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Ecological footprint as a tool for integrated coastal zone management

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ABSTRACT

The Ecological Footprint (EF) is a widely accepted tool for translating all human activities so as to assess their environmental impact and has been often used as an indicator for environmental sustainability, over the last few years, providing information on the impacts of human activities on environmentally valuable ecosystems. On the other hand, Integrated Coastal Zone Management (ICZM) sets the basic principles and methodologies for the sustainable development and management of coastal areas. ICZM is a dynamic, continuous and iterative process designed to promote sustainable management of coastal zones. The continuous human activities development without an effort of a minimization of their EF could jeopardize the future sustainability of the coast. Therefore, in this article, it is attempted to find the gaps in coastal management which the EF could fill in by acting as a planning and management tool. More specifically, this paper examines whether EF could be used in the case of a major transport infrastructure project situated in coastal areas.

Keywords: Ecological footprint; Integrated coastal zone management; Decision making; Sustainability; Infrastructure projects

1. Introduction

This paper is based on two doctoral dissertations researching the environmental processes in planning and management at the European level by examining, on the one hand, the Ecological Footprint (EF) and its spatial dimensions and, on the other, the Integrated Coastal Zone Management (ICZM) and its implementation at a local level.

The main question of this paper is to examine whether the EF could provide an integrated model to be used as an indicator, involving the measurements of data for a certain local area for the purposes of ICZM implementation.

For this purpose, there has been an investigation of the methods through which EF could act as an indicator in the context of ICZM and for human impacts on certain coastal areas and be implemented in decision-making processes while the interest focuses on the diversity of the European coast and its environmentally fragile ecosystems.

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The goal of this paper is not to propose solutions and numeric applications but to raise important issues for new methods for achieving sustainability, increase awareness on the part of stakeholders and improve planning methods for sustainability in local actions.

2. Integrated coastal zone management

ICZM is considered to be a dynamic tool for promoting sustainable development in the coast. It usually covers various geographical territories, from specific local areas to extended areas. The term "integrated" refers to the integration of goals and the tools for their achievement. ICZM includes the combination of policies, sectors and levels of administration as well as spatial elements of an area. Generally, it could be said that, the term "integrated" refers to four dimensions of integration: spatial, temporal, horizontal and vertical [1]. More specifically, there are five different dimensions of integration: between sectors, between levels of government, across the land–water interface, between disciplines and between nations (especially when nations share an enclosed or semi-enclosed waterbody) [2].

The reasons that impose the need for an integrated management are mostly related to the protection of the environment, the sustainability and the economic development. The strategic goals of ICZM include the protection of natural resources, the preservation of the quality of the environment and the attractiveness of the coastal zone.

According to the European Commission, the basic principles of ICZM are as follows:

- Integrated perspective of the coast (geographic and thematic) that takes the interdependencies and differences between the natural ecosystems and human activities into consideration
- Long term perspective that incorporates the present conditions and the future scenarios
- Management processes easily adaptive to changes (economic, political, spatial etc.)
- Incorporation of local particularities and coastal diversities aiming to reduce coastal problems and create flexible solutions
- Respect of natural processes and carrying capacity of coastal areas
- Involvement of all the public and private coastal stakeholders
- Design and use of appropriate tools that that enable coherence between sectoral policy objectives and coherence between planning and management.

The successful implementation of ICZM has the following benefits:

- The ICZM principles could enhance the sensitivity on coastal issues
- It could lead to the redefinition of spatial planning promoting the harmonization with economic, social and environmental factors
- It could promote the increase in participation procedures of the involved stakeholders in the decision making and planning process
- It could act as the linking tool between land and sea
- It could contribute to an area's socioeconomic development [3].

According to the EU ICZM Demonstration Programme, the reasons for the past unsuccessful applications are: limited perception of the coastal zone, inadequate participation of the interested factors in stressing and proposing solutions for the various problems, inappropriate and single planning decisions, dysfunctional bureaucratic systems and lack of coordination and inadequate resources and support by the upper administration levels and lack of data for measuring and monitoring sustainable development at the coast [4,5].

