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An Approximation to the Footprint of Catalonia

Aproximació a la petjada ecològica de Catalunya

Aproximación a la huella ecológica de Catalunya

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An approximation to the Ecological Footprint of Catalonia

1. Introduction

In 1996, the Canadian researchers Mathis Wackernagel and William Rees published the book *Our Ecological Footprint*, in which they proposed a new indicator for attempting to estimate the effects of human activities on the environment: the ecological footprint. This indicator, which has a very interesting educational potential because it is easy to visualise, calculates the space that would be needed by a given territory in order to maintain its model of development (in terms of obtaining resources and assimilating waste) in an ecological way.

In 1998, Ferran Relea and Anna Prat applied the methodology of Wackernagel and Rees to calculate the ecological footprint of the city of Barcelona. Though they did not set out to determine the footprint of Catalonia, in order to calculate the footprint of Barcelona they estimated that of the whole country. They then applied correction factors related to the population of the city, the inhabited area and the habits of consumption of its inhabitants until they reached the value corresponding to Barcelona.

In 2003, the Advisory Council for Sustainable Development of Catalonia (CADS), which is attached to the Department of the Presidency of the Generalitat (government) of Catalonia, commissioned the updating of this indicator for the whole country. The present publication presents the results of the study commissioned by the Council, which was directed by Dr. Xavier Mayor.

This volume is divided into several sections, the first of which contains a description and a critical analysis of the original methodology used by Wackernagel and Rees for calculating the ecological footprint. The second section explains the result of applying this methodology to the territorial area of Catalonia. It also presents an approximation to this indicator by applying a modification of the calculation methodology proposed by its creators, and explains the reasons for this modification. The final section discusses the value of the ecological footprint of Catalonia and its value in the international context, and presents an interpretation of this indicator in terms of ecology and sustainability.

2. The concept of the ecological footprint

In 1996, Mathis Wackernagel and William Rees defined the ecological footprint as **the ecologically productive area that is required in order to satisfy our current lifestyle indefinitely.**

The indicator proposed by these two researchers thus estimates the minimum area that would be necessary in order to supply the basic materials and energy required by a given population at a given moment or in a given period. It therefore offers an approximate image of the relation between a population, its consumption of resources, the alteration of the state of the environment, and its carrying capacity.[1]

The method of calculation of the footprint proposed by Wackernagel and Rees was based on the assumption that each unit of matter or energy consumed requires a certain amount of land in order to supply resources for consumption or process the waste that is generated. This is why this indicator is calculated by estimating the area of land necessary for the production of each element of consumption per person. This area is obtained by dividing the average annual consumption of each of these elements *(kg per capita)* by the average annual productivity *(kg per hectare)*.

Wackernagel and Rees focus their calculation on five categories of resources: **food, housing, transport, consumer goods and services.** These categories can be subdivided into smaller ones, according to the level of detail of the information available and the exactness and precision of the calculation (which will depend on the specific objectives of each study). For each of these five categories, then, one estimates the area needed in order to produce the resources consumed and absorb the waste produced (recycling, recovery, reabsorption, etc.) by a given population in a given territory.

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[1] The **carrying capacity** of a system (a given environment, territory, etc.) must be understood as its maximum capacity to support a population, or populations of different species, in such a way as to guarantee their permanence. In the case of the human population, it would be equivalent to the maximum population that the planet can contain without preventing its reproduction as a species (It does not, however, specify the living conditions of this population.)

With a view to facilitating and enabling the calculation of the ecological footprint, Wackernagel and Rees made a series of assumptions that must be taken into account in interpreting the results, because they may lead to a considerable simplification of the reality that is to be analysed. Thus, one must bear in mind that the method proposed by Wackernagel and Rees:

- Assumes that large-scale farming and forestry practices are sustainable.

- Considers exclusively the basic services provided by the environment: the provision of energy from renewable and non-renewable sources, the absorption of waste, the substrate or the land for living on, etc.

- Attempts to avoid counting the same area of land twice if it provides two or more services simultaneously.

- Establishes eight different categories of land according to their ecological productivity (in fact, the number of categories could vary considerably according to how they are qualified and the information available).

- Does not take into account the marine area that humans require.

In calculating the ecological footprint of a given zone or region, the method proposed by Wackernagel and Rees attempts to determine the area per capita (in hectares) that is necessary for the consumption of a given number of products and the associated area in terms of energy. For each of the five categories of resources mentioned above (food, housing, transport, consumer goods and services), the area of land required to generate these resources is calculated. To do this, the following types of land are considered:

1) Land required to produce energy

In order to convert the consumption of fossil energy into the area of land that would be necessary to produce it (considering ecological production as they defined it in 1996, i.e. based on the productivity of organic and biotic resources), Wackernagel and Rees considered three possible approaches, which led them to estimate that the consumption of 80 to 100 GJ of fuel per year would correspond to the use of one hectare of productive land. The approaches are the following:

- *The first approach* consists in calculating the area necessary for the durable production of a biological product to replace liquid fossil fuels. Taking as a reference ethanol, which is technologically and qualitatively similar to fossil fuels, the area necessary to produce energy could be represented as the farmland required to produce the amount of vegetables necessary to obtain the equivalent amount of ethanol, and to supply the energy necessary for carrying out the process.

- *The second approach* consists in estimating the area of land necessary to capture or absorb the CO_2 emitted by the burning of fossil fuels (here forest and bog ecosystems play a major role as carbon sinks).

- *The third approach* consists in estimating the area necessary for rebuilding the natural capital at the same rate as the fossil fuels are being consumed. The available data showed that 1 hectare of an average forest could accumulate 80 GJ of recoverable biomass.

In the definitive calculation of the ecological footprint, Wackernagel and Rees adopted the second approach, i.e. the one based on the assimilation of CO_2, using the corresponding ratio of 1 ha for every 1.8 metric tons of carbon emitted per year (1 ha / 100 Gj^{-1} / $year^{-1}$).

However, the other two approaches have other added values from a purely ecological viewpoint. For example, taking biomass as the reference for an energy that is mainly derived from petroleum (the third approach) is a far sounder option in ecological terms, because in order to obtain a certain amount of petroleum one must previously produce a certain amount of biomass that one can convert, in the course of time, into this type of fossil fuel. Furthermore, taking a given amount of ethanol as the reference for the energy consumption (the first approach) is an interesting idea, though it should not be forgotten that ethanol is also obtained from biomass.

2) Accounting for built-up land

This category would include the land that has in some way become immobilised for the purposes of production. It includes paved zones, built-up areas and eroded or degraded land whose future use for ecological production is limited. The fact that it is considered as a space that is occupied almost permanently means that it is considered as a consumed ecological resource.

3) Currently used land

According to the authors, this category would include two different types of land: that which corresponds to an environment built or manufactured by man, whose use as a productive area in the future is still possible (this would be the case, for example, of gardens, golf courses, etc.); and that which corresponds to systems modified by man, which includes lands such as cropland and pastures and forest lands that provide marketable products.

4) Land of limited availability

This type of land would include essentially undisturbed ecosystems such as virgin forests, protected woods or unproductive areas, including deserts, glaciers and ice caps.

This classification and terminology are difficult to use because of their complexity, both in the international context and in the specific case of Catalonia. However, it is proposed to distinguish: (i) spaces that would be necessary to produce the energy that we consume (in terms of durable production); (ii) the land that is necessary for the human settlements (cities, towns, etc.); (iii) the land or area necessary for organic production (crops, livestock, forestry, fish, etc.); (iv) and the lands corresponding to biodiverse spaces (woods, scrubland, grassland, bare zones), which may be used for sundry purposes such as conservation and leisure.

3. The ecological footprint of Catalonia

The report on which this publication was based wished to determine the current value of the ecological footprint of Catalonia according to the methodology proposed by Wackernagel and Rees in 1996. As stated in the introduction, there existed the precedent of Relea and Prat, who in 1998 estimated the ecological footprint of Barcelona corresponding to 1996 by calculating that of Catalonia and correcting it according to a series of specific factors for this city. The indications of Wackernagel and Rees were followed in the recalculation of this indicator, so the value obtained is comparable to others calculated in the world following the same methodology (see Section 3.2 and Appendix 6).

A key aspect in calculating any indicator is the availability of data, which must be reliable and up-to-date. In the creation of the report on which this publication was based, all the necessary data for 2002 was not available, because some data are not processed and others are obtained with a periodicity that does not coincide with the year in question. Therefore, for each numerical category, item or piece of information we used the most up-to-date data available in the period dedicated to collecting information. Though the most recent data are for 2002, most of them correspond to 2001, and the oldest to 1999. It must therefore be stated that this report determined the value of the ecological footprint with the most recent data available up to the cut-off point of 2002.

From the viewpoint of ecology, it is possible to introduce certain improvements in some of the comments that form the basis of the calculation methodology proposed by Wackernagel and Rees. In the context of Catalonia, the maturity of ecological aspects related to the treatment of the environment (see Mayor 2002a and 2202b) and the current availability of information allow one to go a little further in the evaluation of this indicator from an ecological viewpoint. Therefore, in this section we analysed specifically some conceptual aspects that modify the result of the calculation and could be worth taking into account when the original methodology of calculation is applied in the future (see Section 4.3).

3.1. Determining the value of the ecological footprint

The calculation made by Relea and Prat using the method of Wackernagel and Rees indicated that in 1996 the ecological footprint of Catalonia was 3.26 hectares per capita, whereas that of the city of Barcelona was 3.23 hectares per capita, i.e. slightly lower.

The recalculation made in 2003 for the Advisory Council for Sustainable Development of Catalonia (CADS) gave a higher value than that of 1998: 3.92 hectares per capita. The basic categories and values used to make this calculation are represented in Tables 1 and 2.[2]

Table 1. Production (export and import) and consumption for each category of resources according to the method proposed by Wackernagel and Rees

	Production (P) (t)	Export (E) (t)	Import (I) (t)	Consumption*		**EF****
				Internal (P-E)	External (I)	
Consumption of land associated with food						
Stockbreeding sector	2.049.087	200.435,1	312.745,2	290,61	49,16	0,53
Fisheries sector	43.826	42.017,7	162.171,9	0,28	25,49	0,89
Crop farming sector	6.966.550	1.320.639,3	7.347.685,2	887,53	1.155,05	0,61
Consumption of land associated with other crops						
		90.449,5	88.412,1	-14,22	13,90	-0,00037
Consumption of land associated with the forestry sector						
	145.276	278.539,1	651.675,5	-20,95	102,44	0,043
Consumption of energy and area associated with the importing of goods				Consumption of primary energy (Gj/inhabitant)		
Energy consumption				157,78		1,60
Consumption of area associated with the importing of goods				18,7		0,21
Consumption of land by urban zones						0,033
TOTAL						**3,92**

Drawn up by the author.

** The consumption is expressed in kg per capita.*

*** The ecological footprint (EF) is expressed in ha per capita.*

[2] *The appendices contain more detailed information on each of the categories considered, and additional data that are necessary for making the calculation.*

Table 2. Value of the categories used to calculate the ecological footprint per capita according to the method proposed by Wackernagel and Rees

Categories	EF (ha per cap.)
Space for urban settlements and communications	0,033
Space for production of food	2,03
Space for production of other organic goods	-0,00037
Space for forest production	0,043
Space associated with the consumption of energy	1,60
Space associated with the importing of goods	0,21
TOTAL	**3,92**

Drawn up by the author

As stated above, the calculation of the ecological footprint is based on determining, for a given territory and population, the area necessary for obtaining resources of biological origin, the total energy consumption, and the energy consumption related to the production of goods. To these values one must add the consumption of land by human settlements and communication infrastructures.

The calculation of the consumption of products in Catalonia refers to the production of Catalonia, subtracting exports and adding imports from abroad. For the calculation of the ecological footprint of these variables or items, one must associate the total consumption with a given area. This ratio of the consumption in metric tons to the area occupied is known as **productivity**, which is then divided by the census population of the country (see Appendices 2 and 4). Below is a brief description of the calculation of each of these factors:

1) Obtaining resources of biological origin

The productivity can be understood as the ratio of the production of different products to the area necessary for obtaining them. This is the case of crop farming, forestry, stockbreeding and fisheries. It is relatively simple to determine this area. However, in order to improve the calculation of the ecological footprint one must take into account other factors, such as the land necessary for feeding the animals and for treating their waste. In other words, one must take into account their life cycle and their impact throughout the whole cycle and express it in terms of area.

