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An approach for the application of the Ecological Footprint as environmental indicator in the textile sector

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Abstract

The Ecological Footprint (EF) is a recent concept which has widely been used as an indicator of environmental sustainability applied to individual lifestyles, regions, nations or even the world. Recently, its application to enterprises has been proposed. In the present study, a textile tailoring plant has been analysed. The overall purpose of this study was to develop a tool useful for evaluating the environmental impact evolution due to the performance of the plant, as well as for comparing the environmental behaviour of different tailoring processes. Therefore, the selected data were those from the manufacturing work. Data were divided in three main categories: energy, resources and waste. The principal contribution to the final EF (expressed in hectares of land) was the resources category, mainly due to the high value associated to the cloth. The consumed energy was the second contributor, while the waste category remained in third place. The final outcomes were divided by the production rates to obtain a comparable relative index, easy to be interpreted by the different stakeholders. This is of special importance for a Company involved in Corporate Social Responsibility and thus meant to have a general communication strategy.

Keywords: Ecological Footprint; Textile sector; Environmental sustainability indicator; Simplified tool

1. Introduction

The textile sector in Spain is composed of 6350 companies with 223,200 workers [1]. This figure means the 8% of the total industrial employment, thus situating this sector between those more outstanding in the Spanish industrial structure. In fact, it is considered the sixth most important sector in the Spanish industry considering its economical results with a contribution to gross domestic product (GDP) increasing from 1% in 2001 to 5% in 2005. In the particular case of the tailoring sub-sector the significance is even higher [2].

In Galicia (NW Spain), the fashion industry has acquired especial importance in the last years due to the presence of several designers of national and international renown. This caused a strong development of this industry, which generated a great impact in the Galician economy (Table 1) and at the same time contributed to develop this source of employment.

There are near 400 textile enterprises in Galicia [4]. The factories are concentrated in few main locations (Fig. 1). Arteixo is the most representative one, since it is where Industrias de Diseño Textil, S.A. (Inditex), the best example of this major development, has most of its factories (15 in total in Galicia).

In the last years, there has been an increase in the number of regulatory laws (i.e., Integrated Pollution Prevention and Control Law [5]) and voluntary and administrative instruments affecting different environmental management issues (ISO 14000, EMAS, Eco-Label, Integrated Policy Product, Corporate Social Responsibility, etc.). This trend, together with the growing concern of the general public, has posed a change in management in all those companies willing to fulfil both the Administration requirements and society's demand of information. As a result, the evaluation of the environmental behaviour of the textile sector in Spain and, particularly, in Galicia is of great interest. However, the lack of suitable evaluation tools makes necessary

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Table 1
Enterprises classification depending on the income [3]

Income	Galicia		Spain	
	Number of enterprises	%	Number of enterprises	%
€240,000–1.5 million	118	67.43	227	33.83
€1.5 million–7 million	31	17.71	305	45.45
€7 million–40 million	15	8.57	119	17.73
>€40 million	11	6.29	20	2.98
Total sector	175	100.00	671	100.00

(Data related to 2003).

to develop adapted or simplified tools for being applied to a particular sector, as it is stated in the Integrated Policy Product [6]. Furthermore, those enterprises involved in a Corporate Social Responsibility (CSR) strategy have the need for tracking their impact through indexes easy to be interpreted by the different stakeholders [7,8].

Many inventory data are required when applying environmental evaluation tools. This common first methodology stage is maybe the most laborious task [9]. Although the whole information is undoubtedly valuable at specific decision-making level [10], it is also especially appealing the idea of summarizing all these values in only one index. In this sense, the Ecological Footprint (EF) fits all the characteristics desirable for this kind of indicator [11].

Rees and Wackernagel defined the EF as the amount of land and water area a human population would hypothetically need to provide the resources required to support itself and to absorb its wastes [12]. It has traditionally been applied to evaluate the environmental sustainability of individual lifestyles, regions, nations or even the world. The Global Footprint Network publishes every year in the Living Planet Report a list of the calculated Ecological Footprints [13], as well as the biocapacity, of a large number of countries. Many other studies have been carried out to estimate the EF of regions, cities, etc., throughout the world [14,15–17].

Recently, it has been suggested its application to enterprises, taking into account that they are also goods and services consuming organizations which generate wastes [18]. It was considered that this tool could also be used to scrutinize the ecological sustainability of processes and projects, rather than merely applying the analysis at various geographic or social scales [19]. So far, there have not been found in literature references in which EF was applied with this purpose to an industrial production process. A close example could be the calculation of a hospital's EF [20], or the associated one to a sports event audience [21]. Other cases are the estimation of this indicator in educational centres [22,23]. However, there are other case studies which approximate most to what an EF calculation of a production process is, like the Port of Gijón (NW Spain) [18] or the dairy production [24].