3. Ecological footprint

It is well known that the current conditions of living at the developed countries are not in compliance with sustainable methods. There have been many efforts for a more sustainable future through implementing spatial policies and initiatives. This issue has been engaged by different scientific circles and there have been many theories developed, one of which is the EF. EF is a tool that measures how much biologically productive land and sea is used by every human activity, its impact on the environment and the wastes generated by it [6–8].

The EF of a person is calculated by the annual *per capita* consumption (tonnes per year) by dividing total consumption by population size. After calculating the *per capita* productive land which is used to produce the item to be consumed and dividing by the average consumption of this item with the average annual production. Through this method the EF of a particular ecosystem could be calculated. This process must be followed for all the ecosystems necessary so as to calculate the overall EF. Finally, to identify the EF of the total population the *per capita* average of the EF is multiplied by the population [7].

The EF is a useful tool that can be applied in many different situations using appropriate data and has been widely used. There have been a great number of published studies focusing on different scales (from lower to global) and issues (from generic to specific). More specifically, the EF has been calculated for cities and regions [9,10], for nations [7,11], also for present, future or specified time periods of nations [12–14]. It has also been used for national capital accounting [15], tourism management [16], transport policy [17] and system dynamics [18], planning for local and regional energy strategies [19], environmental consequences of economic growth [20], production processes [21].

The EF has also accepted critiques because of some shortcomings [22] in crucial issues such as:

(a) According to van den Bergh and Verbruggen [23] the theory of EF has a major unclarity, the comparison of EF with the land of an area or a city. As expected, in most cases, the EF is much greater than the boundaries of the area. The fact is that economically developed countries have higher consumption of resources and density.
(b) Lenzen and Murray [13] indicate that there is a difficulty of assigning a surface area associated to the resources coming from the sea.
(c) It is also considered a failure that the EF does not take into account the diversity of the land regarding its natural resources [24], not all productive land is the same.
(d) Finally, the development of new technologies that affect the consumption is disregarded.

Nevertheless, the EF also generates advantages which are widely recognized. The most important of these is that it constitutes an indicator that translates consumption into a number and specifically in hectares *per capita* [16] and this makes it easily understandable to everyone because all people have a sense of space [25]. The process of EF provides clear and understandable calculations that are easy to communicate and can easily support the planning and assessment process [19]. These are the reasons why it is also used as a tool for environmental education [26].

Finally, EF can be used in policy issues about sustainability and also as a different way of policy making [27] because – as mentioned above – it is using 'difficult' data and translates these into one simple number. This allows decision making to be quick and easy. Of course it requires great attention to the data that will be used so as to prevent errors from occurring.

4. Gaps to be filled in

The implementation of ICZM is considered often difficult for local stakeholders mainly for the reasons mentioned above. The need for a simple method is crucial in order to better identify, understand and quantify the problems located in a coastal area. The lack of such a method in the decision making process usually leads to single planning decisions offering solutions for specific problems of the coast in contrast with an integrated approach, which is the key issue for ICZM. Aiming at the quantification of costal issues, the European ICZM Expert Group has developed two sets of indicators:

- The Progress Indicators that measure the progress of the implementation of ICZM in each country. Those indicators offer qualitative information considering the implementation phases of ICZM and regarding planning and management processes, tools and legal framework, participation procedures, political and economic issues [28].
- The Indicators of Sustainable Development (ISD) that monitor sustainable development at the coast (Table 1).

The indicators mentioned above, although easy to develop, are orientated to specific sectors and issues taking place at the coast. The EF, on the other hand, offers the opportunity for additional benefits that stem from the incorporation of the above measurements in the same model.

Here it must be mentioned that the intention of this paper is not to propose that the EF should substitute for these indicators. The issue here is whether EF could act as a supplementary indicator/model that would include and combine data for coastal natural and human resources so as to provide a more integrated perspective of the given coastal area.

This supplementary indicator could prove to be essential for stakeholders that usually need a flexible and easy to update tool in order to develop integrated approaches on coastal problems and improve their planning systems.

For the calculation of the EF, Wackernagel and Rees [8] have proposed the categorization of consumption into five major categories:

(1) Food
(2) Housing
(3) Transportation
(4) Consumer goods and
(5) Services.