In this case, to calculate the ecological footprint one considers the productivity of each variable of production. In the corresponding calculation we used all the data on productivity available for Catalonia, and when they were not available we used those corresponding to world productivity provided by Wackernagel and Rees (1996). Also, in the calculation we considered different subcategories that allow productivity to be refined according to the production characteristics of each product. These are the following:

- Consumption of land associated with food (subdivided into the stockbreeding sector, the fisheries sector and the crop farming sector)
- Consumption of land associated with other crops
- Consumption of land associated with the forestry sector

In the calculation, the consumption from internal products was divided by the local productivity. The consumption from imported products was divided by the value of world productivity. The value corresponding to exports was subtracted from the production obtained, in order to make a global balance of what a territory produces considering import and export. Finally, the value obtained was divided by the population of Catalonia, which in 2001 was 6,361,365 inhabitants (data on the de jure population). The total value of the contribution of each subcategory of resources of biological origin to the ecological footprint is 2.03 ha per capita

2) Energy consumption and associated area

The energy consumption is obtained from the sum of the consumption of fossil fuels, hydraulic energy and electrical energy from other renewable sources. The energy consumption associated with the import and export of manufactured goods is also added, because it is a way of considering them and associating them with a given area.

Different methods of calculation were used for each type of energy according to its impact on the environment. In the case of the fuels that emit CO_2 in their production or consumption, a multiplication factor was used that consists in the kilograms of CO_2 emitted per Gj of fuel consumed. In the case of coal, for example, in which this factor is 141.2 kg CO_2/Gj, we can calculate the ecological footprint corresponding to the consumption of this fuel, also considering that on average each citizen consumes 1.79 Gj of energy from coal and that 1 hectare of average forest can absorb 6.6 metric tons of CO_2. Making the corresponding arithmetic operations, the value that is obtained as the ecological footprint is 0.038 ha per capita, which must be understood as the area necessary for absorbing the CO_2 emitted by the consumption of coal in Catalonia. This calculation can be extrapolated to the other fossil fuels and to all those that emit CO_2, taking into account the differences in the emission factor.

In the specific case of electrical energy of nuclear origin, its emission was considered to be similar to that of liquid fossil fuels. For energy from hydroelectric plants, wind farms or solar panels, the area that they occupy was taken into account because the same area can stop being productive but continue to perform some ecological functions. In global terms, then, the ecological footprint of the energy consumption is 1.805 ha per capita

3) Energy consumption related to the production of goods

One must also consider the consumption of goods that involves products manufactured or produced industrially (see Appendix 4). These are chemical products, manufactured products, industrial products, elementary products, etc. The corresponding data were obtained from the databases of the Statistics Institute of Catalonia (2002). The data are highly detailed by groups of products and we assigned to each product category considered the current data for the corresponding group of products established by Relea and Prat (1998). However, there are groups that do not show a direct correspondence. In this case we used the categorisation made by the Uniform Classification for International Trade (UCIT) and the Integrated Community Tariff (TARIC) and we assigned them to the category that we found most suitable among those considered by Relea and Prat.

It must be remembered that the methodological approach adopted by Wackernagel and Rees (1996) makes a balance on a global level. Thus, in this section (in fact, in general) they consider the compensation of matter and energy of the exchange between imports and exports of goods (see Appendix 4).

The data of imports and exports (in metric tons) are related to a unit of energy consumption using a multiplication factor. This factor refers to the energy associated with the life cycle of each element. To relate each product to its associated energy consumption, Wackernagel and Rees determined complete standard processes of the life cycle of each product. The calculation consists in subtracting the energy consumption in Catalonia used to manufacture products for export. The energy consumption outside Catalonia corresponding to the products imported by Catalonia is added to the general energy consumption (corresponding to the data in Appendix 4).

In our case, the result of this operation is 18.70 Gj per capita, which was added as energy consumption for the importing of goods. The multiplication factor used in this case is that of liquid fossil fuels, because in general they are the ones that make the greatest energy contribution.

4) Land consumed

This category refers to the built or developed land whose use for biological production has been compromised. According to the Statistical Yearbook of Catalonia (2002), 6.47% of the area of Catalonia had this category in 2001. This represents a total of 207,526 ha of non-productive land, and therefore 0.033 ha per capita.

3.2. Contributions to determining the ecological footprint of Catalonia

Though the ecological footprint of Catalonia was determined following the methodology proposed originally by Wackernagel and Rees, the authors of the report on which this publication is based found it necessary to consider additional aspects that could help to understand and provide a more accurate estimation of the value of the ecological footprint of Catalonia.

Before discussing each individual consideration, we must first establish what is understood by a production and an absorption based on the ecologically productive area (according to Wackernagel and Rees: cropland, pastures, woods, continental and marine aquatic systems, etc.). This leads us to at least two fundamental considerations:

1) The limits of the carrying capacity are considered to be outside the dynamics of technology, which indeed has a profound meaning, because technology depends on our capacity of cultural transmission as a population (more specifically a metapopulation) and on the availability of natural resources. Both are variables or factors that are difficult to control in the short, medium and probably the long term. Nevertheless, the current situation is one that is not very realistic, because the dynamics go precisely in the opposite direction, giving precedence to the growth

of the population and the importance of technology in an exhaustive use of the most important resources.

2) The method does not take into account the capacity of exosomatic use of energy by humanity. Again this generates two major points of view. On the one hand, it considers energy use as a capacity that we have and must take advantage of, because it provides benefits. On the other hand, it considers that in the last few decades it has been based on the exhaustive use of fossil energy, which naturally entails the possibility of the supplies coming to an end. The fact is that regardless of the good or bad management of a finite resource on a temporal and strategic scale, it is an organic resource. Therefore, it is included in the processes of the biosphere, so one must clearly consider its biological origin. This is a viewpoint that is considered by the concept of the “ecological footprint”, but the irreversibility of its consumption is not.

The ecological footprint places us at a level of consumption of land based on an ecosystem productivity that is not greatly altered by human action. Therefore, one must remember that cropland, pastures and the other productive uses are also systems in which man has intervened, and not exactly in a tangential manner. Furthermore, the incorporation of technological aspects in the calculation of the ecological footprint—at least those that we could ideally consider to be sustainable—could partly modify the result. We are probably not yet able to make this sort of approximation, but attempting to do so would make us progress a little further in the aspects of how to implement the concept of sustainable development socially and economically. Contributions of this type are thus necessary in order to develop the basic concept of sustainable development.

This is why some of the contributions that we make to the calculation of the ecological footprint of Catalonia focus on the working discussions that were held during its development. Obviously, it is not intended to be an exhaustive academic review but rather a reflection that should enrich and improve our understanding of what the ecological footprint means. It was also intended to adopt an approach with a more ecological interpretation rather than the economic and environmental approach taken by other authors who, in addition, always consider the footprint from the global viewpoint of the whole planet. It is interesting to balance the figures on the carrying capacity of the planet, but it is also interesting to consider the reality of a specific territory and human population such as Catalonia.

3.2.1. In relation to the preservation of biological diversity

One of the aspects that does not tend to be considered in the calculation of the ecological footprint is the need for a territory in which to preserve the ecological elements and processes. This is not considered formally in the calculation, though in the conceptual definition of the term “ecological footprint” the authors (Wackernagel and Rees, 1996) state the need for it. They even provide very general data on it, based mainly on very rough approximations of the need to conserve ecological systems or protected areas, through they do so under the questionable approach of conserving only a representative sample of it.

It is easy to understand that as a biological species we are included in the systemic, dynamic and evolutive functioning of nature. This means that it is not possible to disconnect us from it, so the surrounding elements and the ecological processes that relate us cannot be ignored. We can, however, posit theoretically extreme prospects such as the destruction of the species or a highly dominant position of this species, in which the only essential factors are our maintenance and survival, involving the simplification of the ecological elements and processes that surround us, both in terms of abundance or distribution and in terms of presence.

We can consider that ours is the only species that is able to act on others in such a way that it leads to a very significant simplification of the biological diversity. In other words, our species is currently the only one that is apparently able to displace the others to the point at which they disappear, and to conserve only clearly productive species whose main purpose is to provide it with resources.

It is difficult to define the limits of this situation of ecological impoverishment. A minimum amount of photosynthetic area seems essential and a large part of the rest of the land could be used for human settlements and for the production of resources for the human population.

However, this hypothetical vision or situation has many limitations. Let us consider two of them: the enormous amount of energy that must be invested in order to maintain it, and the difficulty of keeping the situation stable even if sufficient energy is available. No less important is the strategic value of the enormous and irreversible loss of degrees of freedom that a situation of ecological simplification such as this would cause, and how this would place us in a weaker position for dealing with any disturbances that our species might encounter. The capacity of reaction and manoeuvre would then be far lower. One interpretation of the value of biodiversity is precisely that of preserving this potential that gives us a greater capacity of resistance and resilience towards disturbances.

Having established how important the preservation of biodiversity is for us, the challenge is to calculate the ecological footprint by means of an approach that integrates this variable. Wackernagel and Rees consider this need conceptually but fail to include it in the calculation of the world ecological footprint, so there is no clear methodological indication of how to do it. Nevertheless, it does not seem logical to calculate the ecological footprint without considering one of the key variables: biodiversity. Those who largely followed the method of calculation proposed by Wackernagel and Rees also failed to include it. This is the case, for example, of the calculation of the ecological footprint of Barcelona (Relea and Prat, 1998).

With regard to the protection of biodiversity, Wackernagel and Rees state that it may be threatened by the loss of habitats and the fragmentation of the territory. They also mention the debate on the area of land that is necessary in order to ensure a suitable biodiversity and a general ecological stability. However, though it is noted in their book, this approach to evaluating the environment is slightly outdated and not very sound from an ecological viewpoint, because it also implicitly expresses a certain level of discordance. For example, in the more conceptual section of their book they refer to the unquestionable quality of humankind as a biological species. They also refer to Odum, a prestigious ecologist who suggested that a third of each ecosystem of the world (a unit that is difficult to define in order to give it this pragmatic meaning) should be protected in order to conserve the biodiversity. They also refer on this point to the Brundtland Comission, which proposed the need to protect 12% of the land area with this aim. Based on this, they even determine that, in order to conserve the world's biodiversity, an area of 1,500 million hectares of untouchable (wooded) forest ecosystems is necessary, which corresponds to 9% of the land area of the planet.

These approaches of protecting a part of the planet are interesting, provided that—in conceptual terms—they are placed within a far wider and sounder strategic framework. In isolation they are not very suitable approaches, for two basic reasons: firstly the biosphere acts as an ecosystem, and this involves interrelation; and secondly these approaches tend to ensure the protection of what seems most important, interesting or emblematic, and many conservation policies have suffered from these "preferences" of those charged with implementing them. Therefore, one must overcome old and less sound assessments based on the elements that are considered to be outstanding and/or emblematic for aesthetic, educational, ecological or conservationist reasons.

One possible coherent way of achieving this is to make a strategic proposal of a suitable treatment for the whole environment, including of course the maintenance of protected areas, but as spaces of great functional value rather than sanctuaries (Mayor, 2002a, 2002b, 2003). This is why, currently, when we speak of conserving biodiversity we refer more to the need to preserve the environment as a whole. We also speak of fitting our actions into this framework whilst respecting the value of the ecological elements and processes (Mayor, 2002b). It does make sense to understand that the territory, the territorial matrix, must have real and potential possibilities for maintaining high levels of biodiversity and—as far as possible—maintaining the values and avoiding sharp fluctuations (especially negative ones) at a reasonable cost.

In this more up-to-date conceptual context, for Catalonia we have information that allows us to incorporate the preservation of biodiversity in the calculation of the ecological footprint.