In this work the EF methodology has been adapted to be used in the textile sector. Based on this concept, a tool for evaluating the sustainability of a dressmaking plant was developed. The product outputs of the plant are cotton jackets, which can be either for men or women, already packed in a plastic bag. This tool was tested by data obtained during the period 2002–2005. Its application in the future will allow for comparing the environmental behaviour of this plant with other similar ones [25].

2. Methodology

The estimation of the Ecological Footprint is based on a sequence of mathematical operations that will change the original value of the input considered, expressed in its own units, into an output expressed in space units, generally hectares (ha). All these operations are gathered together in a spreadsheet (Microsoft Excel®) which enables an easy and simplified way of obtaining the final result after entering the required data [26].

Therefore, the selected data were those referred to the manufacturing work. A brief description of the productive process is shown in Fig. 2. To manufacture the jackets, the cotton fabric enters the factory where it will be cut and sewed according

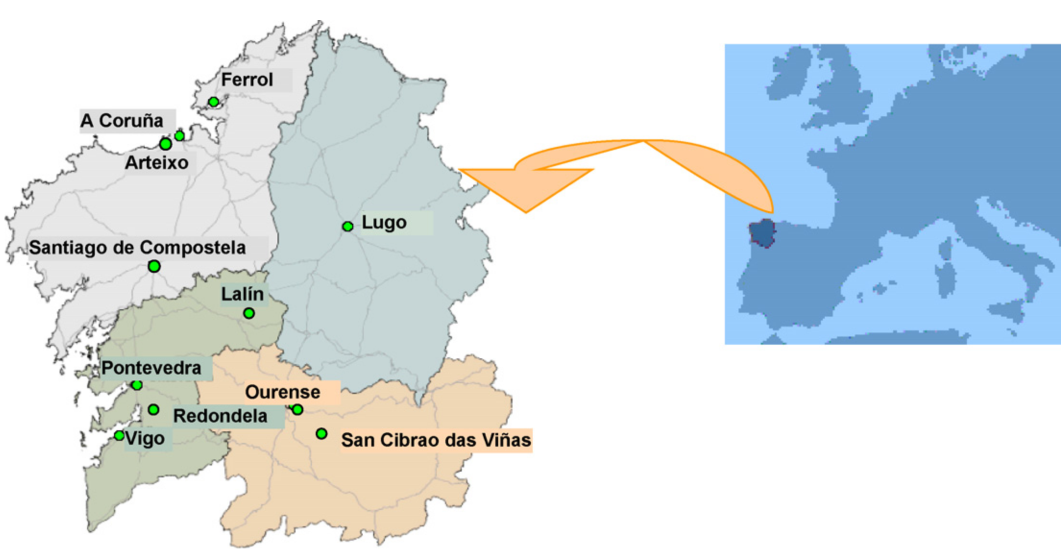

Fig. 1. Geographical situation of the main locations where the textile sector enterprises are established in Galicia.

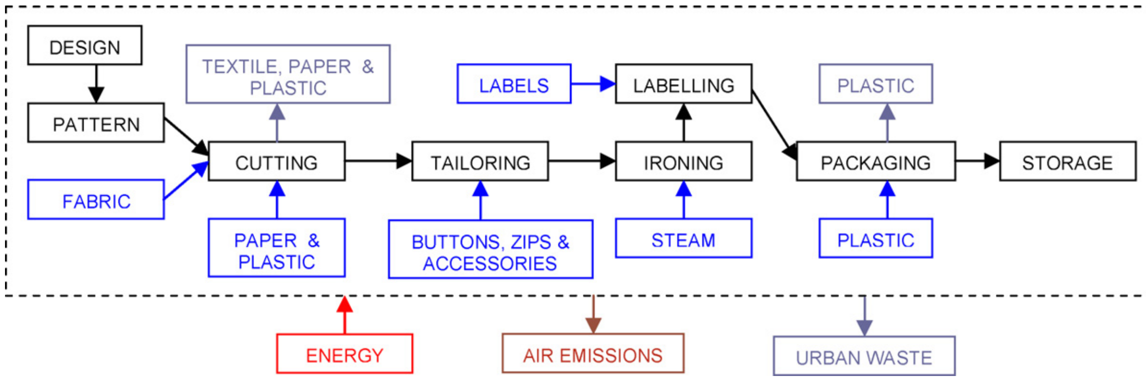

Fig. 2. Dressmaking factory process flowsheet.

to a given pattern. Buttons, zips and other ornamental elements are added to the item of clothing, which needs to be ironed (steam supply is required for this part of the process). Finally, the jackets are labelled and packed into bags to be stored and later distributed. The sources of energy are: electricity, wind-power, propane and gas–oil.

