Chapter 28
Sustainability and the Firm: From the Global to the Corporate Ecological Footprint

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Abstract Nowadays, sustainability is a topic of fundamental importance, having its roots in a large body of literature. The concerns of overpopulation putting pressure on scarce natural resources are not new, but the search for appropriate indicators to assess the performance of a geographical space or entity is becoming more and more urgent. The ecological footprint is one of the most widely used sustainability indicators on a global scale, extending its influence down to local firm level. In this section, we briefly review its origins, main features, strengths, and weaknesses. Companies are increasingly seeking metrical sustainability measures as a means of differentiating in competing markets. The account of a corporate (ecological) footprint may help the firm to find gaps and opportunities for enhancing its behavior, reducing internal and external costs, while improving its market image. However, results from this tool must be analyzed carefully and may lead to some misunderstandings. We illustrate the vulnerabilities of relying solely on the outcomes from the corporate footprint with the case study of a firm operating in Portugal, using a method which has been recently applied to some firms on the Iberian Peninsula.

Keywords Sustainability · Carrying capacity · Ecological footprint · Corporate footprint's accounting method · Portuguese company

Introduction

The question of overpopulation as previously envisaged by Malthus in his essay on the principle of population emphasizes the problem of overconsumption in a world of limited resources. The barrier of limited natural capital which is not able

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to support an exponentially growing population raises a fundamental question about growth and sustainability.

Concerns about how to deal with overconsumption and/or overproduction in a context of increasing depletion of our natural resources have resulted in an extensive literature relating to sustainability indicators. Traditional monetary indicators, such as GDP, proved to be unsuitable for measuring these complex variables. The need to look for new tools and means of calculation that are able to capture the different dimensions of sustainability (social, economic, and environmental) has become urgent. Moreover, sustainability has increasingly become a key issue at every level: the national, regional, urban, individual, and last but not the least, the corporate level.

The *Ecological Footprint* (*EF*), first proposed by Wackernagel and Rees, plays a central role in the quest to find ways of dealing with our current economic behavior patterns. With concrete advantages as well as some recognized negative aspects, the extent of the EF's calculations went beyond its original main scope, analyzing and scoring the situation of some nations. It extended its influence to various applications, namely to the behavior of companies, which constitutes our main focus here.

Being aware of its increasing importance, we want to emphasize that the calculation of the *Corporate Ecological Footprint* (*CEF*) may have a double advantage. It may be beneficial for the company's image, being seen as a sign of goodwill toward the central national and international powers, both faced with commitments regarding the sustainability issue. It is becoming a vital tool for presenting suppliers, investors, customers, and other competition partners with the desired social and environmental performance. For the internal sphere of the firm, it may constitute a basis both for furthering improvements in efficiency and also for allowing for a mitigation of eventual negative effects of the company's operation on social, environmental, and thus economic results, especially in the long run. Technological advances may be a key issue in this regard, helping to solve the problem. After analyzing its CEF in detail, a firm is able to come up with a structured plan of how to reduce its footprint, by investing in greener technologies and even developing new ones.

However, external factors beyond the firm's control may offset the effects of the internal will to adopt accurate measures. Therefore, given both points of view, if the CEF is seen primarily as a work tool, it is worth pointing out that it may also be viewed as a source of uncertainties and misunderstandings, and thus its cautious use and interpretation are recommended.

We begin with a general framework, defining some basic and crucial concepts related to a view of sustainability suitable as background for the ecological footprint approach. The "tricky" notion of carrying capacity will be emphasized as playing an essential role in the definition of the EF. After presenting and discussing the methodology of the EF, pointing out its aims, components, strengths, and weaknesses, we turn to the application of its traditional scope to the particular sphere of the firm. We then focus on the CEF, its definition, and goals. Afterwards, we briefly present a possible methodology for calculating the CEF (the so-called

MC3 method), which we see as the most appropriate, and which is being expressly applied in some organizations in the Iberian Peninsula. Thereafter, some possible general internal measures to reduce the CEF are listed. A brief case study of a Portuguese firm is presented, to illustrate some points of view and to strengthen the standpoint that external factors are also a key to understanding the value obtained via the calculations of the CEF.

A Path to Sustainability: Roots and Main Concepts

During the last two centuries, a large body of economics literature focused mostly on a somewhat "simplified" and "optimistic" view of the future of mankind. "Mainstream economics,"[1] based on the strong assumptions of the "homo economicus," sees the economic system as one in which the increase in the intensity of use of production factors (mainly limited to labor and capital) ensures an increase in production output.

According to this view, the environment may not be an issue. Even if it were, scarcity of resources and pollution are not properly addressed as constraining factors of economic growth. This approach points in a different direction from the classical school of economics. Thus, Malthus' "pessimistic" message confronted the issue of a food supply which was supposed to increase following an arithmetical progression, whereas population growth was expected to increase geometrically (for more details, see Kula 1998).

Some authors in the twentieth century distanced themselves from the mainstream, "revisiting" the Malthusian perspective, but also making some notable individual contributions, which have broadened the discussion about the scarcity of resources in a finite world.

Georgescu-Roegen (1976) also provides a well-known contribution, criticizing the way in which mainstream economics sees the economic process as an isolated, self-sufficient, and ahistorical process. The bioeconomic framework of his work points out that on the basis of the entropic process, there is an escalating extraction of natural resources and production of wastes deriving from human economic activity.

Furthermore, the allegories used by Kenneth Boulding of "cowboy economy" (an open system with no concerns about resource limits), contrasting with a "spaceman economy" (a closed system representing the earth) draw special attention to the importance of constructing a new way of thinking about mankind. As he states: "The closed earth of the future requires economic principles which are somewhat different from those of the open earth of the past" (Boulding 1966, p. 7). In his

[1]We call "mainstream economics" the body of literature which developed from the works of Adam Smith, and which specifically refers to features of the neoclassic school of thought.

words, "in the spaceman economy, the throughput is by no means a desideratum, and is indeed to be regarded as something to be minimized rather than maximized" (Boulding 1966, p. 8). This approach conflicts with the mainstream theoretical constructions, where growth (in production and consumption) is seen as possible, positive, desirable, and "unlimited."