We must take as a starting point the idea that a suitable treatment of the territory as a whole is the key to preserving the biodiversity that it contains, and that one must guarantee spaces in which the ecological conditions are favourable to biodiversity and the states of disturbance are low. Considering that a network of spaces currently means protected nodal spaces and internodal spaces of ecological connection, we can then establish an approach to the minimum functional area in order to preserve a strategic and functionally important part of the territory. Again, we stress that an approach in these terms for Catalonia is possible.

Based on these considerations we can establish an approximate calculation of the area necessary for establishing a network of protected spaces in Catalonia. The basic nodal network is formed by the spaces of the Plan of Areas of Natural Interest (henceforth PANI), which, rather than zones of protection, act as functional spaces for containing, receiving and spreading biodiversity in the spaces of the surrounding matrix. The area covered by the PANI is 20% of the area of Catalonia.

The internodal spaces are another key element in the network. These spaces of ecological connectivity link the different protected spaces and are essential elements in order for the network to be fully functional. Their function is to ensure the ecological connectivity between protected spaces, a condition without which the protected spaces of the PANI are unlikely to enjoy the minimum health necessary to fulfil the function of preservation stated above.

In recent years several studies have been conducted in Catalonia in order to determine spaces of ecological connectivity. Despite the studies of connectivity that have been carried out, as yet few spaces of ecological connectivity have been determined, because it is a discipline of applied ecology that has been introduced only recently. However, we already have experience in determining systems of ecological connection between spaces of the PANI. Currently, we can use this information with regard to two very different territorial situations: the county of the Vallès Occidental (Mayor, 2000b) and the county of the Garrotxa (Mayor, 2000a). These are two counties of highly differentiated characteristics, one closely linked to, and forming part of, the Metropolitan Region of Barcelona and the other representing the Catalonia further inland. In simple terms, one represents the urban counties and the other the rural counties.

Therefore, we can make a selection of counties and distribute them into two categories: the urban ones and the rural ones. We can then assign to each county, according to the category to which it belongs, the percentage of area corresponding to the spaces of connecting interest determined in each type of county (predominantly urban or rural, according to the case). The direct application of a percentage of area of ecological connectivity to each county according to its predominant characteristics involves limitations and a bias. Not all systems of connectivity are based on continuous areas. Not all the counties have similarities in reference to the spaces of connectivity, especially those with characteristics that are highly differentiated from the rest. There are also some that have practically no area with spaces of the PANI, because the distribution of the spaces in the territory of Catalonia is not homogeneous. However, the non-presence or the low representation of spaces of the PANI in a given county does not necessarily mean that it cannot contain spaces of interest for ecological connectivity. Nor does it mean that it must have them, though this is less likely.

One way of considering this is to combine this information with the data corresponding to the consideration of the Remaining Territorial Matrix (RTM) defined by Mayor et al. (2002b). The RTM considers the area of territory that is obtained by subtracting from the area of Catalonia the spaces that are included in the PANI, the spaces occupied by the existing road network, the built-up areas, and the large agricultural areas (which the author established at over 100 ha). In fact, the main processes of ecological connectivity take place in this remaining space. The area of the MTR calculated for Catalonia is 47% (Mayor et al., 2002b). Therefore, we can relate this area in each county and the percentage of land that would potentially correspond to it according to whether it is rural or urban, based on the available studies of connectivity.

Therefore, we have calculated how much MTR is occupied by the spaces of connectivity. In order to obtain this area of spaces of connecting interest in each county, two counties were taken as models: a rural one and an urban one. The rural county is represented by the county of the Garrotxa, and the urban one by the Vallès Occidental. Based on the corresponding studies of Mayor (2000a and 2000b), we estimated the areas of the remaining territorial matrix that are necessary to guarantee the ecological connectivity between the spaces of the PANI. We also took into account the area of connectivity in relation to the rivers of connecting interest. For the calculation of this area we took a margin of 100 metres on each side of the river (which corresponds to the police zone).

The spaces of ecological connectivity in the Garrotxa cover 32.63% of the area. In the Vallès Occidental they cover 53.44% (see Table 3). Each of these values will be used to estimate the area of the MTR that will potentially be occupied by spaces of ecological connectivity in the different counties. For this purpose we divided the counties into two types: urban counties and rural counties (see Appendix 5). We considered the counties with less than 10% of anthropic area as rural counties and those with 10% or more as urban counties. Obviously, the limit between what is predominantly urban and non-urban is not clear, and many other criteria could be established for categorising them. Some counties, such as the Baix Camp, the Selva, the Gironès, the Alt Penedès and the Baix Empordà, are difficult to categorise.

Table 3. Values of RTM and spaces of connectivity applied to each county of rural type or urban type

County	Area of connectivity (ha)	Area of Remaining Territorial Matrix (ha)	Area of connectivity
Rural (Garrotxa)	9.524	29.185	32,63 %
Urban (Vallès Occidental)	15.413	28.841	53,44 %

Drawn up by the author.

Using this approach, we can determine that the area of connectivity in Catalonia would be potentially 524,501 ha, approximately a third of the total area of remaining territorial matrix of Catalonia (1,515,579 ha).

Another interesting and highly important approach is to establish a minimum and maximum estimation of the area of ecological connectivity. To do this, one only needs to apply the percentage of area of ecological connectivity determined in a clearly rural county such as the Garrotxa to the area occupied by the whole MTR for the whole of Catalonia. The value obtained is 494,585 ha. One then continues in the same way, considering the percentage of area of ecological connectivity determined in a clearly urban county such as the Vallès Occidental. The value obtained is 809,938 ha. Naturally, the sum of the area of connectivity that we have calculated for each county individually (524,501 ha) falls within this range, though it tends more towards the minimum than the maximum.

Finally, we must add to the area of the PANI the estimated area of spaces of ecological connectivity. The area of the PANI (according to the environmental information system of the Department of the Environment, updated in 2003) is 648,455.56 ha, whereas the estimated area of potential ecological connectivity is 524,501 ha. The sum of the two areas (1,172,956.56 has), divided by the census population of Catalonia, is a feasible estimation of the space necessary for maintaining the biodiversity of Catalonia in the future, with a value of 0.18 hectares per inhabitant. We thus estimate the minimum area of protection of biodiversity necessary for Catalonia that must be taken into account in calculating the ecological footprint of Catalonia.

Obviously, much of this area includes part of the land necessary for producing goods of organic origin. However, we understand that this production is added to the essential need of preserving biodiversity. Without this biodiversity, a large part of the forests, agricultural systems, etc. would cease to exist as such. What is more, making the calculation in terms of area fails to take into account the vertical dimension of ecological systems, which is precisely so important in essentially biodiverse spaces. Therefore, duplicating the areas has a relative value which deserves a deeper analysis than that which we have made in this study. We therefore do not take into account corrections for these reasons.

Table 4. Calculation of the ecological footprint per capita including the space necessary for maintaining the biodiversity in Catalonia

Categories	FE (ha per cap.)
Space for biodiversity	**0,18**
Space for urban settlements and communications	0,033
Space for production of food	2,03
Space for production of other organic goods	-0,00037
Space for forest production	0,043
Space associated with the consumption of energy	1,60
TOTAL	**4,10**

Drawn up by the author.

3.2.2. In relation to absorption of CO_2 by the sea

One of the weak points of the calculation is the failure to consider the sea as an element of absorption of CO_2. An initial difficulty is that of assigning a marine area of absorption for Catalonia. On a global level this is not complicated, because we have data on the marine area of the planet, though it does not all act in the same way with regard to absorption of CO_2.

Therefore, we must try to determine the area of sea that can be attributed to Catalonia (even though it is only an approximation). For the calculation of the area of absorption of CO_2, we considered the limit of the jurisdictional waters and the length of the coast. The length of the coast of Catalonia is 826.5 km (IDESCAT, 2002) and the jurisdictional waters stretch 22.2 km out to sea (12 nautical miles). If we consider the extremes as the perpendicular of the coast to the twelve-mile limit, the area of sea considered in relation to Catalonia is 18,368.14 km^2.

The productivity of the open sea is lower than that of the continental platforms. It is considered that the productive areas in the sea have an average capacity of absorption of 370 $t.km^2 \cdot year^{-1}$, whereas the rest have an average absorption of 7.3 $t.km^2 \cdot year^{-1}$ (Wackernagel, 1997; Barracó, 1998, cited by Relea and Prat, 1998). The capacity of absorption of CO_2 by the sea is thus obtained by establishing an area corresponding to an estimation of the continental platform of the Catalan coasts. We have figures on this. The area of the upper continental platform (that is, down to 50 metres depth) is 1,890.5 km^2. The area of the continental platform down to 100 metres depth is 4,998.86 km^2 (drawn up by the author from the Digital Maps available in the Geographical Information System of the Directorate-General of Fishing and Maritime

Affairs of the Department of Agriculture, Stockbreeding and Fisheries of the Generalitat of Catalonia [DARP] for 2003).

If we consider the area of the upper continental platform and the corresponding productivity, the area of absorption of CO_2 per capita is 0.02 ha. If we take into account the continental platform with a depth of 100 metres, the area of absorption of CO_2 per capita is 0.046 ha. Therefore, for the calculation of the footprint we can use these data in order to establish a maximum and minimum reference value that will allow us to improve the estimated value of the ecological footprint of Catalonia (see Table 5).

Table 5. Calculation of the ecological footprint per capita including the space corresponding to the absorption of CO_2 by the sea

Categories	EF (ha per cap)
Space for urban settlements and communications	0,033
Space for production of food	2,03
Space for production of other organic goods	-0,00037
Space for forest production	0,043
Space associated with the consumption of energy	1,60
Space associated with the importing of goods	0,21
Absorption of CO2 by the sea (50 m/100 m)	**-0,02/-0,046**
TOTAL	**3,90/3,88**

Drawn up by the author.

3.2.3. In relation to imports and exports

The definition of the ecological footprint was initially based on a global approach. This means that the approximations and estimations of some numerical calculations were considered within a perspective of compensation on a global scale. This opens an interesting discussion on whether one must compensate the imports and exports when one analyses the ecological footprint on the scale of a country or territory.

If we understand the biosphere as a global ecosystem, it seems logical to consider that there is a certain level of compensation in the production and consumption of resources. In terms of balance it can be understood in this way. If we understand it as a global system, the compensated calculation of imports and exports of each territory (in this case each country) is valid. However, though this approach may be valid on a large scale and in the long term, it is not valid in the short-term because the rates of renewal may vary greatly according to each product.

Outside the global context the situation changes. As we have seen, the concept of the ecological footprint is linked to a certain status quo of each country at a given moment. The environmental indicator reflects an environmental situation of the country and assesses it in terms of continuity. The concept defines the area that is ecologically productive in order to maintain the current level of consumption of resources of a country. The footprint of a country depends on this status quo. Compensating the imports and exports conceals or dilutes the country's intrinsic need to consume this energy in order to maintain this status. The possibility of ceasing to import energy does not exist (it is only theoretical and long-term) and this causes the balance model to break down. At a country scale rather than a global scale, global compensation does not, therefore, make much sense. Rather, what has been generated is a state of dependence, provided that the current status can be maintained.

A different approach to the ecological footprint leads us to take the above into account. The fact that maintaining the levels of import and export is almost obligatory leads us to consider an opposite model in which their behaviour is added rather than subtracted. This provides a better interpretation of the ecological footprint at a country scale.

Thus, we can modify the result of the calculation of the ecological footprint of Catalonia by adding imports and exports and considering that both the energy and the materials involved in the consumption of goods are necessary for maintaining its status. It is thus considered that all production that affects our territory has a direct effect on the consumption of materials and energy, and therefore on our ecological footprint. The difference between the traditional calculation and this "rectification" is 1.35 ha per capita. That is to say, if one takes into account all the consumption carried out in Catalonia and that carried out in other parts of the world in order to maintain our quality of life, our ecological footprint increases (see Table 6).

Table 6. Calculation of the ecological footprint per capita including the rectification of the imports and exports of products

Categories	FE (ha per cap.)
Space for urban settlements and communications	0,033
Space for production of food	2,03
Space for production of other organic goods	-0,00037
Space for forest production	0,043
Space associated with the consumption of energy	1,60
Space associated with the importing of goods	0,21
Rectification of import/export	**1,35**
TOTAL	**5,27**

Drawn up by the author.