Data were divided in three main categories: energy, resources and waste, referring the first two ones to consumption, whilst the last one refers to generation. The entries included in each of them are those shown in Table 2. Electricity is not a direct energy source that can be obtained from nature, so it had to be broken down according to the power supplier company's rates (which may vary in the course of time) in order to transform it into the categories shown in Table 2 [27]. The resources consumption and the waste generation boxes in the spreadsheet must be filled with the appropriate inventory data. These are the V_i values explained later in the EF estimate section.

Table 2
Categories included in the estimate of the Ecological Footprint

Category	Units
Energy	
Carbon	kWh
Liquid fuel	kWh
Gas fuel	kWh
Nuclear	kWh
Hydroelectric power	kWh
Wind power	kWh
Solar energy	kWh
Biomass	t
Resources	
Plastic	t
Paper and cardboard	t
Cotton textile	t
Synthetic stitch	t
Wool stitch	t
Wood	t
Metal	t
Water	m^3
Waste	
Paper and cardboard	t
Plastic	t
Textile	t
Urban waste	t

It must be noticed that in the considered case only the dressmaking is studied within the textile chain. Accordingly, the material inputs to the plant are constituted by already manufactured products, while the output is made up of items of clothing ready to be sent to the shops.

Assessing the Ecological Footprint associated to the production of goods grown in land requires investigating its natural productivity, by which the initial value must be divided in order to obtain the final area. However, when discussing about other materials, they must be converted into the equivalent energy used in their production. In this case, the transformed value in energy units must be divided by the energy productivity of the land, i.e., the amount of energy that can be produced or assimilated by a hectare of land. The whole EF of the materials is attributed to fossil fuel.

There are three different approaches to calculate the footprint of fossil fuel consumption [12,28]. Each of them has a sustainability basis and thus provides with similar results. The first one would be to account for the corresponding area needed for the sustainable production of bio-fuels, such as methane or ethanol, built on closed carbon cycles. A second method calculates the area needed to compensate only the biochemical energy from different combustion fossil sources, without taking into account that the biochemical energy of woods has not the same technical quality as fossil fuel or bio-fuels. Meanwhile, the third method is based on carbon dioxide sequestration, in accordance with which the area is calculated by assessing the extension of newly planted forest required for sequestering the CO_2 released by the combustion of fossil fuel. When carrying out the calculation of the EF, it is important not to exaggerate the final outcome. For this reason, the third method, which leads to the smallest footprints for fossil fuel use, is the most frequently chosen. Also, the total load is underestimated, as the CO_2 emission is not the only environmental impact of fossil fuel use. Still, this will be the method employed in the current study.

2.1. EF estimate

The structure of the spreadsheet is divided into a series of columns. In the first one the categories of resources consumed are gathered, and the units indicated in the next one (Table 2), followed by another one that will be filled with the consumption/generation values of the plant during a year (V_i).

Associated to each kind of resource there is a rate of energy intensity (EI_i) for which the consumption/generation value will be multiplied in order to express it in energy units (EV_i).

$$EV_i = V_i^* EI_i \quad (1)$$

In the next two columns, either the natural productivity (NP_i) or the energy productivity (EP_i), or both in some cases, are compiled, depending on the category.

In general, six different types of space are separated from the whole EF value: space needed to absorb the carbon dioxide emissions caused by the fossil energy consumption, built-up area, arable land, pasture land, forest and sea. However, in the current study only four of them (fossil energy, arable land, pasture land and forest) have been taken into account, since no sea resources are consumed and the built-up area is not included in the performance of the plant.

Two columns may be considered for the subsequent operations: the one with the original values of each category (V_i) and the one with these values expressed in energy units (EV_i). The former is divided by the natural productivity (NP_i), while the latter is divided by the energy productivity (EP_i) in order to express them in space units. Thus, a last step in the estimate must be performed: the outcome of the previous division has to be multiplied by an equivalence factor (F_j) which will normalize and homogenize the different kinds of land (j) in relation to their productivity (Table 3).

$$A_{ik} = \sum_j \frac{V_i}{NP_i} F_j + \sum_j \frac{EV_i}{EP_i} F_j \quad (2)$$

where A_{ik} is the area, expressed in ha, required for the category i belonging to the main category k namely energy (E), resources (R) or waste (W).