The widely known Report "Limits to Growth" (Meadows et al. 1972), although seen as controversial, reinforces the idea that the future of humanity may be threatened by scarce resources, focusing on the to some extent arguable relationship between growth and sustainability (concerning the topic of the "de-growth" concept see Juknys et al. 2014). However, the decisive turning point in the literature and in terms of "common sense" relating to this issue came with the Report of the United Nations World Commission on the Environment and Development (WCED 1987). A "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" constitutes the main and most popularized definition of sustainable development (see Pezzey 1992, Appendix 1, for an interesting survey of sustainability definitions in the literature). Furthermore, concerns about social equity and the "limitations imposed by the state of technology and social organization on the environment's ability to meet present and future needs" were explicitly stressed by the Commission as guidelines. Some mention was made in the publication regarding the "potential population-supporting capacity of land" or "population carrying capacity of the Earth" (see WCED 1987, Chap. 4, paragraph 47), a vital concept within the meaning of the ecological footprint.

Carrying Capacity: The Takeoff to the Ecological Footprint

Malthus' essay on the limited capacity of land to feed a growing population may be considered as providing a basis for the notion of carrying capacity. Much research was undertaken in several fields concerning this emerging concept. It was first theorized by Verhulst in 1838 and later consolidated by Pearl and Reed in 1920 (Seidl and Tisdell 1999; Manning 2007), whose works gave rise to the so-called logistic growth equation. This rationale was based on the theory that populations begin to grow slowly, and then increase faster until they reach an inflection point associated with achieving the environment limits. Afterward, they grow more slowly, tending to an asymptote, which represents the carrying capacity, an ultimately limiting factor in the environment (Manning 2007), also termed "saturation level" (Monte-Luna et al. 2004).

Despite all efforts to clarify the definition of carrying capacity, defining it as suitable for any level—populations, communities, ecosystems, and the biosphere (Monte-Luna et al. 2004)—the concept remains vague (Catton 1987).

Carrying capacity is generally seen as the maximum number of individuals of a given species that can be supported by a particular level of resources, without impairing the productive capacity of the occupied habitat in the future (Hanley et al. 1999; Rees 2002; Ayllón et al. 2012). In the words of Hardin (1986), the "carrying capacity of a territory is defined as the maximum number of animals that can be supported year after year without damage to the environment". In short, it states how much we can use an environment without spoiling it (Manning 2007).

The application of this concept to human beings has raised concerns about the maximum human population that a given environment can support, taking account of the available finite resources (such as food and water), that is to say, its "logistic growth" (Monte-Luna et al. 2004). In this perspective, we are measuring, so to speak, the number of persons supported per habitat/area.

An alternative to characterizing carrying capacity is to "reverse" that definition, emphasizing our concern relating to the needs of area per person. Bearing in mind the need to avoid progressive damage to the bioproductivity and ecological integrity of relevant ecosystems, the carrying capacity may be defined as the maximum rate of resource harvesting and waste discharge that can be sustained indefinitely, independently of the location of those supporting ecosystems (Rees 1996). This maximum persistently supportable load, including the support of future generations, refers not only to the number of users of that environment but "to the total demands they make upon it" (Catton 1987).

The "human load" imposed on the ecosphere by the people who live there underlies the concept of ecological footprint. It "is the product of population size times average per capita resource consumption and waste production. The notion of 'load' recognizes that human carrying capacity is a function of both population size and material/energy throughput" (Rees 2002). Furthermore, sustainability as the basis of the construction of the EF comprises two vital factors which are seen as constraints: overpopulation and human lifestyle. As Catton states: "The world is being required to accommodate not just more people, but effectively 'larger' people" (Catton 1986 cited in Rees 1996, p. 197).

Likewise, the load imposed by the population on a certain habitat is not static; it changes constantly with the available resources and with the needs of that population (Catton 1987; Ayllón et al. 2012). Furthermore, trade and advances in technology are often seen as a means of counteracting the danger of an excessive human load. However, according to Wackernagel and Rees (1996), this argument is refutable, acknowledging that technological innovation does not increase the carrying capacity, but only the efficiency of resource use. With regard to the possible gains from trade, the authors consider them illusory. Despite the redirection of production/supply between countries, there is no apparent reason for a reduction in consumption/demand for resources, a topic which supports the definition of ecological footprint.

Ecological Footprint: General Framework, Discussion, Strengths, and Weaknesses

In the 1990s, William Rees and Mathias Wackernagel proposed and developed a measure of sustainability based on the concept of the ecological footprint (Rees and Wackernagel 1994; Wackernagel and Rees 1996), which constitutes an unavoidable tool as regards sustainability issues. "The ecological footprint is a measure of the 'load' imposed by a given population on nature. It represents the land area necessary to sustain current levels of resource consumption and waste discharge by that population" (Wackernagel and Rees 1996, p. 5). Likewise, according to Kitzes and Wackernagel (2009, p. 812), the EF "measures the amount of biologically productive land and water area required to support the demands of a population or productive activity."

The method underlying the calculation of the EF was developed as an accounting tool to assess the relationship between nature and humans, given the fact that each person requires an area that provides essential goods and services, including waste assimilation (Nunes et al. 2013).

The measuring unit of the EF in the majority of the ecological footprint accounts is the *global hectare* (*gha*), meaning a standardized average productive hectare, i.e., representing an equal amount of biological productivity (Wackernagel et al. 2005; Moore and Rees 2013). This metric, which represents the global average biological world's productivity, was meant to facilitate the comparison of EFs between countries (Wackernagel et al. 2005; Wiedmann and Lenzen 2007).

Like the EF, the *biocapacity* or *biological capacity* (*BC*) is measured in gha. It may be defined as the regenerative capacity of the existing natural capital (Wackernagel et al. 2005), and therefore as the ability of ecosystems to produce useful biological materials and to absorb waste, keeping up with human demand (Moore and Rees 2013), according to current management schemes and extraction technologies (GFN 2012b). "Natural capital is …the totality of nature - resources, plants, species and ecosystems - that is capable of providing human beings with material and non-material utility" (Neumayer 2003, p. 8).

Biocapacity and ecological footprint also have in common the sum of five types of components (Fig. 28.1): cropland,[2] grazing land,[3] forest,[4] fishing grounds[5], and

[2]Type of land devoted to agriculture activities yielding vegetables, fruits, oil, coffee, cereals for animals, cotton, etc.

[3]Area intended to produce meat, milk, wool, leather, and so on.