3.2.4. In relation to energy

We can consider energy in terms of energy use. The functioning of the biosphere is based on the use of solar energy and the corresponding transformation into organic chemical bonding energy. Other primary sources of energy are also possible but make a far lower general contribution (for example, pyroclastic surges on the seabeds).

Alternatively, there are energy sources that come mainly from physical transformation, in which energy is obtained from normal processes occurring in the environment. This is the case of hydroelectric energy and wind energy, which have so far been introduced asymmetrically.

Energy from fossil fuels is a very special case. It involves a transformation of chemical bonding energy from organic matter to inorganic matter. Unlike the sources mentioned above, it is a type of energy that we can consider in biological time as being clearly exhaustible on this scale.

Another consideration refers to the fact that the energy accumulated in fossil fuels comes from solar energy transformed into organic bonding energy on a geological rather than a biological time scale. It is therefore a valuable reserve that is stored by an evolutive biological process that is totally beyond our control. The placing in circulation of the matter and energy contained in fossil fuels as a result of their combustion leads to the exhausting of this energy resource and the modification of the carbon cycle.

We can also consider nuclear energy as a durable possibility of obtaining energy. Though it is a finite resource, the time scale involved probably offers a greater durability. However, nuclear energy has two important disadvantages. Firstly, it seems that its production in nuclear power stations fails to show a good economic performance, especially if it is analysed according to the life cycle of a power station. Secondly, and far more importantly, generating power in this way involves a risk. Unfortunately, we have experiences that show this. The effects that a nuclear accident has on a territory are highly negative—above all the harmful effects on living beings and especially persons. Another cause for concern is that these effects certainly have an extraordinarily long duration, and we are far from having sufficient measures to counteract them. It is in this context that we considered the possibility of a disturbance occurring in the form of a nuclear accident in Catalonia, and we calculated approximately what this would mean in relation to the ecological footprint of the country.

The likelihood of a nuclear accident occurring is considered to be very low. However, if a major accident did occur, the area affected would be sufficiently large to take into account in the calculation of the ecological footprint. In the nuclear accident that occurred at Chernobyl in 1986, the exclusion zone that was established after the accident was a radius of 30 km (*European Environment Agency*, 1995). This is an area of 282,743.3 ha that was evacuated and that became useless for the purpose of productive crop growing, stockbreeding, etc. for a period of many years.

In relation to Catalonia, this area would correspond to 0,044 ha of land per inhabitant. The size of the area that was damaged would be similar to that of Luxemburg (2,586 km^2) or the Camp de Tarragona (2,998 km^2), i.e. 9.4% of the territory of Catalonia.

Furthermore, one would have to take into account the areas contaminated by the deposition of radioactive substances. A zone is considered to be contaminated if it has an average deposition of Cesi-137 greater than 37 $kBq.m^{-2}$. The area affected by the deposition may vary greatly according to the climatic conditions of the country, and this is why it was not taken into account in the calculation of the ecological footprint. The zone affected by the Chernobyl accident was 150,000 km^2, whereas in the rest of Europe it was 45,000 km^2.

The thermal power of the damaged reactor of Chernobyl (Number 4) was 3,200 MW, and the electric power 1,000 MW. The electric power of the nuclear power stations in Catalonia is similar in all cases: 1,009 MW (Vandellòs II), 940 MW (Ascó I) and 966 MW (Ascó II). However, in Catalonia there has been no nuclear accident similar to that of Chernobyl.

For the purposes of calculating the ecological footprint, it must not be interpreted as an improvement in the calculation but as the exploration of a possibility and of the basic levels of contribution that it could involve if it occurred (see Table 7).

Table 7. Calculation of the ecological footprint per capita including the area affected by a possible nuclear accident.

Categories	FE (ha per cap.)
Space for urban settlements and communications	0,033
Space for production of food	2,02
Space for production of other organic goods	-0,00037
Space for forest production	0,04
Space associated with the consumption of energy	1,598
Space associated with the importing of goods	0,207
Area affected by a possible nuclear accident	**0,044**
TOTAL	**3,96**

Drawn up by the author.

3.2.5. In relation to urban occupation

When we analyse the conceptual basis for calculating the ecological footprint, we observe that the division into categories equivalent to land areas (space for urban settlements and communications, space for production of food, space for production of other organic goods, space for forest production, space associated with the consumption of energy and space associated with the importing of goods) does not account for some aspects that do not take place at ground level and that include resources. In some cases this is considered through productivity. For example, the biomass of a forest is counted as a forest area, but the wood produced is also considered as an estimator of vertical development and accumulation in time. However, this does not work when one considers urban spaces, which also have a very considerable vertical development and an accumulative factor in time that is by no means negligible.

Previous studies have counted urban space, development land, etc. as non-productive land. Human settlements have inherited components of consumption of resources, but they are not counted as previous consumption. Therefore, cities and other anthropic settlements were formed and developed with a consumption of previous material resources and energy which are not accounted for in the calculation of the ecological footprint. In this study we have taken a simple but consistent approach to this problem.

The estimation is based on determining the built-up area of Catalonia. From this figure we can differentiate between highly developed urban zones (cities, neighbourhoods, suburbs, urban centres) and developed zones with less urban intensity (towns, villages, groups of farms, etc.). In order to differentiate them, we used the digital cover of urban land of Catalonia. The high-intensity urban zones occupy 25,098,325 m^2. The low-intensity urban zones occupy 55,576,128 m^2.

We attributed an average height of six floors (a common height in the Eixample of Barcelona) to the high-intensity urban zones, whereas we attributed an average height of three floors (a fairly common situation in many of the towns of Catalonia) to the low-density urban zones. This means that the built-up area is 1,505.9 km^2 in zones of high urban intensity and 1,667.3 km^2 in areas of low urban intensity. The total comes to 3,173.2 km^2. With this simplification we are able to calculate a certain volume for each one.

However, buildings are not solid, so we must include a variable of density in this volume, a density that is given by the amount of material used in the construction of the buildings. Better still, we could use a figure that relates building density (taking into account the total floor area of all the floors) and the emission of CO_2 that corresponds to it in terms of energy.

The MIES report of the Technical University of Catalonia (1999), based on a study of the environmental impact by the School of Architecture of the Vallès, considered that in Catalonia 1 built square metre involves an average emission of 450 kg of CO_2. Therefore, for the construction of the settlements that now exist, approximately 1.43·1012 kg of CO_2 was emitted over the years. If we consider that 1 ha of average forest absorbs 6.6 t of CO_2 (Wackernagel and Rees, 1996), then 216,355,397 ha of forest are required in order to absorb the "CO_2 emitted" during this whole period for the construction of buildings in Catalonia. The contribution to the footprint of this estimation of the accumulative effect of the urban zones in Catalonia per inhabitant is 34.01 ha. It could also be interpreted as the productive area necessary in terms of ecological footprint to perform all the construction, for example, this year (see Table 8).

Table 8. Calculation of the ecological footprint per capita including the cost of accumulation of the construction of developed spaces

Categories	FE (ha per cap.)
Space for urban settlements and communications	0,033
Space for production of food	2,03
Space for production of other organic goods	-0,00037
Space for forest production	0,043
Space associated with the consumption of energy	1,60
Space associated with the importing of goods	0,21
Space referring to the accumulation of building costs	**34,01**
TOTAL	**37,93**

Drawn up by the author.

3.2.6. In relation to organic production

The ecological footprint was conceived as a macroindicator, so the estimations proposed by the original method are not very precise or exact. However, this does not detract from their value if they are interpreted correctly. In the calculations of the ecological footprint we have observed that there is a certain tendency to go into greater detail whenever more specific figures are available, and to ignore those aspects for which no figures are available, for which the figures are not directly applicable or for which the figures must be generated imaginatively.

The existing figures that we can find in categories and subcategories of quantification habitually correspond to those that are most related to the production of resources. For example, we have figures on agricultural production, and within this category there are figures on vegetable production; within vegetables we have figures on legumes (see Appendices 2, 3 and 4), and we could continue successively with increasingly specific figures. However, for the calculation of the ecological footprint it is necessary to use conversion factors in order to convert these figures of production into units of area. The conversion factors are normally not very precise, and in general when they are obtained they are applied to relatively broad categories. For example, we can certainly use a general conversion factor to convert the agricultural production of a whole country into ecologically productive hectares, without committing an error in not separating legumes from vegetables. Therefore, in these approximations there is greater precision in some of the variables of calculation than in others, but in fact for a calculation of such large figures great precision is not necessary.

In this section of the study we are considering some adjustments of aspects which received little consideration in the original calculation. One of these aspects is organic production or the production of material with a biological base. In obtaining and processing the figures on this aspect an economicistic approach predominated, so there are interesting aspects of an ecological type that do not emerge. Below we will discuss several areas in which it would be interesting to do further research, but which go beyond the scope of the present study.

The first is the effect of the accumulated inheritance in the biodiverse spaces of Catalonia, such as biomass and production capacity (for example woods, scrubland, grassland, zones that are bare or have little vegetation, and river spaces). This approximation requires a certain amount of detail so that, though the numbers involved are large, they provide a methodological contribution to the calculation of the ecological footprint of Catalonia.

Another interesting aspect is the production of stockbreeding or crop growing resources that are not included in the elements that are valued economically. The production figures often fail to consider the parts of organisms that will not be used but have been produced, and without which the production would not have taken place (for example, the roots of vegetables or unused parts of animals). We attempted to seek information on the Internet on this but the results were not very satisfactory. This question probably also requires further research.

Another area of study is that of fisheries—above all sea fisheries because inland fishing is of little importance in Catalonia. We have figures for catches of fisheries in Catalonia, but because of the fishing systems a large amount of fish that are caught are returned to the sea unused because they have no commercial value. This alters the life cycle and the possibilities of natural regeneration and is not accounted for in the calculation of the ecological footprint. This is an important question because it is estimated that between a twentieth and a third of the catch (i.e. of the production) is not used. It would also be interesting to study this question further.

Finally, there still remain some minor aspects. One of these is hunting and inland fishing, which are small in scale but could be quantified. Unfortunately we have not obtained figures in terms of biomass of the catches, though we have figures on the number of licences that are not directly useful to us. Once again, an additional effort should be made to obtain figures on catches and transform them into values of biomass.

3.2.7. In relation to population

One of the key aspects of the ecological footprint is to consider the effects of a specific human population in relation to each inhabitant. The estimates of the population of a given territory may vary greatly, but they all seek to measure the number of inhabitants as precisely and exactly as possible. The census, an exhaustive and fairly reliable inventory of the population of a given territory, is normally used. In fact, for the calculation of the ecological footprint of Catalonia it is logical that the reference that is normally used is the main census population, a fairly up-to-date estimation of the population. The Catalan population is composed of a metapopulation, i.e. different populations spread over different territories with varying degrees of connection and distributed over the planet in a non-random fashion. In the case of Catalonia, we have the largest and main population living in Catalonia, and some, not many, satellite populations spread over the planet. The population as a whole is subject to the dynamics of birth and death, immigration and emigration. It must therefore be borne in mind that this study considers only the population that lives in Catalonia.

The characteristics of the country and the moment in history are also important factors. The climate, geostrategic situation and general quality of Catalonia (in terms of welfare, health services, economic and social stability, etc.) make it a popular tourist destination. For similar reasons it is also currently attractive to immigrants, and emigration is low. The contribution of these tourist or immigrant inhabitants to the consumption of resources may be significant in the calculation of the ecological footprint of Catalonia.

Legal immigrants are normally included in the census, but no figures are available on illegal immigrants so they cannot be accounted for. The number of foreign tourists who visited Catalonia in 2001 was 20,485,000 (IDESCAT, 2002). Furthermore, the number of non-Catalan Spaniards (for holidays, business trips, education, etc.) visiting Catalonia came to a total of 4,751,800. Catalonia was thus visited by 25,236,800 persons.

Table 9: Calculation of the ecological footprint per capita including the de facto population.

Categories	EF (ha per cap.)
Space for urban settlements and communications	0,033
Space for production of food	2,03
Space for production of other organic goods	-0,00037
Space for forest production	0,043
Space associated with the consumption of energy	1,60
Space associated with the importing of goods	0,21
Incorporation of the de facto (existing) population	**-0,25**
TOTAL	**3,63**

Drawn up by the author.