It must be notice that at the end of the waste production rows a space to indicate the recycling percentage is displayed. This is because the waste's footprint is calculated in the same manner that the materials, with the same energy intensity, but subtracting the percentage of energy that can be recovered through recycling. Thus, in the case of the entries included in the main category waste, the required area is calculated as follows:

$$A_{iW} = \sum_j \frac{V_i}{NP_i} \left[1 - \frac{RP_i}{100} ER_i\right] F_j + \sum_j \frac{EV_i}{EP_i} \left[1 - \frac{RP_i}{100} ER_i\right] F_j \quad (3)$$

Table 3
Equivalence factors (F_j) used to normalize and homogenize the different kinds of land [26]

Land category	Equivalence factor
Fossil energy	1.4
Arable land	2.1
Pasture land	0.5
Forest	1.4

where RP_i represents the recycling percentage and ER_i represents the estimate of energy recovery through recycling for each kind of waste i.

Finally, the hectares calculated for each sort of space are added up in the last column, hence expressing the EF for every category, which are grouped together by main category thus obtaining the EF for energy, resources and waste (A_k).

$$A_k = \sum_i A_{ik} \quad (4)$$

where A_{ik} are the single entries included in the main category k (E, R or W).

Thus, the sum at the bottom of the previously mentioned column corresponds to the overall Ecological Footprint due to the plant performance during a year.

$$EF = \sum_i A_{ik} = \sum_k A_k \quad (5)$$

Additional information is given in two extra columns. On one side, the percentages of contribution of each single (C_{ik}) and main category (C_k) to the whole EF are shown,

$$C_{ik} = \left(\frac{A_{ik}}{EF}\right) \times 100 \quad (6)$$

$$C_k = \sum_i C_{ik} \quad (7)$$

while on the other side the percentage of contribution is calculated within the energy category (EC_{iE}):

$$EC_{iE} = \left(\frac{C_{iE}}{C_E}\right) \times 100 \quad (8)$$

Finally, at the bottom of the spreadsheet the overall Ecological Footprint is divided by the number of items of clothing produced in the year considered (P_{year}). Thus, a relative index (EF_r) expressed as ha/item which allows for making comparisons between different years and also different plants is obtained. It will register the evolution of the environmental impact of the performance of the plant through out the years.

$$EF_r = \frac{EF}{P_{year}} \quad (9)$$

An additional concept must be considered: the Net Ecological Footprint (NEF). Until now, only those aspects referred to land consumption have been discussed. However, the opposite idea of Counter Footprint (CF) must be taken into account, since it represents the available hectares of land. Thus, the NEF can be calculated as follows:

$$NEF = EF - CF \quad (10)$$

Consequently, a good way to diminish the net impact in the environment is to invest in natural capital protection (forest, pastureland, marine reserve, etc.) thus increasing the CF value.

Table 4
Process inventory data

	2002	2003	2004	2005
Input				
Raw materials				
Cotton fabric (kg)	643,402	651,881	798,199	919,504
Stitch (kg)	–	–	15,800	35,500
Lining (kg)	–	–	300,000	350,000
Paper and cardboard (kg)	5,867[a]	5,740[a]	6,971	7,173
Plastic (kg)	32,153[a]	31,459[a]	24,419	39,313
Buttons (kg)	28,000	28,000	28,000	31,864
Zips (kg)	13,500	8,100	6,300	7,164
Labels (kg)	650	650	650	740
Energy				
Electricity (kWh)	236,193	210,660	322,059	386,621
Wind power (kWh)	0	8,980	14,711	15,244
Propane (kg)	0	96.3	123.9	133.9
Gas–oil (m^3)	61.9	35.5	19.5	34.1
Water				
Water (m^3)	777.5	160.9	110.3	124.6
Output				
Production				
Number of items	519,399	508,188	558,078	635,055
Air emissions				
SO_2 (kg)	575[a]	330[a]	182[a]	316[a]
NO_x (kg)	18,194	3,542	3,554	6,086
CO (kg)	11,529	11,502	3,652	4,623
CO_2 (kg)	261,901	184,975	196,896	262,527
Urban or assimilable waste				
Textile (kg)	81,765	83,353	104,632	119,065
Paper and cardboard (kg)	5,867[a]	5,740[a]	6,971	7,173
Plastic (kg)	605[a]	592[a]	660	740
Urban waste	–	–	–	–
Hazardous waste				
Paint (kg)	–	–	–	1.2
Batteries (kg)	1.5	15.0	4.8	2.4
Fluorescent lamp (kg)	11.1	5.4	13.7	6.8
Ofimatic waste (kg)	–	3.4	3.6	92.3
Oil filters (kg)	60.7	11.6	7.7	4.8
Mineral oil (kg)	104.4	115.7	100.8	–
Contaminated containers (kg)	0.7	1.6	4.6	3.2

[a]Estimated values.