[4]Land occupied by forests which produce timber resources used in the production of goods, as well as wood for fuel.

[5]Biologically productive marine surface exploited by humans for fish and other marine food products.

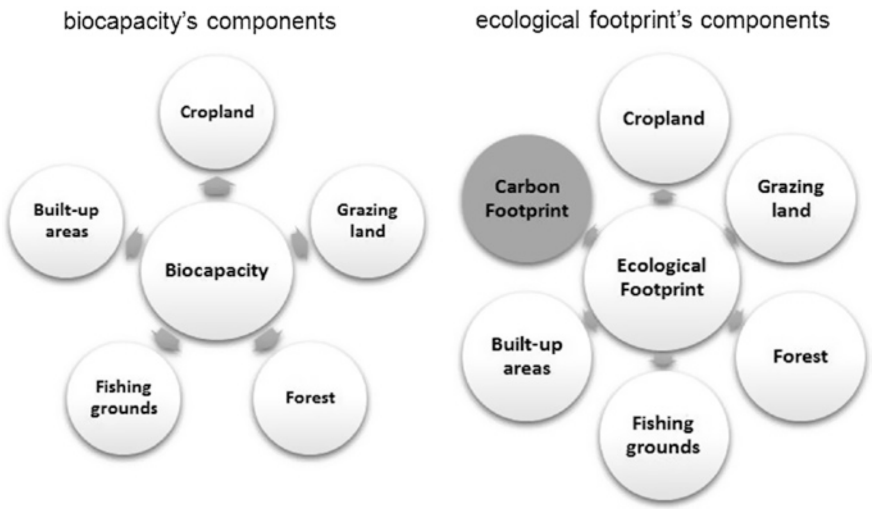

Fig. 28.1 Components of the biocapacity and the ecological footprint

built-up areas.[6] But an extra component in the calculation of the EF, in fact the most important one, is the so-called carbon footprint (CF), also termed "CO_2 area," "CO_2 land," or "energy land," consisting in the demands on the bioproductive area required to sequester the carbon dioxide emissions from fossil fuel combustion (Wackernagel and Rees 1996; Kitzes and Wackernagel 2009; Malghan 2011; GFN 2012a). It is measured in global hectares, as in the case of the other components. This corresponds to the "earlier" concept of "carbon footprint" embedded in the ecological footprint calculations (Cranston and Hammond 2012).

Meanwhile, the expression "carbon footprint" has gained a somewhat different meaning (Muthu et al. 2011; GFN 2012a). Cranston and Hammond (2012) point out this differentiation, because as a component of the EF, a carbon footprint would normally be measured in spatial units, namely global hectares, being actually presented in kilograms of carbon dioxide emitted per person or activity. "Carbon footprints represent the amount of carbon (or carbon dioxide equivalent) emissions associated with a given activity or community, and are closely related to ecological or environmental footprints. But unlike the latter, they are generally presented in terms of units of mass or weight (kilograms per functional unit), rather than in spatial units (such as global hectares). These carbon footprints have become the 'currency' of debate in a climate-constrained world. They are increasingly popular ecological indicators, adopted by individuals, businesses, governments, and the media alike" (Cranston and Hammond 2012, p. 91). To avoid ambiguity, we will adopt the first meaning (measured in gha).

[6]areas occupied by all buildings and other infrastructure related to housing, transportation, and industrial production. Part of the area is paved, and other areas remain bioproductive as gardens or parks (Costa 2008; Pereira 2008; GFN 2010)

In short, EF and BC are "two sides of the same coin," with the same metric, and using both the global yield and equivalence factors for their calculation (for a critique of the use of these measures, see Wiedmann and Lenzen 2007). The yield factor compares national average yield per hectare to world average yield in the same land category, i.e., it is the ratio between national and world average yields (GFN 2010). The equivalence factor translates the area of a specific land-use type (e.g., world average cropland or grazing land) into units of world average biologically productive area—global hectares (GFN 2010). At the core of this balance is the key concept of overshoot, a negative outcome in the comparison between the demand and supply of productive ecosystems. When the EF exceeds the BC, the area faces a depletion of productive ecosystems.

On the issue about the role of trade in solving this deficit, it seems obvious that not all countries can have a positive EF and be net importers of biocapacity, but those who are importing transfer their EFs to the exporting countries (Hanley et al. 1999; Wackernagel et al. 2006). In fact, there is a trade-off between importing and exporting regions, with a transfer of pressure on the local resources from the former to the latter. Hence, a change in the global EF does not necessarily ensue, being only dependent on a variation in the consumption/demand for resources. In fact, the importing countries are consuming areas of land/water outside their own ecosystems, but independently of their location they remain the consumer party in this trade; therefore, the potential damage to the ecosystems' regenerative capacity is still being assigned to them. On the other hand, trade is a temporary solution. Thus, if local overshoots are expected to occur, global ones cannot continue indefinitely (Moore and Rees 2013), leaving humanity "in a state of 'overshoot' living, in part, by depleting accumulated stocks of 'natural capital' … and degrading critical ecosystems" (Rees 2010, p. 18). Society is then seen to be heading along an unsustainable path.

In short, a global EF which is higher than the global biocapacity indicates unsustainability. On the other hand, a value of the EF lower than the global biocapacity is a necessary but not sufficient condition to attain sustainability (Moffatt 2000; Wackernagel et al. 2006; Kitzes et al. 2009; Kitzes and Wackernagel 2009).

Despite the apparently intuitive concept and its seemingly "unchallenged" use, the notion of ecological footprint has led to controversial debates and several criticisms in the literature (see for instance van den Bergh and Verbruggen 1999).

In order to provide a brief albeit broad picture of the debate surrounding the use of the EF, some of its most frequently quoted strengths and weaknesses, those considered most relevant for the present study, are summarized in Tables 28.1 and 28.2.

This short summary of advantages and shortcomings presented in Tables 28.1 and 28.2 points out the need to be aware of the weaknesses and misleading aspects of the calculation of the EF as well as the need to refine and improve the concept and its scope, a process which has already begun.

However, the demand for a measure of sustainability with the above-identified features has grown steadily, broadening its scope and persuading the economic agents, especially firms, of its importance.