Though the number of these persons is high (almost four times the census population of Catalonia), they do not tend to remain in the Catalan territory for very long periods. One can calculate the number of permanent inhabitants to which this population would be equivalent, which would increase the census population for the purposes of our calculation. According to the Statistical Yearbook (2002), the average stay of tourists in hotels was 3.59 days; on camp sites it was 6.13 days, and in apartments it was 9.48 days. The corresponding average value of the stay of a tourist in Catalonia was thus 6.4 days for 2001. With these figures one can estimate that the over 25 million visitors would be equivalent to an increase of 442,508.13 in the census population, and that the equivalent population of Catalonia (including visitors) would be 6,803,873.27 inhabitants. The application of this correction to the original calculation of the ecological footprint gives us a slightly lower value: 3.67 ha per capita (see Table 9).

4. Analysis and evaluation of the ecological footprint of Catalonia

In the previous sections we have given a conceptual introduction to the ecological footprint, together with an estimation of its value for our country based on the original methodology proposed by Wackernagel and Rees and some proposals that have been developed in order to refine the calculations of this indicator. In this chapter we attempt to make a precise interpretation of the results obtained.

4.1. On the values obtained in the approximations

In 1998, Ferran Relea and Anna Prat estimated the ecological footprint of Catalonia as being **3.6 hectares per capita**, a value 1.5 times higher than that calculated on a world scale by Wackernagel and Rees in 1996, which was **2.36 hectares per capita**. In terms of production and ecological assimilation, a citizen of Catalonia consumes 1.24 hectares more land than an average citizen of the world.

Using the same methodological approach, the present study determined the current ecological footprint of Catalonia to be **3.92 hectares per capita**. This means that in comparison with 1998 there has been an increase in the ecological footprint of Catalonia of the order of 8.9%. The difference in the consumption of territory shows that a citizen of Catalonia consumed 0.32 hectares more in 2003 than in 1998. Considering the economic growth of the last few years, the fact that some of the variables were not brought up to date in 2002 could mean that we are moderately underestimating the value of the ecological footprint of Catalonia. Furthermore, some of these variables, such as the energy consumption, may be important.

Several comments must be made on these values. Firstly, the ecological footprint per capita of Catalonia varies due to both the consumption of resources and the demography of the country. Therefore, an increase in the population accompanied by an increase in the consumption of resources could give us a similar value of the ecological footprint (expressed in hectares per inhabitant) at two different moments (for example, several years apart), though one would have a greater environmental impact on the planet. In order to assess this, one can compare the value of the ecological footprint of the Catalan population of

1996 with that of 2002. Whereas in 1996 it was **6.19 times the area of Catalonia**, in 2002 the figure was **7.77**. This represents a 25.5% increase over 1996. Therefore, in Catalonia the demand for area of the planet in order to maintain our standard of living has increased considerably (by 1.58 times the area of Catalonia).

4.2. The ecological footprint of Catalonia in the world

The data corresponding to Catalonia give us a perspective of how the country is changing in the course of time and indicates its tendencies with regard to environmental impact and sustainability.

We have estimates of the ecological footprint of the population (EFP) of other countries (see Appendix 6). Though the values do not correspond to the same period as this study for Catalonia, they are all relatively recent estimates (of the last five years), so they are fairly comparable.

Appendix 6 shows the estimates of the ecological footprint of the population of approximately 50 countries. We are therefore considering only 20% of the 247 countries in the world, but in terms of size they represent 56.38% of the land area of the planet. Of the 50 countries, 27 form part of the Organisation for Economic Cooperation and Development (OECD).

In the size of its ecological footprint per capita, Catalonia occupies the 25th place and has a higher level than the general figure for the world population (2.36 ha per capita). Below we present some comparative figures of interest:

- The smallest ecological footprint per capita corresponds to Bangladesh, at 0.53 ha per capita, whereas the largest is that of the United States, at 9.84 ha per capita.

- The countries that are just below Catalonia, with very similar values, are Poland (3.62 ha per capita) and South Africa (3.79 ha per capita).

- Above Catalonia there are countries that are fairly different from each other, such as Italy (4.11 ha per capita) and Japan (4.30 ha per capita).

- There are states with an ecological footprint that is approximately half that of Catalonia, such as Colombia (South America), Jordan (Middle East) and Thailand (Asia), with figures of 1.61, 1.97 and 1.97 ha per capita respectively.

- There are also states with an ecological footprint that is double that of Catalonia, such as Canada and Australia, with 7.79 and 7.85 ha per capita respectively.

A direct relation can be observed between economic development, understood in classical terms, and the value of the ecological footprint per capita. Regardless of methodological considerations, which could improve the estimates in very different contexts (which is one of the limitations of the method), the tendency seems clear.

In order to characterise the situation of Catalonia in comparison with other countries, we can seek comparisons of the area of each country. This has a significance beyond that of comparisons between countries with similar characteristics, because the ecological footprint is an indicator that for a given area relates the environmental effects of the size of the country or territory analysed, particularly if one considers the limitation of space on a planetary scale. The intuitive idea is easy to understand: a country that occupies a high percentage of the land area (such as Australia) and has a very high ecological footprint is not the same as one that has a very low ecological footprint.

Catalonia is a small country, with an area of 32,087 km^2. Among the countries for which we have estimates of their ecological footprint, we find a similar area (within a range of ± 10,000 km^2) in Belgium (30,230 km^2) and Luxembourg (2,586 km^2) with a joint ecological footprint of 6.30 ha per capita; Denmark (42,394 km^2), with an ecological footprint of 6.65 ha per capita; Holland (33,883 km^2), with an ecological footprint of 5.34 ha per capita; Israel (20,330 km^2), with an ecological footprint of 5.55 ha per capita; and Switzerland (39,710 km^2), with an ecological footprint of 5.2 ha per capita. It can be seen that in all these cases the ecological footprint per capita is higher than that of Catalonia.

The other variable that characterises the ecological footprint as an environmental indicator is that it refers to a given population. The size of the population considered in the analysis is therefore important.

Catalonia, with a census population in 2001 of 6,361,365 inhabitants, is comparable to Denmark, Israel and Switzerland, because the other countries of a similar area have a far higher population. However, there are other countries that have similar numbers of inhabitants but are not considered in the comparison because of their land size. This is the case of Austria (8,170,000 inhabitants) and Finland (5,184,000 inhabitants), both with an ecological footprint higher than that of Catalonia: 4.92 and 8.37 ha per capita respectively. It is worthy of note that the ecological footprint of Finland is almost twice that of Austria (see Appendix 6).

With regard to GDP (see the definition in Appendix 6), the figure for Spain has been accepted as valid for Catalonia, because no figures are available for Catalonia alone. In 2002 the GDP per inhabitant of Spain was approximately $20,700. Of the countries considered so far in the comparative assessment, only Israel, at $19,000, is fairly similar. In the rest of the cases the figures of GDP per inhabitant are far higher, ranging from Holland's $26,900 to Luxembourg's $44,000. We can also consider other countries such as Greece with $19,000 and New Zealand with $19,500, both of which have an ecological footprint higher than that of Catalonia (5.19 and 8.80 ha per capita respectively). However, they both have a land area far greater than that of Catalonia. As for the population, Greece has 4,000,000 inhabitants more than Catalonia, whereas New Zealand has approximately half the population of Catalonia.

Finally, the consumption of electricity of Catalonia is 77.9 billion kWh per year. The only country similar to Catalonia in this sense is Belgium (in this case without including Luxembourg), with a consumption of 78.13 billion kWh. The consumption of electricity varies greatly in the other countries compared, and may be far higher or far lower.

Therefore, it is observed that Catalonia follows a pattern of a moderate ecological footprint per capita in comparison with other countries that are similar in area, population, economy or energy consumption. In general, Catalonia has a lower value than the other countries. However, two comments must be made: firstly, the comparative figures show a moderate time lag, and secondly, the calculation of the ecological footprint is always based on the original method, without considering the additional contributions proposed in the report on which this publication is based.

4.3. Interpretation in terms of ecology and sustainability

It was stated at the beginning of this study that the analysis of the environment is of greater importance than other aspects that surround us and have a positive or negative effect on us. The environment surrounds us and we also form part of it. The concept of the ecological footprint gives us a value, a number that in itself explains relatively little. We have seen that it is a number that is subject to a wealth of possible improvements, conditioning factors, nuances, specifications and degrees of exactness. The complexity of what this figure is intended to convey is so great that it is difficult to transmit the scope of its numerical significance.

It has been seen that the ecological footprint conveys an interaction or an intensity of interaction between us and the environment. It also gives us the possibility of measuring the asymmetry of this interaction between territories or between human populations of different cultures. Furthermore, the ecological footprint allows us to carry out a simple numerical assessment of questions of the economic, social and environmental model of each country and the world as a whole.

In the case of Catalonia, the value of the ecological footprint indicates that we would need a larger territory than the current one in order to carry out an ecological production of the resources that we consume and an ecological assimilation of the waste that we generate. This is especially relevant, because here "ecological" means having a space with suitable environmental conditions and ecological resources, in which the basic energy is obtained from the sun, and the exosomatic consumption is low or at minimum levels; a space in which non-living matter and especially living matter has been used with an intensity that does not threaten its availability; a place in which the species interact and remain in dynamic evolution.

Though this conceptual situation is fairly easy to understand, it is difficult to put into practice. It also represents a situation that is far from our reality as a biological species. Within our current model, which is clearly not very sustainable, we have only been able to establish fairly timid regulations or adaptations. However, we can consider paths to explore in order to substantially modify the current model and put into practice a sustainable model (understood as one in which it is possible to plan and manage within a range of action that does not involve calamities). To achieve this there are three essential paths of action, not all of which are plausible.

The first would be to establish control of the territory by increasing its size, which is not possible on a global scale. The second, which is more feasible, would be to regulate our population, but this does not seem easy and would raise enormous problems of all types (regarding our nature as a biological species and our essential, cultural, ethical, social, economic, rights, etc.). The third would be to establish a sustainable use of the resources that helps to control the population growth and fits in with the limitation of the space. It is therefore not a different solution but a combination of solutions.

This approach leads us to study the theoretical solutions a little more closely. The territory is limited not only in its extension but in the fact that within it not all spaces are inhabitable or productive for us. We have a vital need for other species, and not all of them must necessarily be direct suppliers of resources for our consumption; furthermore, they provide us with degrees of freedom in our population dynamics. Overpopulation does not lead to wellbeing, as we know from the study of ecology, and economic growth for an indefinite period of time is not feasible, as is indicated by the dynamics of energy and matter, and the alternative processes of indefinite stability and disturbance. Finally, sustained growth is only a nice expression of growth, but is unsustainable in itself. If we consider all these factors, a possible path towards overcoming them is to establish a standard level of quality of life, understood as a range rather than a fixed value. This standard of quality of life could serve to establish new bases of action that are adapted to the principles of social welfare and environmental quality.

This proposal involves a whole new field of knowledge that can be developed. It is a fertile conceptual field because we have never before been in such a good position—and even in a state of such need—to do this. Appendix 7 shows the ecological footprint values of some countries, considering a series of very basic indicators of what could be called basic quality of life. They are values referring to the mortality rate, life expectancy, the migration rate, the unemployment rate, the poverty threshold and the literacy rate. These are very basic indicators of a possible model of quality of life in relation to the limited possibilities of the planet—a model of sustainability based on this level of welfare. As they are very basic indicators, the model can be extended and improved. Therefore, nothing prevents us from developing a complex and solid welfare model. The material and technological possibilities for achieving this are excellent.

Let us consider some figures from the calculations of the ecological footprint. Though we do not wish to make a comparison with any specific country, it can be seen that Catalonia has an ecological footprint per capita that is fairly moderate among similar countries, and it has very high essential values of quality of life.

For example, in theory, the sum of the ecological footprint of all the countries of the world should give at most the earth's surface. This is an extreme approach, because not all of the earth's surface has the same ecological potential. Let us recall that this has so far been avoided through an enormous consumption of energy based largely (though not exclusively) on the consumption of fossil fuels. Let us also recall that this has obviously involved an apparent deterioration of the environment in some territories, and unfortunately a dwindling of the potential for wealth that the environment offers us.