In this case, performing data of the analysed tailoring plant were compiled from 2002 to 2005 and the Ecological Footprint has been estimated for these years. Energy intensity values, natural and energy productivity indexes and equivalence land factors have been extracted from different original works [12,17,29].

3. Results and discussion

The results presented here show the suitability of a new approach for the application of EF to an enterprise (a dressmaking factory). The aim was to develop a tool for evaluating the environmental impact evolution due to the performance of the plant. Furthermore, a simple and wide understandable indicator for giving information of sustainability, useful for a comparative analysis in a Corporate Social Responsibility framework, was chosen.

3.1. Inventory

The inventoried data were those from the manufacturing process (Fig. 2). Most of the information used came from sustainability reports and data directly inventoried in the plant. The raw materials were used in the tailoring and packaging of the jackets. The paper and plastic consumption for 2002 and 2003, as well as the waste generated, were estimated based on production rates in order to obtain complete series for the four studied years. The number of jackets produced has risen in the last 2 years, with a consequent increase in energy requirements. Thus, in spite of introducing own renewable energy sources (wind power) the external electric energy supply has gone on increasing. The wind-power energy comes from a direct source of the plant, as the company has a wind turbine (1.5 MW of nominal power) in its productive centre in Arteixo which supplies electricity to the manufacturing plants. The gas–oil and the propane were used in cogeneration units, in which air emissions were released. SO_2 emissions have been estimated through gas–oil consumption and air emission factors [30], considering 0.2% sulphur content [31]. Thus, these emissions showed an equal tendency to the gas–oil burnt up. Reduction in NO_x and CO emissions is more remarkable in 2004 than in 2003. In 2005 emissions increased again, as well as the gas–oil consumption did. CO_2 emissions show the same evolution that the electric energy consumption, which was the main energy source of the plant. Hazardous waste was mainly generated in maintenance works.

Despite there were some gaps, inventory data provided by the company were comprehensive enough to accomplish an approach of the tool (Table 4).

3.2. EF estimate

According to the methodology explained in the previous section, and using the inventory data for the dressmaking plant (Table 4), the EF was calculated. In a first approach the EF was obtained considering the use of synthetic stitch material together with the cotton fabric for the manufacture of the jackets in 2004 and 2005, and without recycling of waste (Fig. 3).

An increasing tendency since 2003 was observed, both for the total and the relative Ecological Footprint (considering the number of items produced per year). The contribution of each category to the total EF was also determined, observing the high influence of the cotton textile (Table 5). The area required for its natural production was the main cause of the high values obtained.

As it was stated in Section 2, the built area was not included in the spreadsheet since it did not influence the performance of the plant. Besides, the plant takes an extension of 0.63 ha, and therefore it would not affect the final value of the EF.

The EF values obtained were not very high in comparison with that found for Lions Gate Hospital [20] which was 2841 ha, taking into account that in this case a productive process was considered; meanwhile, values near 6500 ha were calculated for the Port of Gijón [18]. The balance of the footprint of the process would require the investment in ecosystems conservation, reforestation, etc. However, there was no counter footprint contribution to calculate the NEF. Enterprises investments in natural capital would not only reduce the EF and supply the means for an ecological development, but it would also contribute to the fulfilment of the Kyoto Protocol. Furthermore, these actions would be accompanied by the creation of new local employments, thus including a social component in the EF estimate [18] as sustainable development should combine the ecological and social matters [32].

Sensitivity analyses were carried out for determining the way each category influenced the EF, by incorporating different materials into the composition of the jacket, varying the source of energy or introducing percentages of recycling for the waste. Furthermore, limitations of EF found for the studied case, as well as the usefulness of this indicator, were discussed.

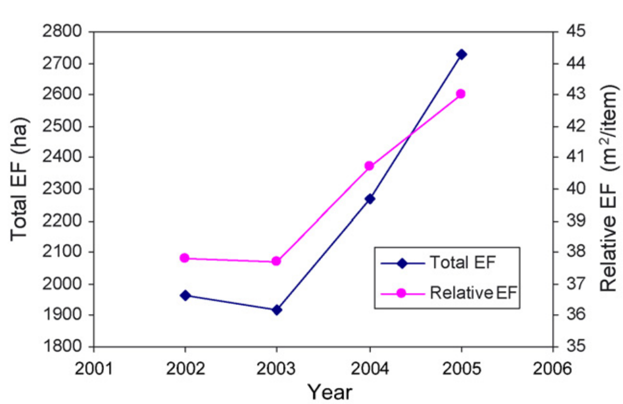

Fig. 3. EF estimates considering cotton and synthetic stitch in the jackets design and no recycling of waste.