Table 28.1 Strengths of the ecological footprint

Strengths	Comments	References
Aggregation in a single measure	It aggregates in a single measure the environmental pressures on the ecosystems	Wackernagel et al. (2004), White (2007), Fiala (2008), Bagliania and Martini (2012), Gondran (2012)
Balance between complexity and simplicity	Making abstractions of complex functions of the ecosystems makes it workable	Wackernagel and Rees (1996)
Clear and simple communication	Public opinion may become aware of the relationship between humanity and the ecosphere	Holland (2003), Lenzen et al. (2007), White (2007), Wiedmann and Lenzen (2007), Carballo-Penela et al. (2008), GFN (2010), Bagliania and Martini (2012), Browne et al. (2012), Gondran (2012)
Availability of data	Data to calculate the EF are mostly available in national statistics, international organizations, or firms' accounting records	Browne et al. (2012)
Application to different levels	It may be employed at global, national, local, corporate, and individual levels	White (2007), Mostafa (2010)
Consistency with the laws of thermo dynamics	In the opinion of some authors, the EF is consistent with the thermodynamics laws and is appropriate for measuring strong sustainability, considering the complementarily between natural and manufactured capital	Carballo-Penela et al. (2008)
Ability to measure strong sustainability		Neumayer (2003), Dietz and Neumayer (2007), Carballo-Penela et al. (2008)
Comparison between environmental impacts	It allows the comparison of the environmental impacts at several levels: countries, families, or organizations	Mostafa (2010)
Emphasis on the distance to ecological overshoot	The analysis of an EF time series can reveal whether the population under study is getting closer or further away from the ecological overshoot	Barrett and Scott (2001), Wackernagel et al. (2004), Doménech (2006), Bagliania and Martini (2012), Browne et al. (2012)
"Fairness" of distribution of responsibility concerning climate change	Most of the effort demanded by the Kyoto Protocol falls on the manufacturers. With the EF, everyone (families, countries, all types of organizations) became aware of their share of responsibility and can take action to reduce it	Doménech (2006)

(continued)

Table 28.1 (continued)

Strengths	Comments	References
Identification of critical issues and possible answers	Despite being not normative (it only accounts for the demand of environmental resources in various areas), this measure allows recognition of some of their critical spots and the proposition of better measures	Wackernagel et al. (2004)
Recognition of critical questions concerning the (dis) advantages of trade	The establishment of a series of regional ecological accounts may help countries to estimate their true ecological load and monitorize their ecological trade balances	Wackernagel and Rees (1996), Browne et al. (2012)
Helpfulness in designing policies to reduce the environment's overexploitation and monitor the progress toward sustainability	The EF analysis recommends that the carrying capacity stays below the Earth's biocapacity, which means that it is essential to implement an alternative strategy to "business as usual"	Wackernagel and Rees (1996), Barrett and Scott (2001), GFN (2010), Peters (2010), Browne et al. (2012), Galli et al. (2012)

Table 28.2 Weaknesses of the ecological footprint

Weaknesses	Comments	References
Oversimplistic vision of complex systems	The result of the EF used in an isolated manner can create a too simplistic vision of complex systems	Kitzes and Wackernagel (2009), Browne et al. (2012)
Linear relationship	It assumes a linear relationship between the ecological impact and its effects. But, in reality, ecological systems are complex and nonlinear	Holland (2003)
Difficulty in making comparisons	Data needed for the calculations are very different, and there is an intrinsic uncertainty in the application of the methodologies	Nunes et al. (2013)
Weak capacity for showing the dimensions of sustainability	It is unable to reveal the sociopolitical, economic, and eco-justice dimensions of sustainability, constituting more a measure of unsustainable overshoot than of ecological sustainability. Therefore, it should be complemented with other indicators	Moffatt (2000), Holland (2003), Wackernagel et al. (2004), Nourry (2008), Kitzes and Wackernagel (2009), WWF (2010), Browne et al. (2012)
"False concreteness"	The EF represents hypothetical land area, but there is a serious danger that it will be interpreted as representing realistic land use	van den Bergh and Verbruggen (1999)
Inconsistencies in converting hectares to global hectares	Loss of locally important information about the management of natural resources	Wiedmann and Lenzen (2007)

(continued)

Table 28.2 (continued)

Weaknesses	Comments	References
Focus on stock measurement	It does not take into account the inflows to and outflows from an area	Moffatt (2000)
Static calculations	It only takes a "picture" of the relationship between the economy and the land at a given moment in time	Wackernagel and Rees (1996), Moffatt (2000)
Difficulty in identifying where the environmental degradation takes place	Due to international trade, the EF is spread all over the planet. It is accounted for in the country where the goods are consumed, but the use of resources occurs in the exporting countries	Costa (2008)
Desire for "ecological autarky"	Calculating the ecological deficit through the comparison between the footprint and biocapacity implies the desire for "ecological au-tarky" because the more the country imports, the bigger is its EF, so that each country prefers to use natural resources that are locally available	van den Bergh and Verbruggen (1999), Pearce (2000), Ayers (2000) *in* White (2007)
Disregard for technological changes	The EF ignores the role of technological changes; if they were considered, the EF could decrease	Costa (2008), Fiala (2008)
Provision of misleading signals to policy makers	The issue of bioproductivity and metric used can be elusive, when for instance an increase in biocapacity takes place at the expense of the damage induced in biodiversity and the health of ecosystems	Lenzen et al. (2007)
Lack of political adequacy	On the one hand, it is only used to describe the human demand on natural resources. On the other hand, in the local and regional sphere, there are difficulties in calculation: (a) the smaller the area and population analyzed, the bigger the difficulty in obtaining correct consumption data; (b) the use of different methods and data makes the comparability difficult	Moffatt (2000), Wiedmann et al. (2006), White (2007), Nourry (2008)
Difficulty of comparison with a country's physical area.	The obstacles in comparing the EF with the physical area of a country relate to the fact that the borders are environmentally irrelevant	van den Bergh and Verbruggen (1999), Fiala (2008)
"CO_2 land" in carbon footprint calculations	This is one of the most controversial issues because it usually concerns the biggest portion of the EF. It is doubtful that the amount of land-intensive forestry for sequestering CO_2 is the most appropriate measure for calculating the fossil fuel footprint	van den Bergh and Verbruggen (1999), Pearce (2000), Neumayer (2003), White (2007), Browne et al. (2012)