Table 1
Examples of ISD indicators

Goals	Indicator	Measurement
To control further development of the coast	Area of built-up land	Percent of built-up land by distance from the coastline
To protect, enhance and celebrate natural and cultural diversity	Change to significant coastal and marine habitats and species	Status and trend of specified habitats and species
		Number of species per habitat type
		Number of Red List coastal area species
To promote and support a dynamic and sustainable coastal economy	Patterns of sectoral employment	Full-time, part-time and seasonal employment per sector
		Value added per sector
	Sustainable tourism	Number of tourist accommodations holding EU Eco-label
		Ratio of overnight stays per number of residents
To ensure clean beaches and unpolluted coastal waters	Quality of bathing water	Percent of coastal bathing waters compliant with the guide value of the European Bathing Water Directive
To reduce social exclusion	Relative household prosperity	Average household income
		Percent of population with a higher education qualification
To use natural resources wisely	Water consumption	Number of days of reduced supply
To recognize the threat of climate change and ensure protection	Sea level rise and extreme weather conditions	Number of "stormy days" land
		Rise in sea level relative to
		Length of protected and defended coastline

Source: DEDUCE [4].

These categories could be subdivided according to each case and they are based on the consumption of basic natural resources (water, energy, land, atmosphere). In the case of ICZM the focus is pointed at the consumption taking place on land and sea, incorporating all the natural and human processes affecting it.

According to Table 1 and with regard to the variables mostly used in EF, there seems to be a resemblance between them that generates the question for this research whether those SD Indicators proposed by the EC could be imported in the EF model. The existence of these (sub)indicators in the same model provides the opportunity to examine their interdependencies and interactions. For example, the increase of a variable determines the course of another and both of those changes affect the final result of the EF. Therefore, the application of the EF creates a wide image of the factors affecting the coastal environment and the relations between them.

As already stressed, the EF is considered to be a tool that indicates and predicts the future impacts of a decision on the environment. It is a number that cannot be questioned because it provides numeric data on issues that form a policy. Through this method the decision making process – at any level – follows the same goals and directions. Its main strengths are related to the numeric calculation of human pressures, the ability to extract results on overconsumption and the simplicity of the communication methods to a wide audience. Despite the unquestionable nature of the EF, it has been highly doubted regarding the methods of its calculation broken into smaller parts and application to different scales and levels. According to a survey based on interviews of 50 EF stakeholders and 150 EF related papers, it has been identified that the EF is perceived as a strong communication tool with a limited role in a policy context and scope. It has also been stressed that it should be developed in accordance with international accounting systems and as a part of a system of indicators for supporting the decision making process [29].

Its role in decision making process is threefold. It contributes to the analysis of the existing environmental condition, the evaluation of the environmental impacts and the monitoring of the research activity results [30]. Each of these dimensions requires the appropriate data that would describe the existing conditions, examine the issues that need to be tackled and create the opportunity for further updating of the monitoring procedure [19].

Although the need for ICZM has led to a lot of efforts for the development of a common assessment framework and the creation of a methodology to assess spatial impacts, there is a considerable lack of data and tools for sharing information and gaps in effectively collecting information for the development and analysis of coastal indicators. These gaps have become an obstacle for the effective implementation of ICZM policies and the decision making procedure.

To support the development and analysis of EF and the implementation of ICZM, there should be a focus on the part of local stakeholders (planners, administrative bodies, coastal actors) in collecting and analyzing information, sharing the gathered information and results with decision makers and communicating it with the public. At the EU level, there have been some initiatives to support such actions such as the INSPIRE Directive that provides the infrastructure for spatial information in Europe to support environmental policies, and policies or activities which may have an impact on the environment [31]. Especially for coastal zone issues, the Shared Environmental Information System which has been developed by the Commission, the European Environment Agency and the Member States in the context of INSPIRE could support the availability and quality of data needed for is effective planning and management [32].

The main challenge here is also the translation of such initiatives into local actions which requires a considerable amount of economic and human resources and long-term planning and management processes.