Table 5
Contribution of the considered categories to the final year 2005 EF estimate for synthetic stitch and cotton jackets and no recycling

Category	Contribution (%)
Energy	5.3167
Carbon	1.2979
Liquid fuel	3.0561
Gas fuel	0.6265
Nuclear	0.2111
Hydroelectric power	0.0001
Wind power	0.0000
Solar energy	0.0000
Biomass	0.1248
Resources	91.3333
Plastic	12.3040
Paper and cardboard	0.5197
Cotton textile	77.3834
Synthetic stitch	1.1220
Wool textile	0.0000
Wood	0.0000
Metal	0.0000
Water	0.0043
Waste	3.3500
Paper and cardboard	0.2855
Plastic	0.0234
Textile	3.0411
Urban waste	0.0000

3.3. Resources contribution to EF

This category was the principal contributor to the Ecological Footprint. The type of the material used could change from one year to other, depending on fashion tendencies. Therefore, a simulation changing synthetic stitch by wool stitch in 2004 and 2005 was carried out to evaluate the influence of using different materials. A more noticeable increase is obtained in this case than the one observed when considering synthetic stitch. The EF values are 16.9% and 31.6% higher for 2004 and 2005, respectively. The increase in 2005 was almost twice higher than in 2004, following a close relationship with the increase in the amount of stitch material consumed in 2005 with respect to 2004 (2.2 times higher). This reflected the great influence the manu-

Table 6
Contribution of the considered categories to the final year 2005 EF estimate for wool stitch and cotton jackets and no recycling

Category	Contribution (%)
Energy	4.0385
Carbon	0.9859
Liquid fuel	2.3214
Gas fuel	0.4759
Nuclear	0.1604
Hydroelectric power	0.0001
Wind power	0.0000
Solar energy	0.0000
Biomass	0.0948
Resources	93.4168
Plastic	9.3461
Paper and cardboard	0.3948
Cotton textile	58.7804
Synthetic stitch	0.0000
Wool textile	24.8922
Wood	0.0000
Metal	0.0000
Water	0.0032
Waste	2.5447
Paper and cardboard	0.2169
Plastic	0.0178
Textile	2.3100
Urban waste	0.0000

factured materials employed had on the EF value. This is also illustrated in Table 6 in which the contribution percentages of every category are shown in the 2005 estimate when considering wool stitch.

Now the wool has a weight of 25.0% in the total EF, while the value for the cotton has decreased from 77.4% to 58.8%. The wool mainly contributes to the required pastureland, while the cotton influences mostly the needed arable land. Farms, regardless of their dairy or crop function, are intensive operations that impact the environment [24]. In addition, the materials here obtained are later treated in order to obtain the fabric ready to be tailored. Consequently, their EF is much higher than the corresponding to synthetic ones.

Other materials (metal and wood) have been included yet not filled in the spreadsheet, since it was unknown what buttons or zips were composed of. These boxes were kept back for later studies when the inventory data would be more comprehensive. As an example, if all buttons in 2005 were considered to be made of metal, the EF would increase in 51 ha; if they were supposed to be made of wood the increment would be of 33 ha; finally, the lower augment occurred when they were considered to be plastic buttons. Anyway, this would not change the total EF in more than 2%.

3.4. Energy contribution to EF

In all cases, the resources main category represented more than 90% of the total EF. As a result, the methodology might result not to be clear enough when assessing the influence of changes in either the amount or the sort of energy used. This

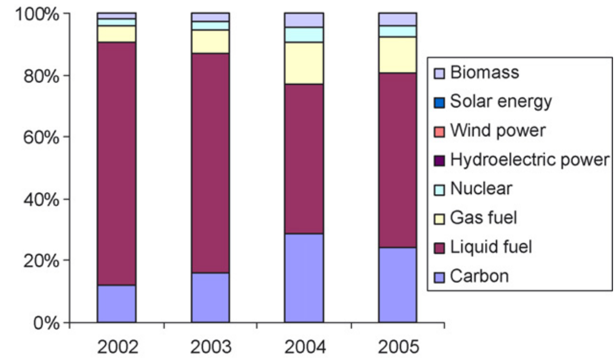

Fig. 4. Analysis of the contribution to EF within the energy category.

difficulty can be overcome analysing the energy main category separately. Thus, percentages of contribution within this group, which would not depend on the suppositions made in the materials used, have been calculated (Fig. 4). Though, it must not be forgotten that the input materials were already manufactured, and their contribution to the EF involved not only the land associated to the natural productivity (like for cotton or wool) but also the energy necessary for their subsequent elaboration. Anyway, this amount of energy does not depend on the performance of the tailoring plant and thus it cannot be a vector for further environmental improvements.