(continued)

Table 28.2 (continued)

Weaknesses	Comments	References
No distinction between sustainable and unsustainable use of land	A big footprint might be more sustainable than a smaller one, depending on how the land is used. If the population uses the land ineffectively but without destroying it, the system maybe sustainable. On the other hand, the destruction of land and the need to transfer the production to other areas may lead to unsustainability	van den Bergh and Verbruggen (1999), Fiala (2008), GFN (2010), Browne et al. (2012)
Solely valorization of the land with human value	This tool excludes deserts, oceans, and subsoil resources. This has two consequences: the underestimation of Earth's biocapacity potential and the omission of the human impacts caused in these "nonproductive" although crucial areas	Moffatt (2000), Browne et al. (2012), Hopton and White (2012)
Treatment of areas as exclusive	The different areas are treated as exclusive, regardless of the multifunctional possibilities of an area	van den Bergh and Verbruggen (1999), Browne et al. (2012)
Omission of a large spectrum of environmental pressures and impacts	EF takes no notice of a large part of the environment's problems	Hanley et al. (1999), Costa (2008), GFN (2010), Bagliania and Martini (2012), Browne et al. (2012)
Impossibility of considering all aspects of economic activities	This is due to the impossibility to convert most aspects into physical units	Nourry (2008)
False easiness in measuring wastes	The EF considers that it is easy to measure waste flows and convert them into land area, which in reality is quite complex	Pearce (2000), Costa (2008)

From the General Footprint to the Level of Firm: Corporate Footprint as a Trademark of Sustainability

The development of tools for analyzing the environmental performance of organizations is essential in order to evaluate how much of the biosphere is required for a company to maintain its business activity without necessarily impairing the sustainable use of resources and to help contribute toward a global sustainable development (Carballo-Penela et al. 2008; Doménech 2009). Besides, it is unthinkable that governments will achieve sustainable development without the support of organizations and the public in general (Barrett and Scott 2001).

It is a fact that many organizations see sustainability as a means of differentiating, which is vital for raising productivity and competitiveness (Carballo-Penela et al. 2009; Doménech 2009; Lee 2011). The corporate footprint (CEF) allows companies to establish clear and concrete aims relating to environmental sustainability, providing a method for the support of decision making and for monitoring the effectiveness of the implemented policies (Barrett and Scott 2001; Doménech 2006; Gondran 2012; Branco 2012). Accordingly, having a single measure of the firm's ecological impact means owning a tool (Holland 2003; Doménech 2006; Carballo-Penela et al. 2008, 2009; Peters 2010; Lee 2011), which:

- Identifies unsustainable demands of the biosphere, seeking alternative resource use;
- Allows the identification of unnecessary costs and unexploited opportunities at the internal management level;
- Attempts to facilitate external communication and improves image, with possible economic benefits;
- Enables forecasting, by identifying the products which have a bigger impact on the ecological limits;
- Encourages companies to create ecolabels and consumers to choose the ones that are most environmentally friendly.

In consequence of the exposure to carbon markets, the analysis of the CEF may also help the firm to recognize opportunities to reduce carbon emissions, diminishing risks, and costs associated with that exposure. The scrutiny of the components resulting from the calculation may also be paramount for success in identifying areas for a possible reduction in energy consumption costs, or where it is reasonable to do so, in adopting new greener technologies (Lee 2011).

The use of an indicator expressed in hectares of productive surface could be seen as inappropriate for use at the level of the firm, but the conversion of different units (energy consumption, waste generated, etc.) into a common metric will provide relevant information to companies (Carballo-Penela et al. 2008). Moreover, hectares can mostly be converted into CO_2 tones, as in the case studies which are presented in the following sections.

Calculation of the Corporate Footprint Applying One Possible Methodology: Some Case Studies from the Iberian Peninsula

The "Composed Method on Financial Accounts", abbreviated as MC3, also called "method composed of financial statements" (Carballo-Penela and Doménech 2010) is an organization-product-based-life-cycle assessment type of methodology (Cagiao et al. 2011; Carballo-Penela et al. 2012). It was first developed by Doménech (Carballo-Penela et al. 2008; Carballo-Penela and Doménech 2010) based on the Composed Method developed by Wackernagel and Rees (Carballo-Penela et al. 2012). Even if we acknowledge that there are several important methodologies for calculating firms' footprint, we consider that the scope of this section is not to survey them. We therefore decided to focus on the MC3 methodology, not only because its quality is widely acknowledged, but also because we find it appropriate for this case study. The "Método Compuesto de las Cuentas Contables"—MCCC, as it was called by its authors, was first developed by Doménech between 2000 and 2002 (Carballo-Penela et al. 2012) and ever since has been improved to embrace different sectors of activity.

The footprint can be expressed in both land area (global hectares) and CO_2 tones (Doménech 2006; Carballo-Penela and Garcia-Negro 2008; Carballo-Penela et al. 2008; Carballo-Penela and Doménech 2010).

The authors of MC3 created a consumption land-use matrix similar to the one used in the calculation of countries' footprints, which enables the registration of the company's main consumption categories (Carballo-Penela et al. 2009). The matrix lines show each product's category footprint, and the columns include, among other things, the different land types which constitute the footprint (Carballo-Penela et al. 2008, 2009).

Supported by the developments based on the MC3 methodology (the so-called version MC3 V.2.0), a new picture of the calculation matrix was summarized (Table 28.3). Consumption data are mostly obtained from company accounting, which makes it applicable to any organization on any scale. Yet, the difficulties are noteworthy, starting with the fact that several data on the basis of the calculation using the MC3 methodology are difficult to obtain for the populations and periods analyzed, bringing about the need to make several proxies and assumptions, which directly influence the results. Furthermore, we can mention the difficulty of matching the accounting information with the consumption categories. Several problems arise, such as finding information about equivalence factors for the year under study, productivity factors for the specific year and country, and the composition of energy mix, just to name a few.

Some advantages were pointed out by the followers of this approach. It is considered a complete, transparent, flexible, and technically feasible method, which allows researchers to add or update the factors used in the calculations, customizing the tool to the specificities of the company (Carballo-Penela et al. 2008, 2009; Carballo-Penela and Diz 2011). Further, it has a mixed approach: (a) bottom–up for the input products (all the firm's consumptions), and (b) top–down for output products. In other words, the footprint is distributed among the firm's products (goods and services). It allows us to calculate the organizations' and products' footprint(s) simultaneously (Doménech et al. 2010; Carballo-Penela et al. 2012).