5. International experience

The European Commission has included the EF Index in a set of ten indicators (European Common Indicators Process) for the evaluation of the environmental sustainability at the local level and recommended the use of EF as an umbrella indicator for rest of the indicators of the list. Furthermore, in the context of the Mediterranean Strategy for Sustainable Development Blue Plan and due to the lack of a composite indicator able to summarize the progress assessed by Mediterranean countries towards sustainable development of the coastal zone, it was proposed to apply the Ecological Footprint. In most applied methodologies, EF is considered as a method that allows the assessment, in a whole system approach, of the sustainability level of a territory giving a unique perspective on the behaviour of the system [33].

The experience on the application of the EF so far, has provided the scientific community with case studies referring mostly to a national level and little has been done on a smaller scale. However, recent attempts have been generated especially in the context of research programmes in order to calculate the EF at a local scale and for issues concerning specific spatial units. For example, at the Barcelona Metropolitan Area a research has initiated to calculate the EF using as reference the urban transportation that generates considerable energy consumption and therefore important environmental impacts that extend beyond the metropolitan area. The variables used in this case (and in most cases) were related to the area's population, the city travels, the energy consumption for particular human activities, land cover, distance and time distance, etc [10].

This paper examines whether EF could be applied in the context of transport infrastructure projects in order to measure their environmental impacts. This research will be also focused on transport projects located at the coast seeking to evaluate the methods through which EF could act as an indicator for decision making in the context of ICZM.

The experience already gained in the transport infrastructure sector has provided numerous examples. For instance, a study conducted in Ahmedabad, India, has used transport EF analysis in order to represent and communicate effectively the issues of environmental impact and sustainability related to transport. The results have revealed that the EF of the existing transportation system is exceeding the carrying capacity of the area creating the need for a modal shift. Additionally, it has been suggested to encourage modal shift in the case of the overall city to help reduce the footprint even more. The method used has effectively addressed economic and environmental issues providing planners and policy makers a precise idea of the implications of each scenario generated through the analysis. The calculation of the EF has also incorporated travel and socioeconomic characteristics that gives the analysis a more integrated character [34].

The international experience has also stressed issues concerning the connection of the EF to spatial terms. The development of scenarios that could be visualized spatially through maps and the evaluation of these scenarios through the EF create linkages between the area covered by the footprint and each proposed scenario area. The studies have also shown that the use of the appropriate footprint visualization techniques helps to analyze the spatial variation on the examined area providing important information for land-use planning.

However, in the cases of the EF application there are considerable limitations related to the data availability. The lack of the correct and precise data could lead to inaccuracies in the interpretations of the final results but despite these limitations the EF still manages to offer an important sight for planning issues.

6. The EF of a bridge

According to Wackernagel and Rees [8], large scale development such as transportation infrastructure projects can have long-ranging impacts on energy consumption and material that are usually ignored in traditional environmental impact assessment incorporating also indirect changes in living conditions. There have been studies about estimating the ecological impacts of bridges. These studies have revealed the indirect impacts of the creation or expansion of such infrastructure and thus contributing to the policy, programme and budget assessment. This paper investigates the estimation of the EF of such infrastructure resulting by its function and not its creation. The case study chosen for this research is the Bridge of Rion–Antirion in Greece. The example of the Rion–Antirion Bridge combines the examination of a large scale transport infrastructure project connecting two small coastal cities that has changed and continues to affect the conditions at the coastal natural and built environment of its direct and indirect influence through the last seven years since its creation (Figs. 1 and 2).

The Rion–Antirion Bridge is located in the Region of Western Greece and crosses the Gulf of Corinth connecting Peloponnese region with the mainland of Greece and linking the towns of Rion (Prefecture of Achaia, south coast) and Antirion (Prefecture of Aitoloakarnania, north coast). This bridge is the longest multi-span cable stayed bridge in the world and is considered as a twenty-first century landmark for Greece. It has a 2.252 metres deck, which is based on four pillars, whose height above sea level reach 159 metres and are founded at depths ranging from 48 to 64 metres with pedestals [36–38]. It was a knotty construction not only because of the difficult physical conditions of the strait such as the high water depth, the strong seismic activity, the winds and the quality of the soil but also because the non-stop serviceability of the link and the risk of ship collision had to be taken into account [39–41] (Fig. 3).