Liquid fuels consumption contributed nearby a 57% of the total, mainly due to the consumption of gas–oil. Meanwhile, a low contribution of the so-called renewable energies is observed. As it has been stated in the inventory section, only the wind-power energy comes from a direct source of the plant. The hydroelectric, the biomass and the nuclear categories come from the default breakdown of the electric energy in its sources, according to the power supplier company's rates [27]. Consequently, the choice of the electricity supplier company based on sustainability criteria would lead to select the one with highest renewable energies contribution, thus decreasing the EF of the tailoring plant. These different offers could be possible in Spain, the second country in the world with highest installed wind-power, despite the renewable energies only represent the 7% of the total primary energy consumed nowadays [33].

To assess how changes in energy sources could affect the EF estimate, a sensitivity analysis has been carried out. The results obtained are shown in Table 7. It was observed that changes in electricity and gas–oil supply had the major effect in energy EF value. However, the consequences were not very noticeable in the EF estimate, as it is shadowed by the high weight of resources consumption in the global EF.

Table 7
EF sensitivity to a 10% increase in energy sources, considering no recycling and synthetic stitch (data related to 2005)

EF (ha)	Initial	ΔElectricity	ΔWind power	ΔPropane	ΔGas–oil
Energy EF	145.1	152.0	145.1	145.2	161.1
Δ EF (%)	–	4.8	<0.01	0.07	11.0
Total EF	2730	2736	2730	2731	2746
Δ EF (%)	–	0.22	<0.01	0.04	0.59

Table 8
Influence of waste recycling on EF considering synthetic stitch (data related to 2005)

Category	EF with recycling (ha)[a]	EF without recycling (ha)	Reduction percentage (%)
Paper and cardboard	2.5	7.3	65.8
Plastic	0.2	0.5	60.0
Textile	22.4	83.5	83.3

[a] 100% of the assimilable to urban waste generated in the plant is recycled.

3.5. Waste contribution to EF

Based on the inventory data, four entries have been defined within the waste main category (Table 4). The high amount of fabric used in the process and the waste generated were especially important, hence being the main contributor to the area associated to waste assimilation. There were not available data for urban waste, but the entry has been included in the spreadsheet for further studies.

A good alternative for reducing the waste impact on the environment is recycling. A high decrease in the waste contribution to the EF was observed when the assimilable to urban waste generated in the plant (textile, plastic, paper and cardboard) were considered to be recycled (Table 8). Since the weight of waste is very low in the total value of the EF, these results were not very noticeable in the overall estimate (a decrease of 2.0% when considering the recycling of the wastes altogether).

3.6. EF usefulness as environmental indicator

In the previous sections, it was shown how the EF was sensitive to changes in the materials employed in the manufacturing of the jackets, as well as in the kind of energy sources introduced in the process. This means that this indicator is suitable to effectively assess the environmental performance of different competing management and manufacturing options that may be considered in an industrial production process.

The greatest benefit is that a great amount of handled information is synthesized and expressed in a way easier to communicate than that stem from the application of other methodologies used with similar purposes as Life Cycle Assessment (LCA). The EF would also allow people to relate the documented ecological demand to the biosphere's regenerative capacity [19], since this indicator constitutes a good way for accounting the natural capital. Consequently, it could also be helpful in determining the ability of an industrial system to adapt to the local natural limiting factors [34].

Another advantage of the EF in comparison to LCA is the absence of a requirement for an exhaustive data collection, as it is necessary for a complete LCA. Especially in the dressmaking process, where the input of the plant is not composed by raw materials but by manufactured ones (fabric, plastic, etc.), a simplified tool is demanded and therefore, the use of the EF could be much more appropriate. Conversely, to analyse in depth the environmental impact of the process via LCA it would be necessary to start studying all the processes involved in the production of these input materials. This is a more time consuming task which would imply a higher effort, even supposing that all necessary data were available in practice [35].