We have the calculation of the ecological footprint of almost 50 countries of the world. Appendix 8 shows a comparative table of the values of the ecological footprint of the population (EFP), the ecological footprint per capita (EF), the total land area, the population, and the population density of each country. The ecological footprint per capita (EF) of the world is 2.36 ha per capita, the world population is 6,233,821,945, and the land area is 148.94 million km^2. With these figures the ratio of EFP to total land area of the planet is 0.99, which is in theory almost the limit of the carrying capacity of the planet. Also, if all the EFPs of the countries analysed (with a land area of 113.35 million km^2) are added together and related to the earth's surface, they result in a value of 0.76. If these countries had been selected at random among all the countries of the world, there would only remain 23% of the area consumable for ecological footprint for the rest of countries to reach 0.99 of the world ratio. However, we know that the countries were not selected at random, and that they include almost all the countries of the OECD, i.e. the developed countries. Obviously, the figures we are dealing with are very large, and there may be considerable variations, but they serve to offer a vision that is probably different from the habitual one.

Looking a little more closely at the figures, we find that Bangladesh has an ecological footprint per capita (EF) of 0.53 ha per capita, but as it has a very large population, the area used by the population is 5.28 times greater than that of the state. In comparison, the United States of America, with the highest ecological footprint on the planet (9.24 ha per capita), needs a territory that is only three times greater. If we analyse the situation of Catalonia in terms of the total ecological footprint of the country (EFP) and its total area, we see that, though it has a moderate value, it uses an ecologically productive space 7.77 times greater than the territory of Catalonia. Furthermore, this figure is higher than that based on the calculations of 1996 (Relea and Prat, 1998), which shows a value of 6.19 times the existing territory. There has therefore been a considerable increase.

Comparing different countries with Catalonia according to several parameters or variables, we find that Italy, Israel and Belgium show higher values. In general the small countries, with a large population and high standards of living, have a greater impact in terms of the ecological footprint of the population than large developed countries with fewer inhabitants, such as Canada, the United States and Australia. However, there are countries such as New Zealand that have an ecological footprint per inhabitant greater than that of Catalonia (8.8 compared with 3.92 respectively) but show a great difference in the ecological footprint of the population (in relation to the area of the country), in which the relation is clearly inverted (7.69 for Catalonia and 1.28 for New Zealand).

In conclusion, the ecological footprint per capita (EF) shows more clearly the consumption of resources, and how far from sustainability the citizens of a country are in their patterns of consumption. The ecological footprint of the population (EFP) gives us a measure of the impact of a country in relation to the other countries and especially in relation to the carrying capacity of the planet.

5. Conclusions

According to the calculations made by Relea and Prat, the ecological footprint per capita of Catalonia in 1996 was 3.26 ha. A few years later, according to the estimates described in this publication, the value has increased to 3.92 ha. In absolute terms (i.e. without dividing the necessary area by the number of inhabitants), the value of the ecological footprint of Catalonia has risen from 6.19 to 7.77 times the area of our country in this period.

However, this publication also includes some original contributions to the calculation of the footprint proposed by Wackernagel and Rees, with a view to improving its accuracy from an ecological viewpoint. These improvements include the consideration of factors such as biological diversity, the sea surface, the real population of Catalonia and the effects of imports and exports.

With the introduction of these new factors, the value of the ecological footprint per capita of Catalonia would be around 5.15 ha, an area 11 times greater than that resulting from the strict application of the method proposed by Wackernagel and Rees. One must bear in mind, however, that if the importance of the legacy of accumulated consumption in the urban zones of Catalonia were taken into account, this value would be even higher, reaching 39 ha per capita (i.e. in absolute terms, 83.1 times the area of Catalonia).

If we compare the value of the ecological footprint of Catalonia calculated using the method of Wackernagel and Rees, without additional contributions, with that calculated for different states of the world by applying the same method, we observe that Catalonia is at an intermediate level, close to states such as Italy and South Africa. As shown in the table in Appendix 7, the countries with far higher levels than ours are the United States and New Zealand and those with far lower levels are Pakistan and Ethiopia.

Table 10: Calculation of the ecological footprint considering additional aspects of improvement.

Categories	EF (ha per cap.)
Space for urban settlements and communications	0,033
Space for production of food	2,03
Space for production of other organic goods	-0,00037
Space for forest production	0,043
Space associated with the consumption of energy	1,60
Space associated with the importing of goods	0,21
Space for biodiversity	**0,18**
Absorption of CO_2 by the sea (50 m)	**-0,046**
Rectification of imports/exports	**1,35**
Incorporation of the existing population	**-0,25**
TOTAL	**5,15**

Drawn up by the author.

A very interesting exercise is to consider the general ecological footprint (in absolute terms rather than per capita) of the fifty states of which we know the individual ecological footprint. According to the calculations, they alone require an overall area of 113,353,746 km^2, a very high figure bearing in mind that the total area of the planet above sea level is 147,118,198 km^2. Though this is a limited approximation, this would mean that 75% of the land area of the planet would be occupied by the "ecologically productive area" of only 50 countries, though they certainly include the largest and most productive ones.

This inevitably leads one to reflect on the carrying capacity of the planet and the unsustainability of the current model of development on a global scale.

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7. Appendices

Appendix 1. Basic figures of ecological areas of use of biological resources for the calculation of the ecological footprint.

Appendix 2. Basic figures of organic production for the calculation of the ecological footprint.

Appendix 3. Basic figures of energy consumption for the calculation of the ecological footprint.

Appendix 4. Figures of production of manufactured and industrial goods in Catalonia (expressed in terms of energy consumption).

Appendix 5. Figures on the relation between ecological connectivity and the territorial matrix by counties. (The areas are in hectares).

Appendix 6. Figures of the ecological footprint by countries in relation to basic socio-economic indicators of each country.

Appendix 7. Figures of the ecological footprint by countries in relation to basic indicators of quality of life of each country.

Appendix 8. Figures for interpretation in terms of ecology and sustainability.

Appendix 1. Basic figures of ecological areas of use of biological resources for the calculation of the ecological footprint

Crops	Production (t)	Area (ha)	Source	Productivity of Catalonia (kg/ha)	World productivity (kg/ha)
Cereals	1,432,125	343,735	1	4,166	2,744
Fodder	3,441,601	113,454	1	30,335	2,744
Vegetables	513,764	20,748	1	24,762	18,000
Legumes	3,380	3,495	1	967	852
Tubers	101,138	6,146	1	16,456	12,607
Fruits	1,162,968	155,629	1	7,473	18,000
Vines	454,169	64,638	1	7,026	7,623
Olives	88,385	128,102	1	690	1,758
Industrial crops					
Oil seeds	25,137	15,733	1	1,598	1,856
Sunflower	16,423	11,391	1	1,442	
Soya					
Rape seed					
Tobacco					1,548
Cocoa	125,502			-	454
Coffee/tea	46,240			-	566
Cotton					1,000
Cane					4,278
Gum, resin and others					1,000
Sugar					4,893
Pastures: meat	1,407,545			-	74
Pastures: dairy	641,542			-	502
Sea: fish and seafood	43,826			-	29
Forest: wood	136,787			2,400	1,990

Source: 1, DARP, 2000.

Appendix 2. Basic figures of organic production for the calculation of the ecological footprint. *(It continues on the following page).*

		Production (P) (t)	Source	Export (E) (t)	Source
Consumption of land associated wih foold					
Stockbreeding sector					
Meat	TOTAL	1,407,545	1:271	60,646.0	1:252
	Beef	130,036	1:271	29,927.0	5
	Mutton and goat	29,230	1:271	12,121.0	5
	Horsemeat	2,520	1:271	54.0	5
	Pork	894,380	1:271	207,305.0	5
	Poultry	327,679	1:271	20,724.0	5
	Rabbit	23,700	1:271	965.0	5
Milk and dairy products		641,542	1:270	139,789.1	3
Eggs		141,598	1:270	12,573.1	3
Fisheries sector		43,826	1:276	42,017.7	3
Crop farming sector					
Green vegetalbes	TOTAL	618,282	1:260	99,160.0	5
	Vegetables	513,764	1:260	72,267.0	5
	Legumes	3,380	1:260	23,161.0	5
	Tubers	101,138	1:260	3,732.0	5
Crop farming sector					
Fruits	TOTAL	1,214,415	1:260	380,811.0	5
	Citric fruits	132,157	1:260	76,737.0	5
	Other fruits	1,082,258	1:260	301,905.0	5
Cereals	Vines	454,169	1:260	2,169.0	5

Import (I) (t)	Source	Consumption (in Kg per cap.)		Productivity		Ecological footprint (ha/hab)
		Intern (P-E)	Extern (I)	Local (Kg/hab)	World (Kg/hab)	
60,646.0	1:252	211.73	9.22			
29,927.0	5	15.74	2.27	74.00	74.00	0.24
12,121.0	5	2.69	0.51	74.00	74.00	0.04
54.0	5	0.39	0.00	74.00	74.00	0.01
207,305.0	5	108.01	1.97	Included in cereals and fodder		
20,724.0	5	48.25	3.55	Included in cereals and fodder		
965.0	5	3.57	0.01	Included in vegetables		
139,789.1	3	78.88	39.94	502.00	502.00	0.24
12,573.1	3	20.28	0.74	Included in poultry		
42,017.7	3	0.28	25.49	29.00	29.00	0.89
99,160.0	5	81.61	143.46		18,000.00	
72,267.0	5	69.40	5.35	24,762.00	18,000.00	0.00
23,161.0	5	-3.11	56.28	967.00	18,000.00	0.00
3,732.0	5	15.31	81.83	16,456.00	18,000.00	0.01
380,811.0	5	131.04	49.24	7,324.00	18,000.00	0.02
21,097.0	5	8.71	3.32	7,473.00		
279,794.0	5	122.67	43.98	7,473.00		
12,326.0	5	71.05	1.94	7,026.00		

		Production (P) (t)	Source	Export (E) (t)	Source
Fodder		1,432,125	1:260	441,618.9	3
Oilseed		3,441,601	1:260	124,319.0	5
	TOTAL			131,524.0	5
	Sunflower			2,073.0	5
Olives	Soya			5,132.0	5
Oil		88,385			
		16,339	1:260	377,997.0	5
	Sunflower			17,684.0	5
	Soya			172,458.0	5
	Olive			100,468.0	5
Sugars	Others			87,387.0	5
Cocoa				64,871.3	3
Coffee/Tea		125,502	2	52,148.5	3
		46,240	2	26,186.6	3
Consumption of land associated with other crops					
Tobacco				1,351.3	3
Cotton				81,265.9	3
Gum, resin				5,284.3	3
Cane				2,548.0	5
Consumption of land associated with de forestry sector					
	TOTAL	145,276	1:276	278,539.1	4
Wood		136,787	1:276	260,827.0	4
Cork		8,489	1:276	17,712.1	4
		TOTAL PRODUCTION 9,204,739		**TOTAL EXPORT 1,932,080.7**	

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Import (I) (t)	Source	Consumption (in Kg per cap.)		Productivity		Ecological footprint (ha per cap.)
		Intern (P-E)	Extern (I)	Local (Kg/hab)	World (Kg/hab)	
3,096,635.3	3	155.71	486.79	4,166.00	2,744.00	0.21
162,915.0	5	521.47	25.61	30,335.00	2,744.00	0.03
2,221,255.0	5	-20.68	349.18	1,598.00	1,856.00	0.18
242,058.0	5	-0.33	38.05	1,442.00		
1,816,282.0	5	-0.81	285.52			
		13.89	0.00	690.00	1,758.00	0.02
416,202.0	5	-56.85	65.43			
13,656.0	5	-2.78	2.15			
101.0	5	-27.11	0.02			
4,406.0	5	-15.79	0.69			
398,039.0	5	-13.74	62.57	Included in oilseed		
373,448.6	3	-10.20	58.71		4,893.00	0.01
118,890.5	3	11.53	18.69	454.00	454.00	0.07
148,735.8	3	3.15	23.38	566.00	566.00	0.05
18,265.5	3	-0.21	2.87		1,548.00	0.00266
61,172.5	3	-12.77	9.62		1,000.00	-0.00316
6,048.1	3	-0.83	0.95		1,000.00	0.00012
2,926.0	5	-0.40	0.46		4,278.00	0.00001
651,675,5	4	-20,95	102.44	2,400.00	1,990.00	0.0428
635,294,9	4	-19,50	99.87			
16,380,6	4	-1,45	2.58			2.05
TOTAL IMPORT 8,562,689.9						

4.4. Institut d'Estadística de Catalunya. Comerç amb l'estranger. TARIC (2002).
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5.5. Comerç exterior agrari (Agricultural Foreign Trade), Catalonia, 2000

Appendix 3. Basic figures of energy consumption for the calculation of the ecological footprint

Type of energy	Primary energy consumption (Gj per cap.)	Source
Fossil fuels		
Solids: coal	1.790	1
Liquids:	77.320	1
Gases: NG (in the form of LNG)	25.970	1
Electricity		
Conventional thermal origin	Included in other fuels	
Nuclear termal origin	40.004	1
Thermal origin - self-producers	Included in other fuels	
Hydraulic - power stations	10.060	2
Renewable Energies		
Mini-hydraulic power stations	1.330	2
Solar thermal / photovoltaic	0.008	2
Wind energy	0.360	2
Biofuels	0.000	2
SMW	0.199	2
Biomass	0.704	2
biogas	0.035	2
Energy in import of goods	18.700	3

* *Does not include the area of the* Calobres *Wind Farm,*

Sources:

1. www.idescat.es Indicadors de consum, (Consumption Indicators), 2000.