Source: http://www.wolframalpha.com [35]

Fig. 1. Location of the bridge.

Source: http://www.wolframalpha.com [35]

Fig. 2. Bridge connection.

The main objectives of this link were [42]:

- Reduction of the travel time
- Safe movement of people and goods
- Prospect for the development of the regions of Peloponnese and Western Greece
- Provision of a segment of Patras-Athens-Thessaloniki-Evzoni motorway (PATHE) and connection PATHE with Egnatia Road
- Contribution of the economic and cultural development of the geographical areas of Peloponese, Western Sterea Ellada and Epirus
- Improvement inof the comfort, reliability and quality of service and ensuring the continuation of service in any weather condition
- Reduction in of the pollution (caused by the car and truck congestion in the ports of Rion and Antirion)
- Provision of a basis for the housing development and the production restructuring of the wider area around the bridge.


Source: www.gefyra.gr [36]

Fig. 3. Rion–Antirion bridge.

The project links two coastal cities, Rion with 5.231 citizens [43] and Antirion with 1.108 citizens [43]. Rion was a rural area but through the years it became second housing area of the residents of Patra. Today it acts as a suburb of Patra hosting tourist infrastructure and services such as hotels, restaurants, bars etc. in the coastal zone. Like Rion, Antirion was also a rural area that transformed to an area of second housing because of the repletion of Rion. The cities also host leisure activities but they are not considered as resorts because of the port activities located at their urban coast.

The impacts of the creation and operation of the bridge are of great importance for these two cities. According to the Environmental Impact Assessment (EIA) study for this project, the impacts during the construction were air pollution, noise, direct impacts of the location worksite and the worksites being permanently under sea level, which have affected marine life [41,44]. The impacts during the operation were also noise and air pollution from the traffic in the Rion and Antrrion area, the conjunction of the bridge, impacts on cultural heritage sites located at the coastal area, the marine environment of the area and the change of the land use in a local (direct) and regional (indirect) level [44].

The coastal areas being directly affected by the operation of the examined bridge, have been characterized as saturated areas hosting uses and activities with significant conflicts between them such as tourism, port activities, cultural sites, housing development etc. Therefore a cross sectoral cooperation is essential in order to achieve an integrated approach for the coast and—in the long term—a high level of sustainability and economic development. It should also be stressed that Greece has experienced administrational changes lately that have caused the expansion of the municipal and regional boundaries and have transformed the administrational responsibilities making the need for an integrated approach and cooperation between levels more imperative. Moreover, these new developments have created also the need for tools and methods that promote simpler processes of decision making.

The first outcomes stemming from the operation of the bridge include the expansion of the activities of the city of Patra that tends to incorporate the smaller cities of Rion, Antirion and Nafpaktos. Patra, as an industrial and port centre of western Greece is being enhanced while the pressures on its coast (Rion coast) are increasing. As mentioned above, the two coasts that the bridge is linking involve land uses related to tourism and culture, port activities and housing. These areas are facing these days the transformations that result from the development of the coast due to emerging role of the bridge. Therefore, an integrated approach is required in order to examine the coastline as a whole, act proactively on the expected land use changes and pressures and avoid conflicts and environmental degradation.

Given that the areas immediately affected by the operation of the bridge are the urban conurbations located at the areas around the bridge, in this paper, it will be attempted to make suggestions on calculating the EF concerning the three land uses that seem to be met more often in the areas around the bridge: tourism, port uses and housing. Through the calculation of the EF for these urban dimensions it is attempted to contribute to the formulation of new integrated local policies on the part of the new local actors in order to incorporate the results in the decision making process.

Starting with tourism, which means hosting people in the given area and increasing the consumption and the emissions of waste [16], it is possible to calculate the EF, which can show the environmental pressure generated by the activities of tourists and local residents. The assessment of the local residents' impacts is very important because these impacts are a result of the rapid economic growth which outpaces the construction of the bridge as an infrastructure.