The application of MC3 has given rise to several calculations of the CEF for different Iberian Peninsula organizations belonging to various sectors. An illustration of some of the results obtained is shown in Table 28.4. Attempting to understand to what extent a value obtained for the CEF would be "high" or "low" yields unsuccessful results, as we would be "trying" to compare data from different industries and companies, even though the methodology is supposed to be the same or very similar. In fact, even in the same sector, no comparison is possible, because of the large number of distinct specific assumptions which are needed to make the calculations feasible. This constitutes a pitfall in the interpretation of the CEF, the problem we turn to now.

Table 28.3 MC3, V.2.0

Column composition	Consumption categories and subcategories	Annual consumption					Emission factor[a]/conversion factor[b]		CCF by ecosystem type, in tCO2/CEF by ecosystem type, in ha[c]						Total footprint and counter-footprint	
Units	–	In units (L; kWh; m^3; ha)	In euros	In tonnes	Energy intensity (GJ/t)	GJ/year	Natural productivity (t/ha/year)	Energy productivity (GJ/ha/year)	Fossil energy	Cropland	Grazing land	Forest	Buildup land	Fishing grounds	tCO_2; ha	tCO_2; ha
									tCO_2; ha							
1. Direct emissions	1.1. Fuel															
	1.2. Other direct emissions															
2. Indirect emissions	2.1. Electricity															
	2.2. “Other indirect emissions”															
3. Materials	3.1. Flow materials (merchandise)															
	3.2. Non-redeemable materials															
	3.3. Redeemable materials (generic)															
	3.4. Redeemable materials (construction)															
	3.5. Use of public infrastructures															
4. Services and contracts	4.1. Low mobility services															
	4.2. High mobility services															

(continued)

Table 28.3 (continued)

Column composition	Consumption categories and subcategories	Annual consumption					Emission factor[a]/conversion factor[b]		CCF by ecosystem type, in tCO2/CEF by ecosystem type, in ha[c]						Total footprint and counter-footprint	
Units	–	In units (L; kWh; m^3; ha)	In euros	In tonnes	Energy intensity (GJ/t)	GJ/year	Natural productivity (t/ha/year)	Energy productivity (GJ/ha/year)	Fossil energy	Cropland	Grazing land	Forest	Buildup land	Fishing grounds	tCO_2; ha	tCO_2; ha
									tCO_2; ha							
	4.3. Passenger transport services															
	4.4. Merchandise transport services															
	4.5. Use of public infrastructures															
5. Agricultural and fishing resources	5.1. Clothing															
	5.2. Agricultural products															
	5.3. Restaurant services															
6. Forestry resources																
7. Water footprint	7.1. Consumption of drinking water															
	7.2. Consumption of non-drinkable water															
8. Soil use	8.1. On land															
	8.2. On water															

(continued)

Table 28.3 (continued)

Column composition	Consumption categories and subcategories	Annual consumption					Emission factor[a]/conversion factor[b]		CCF by ecosystem type, in tCO2/CEF by ecosystem type, in ha[c]						Total footprint and counter-footprint	
Units	–	In units (L; kWh; m^3; ha)	In euros	In tonnes	Energy intensity (GJ/t)	GJ/year	Natural productivity (t/ha/year)	Energy productivity (GJ/ha/year)	Fossil energy	Cropland	Grazing land	Forest	Buildup land	Fishing grounds	tCO_2; ha	tCO_2; ha
									tCO_2; ha							
9. Waste, discharges and emissions	9.1. Non-hazardous waste															
	9.2. Hazardous waste															
	9.3. Radioactive waste															
	9.4. Discharges in effluents															
	9.5. Emissions															
	9.5.1. Kyoto Protocol GHG															
	9.5.2. Other GHG or precursors															
	9.5.3. Other atmospheric emissions															

[a]It allows to convert data in gigajoule (GJ) into tCO_2/GJ, obtaining the carbon footprint: [tCO_2] = [GJ/year] × emission factor [tCO_2/GJ]

[b]It allows to convert the accounting data in Euros into tonnes (t): [t/year] = [€/year]/conversion factor [€/t]

[c]For each consumption category, the calculation formula slightly varies. For example, to calculate the material footprint, first of all it is necessary to obtain the data from the accounts of the company. By entering this information on the worksheet, the calculations are made automatically, following these steps

1. Conversion of Euros to tonnes of product: [tonnes/year] = [€/year]/conversion factor [€/tonnes]
2. Conversion of tons to gigajoules consumed during the life cycle: [GJ/year] = [tonnes/year] × energy intensity [GJ/tonnes]
3. Carbon footprint ("energy land"): [tCO_2] = [GJ/year] × emission factor [tCO_2/GJ]
4. Ecological footprint ("energy land"): [ha] = carbon footprint [tCO_2]/absorption factor [tCO_2/ha]

Table 28.4 CEF of several firms, calculated using MC3—Iberian Peninsula

Firm	Year	Activity	Country	CEF (gha)	CCF (tCO_2)	References
"*Trans*"	2011	Perishable goods transportation	Portugal	2,136.3	5,915.0	Soares (2013)
"T"	2011	Perishable goods transportation	Portugal	5,736.1	15,860.9	Soares (2013)
"E"	2011	Electric equipments producer	Portugal	32,430.6	39,493.2	Branco (2012)
APG	2004	Port services	Spain	5,297.9	30,426.2	Doménech (2009)
"Gamma"	2006	Wine producer	Spain	–	152.7	Carballo-Penela et al. (2009)
"Alfa"	2007	Mussel producer	Spain	11.0	52.2	Carballo-Penela and Garcia-Negro (2008)
"Anónima"	2006	Car dealership	Spain	4,945.9	22,547.7	Moncho et al. (2008)
"Bl"	2006	Fishing	Spain	1,083.5	1,678.2	Carballo-Penela et al. (2008)
"B2"	2006	Fishing	Spain	540.2	1,026.4	Carballo-Penela et al. (2008)

Measures to Reduce the Corporate Footprint: The Pitfall of Interpreting Variations Based Solely on Internal Measures: An Illustration

The difficulties in the interpretation of a specific value of the CEF raise some questions about how important it is to know companies' CEF. An obvious benefit is that firms want to win recognition from their stakeholders, and the CEF is an additional tool which contributes to this aim. In addition, from an internal perspective, it is no less relevant, because it gives an indication of what can be done in order to reduce the footprint, which is normally associated with increasing cost efficiency. Thus, depending on the specific activity of the firm under consideration, there are various measures that can be applied in order to reduce the CEF. These are controlled by the firm and allow it to come closer to being "sustainable," while at the same time becoming "more efficient" in reducing costs.

