A0001- 99

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, as they are also goods and services consuming organizations that generate waste. A tailoring plant which is part of the textile product chain has been studied. Many inventory data are required to calculate the whole EF. However, the overall purpose of this study was to develop a tool which will be 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 value of the EF (expressed in hectares of land) was the resources category, mainly due to the high value associated with the cloth. The consumed energy was the second contributor, while the waste category remains in third place. The final outcomes are divided by the number of items produced each year in the factory 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.

Conference Theme: Applications and Case Studies

Keywords: Ecological Footprint, textile sector, environmental sustainability indicator, simplified tool

INTRODUCTION

The textile sector in Spain is composed of 6,350 companies with 223,200 workers (Cityc, 2005). 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 (Table 1). In the particular case of tailoring sub-sector the significance is even higher (INE, 2000).

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 (Tables 2 and 3). This caused a strong development of this industry, which generated a great impact in the Galician economy and at the same time contributed to develop this source of employment. There are near 400 textile enterprises in Galicia (IGE, 2004), distributed in the 4 provinces of this region as shown in Figure 1. The factories are concentrated in few main locations. Arteixo is the most representative one, 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). Nonetheless, there are many other factories in locations as A Coruña, Ferrol, Lalín, Ourense, Redondela, San Cibrao das Viñas, Santiago de Compostela and Vigo, where clothes for designers like *Carolina Herrera, Purificación García, Adolfo Domínguez, Roberto Verino* or *Florentino* are created (Figure 2).

In the last years, there was an increase in the number of regulatory laws (i.e. Integrated Pollution Prevention and Control Law, Spanish Government, 2002) and voluntary and administrative instruments affecting different environmental management issues (ISO 14000, EMAS, Eco-Label, Integrated Policy Product, Corporate Social Responsibility…). 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 in suitable evaluation tools makes necessary to develop adapted or simplified tools for being applied to a particular sector, as it is stated in the Integrated Policy Product (European Commission, 2003). 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 (GRI, 2007; Inditex, 2005).

A common first step for the application of these instruments is the compilation of all the inventory data related to the performance of the plant (emissions to air, water or soil; waste generation and treatment; resources consumption; etc.). This methodology stage is maybe the most laborious task (Dahllöf, 2004). It is undoubted the value of these inventories when a decision for reducing a particular emission has to be taken at the process level (Azapagic, 1999). However, handling this great amount of information is not very useful when trying to express the general environmental behaviour of a factory, both for internal and external communication purposes. Furthermore, legislation language is normally too technical to be understood by the general public. Therefore, the idea of summarizing all these values in only one index is especially appealing. The Ecological Footprint (EF) fits all the characteristics desirable for this kind of indicator (Chambers & Lewis, 2001). The environmental behaviour of a system is expressed as an EF value, and its units (hectares of land), which integrates the relevant environmental information of the system for this purpose and can be easily interpreted by all the stakeholders.

The concept Ecological Footprint was first coined in 1992 by William Rees. Together with Mathis Wackernagel, they 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* (Rees & Wackernagel, 1996). It determines to what extent humans reduce the Earth's regenerative capacity (biocapacity). The method takes into account intensity of consumption and depletion of natural resources caused by different activities to calculate exactly how much physical space would be required to ensure sustainability. Thus, it can be used as an indicator of environmental sustainability. With this purpose it has traditionally been applied to 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 (Global Footprint Network *et al*, 2006), 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, towns, etc., throughout the world (Barret & Scott, 2001; IHOBE, 2005; Relea & Prat, 1998; Wackernagel, 1998).

Recently, it has been suggested the application of EF methodology to enterprises, taking into account that they are also goods and services consuming organizations which generate wastes (Doménech, 2004). 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 (Wackernagel & Yount, 2000). 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 the Ecological Footprint of a hospital (Germain, 2001), considering that an institution like this is a social organization with economic activity, being its outcome the health service offered. Other institutions like BRASS (Centre for Business Relationships, Accountability, Sustainability and Society, Wales) have set novel applications in the sports field (Collins & Flynn, 2004), calculating the EF for a sports event or for Cardiff's International Sports Village. Other cases are the estimation of this indicator in educational centres (Flint, 1999; Wood & Manfred, 2003). However, there are other case studies which approximate most to what an EF calculation of a production process is, like the Port Authority of Gijón (NW Spain) (Doménech, 2004) or the dairy production (Beynon et al, 2002).

In an industrial production process, different competing management and manufacturing options can be used. The textile production chain covers from the raw material to the final product. In the case of a plant in which the already manufactured pieces of cloth are tailored, the process includes cutting the fabric; sewing; adding buttons, zips or any other accessories and ironing. Thus, the sustainability of each of them can be measured by calculating its EF, evaluating the evolution of this index related to the operation of the plant through out the years. Besides, a further analysis can be done in order to compare EF to another environmental tool like Life Cycle Assessment (LCA). EF would not only make the results easier to communicate, but would also allow people to relate the ecological demand documented by the life cycle analysis to the biosphere's regenerative capacity (Wackernagel & Yount, 2000), since the EF is the best way for accounting the natural capital.