2. Pla de l'energia a Catalunya en l'horitzó de l'any 2010. (Energy Plan in Catalonia from Now to 2010).

3. Energy table expressed in import of goods. Appendix 4.

Emission factors (Kg CO_2/Gj)	Source	Area of absorption of CO_2 or equivalents 1 average ha of forest=6,6 t CO_2 Ecological footprint (ha per cap.)	
141.2	4	0.038	Area for absorbing CO_2
73.0	5	0.855	Area for absorbing CO_2
65.8	6	0.259	Area for absorbing CO_2
Depends on the fuel used 73.0	5	0.440	Equivalent to fossil energy Area for absorbing CO_2
Area occupied by reservoirs in Catalonia= 12,596 ha (7),		0.002	Area occupied by reservoirs
Negligible in terms of productive area,			
3.3 ha (2002)	2	<0.0001	Area occuppied by solar panels
Area of wind farms* = 108.5 ha		<0.0001	Area of wind farms
The CO_2 generated in the combustion is reabsorbed in biomass		<0.0001	Area for absorbing CO_2
117.0	4	0.004	Area for absorbing CO_2
The CO_2 generated in the combustion is reabsorbed in biomass		<0.0001	Area for absorbing CO_2
73.0	5	0.207	Equivalent to fossil energy
		1.805	**TOTAL**

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6. *Eurogas i Baldasano:* See *Barracó, H. 1998.*

7. *http://mediambient.gencat.net/aca/ca/medi/embassaments*

Appendix 4. Figures of production of manufactured and industrial goods in Catalonia (expressed in terms of energy consumption). *(It continues on the following page)*

Categories	Import	Source	Export (t)
Beverages	101,624	2	88,531.2
Basic products			
Wood and Cork	399,087	1	71,997.2
Paper pulp, paper and cardboard	468,059	1	62,399.3
Glass (includes manufactured products)	334,913	1	185,410.0
Non-metal minerals[1]	2,068,071	1	1,798,547.3
Metal minerals	64,027	1	1,020.6
Metallurgy: cast iron and steel	2,375,528	1	493,050.2
Plastic in primary forms	1,381,315	2	1,338,122.5
Chemical products			
Inorganic	573,936	2	542,405.0
Organic	2,285,821	2	498,889.6
Dyes/colorants	188,582	2	178,554.7
Pharmaceuticals	116,567	2	59,694.6
Other chemical products	997,302	2	1,368,483.1
Basic manufactured products			
Tobacco	18,266	1	1,351.3
Gum	6,048	1	5,284.3
Wood and cork products	252,589	2	206,541.9
Paper and cardboard products	1,031,506	2	769,347.3
Textiles and textile products	370,434	2	312,514.7
Metal products	361,060	2	299,153.5
Non-metal mineral products	1,104,342	2	1,321,512.8
Plastic in non-primary forms	296,009	2	160,534.6
Industrial products			
Industrial machinery:			
Internal combustion machines	64,362	2	7,192.6
Rotary machines: turbines...	33,957	2	37,043.8
Specific machines: tractors...	98,015	2	72,500.1
Machinery for metal processing	24,101	2	8,155.7
General machinery for industry	294,151	2	186,452.3

[1] Non-metal minerals: salt, sulphur, earth and stones, gypsum, lime and cement.

Source	I-E balance (t)	Productivity (Gj/t)	Energy consumption (Gj/10^6)
2	13,092.9	10	0.13
1	327,089.3	5	1.64
1	405,659.6	5	2.03
1	149,502.5	2	0.30
1	269,524.0	2	0.40
1	63,006.1	2	0.09
1	1,882,478.2	2	2.82
2	43,192.2	5	0.22
2	31,530.6	40	1.26
2	1,786,931.3	40	71.48
2	10,027.7	20	0.20
2	56,872.1	20	1.14
2	-371,180.9	40	-14.85
1	16,914.2	35	0.59
1	763.9	35	0.03
2	46,047.1	35	1.61
2	262,158.6	35	9.18
2	57,919.2	20	1.16
2	61,906.8	30	1.86
2	-217,170.8	60	-13.03
2	135,474.4	50	6.77
2	57,169.8	140	8.00
2	-3,087.3	100	-0.31
2	25,514.6	100	2.55
2	15,945.4	100	1.59
2	107,698.4	100	10.77

Categories		Import	Source	Exportn (t)
Industrial machinery:				
Other machinery		9,708	2	4,031.6
Office material and computer accessories		32,334	2	7,362.2
Sound and telecommunications material		86,955	2	141,716.1
Electrical material and accessories		333,955	2	238,446.0
Transport material		1,163,013	2	1,061,595.2
Sundry manufactured products				
Precision instruments		24,119	2	10,735.5
Imitation jewellery		1,726	2	2,682.3
Foreign trade	**TOTAL:**	**16,961,481** Imports t/yr		**11,541,259.1** exports t/yr

Sources:
1. Institut d'Estadística de Catalunya. Comerç amb l'estranger. TARIC (2002)
2. Institut d'Estadística de Catalunya. Comerç amb l'estranger. CUCI (2002)

Source	I-E balance (t)	Productivity (Gj/t)	Energy consumption (Gj/10^6)
2	5,676.8	100	0.57
2	24,971.9	140	3.50
2	-54,760.8	140	-7.67
2	95,508.9	100	9.55
2	101,418.0	140	14.20
2	13,383.4	100	1.34
2	-956.2	150	-0.14
	0.9	**5,420,221.9** t/cap. yr	
		TOTAL (Gj/10^6)	**118.98**
		TOTAL (Gj/cap.)	**18.70**

Appendix 5. Figures on the relation between ecological connectivity and the territorial matrix by counties. (The areas are in hectares).

County	County area	Area of Rem. Territorial Matrix	% matrix
Pallars Sobirà	137,551	72,715	52.9
Alta Ribagorça	42,510	23,042	54.2
Terra Alta	73,906	25,582	34.6
Alt Urgell	144,745	112,757	77.9
Val d'Aran	63,275	33,715	53.3
Pallars Jussà	134,344	91,803	68.3
Solsonès	100,144	72,877	72.8
Priorat	49,693	28,328	57.0
Ripollès	95,598	64,154	67.1
Ribera d'Ebre	82,931	48,924	59.0
Noguera	178,336	88,594	49.7
Berguedà	118,546	73,528	62.0
Cerdanya	54,501	29,956	55.0
Garrigues	79,811	23,007	28.8
Garrotxa	73,557	29,185	39.7
Conca de Barberà	65,019	25,202	38.8
Segarra	72,225	20,297	28.1
Montsià	73,238	9,956	13.6
Urgell	58,004	5,749	9.9
Baix Ebre	100,026	28,324	28.3
Segrià	139,393	19,553	14.0
Osona	125,932	66,648	52.9
Alt Empordà	135,290	49,865	36.9
Pla de l'Estany	26,256	14,253	54.3
Pla d'Urgell	30,630	393	1.3
Bages	129,951	91,158	70.1
Anoia	86,583	47,368	54.7
Alt Camp	53,791	20,834	38.7
Baix Camp	69,548	30,289	43.6
Selva	99,480	59,783	60.1
Gironès	57,578	21,748	37.8
Alt Penedès	59,205	27,523	46.5
Baix Empordà	69,893	14,694	21.0
Vallès Oriental	85,114	35,615	41.8
Baix Penedès	29,592	16,049	54.2
Garraf	18,371	9,025	49.1
Maresme	39,732	19,732	49.7
Tarragonès	31,734	11,454	36.1
Vallès Occidental	58,246	28,841	49.5
Baix Llobregat	48,632	21,512	44.2
Barcelonès	14,343	1,549	10.8
Catalonia	**3,207,257**	**1,515,579**	**47.3**

Anthropic space	% anthr. space	County area of connectivity
143	0.10	23,729
86	0.20	7,519
182	0.25	8,348
386	0.27	36,796
178	0.28	11,002
405	0.30	29,958
368	0.37	23,782
245	0.49	9,244
634	0.66	20,935
578	0.70	15,965
1,520	0.85	28,911
1,112	0.94	23,995
644	1.18	9,776
1,077	1.35	7,508
1,191	1.62	9,524
1,156	1.78	8,224
1,358	1.88	6,624
1,630	2.23	3,249
1,424	2.45	1,876
2,763	2.76	9,243
4,567	3.28	6,381
4,400	3.49	21,749
5,191	3.84	16,273
1,084	4.13	4,651
1,286	4.20	128
5,719	4.40	29,748
4,060	4.69	15,458
2,603	4.84	6,799
4,230	6.08	9,884
6,129	6.16	19,509
3,749	6.51	7,097
3,972	6.71	8,982
5,214	7.46	4,795
11,556	13.58	19,033
4,455	15.05	8,577
3,598	19.58	4,823
8,108	20.41	10,545
6,717	21.17	6,121
14,928	25.63	15,413
12,668	26.05	11,496
11,068	77.17	828
142,380	**4.44**	**524,501**

Source: Mayor (2000a and 2000b), Mayor, Belmonte and Huertas (2002).