We can briefly refer to some well-known general internal steps concerning several fields of action. Broadly speaking, it is appropriate to apply the "3 Rs" (reduce, reuse, recycle) strategy, to demand its application by the suppliers and promote it among clients (Doménech 2009; Muthu et al. 2011; Pasqualino et al. 2011). Concrete measures consist of, e.g., (1) fuel use reduction through the utilization of new technologies or more efficient ones, such as hybrid or electric vehicles (light or heavy); (2) application of "green energy" and renewable energy, such as solar thermal installation in the roofs of buildings (Doménech 2009); (3) purchasing policy with preference for certified suppliers and "green" materials (Doménech 2006, 2009).

These measures focus on internal actions of the company, several of them demanding technological advances and new production and consumption paradigms.

However, the firm works in a market and belongs to a chain in society as well as constituting a "part" of the environment, being subject to changes in all these systems. Factors which are *external* to the company can strongly influence the CEF of that organization, sometimes tending in the same direction as internal measures, and thus contributing to greater reduction in the CEF, but they may also militate against this purpose, neutralizing or even counteracting the effects achieved at the level of the firm. These factors may be due to market structure, regulations, and to more "indirect" factors such as climate conditions among others.

By way of illustration, we refer to a case study based on a Portuguese firm here designated as *Trans*, whose activity is transportation of perishable goods. The deliveries are made in lorries, some belonging to the company and some being subcontracted.

The Illustration: Trans' Corporate Footprint in 2006 and 2011

Trans collects goods from different producers/distributors in an area, placing them all in a single vehicle and delivering it to their destination.

The *Trans'* CEF was calculated for two different years, using the MC3 methodology. The results by ecosystem and by consumption category are presented in Table 28.5 and Fig. 28.2. According to these results, from 2006 to 2011 the CEF of *Trans* hardly altered, showing an insignificant increase, apparently resulting from the increase in the main component (services and contracts), due to the firm's requirements for its activity. However, the causes of that behavior of the CEF's

Table 28.5 *Trans'* total CEF and by type of ecosystem

Year	Footprint by type of ecosystem (gha)						Total footprint (gha)		
	Energy land	Cropland	Grazing land	Forest area	Built-up area	Fishing grounds	Total CEF	Counter-footprint[a]	Net CEF
2006	1983.9	2.4	0.1	128.0	1.0	1.7	2117.0	1.4	2115.6
2011	1981.2	0.5	0.1	153.4	1.0	0.4	2136.6	0.3	2136.3

[a]The counter-footprint consists of a commitment assumed by the firm, which involves buying or taking care of forest or garden areas, contributing to reducing part of its footprint. These investments in natural capital can be made primarily by supporting ONG's nature conservation projects (Doménech 2006; Carballo-Penela et al. 2008; Moncho et al. 2008; Doménech 2009; Carballo-Penela et al. 2009)

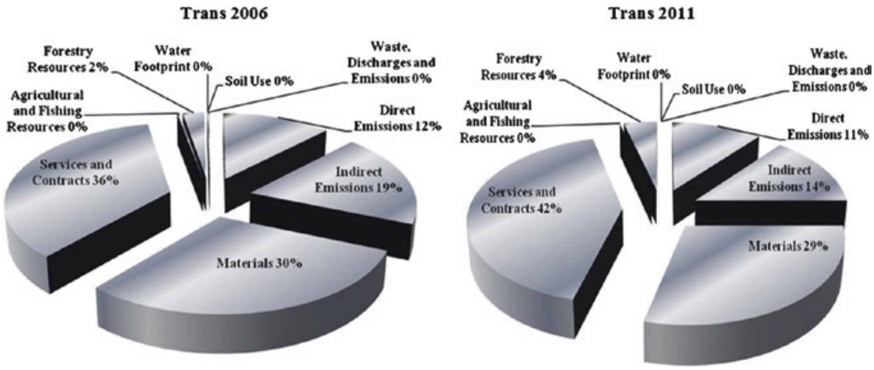

Fig. 28.2 CEF of *Trans*, by category

value can and should also be sought in external factors. To justify that statement, we will explore some simulations relating to the situation of *Trans* in the market and in social interaction.

To achieve the values of CEF, although the MC3 spreadsheet and its features were used and adapted to the case study, several assumptions (which were seen as reasonable) had to be made. The calculations were made for 2011 (based on the most recently available data) and for 2006, a previous selected year, to attempt a temporal comparison of the results (Soares 2013).

Simulation of Alternative Scenarios and Its Impact on the Global EF

Being aware that *Trans* is a firm that delivers food products, we conducted a simulation with two possible situations—Scenarios 1 and 2 (Table 28.6), with two distinct ways of delivering goods to the two major food distribution groups in Portugal—*S* and *J*.

Because *Trans* provides a service which causes a high concentration of transportation and goods, the main question here is whether this service provided by *Trans* (Scenario 1) represents a noticeable contribution to the overall environmental improvement and global sustainability in comparison with an abstract situation in which the firm would not exist, and the deliveries to *S* and *J* would be made by the producers/distributors themselves (Scenario 2). The comparison is made through the simulation of the amount of kilometers and fuel consumption that would result if the deliveries were made individually by each of the *Trans* customers in 2011, using their own fleets.

As a consequence of the services provided by *Trans*, there is a decrease in lorries using the roads and the number of kilometers is cut by half. Consequently, the fuel consumption and CO_2 emissions decrease, which is beneficial for the environment and contributes to reducing the global footprint.