The first step in calculating the EF of a study population is to estimate the *per capita* land area appropriated (*aa*) for the production of each major consumption item "*i*." This is done by dividing the average annual consumption of that item ["*c*," in kg/capital] by its average annual productivity or yield ["*p*," in kg/ha] per hectare:

$$aa_i = c_i/p_i$$

Then the total *per capita* ecological footprint ("ef") is calculated by summing all the ecosystem areas appropriated by individual items in the annual sum of consumption goods and services:

$$\mathrm{ef} = \sum_{i=1}^{i=n} \alpha\alpha_i$$

Thus, the EF_p of a study population is the *per capita* footprint multiplied by population size (*N*): $EF_p = N$ (ef).

In this case study, the populaton refers to the coastal cities that are linked and affected through the bridge.

It is suggested that the EF should be calculated separately for the residents and the tourists taking data from the population census. The consumption for both groups can be calculated by using the typical categories such as food, housing-accommodation, consumer goods, transportation and services. Then the results can be converted to a ecologically productive land and give evidence on the coastal resources that are being consumed for the purposes of the operation of the bridge.

The consumption categories used for the calculation of the EF are very close to the ISD indicators. For example housing could be expressed through the indicator of the area of the built-up land by distance from the coastline which increases in Rio and Antirio after the construction of the bridge and directly affects the environment. Another category, services, could include the sectoral patterns of employment (full time, part time and seasonal employment per sector, value added per sector), that have changed and continue to change since the beginning of the bridge's operation because of the easy transfer. Also, the use of indicators such the number of tourist accommodations holding EU Eco-label or the ratio of the overnight stays per number of residents give special emphasis on the ICZM policies that could be developed in the area aiming at the promotion of sustainable tourism.

The calculation for port activities follows a similar approach. Here the aforementioned typical consumption categories could be used but one of them is more important than the others, transportation. As it was mentioned above, before the construction of the bridge the transfer from Rion to Antirion was undertaken by ferries. After the construction of the bridge these activities have decreased causing major changes for the local ports that need to re-evaluate their activities, sustainability and remain an important part of the local economy.

The above analysis proves that the EF can be easily linked to the evaluation of local coastal processes and help stakeholders to better understand the current situation in a given area and plan for its future according to new changing structures. The incorporation of coastal indicators in the calculation of the EF provides a more focused analysis of the examined infrastructure project and a more localized approach of its impacts.

7. Conclusions

It is clearly evident that EF is a tool that could prove particularly useful in decision making. When the EF provides an increased number, it means that the environmental impacts are severe and the policy action should be immediate. Low values of EF point at minor policy responses.

However, it should be stressed though that such an indicator could easily provide false results if it uses inappropriate or incorrect data. A key issue for EF is the requirement of a variety of information and detailed data. This is the main difficulty in using EF as tool for ICZM because of the excessive lack of data on coastal areas. In consequence, it goes without saying that a lot of emphasis, in the form of interest and resources, has to be given to the collection of data describing the condition of coastal natural and human activities.

The fact that decision making takes place in different levels could become an issue for ICZM. Important decisions should be taken in a strategic character. For example, for key sectors for ICZM such as tourism, the EF could suggest the type of development and services that should be provided in order to avoid conflicts with the coastal ecosystems. Therefore, the decision making process should be characterized by high levels of cooperation and coordination and a clear distinction of functions between different scales of administration in order to have the best possible policy planning for crucial coastal issues.

The connection between EF and ICZM could be located mostly at the third part of the EF's threefold role regarding monitoring of the research activity results through the updating of the applied information which is in full accordance with the ICZM principle that promotes long term perspective that incorporates the present conditions and the future scenarios. In the case of a major transport infrastructure project such as the bridge of Rion–Antirion, the development of an integrated planning and management approach that would incorporate the fragile coastal ecosystems, the urban environment including the bridge as an integral part of the built environment with an important EF in the direct and indirect coastal areas of its influence is essential.

Finally, as mentioned above the purpose of this paper was not to answer in the already raised questions concerning tool usage in coastal zone management but to highlight substantial issues for future research. Some further queries for further research could be:

- Could the EF be used in all levels of governance?
- In what ways could the local stakeholders be stimulated so as to consider data gathering as an important task for the implementation of new methods and the design of coastal policies?
- What are the gaps that the EF could fill in other environmental initiatives and policies?

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