NB: The figures are ordered according to the percentage of anthropic space. The counties with less than 10% of anthropic space (in green) are considered as rural, and the counties with 10% or more (in black) are considered as urban

Appendix 6. Figures of the ecological footprint by countries in relation to basic socio-economic indicators of each country

Countries	EF[1] (ha per cap.)	Area (Km^2)	Population[2]
Bangladesh	0.53	133,910	133,376,684
Pakistan	0.67	778,720	147,663,429
Ethiopia	0.81	1,119,683	67,673,031
India	0.82	2,973,190	1,045,845,226
Indonesia	1.07	1,826,440	231,328,092
Philippines	1.34	298,170	84,525,639
Peru	1.37	1,280,000	27,949,639
Nigeria	1.50	910,768	129,934,911
China	1.57	9,326,410	1,284,303,705
Egypt	1.60	995,450	70,712,345
Colombia	1.61	1,038,700	41,008,227
Jordan	1.97	91,971	5,307,470
Thailand	1.97	511,770	62,354,402
Costa Rica	2.20	50,660	3,834,934
Turkey	2.24	770,760	67,308,928
Brazil	2.35	8,456,510	176,029,560
World	**2.36**	**148,940,000**	**6,233,821,945**
Mexico	2.66	1,923,040	103,400,165
South Korea	3.04	98,190	48,324,000
Argentina	3.18	2,736,690	37,812,817
Hungary	3.31	92,340	10,075,034
Chile	3.49	748,800	15,498,930
Malaysia	3.50	328,550	22,662,365
Poland	3.62	304,465	38,625,478
South Africa	3.79	1,219,912	43,647,658
Catalonia	**3.92**	**32,087**	**6,361,365**
Italy	4.11	294,020	57,715,625
Japan	4.30	374,744	126,974,628
Russia	4.32	16,995,800	16,995,800
Switzerland	4.35	39,770	7,301,994
Portugal	4.60	91,951	10,084,245
Iceland	4.70	100,250	279,384
Spain[4]	4.86	499,542	40,077,100
Austria	4.92	82,738	8,169,929
France	5.07	545,630	59,765,983
Germany	5.19	349,223	83,251,851
Greece	5.19	130,800	10,645,343
Holland	5.34	33,883	16,067,754
United Kingdom	5.46	241,590	59,778,002
Israel	5.55	20,330	6,029,529
Ireland	6.12	68,890	3,883,159
Belgium	6.30	30,230	10,274,595
Luxembourg	6.30	2,586	448,569
Sweden	6.53	410,934	8,876,744
Denmark	6.65	42,394	5,368,854
Canada	7.79	9,220,970	31,902,268
Australia	7.83	7,617,930	19,546,792
Norway	8.01	307,860	4,525,116
Finland	8.37	305,470	5,183,545
New Zealand	8.80	268,680	3,908,037
United States of America	9.84	9,158,960	280,562,489

GDP per cap.[3] ($)	Consumption of electricity en millardos (10^9) de kWh el 2000
1,750	12.55
2,100	58.30
700	1.516
2,540	509.89
3,000	86.09
4,000	37.82
4,800	18.30
840	14.77
4,600	1.21
3,700	64.72
6,300	40.35
4,300	7.092
6,600	90.26
8,500	5.89
7,000	114.19
7,400	360.64
7,600	-
9,000	182.83
19,400	254.08
10,200	80.81
13,300	35.09
10,000	37.90
9,000	58.59
9,500	119.33
9,400	181.52
20,700	**77.87**
25,000	283.74
28,000	943.71
8,800	767.08
31,700	52.62
18,000	41.15
27,100	7.02
20,700	201.16
27,700	54.76
25,700	408.51
26,600	501.72
19,000	46.10
26,900	100.71
25,300	345.03
19,000	34.90
28,500	20.82
29,000	78.13
44,000	6.16
25,400	139.18
29,000	33.92
29,400	499.77
27,000	188.49
31,800	112.50
26,200	81.96
19,500	33.315
36,300	3,613.00

Source:
http://www.odci.gov/cia/publications/factbook/index.html

[1] EF: Ecological footprint calculated in 1998. Source: http://ecologicalfootprint.org

[2] Population, 2002 figures.

[3] GDP: Gross Domestic Product. Value of all the final goods and services produced in a nation in a given year. The figures are calculated on the basis of purchasing power parity (PPP). The PPP method applies the standard international price of the dollar to the amounts of final goods and services of an economy.
GDP per capita: shows the GDP divided by the population on 1 July of the same year. Figures for 2001 and 2002.

[4] Includes the figures for Catalonia.

Appendix 7. Figures of the ecological footprint by countries in relation to basic indicators of quality of life of each country

Countries	Infant mortality rate[1]	Life expectancy at birth[2]	Net migration rate[3]
Bangladesh	68.05	60.92	-0.75
Pakistan	78.52	80	-0.79
Ethiopia	98.63	44.21	0.11
India	61.47	63.23	-0.07
Indonesia	39.4	68.63	-0.21
Philippines	27.87	68.12	-1
Peru	38.18	70.59	-1.05
Nigeria	72.49	50.59	0.27
China	27.25	71.86	-0.38
Egypt	58.6	64.05	-0.24
Colombia	23.21	70.85	-0.32
Jordan	19.61	77.71	6.97
Thailand	29.5	69.18	0
Costa Rica	10.87	76.22	0.52
Turkey	45.77	71.52	0
Brazil	35.87	63.55	-0.03
World	**51.55**	**63.94**	**-**
Mexico	24.52	72.03	-2.71
South Korea	7.58	74.88	0
Argentina	17.2	75.48	0.63
Hungary	8.77	71.9	0.76
Chile	9.12	76.86	0
Malaysia	19.66	71.39	0
Poland	9.17	73.66	-0.49
South Africa	61.78	45.43	-1.56
Catalonia	**3.92**	**79.9**	**-**
Italy	5.76	79.25	1.73
Japan	3.84	80.91	0
Russia	19.78	67.5	0.94
Switzerland	4.42	79.86	1.37
Portugal	5.84	76.14	0.5
Iceland	3.53	79.66	-2.27
Spain[7]	4.85	79.08	0.87
Austria	4.90	78	2.45
France	4.41	79.05	0.64
Germany	4.65	77.78	3.99
Greece	6.25	78.74	1.96
Holland	4.31	78.58	2.35
United Kingdom	5.45	77.99	1.06
Israel	7.55	78.86	2.11
Ireland	5.43	77.17	4.12
Belgium	4.64	78.13	0.97
Luxembourg	4.71	77.48	9.26
Sweden	3.44	79.84	0.95
Denmark	4.97	76.91	2.01
Canada	4.95	79.69	6.07
Australia	4.90	80	4.12
Norway	3.90	78.94	2.1
Finland	3.76	77.75	0.62
New Zealand	6.18	78.15	4.48
United States of America	6.69	77.4	3.5

Unemployment rate[4] (%)	Pop. below the poverty threshold[5] (%)	Literacy[6] (%)
35	36	56
6.3	35	42.7
-	64	35.5
8.8	25	52
8	27	83.8
10	40	94.6
9	50	88.3
0.28	45	57.1
10 urban	10	81.5
12	23	51.4
17	55	91.3
16	30	86.6
3.9	13	93.8
5.2	21	95.5
10.8	-	85
6.4	22	83.3
30	-	**77**
3 urban	40	89.6
3.1	4	98
25	37	96.2
5.8	9	99
10.1	22	95.2
3.7	8	83.5
17	18	99
37	50	85
8.8	-	**98.5**
9.1	-	98
5.4	-	99
8	40	98
1.9	-	99
4.7	-	87.4
2.8	-	99.9
11.3	-	97
4.8	-	98
9.1	-	99
9.8	-	99
10.3	-	97
3	-	99
5.2	17	99
10.4	-	95
4.7	10	98
7.2	4	98
4.1	-	100
4	-	99
5.1	-	100
7.6	-	97
6.3	-	100
3.9	-	100
8.5	-	100
5.5	-	99
5	17	97

Source:
http://www.odci.gov/cia/publications/factbook/index.html

*[1] **Infant mortality rate:** number of infants dying before the age of one per 1000 live births in the same year. 2002 figures.*

*[2] **Life expectancy at birth:** average number of years that a group of persons born in the same year live if the mortality at each age continues in the future. 2002 figures.*

*[3] **Net migration rate:** difference between the number of persons entering and leaving a country during a year per 1000 persons. A surplus of persons entering a country gives a positive net immigration. A surplus of persons leaving a country gives a positive net emigration. The net migration rate indicates its contribution to the change of the population. 2002 figures.*

*[4] **Unemployment rate:** percentage of the population who are able to work and jobless.*

*[5] **Population under the poverty threshold:** this percentage is based on surveys of subgroups. The definition of poverty varies greatly between nations. Figures from 1993 to 2001.*

*[6] **Literacy:** in general, the capacity to read and write among persons aged 15 and over. Figures from 1978 to 2000.*

[7] Includes the figures for Catalonia.

Appendix 8. Figures for interpretation in terms of ecology and sustainability

Countries	EF[1] (ha per cap.)	Area in Km^2	Population[2]
Bangladesh	0.53	133,910	133,376,684
Pakistan	0.67	778,720	147,663,429
Ethiopia	0.81	1,119,683	67,673,031
India	0.82	2,973,190	1,045,845,226
Indonesia	1.07	1,826,440	231,328,092
Philippines	1.34	298,170	84,525,639
Peru	1.37	1280000	27,949,639
Nigeria	1.50	910,768	129,934,911
China	1.57	9,326,410	1,284,303,705
Egypt	1.60	995,450	70,712,345
Colombia	1.61	1,038,700	41,008,227
Jordan	1.97	91,971	5,307,470
Thailand	1.97	511,770	62,354,402
Costa Rica	2.20	50,660	3,834,934
Turkey	2.24	770,760	67,308,928
Brazil	2.35	8,456,510	176,029,560
World (1)	**2.36**	**148,940,000**	**6,233,821,945**
Mexico	2.66	1,923,040	103,400,165
Corea of the south	3.04	98,190	48,324,000
Argentina	3.18	2,736,690	37,812,817
Hungary	3.31	92,340	10,075,034
Chile	3.49	748,800	15,498,930
Malaysia	3.50	328,550	22,662,365
Poland	3.62	304,465	38,625,478
South Africa	3.79	1,219,912	43,647,658
Catalonia	**3.92**	**32,087**	**6,361,365**
Italy	4.11	294,020	57,715,625
Japan	4.30	374,744	126,974,628
Russia	4.32	16,995,800	144,978,573
Switzerland	4.35	39,770	7,301,994
Portugal	4.60	91,951	10,084,245
Iceland	4.70	100,250	279,384
Spain[3]	4.86	499,542	40,077,100
Austria	4.92	82,738	8,169,929
France	5.07	545,630	59,765,983
Germany	5.19	349,223	83,251,851
Greece	5.19	130,800	10,645,343
Holland	5.34	33,883	16,067,754
United Kingdom	5.46	241,590	59,778,002
Israel	5.55	20,330	6,029,529
Ireland	6.12	68,890	3,883,159
Belgium	6.30	30,230	10,274,595
Luxembourg	6.30	2,586	448,569
Sweden	6.53	410,934	8,876,744
Denmark	6.65	42,394	5,368,854
Canada	7.79	9,220,970	31,902,268
Australia	7.83	7,617,930	19,546,792
Norway	8.01	307,860	4,525,116
Finland	8.37	305,470	5,183,545
New Zealand	8.80	268,680	3,908,037
US	9.84	9,158,960	280,562,489
World (2)	**2.36**	**148,940,000**	**6,233,821,945**

Pop. density (inh./km²)	EFP (Km²)	EFP/Area
996.0	706,896	5.28
189.6	989,345	1.27
60.4	548,152	0.49
351.8	8,575,931	2.88
126.7	2,475,211	1.36
283.5	1,132,644	3.80
21.8	382,910	0.30
142.7	1,949,024	2.14
137.7	20,163,568	2.16
71.0	1,131,398	1.14
39.5	660,233	0.64
57.7	104,557	1.14
121.8	1,228,382	2.40
75.7	84,369	1.67
87.3	1,507,720	1.96
20.8	4,136,695	0.49
41.9	**147,118,198**	**0.99**
53.8	2,750,444	1.43
492.15	1,469,049	14.96
13.8	1,202,448	0.44
109.1	333,484	3.61
20.7	540,913	0.72
69.0	793,183	2.41
126.9	1,398,242	4.59
35.8	1,654,246	1.36
198.3	**246,821**	**7.77**
196.3	2,372,112	8.07
338.8	5,459,909	14.57
8.5	734,219	0.04
183.6	317,637	7.99
109.7	463,875	5.04
2.8	13,131	0.13
80.2	1,947,747	3.90
98.7	401,961	4.86
109.5	3,030,135	5.55
238.4	4,320,771	12.37
81.4	552,493	4.22
474.2	858,018	25.32
247.4	3,263,879	13.51
296.6	334,639	16.46
56.4	237,649	3.45
339.9	647,300	12.49
0.2	28,3	10.93
21.6	579,651	1.41
126.6	357,029	8.42
3.5	2,485,187	0.27
2.6	1,530,514	0.20
14.7	362,462	1.18
17.0	433,863	1.42
14.5	343,907	1.28
30.6	27,607,349	3.01
41.9	**113,353,746**	**0.76**

Source: http://www.odci.gov/cia/publications/factbook/index.html

[1] EF: ecological footprint calculated in 1998. Source: http://ecologicalfootprint.org

[2] Population, 2002 figures.

[3] Includes the figures for Catalonia.

World (2). In this case the EFP was calculated from the sum of the EFP of the different countries considered.