Table 28.6 Calculation results for Scenarios 1 and 2

Scenarios			
1.	Deliveries are made by the transportation services of Trans, collecting the products from its clients and distributing them to S and J. This corresponds to the real market and firm situation in 2011		
2.	Deliveries are made by means of transportation of Trans' clients, using their own fleets, to S and J. This situation corresponds to a simulation of deliveries data in 2011		
Items	Results		
	Scenario 1	Scenario 2	Scenario 1 versus scenario 2 (%)
Total (km)	825,730	1,912,367	−57
Total fuel (L)	325,489	650,205	−50
CO_2 emissions (t)	908.1	1814.1	−50

Impact of Market Concentrations on CEF

As mentioned above, there are some external factors which affect the firms and influence their CEF. Bearing that in mind, we propose to make two simulations, assuming either partial or total concentrations in the destinations of *Trans* deliveries.

In the first simulation, we depart from the real fact of the occurrence of a partial concentration in the food supply market. During 2007, a major change took place in the food distribution market in Portugal, which had a strong impact on *Trans*' business: *S* group acquired *C* (n stores), concentrating *Trans*' deliveries at two *S* central purchasing units. Drawing on that fact, we made a simulation for the year 2006 (scenarios A and B, Table 28.7), assuming that the concentration of *S* and *C* had already occurred, estimating the distance in kilometers covered by the transport of goods. If the market change had occurred prior to 2006, *Trans* would have seen a decrease in the number of kilometers by about 41 %, because of the reduction in the number of delivery destinations. As a consequence, there would have been a decrease in the fuel consumption of the fleet, as well as in the subcontracting cost, and the CEF would have diminished to 2106.8 gha. This favorable variation in the CEF occurs with no proactive intervention from the firm, only stemming from market changes.

In the second simulation, we try to calculate the impact on *Trans* of a market change which would involve the *complete* centralization of the deliveries at the two major groups (*S* and *J*). At present, *S* and *J* centralize most, but not all, of their purchases on central platforms. In 2011, the total *Trans* deliveries at the central purchasing unit were 97 % in the case of *S* and 87 % in the case of *J*, the rest being transported to individual stores. Scenarios I and II (Table 28.7) show two

Table 28.7 Impact of concentrations of the food supply market

Concentration of *S* and *C*: simulation for the year 2006									
Scenarios		Results							
A	The deliveries are made in 2006 by *Trans* at all C stores (real situation)	Delivery location	Total kms	Own fleet		Subcontracted services		Total footprint
				Own fleet kms (17 %)	Consumption (fuel liters)	Subcontracted kms (83 %)	Subcontracting cost	(gha)
		C stores	95,791	16,285	6225	79,507	62,104	2115.6
B	Simulation for *Trans* in 2006, assuming that the deliveries are made at the two purchasing centrals of *S*	Delivery location	Total kms	Own fleet		Subcontracted services		Total footprint
				Own fleet kms (17 %)	Consumption (fuel liters)	Subcontracted km (83 %)	Subcontracting cost	(gha)
		S central purchasing	56,415	9591	4028	46,824	36,575	2106.8
Total centralization of S and J: Simulation for the year 2011								
Scenarios		Results						
I	*Trans* deliveries are made mostly at the central purchasing and a small part at the stores (real situation in 2011)	Delivery location	Total kms	Own fleet		Subcontracted services		Total footprint
				Own fleet kms (17 %)	Consumption (fuel liters)	Subcontracted kms (83 %)	Subcontracting Cost	(gha)
		S and J stores	18,979	1708	595	17,271	15,302	2136.3
II	*Trans* deliveries are entirely made at the *S* and *J* central purchasing platforms	Delivery location	Total kms	Own fleet		Subcontracted services		Total footprint
				Own fleet km (17 %)	Consumption (fuel liters)	Subcontracted km (83 %)	Subcontracting cost	(gha)
		S and *J* central purchasing	9656	869	365	8787	7785	2134.5

In order to make these calculations, the MC3 method was again adopted modifications that influence the *Trans'* CEF: fuel consumption reduction and subcontracting cost reduction, as in the previous situation, which generate a CEF of 2134.5 gha, smaller than the actual value.

Although the CEF reduction is very small (in both scenarios), these examples show the importance of considering the significance of the impact of external factors on the footprint, namely market factors. The impact in these cases was not particularly significant because the volume of goods affected by these changes was also minor. Bigger changes would, predictably, have had more substantial impacts.

As a consequence of several market changes occurring in that period, in this case "external factors" played their role, though not a very significant one. In conclusion, we can state that *Trans'* CEF in the period 2006–2011 underwent an evolution that was not entirely within the company's control and was not confined to its decisions and will alone.

Conclusion

It is becoming increasingly difficult to ignore that the future of mankind is dependent on a biocapacity which is not infinitely expandable. In fact, in recent years it has been increasingly recognized that the world is becoming biologically "overloaded," in contrast to the idea that the earth is providing and will be able to provide everything that humanity demands without "limits".

Many sustainability methodologies are being developed in the literature. We have chosen the ecological footprint, which has achieved outstanding popularity among the scientific community as well as institutions, governments, consumers, and organizations.

Even though it is regarded as a "young" instrument, the EF has experienced a rapid growth in attractiveness, being endorsed as a unique indicator of sustainability with different levels of application, where the corporate field constitutes one of the current main applications.

With reference to the current position of companies in a strong competitive global world, sustainability is becoming an unavoidable issue, being an important factor in helping the firm to be a first mover and to capture a higher share of the market. In line with this reasoning, the corporate ecological footprint is becoming more widely used and demanded by stakeholders and society in general. It is not only a tool for measuring a firm's impact on the environment, along with its share of responsibility for the degradation of common natural resources, but also a benchmark for the firm's image in the competition with its peers and a sign of "good behavior" relating to the accomplishment of national and international norms.

Nevertheless, the CEF's assumptions and calculation methodology are engendering several criticisms. In this section, we have surveyed some of the most pertinent advantages and limitations of this instrument, the outcome of which is that it must be analyzed with some precautions, revealing some pitfalls related to its use.

With the illustration presented, a case study applied to a Portuguese firm, the main aims were first to show the advantage of computing CEF for the firm as well as for social well-being, and second to interpret the results obtained with a view to rethinking its procedures. It should however be noticed that corporate and global footprints may interact.

Technology plays an important role, supporting measures to reduce the footprint and achieve more efficiency, two results which can often go hand in hand.

However, there can be a significant influence of exogenous factors, external to the firm's decisions whether to support or counteract its internal action to reduce its footprint, an issue which demands further research.

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