental loading is observed in District 2 where there is the highest population density and where there is a lot of tourists. Districts 5 shows in both cases low environmental

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loading values which are better than two other coastal areas. In order to highlight the presence of brownfileds in the Province of Grosseto we include cost of redevelopments in the district 1 analysis. We transform the monetary cost in emergy cost using the emergy per GDP of the Province of Grosseto (calculated in this study). These new emergy costs are added to imports (F), i.e. to the flow of non-renewable resources. This emergy flux should be accounted in the analysis until the redevelopment will been done and it probably increases in time. In this way the public administrations that do not invest in redevelopments, maintain this flow of non-renewable resource while the administrations that make reclamations of the sites will improve their indicator when the reclamation has done as they don't need redevelopment investment anymore. In the case of District 1 the inclusion of these costs brings to important change in the indicator value, for example the ELR changes from 10.94 to 11.47 with an increase of about 5%, that is not so much in absolute value but is very high if we consider that the costs are only relative to 4 sites instead of the all 20. If the four areas had been reclaimed in the 2000, the same analysis performed in the 2001, considering the system equal to that of 2000, would have produced an ELR of 10.94. Including redevelopments cost enables to describe the system in terms of resources consumption and state of the territory. The two scenarios considered are both valid and allow to give indications about the actual development of the system and to highlight the presence of environmental issues that need to be solved.

5 Conclusions

The analysis has shown high contribution of extractive materials out of the whole of emergy flows of the Province. This is partially due to characteristics of the considered system, firstly based on balneary and naturalistic tourism, on agriculture, on services sector and for a small part on heavy industry and partially due to high value of this resource regardless of system in the emergy analysis. The emergy per person (2.63×10^{16}) of the Province of Grosseto can be partially seen as an availability since the value of ELR is very low. This result is easily explicable considering that the Province of Grosseto has an economic structure principally centred on services and a low population density. Our emergy analysis can account in its assessment for the contribution of the extractive materials and for the imported energy and materials, so that we can assess the direct impact on the territory (extractive materials) and the indirect impact associated to the consumptions of resources. Moreover our analysis has demonstrated it can be useful to describe the effect produced by the human activities on the territory (mining sites), including costs of redevelopment in the calculation of emergy indices.

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