All of the above mentioned does not mean that the EF is a more powerful instrument but that it is a more interesting one when the attention of the study is focused in a more general and less-in-depth analysis. A good measure of the sustainability associated to production changes can be obtained in a simplified and quicker way, so that environmental supporting information is available for decision-making at process level [19,36].

3.7. EF limitations

Nowadays, the analysis of the total environmental impact through Ecological Footprint remains slightly incomplete since it does not take into account other emissions released by the combustion of fossil fuel, apart from the carbon dioxide, or some other contaminants like hazardous waste, heavy metals or dyes [37]. The reason is that they do not have a close cycle in biosphere. Thus, some of the inventoried data could not be included in the EF estimate. The factory air emissions affect two environmental problems: global warming and acidification. The Ecological Footprint accounts for the carbon dioxide emissions, principal responsible for the global warming. Initially, an absorption factor of 1.8 tC/(ha year) [12] was used. Later studies, based on IPCC estimations, yielded to a factor of 1.42 tC/(ha year) [29]. Oliveros et al [38] confirms an absorption rate up to 25 tCO_2/(ha year) for *Eucalyptus*, the third most important species covering Galician forests (it is the dominant species in 174,210.40 ha and in 159,413.93 ha together with the *Pinus pinaster*), and the one with major presence in the surroundings of the factory [39]. Anyway, the most conservative rate was used in the spreadsheet. Using these factors, the CO_2 emissions can be converted into space of land (Table 9). Meanwhile, SO_2 and NO_x are acidifying substances. An attempt to incorporate the acidification category to the total footprint area has been done, considering a critical load of 20×10^{-3} eqv. H^+/m^2 year for Europe [28]. The results obtained are shown in Table 9.

As it can be observed, the highest values were obtained for the area required to assimilate the NO_x emissions, which could mean, for example, an increase of 20.6% of the EF in 2005. In this way, these emissions can be taken into account for the total EF estimate. If this is done, the tool will not only be noticeably sensitive to changes in the material used but it will also be useful to evaluate the effects of changing the sources of energy what will imply changes in the flows of released emissions.

Hazardous waste was also generated in the plant. According to the idea previously posed, it was not included in the Ecological

Table 9
Emissions released in the factory expressed in ha of land

Year	CO_2 (ha)	SO_2 (ha)	NO_x (ha)
2002	50.4	89.9	1684.6
2003	35.6	51.5	328.0
2004	37.9	28.4	329.1
2005	50.5	49.4	563.5

Footprint estimate, as it could never take part of sustainable development. However, it represented less than 0.25% of the total waste and it was properly managed and treated following legal constraints. Therefore, the damage to the environment was under control and minimised.

The complementary use of EF and LCA should be considered for a wider sustainability analysis of the textile process. The former mainly accounting for resource consumption, and the later grouping and characterizing emissions or hazardous waste loads into environment damage categories. A tool integrating both aspects will allow for comparing the environmental behaviour of this plant with other similar ones in future applications [25].

4. Conclusions

The increasing development of the textile sector in Galicia has situated it among the most remarkable positions of the industry in this region. For this reason, it is important to develop a tool which allows for the measurement of its environmental impact. A tailoring plant, part of the productive textile chain, in where cotton jackets are manufactured, has been studied.

As being part of a company that elaborates a Corporate Social Responsibility Report, simple sustainability indicators easy to understand are desirable to be used [7]. In addition, only the impact due to the performance of the plant was analysed. Thus, it was considered that the Ecological Footprint (EF) was the concept that better fit with this purpose, since the already manufactured inputs to the factory can be incorporated directly, without the need of studying their own making processes.

The study has been carried out for the period 2002–2005. The results showed a continuous increase of the EF throughout the years. The overall EF value was strongly influenced by the resource category. The main contributors within this group were the cotton and the wool needed to manufacture the jackets. This means that changes in fashion tendencies will noticeably affect this category, depending on the materials incorporated to the design.

A small contribution to the total EF was obtained for the energy category. However, if the emissions released in the factory were included in the EF account, the influence of the sources of energy would be more noticeable and thus the EF would also be an interesting index for this category. Furthermore, the selection of an electricity supplier company with larger renewable energy contribution has been pointed as another way of reducing the EF.

It has been shown that the EF is an environmental sustainability indicator that can be used in industrial processes (dressmaking plant). Some limitations have been found, as the EF does not include some of the environmental loads that can be found in the textile sector; however, some effective solutions have been considered. An approach to include air emissions in EF estimate has been carried out. Nonetheless, the complementary use of EF and LCA will be considered in the future as an improvement for the comparison of the environmental behaviour of this textile plant with other similar ones.

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