An advantage of applying this method for the measurement of process sustainability opposite to others like 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. 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 are available (Fullana & Puig, 1997).

According to all the exposed ideas, in this work the Ecological Footprint concept 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 (Albino & Kühtz, 2003).

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 (Wackernagel et al, 2005).

Therefore, the selected data were those referred to the manufacturing work. A brief description of the productive process is shown in Figure 3. To manufacture the jackets, the cotton fabric enters the factory where it will be cut and sewed according 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 4. Electricity is not a direct energy source that can be obtained from nature, so it had to be broken down according to the supplier power company's rates (which may vary in the course of time) in order to transform it into the categories shown in Table 4 (Unión Fenosa, 2006). 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.

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 (Rees & Wackernagel, 1996; Holmberg *et al*, 1999). Each of them has a sustainability basis and thus provide 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 leads to the smallest footprints for fossil fuel use, so that it 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.

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 4), 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/regeneration value will be multiplied in order to express it in energy units (EV_i).

$$EV_i = V_i * EI_i \qquad [1]$$

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, forest and sea. However, in the current study only four of them (fossil energy, arable land, pasture 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 5).

$$A_{ik} = \sum_j \frac{V_i}{NP_i} \cdot F_j + \sum_j \frac{EV_i}{EP_i} \cdot F_j \qquad [2]$$

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:

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

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,

$$C_{ik} = (A_{ik}/EF)\cdot 100 \quad [6]$$

$$C_k = \sum_i C_{ik} \quad [7]$$

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

$$EC_{iE} = (C_{iE}/C_E)\cdot 100 \quad [8]$$

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_{yr}). 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.

$$EF_r = EF/P_{yr} \quad [9]$$

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…) thus increasing the *CF* value.

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 (Rees & Wackernagel, 1996; Wackernagel 1998; Doménech, 2006).

RESULTS AND DISCUSSION

The results presented here show the suitability of a new approach for the application of Ecological Footprint 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.

Inventory

The inventoried data were those from the manufacturing process (Figure 3). 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 two 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 (US-EPA, 1985), considering 0.2% sulphur content (Spanish Government, 2005). 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 6).

EF estimate

According to the methodology explained in the previous section, and using the inventory data for the dressmaking plant (Table 6), 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 (Figure 4). 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 7). The area required for its natural production was the main cause of the high values obtained. As it was stated in the methodology section, 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 (Germain, 2001) which was 2,841 ha, taking into account that in this case a productive process was considered; meanwhile, values near 6,500 ha were calculated for Port Authority of Gijón (Doménech, 2004). 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 (Doménech, 2004) as sustainable development should combine the ecological and social matters (Huberg, 2000).

Sensibility 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 are also discussed.

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 manufactured materials employed had on the EF value. This is also illustrated in Table 8 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 pasture land, while the cotton influences mostly the needed arable land. Farms, regardless of their dairy or crop function, are intensive operations that impact the environment (Beynon *et al*, 2002). 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%.

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 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 (Figure 5). 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 can not 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 hydro-electric, the biomass and the nuclear categories come from the default breakdown of the electric energy in its sources; according to the supplier power company's rates (Unión Fenosa, 2006). 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 (IDAE, 2007).

To assess how changes in energy sources could affect the EF estimate, a sensibility analysis has been carried out. The results obtained are shown in Table 9. 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.

Waste contribution to EF

Based on the inventory data, four entries have been defined within the waste main category (Table 6). 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 10). 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).

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 (Moberg, 1999). 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·yr (Rees & Wackernagel, 1996) was used. Later studies, based on IPCC estimations, yielded to a factor of 1.42 tC/ha·yr (Doménech, 2006). Oliveros *et al* (2004) confirms an absorption rate up to 25 tCO_2/ha·yr 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 (Galician Government, 2001). 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 11). 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 $20 \cdot 10^{-3}$ eqv $H^+/m^2 \cdot yr$ for Europe (Holmberg *et al*, 1999). The results obtained are shown in Table 11. 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 sensible to changes in the material used but it will also be useful to evaluate the effects of changing the sources of energy as it will also 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 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 analisys 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 (Albino & Kühtz, 2003).

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 (GRI, 2006). 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. However, 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.

ACKNOWLEDGEMENTS

This work has been supported by the Galician Government (Dirección Xeral de I+D) through the Project PGIDIT 05TAM 023E.

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Table 1
General data of the textile and tailoring sector in Spain (Cityc, 2005).

Number of enterprises	6,350
Number of employees	223,200
Production (million €)	11,650
Exports (million €)	6,659

(Data related to 2005)

Contribution to GDP(*) 2000	1.64%
Contribution to GDP 2001	1%
Contribution to GDP 2005	5%

(*) Gross Domestic Product

Table 2
Textile sector enterprises with highest income (Ardán, 2005).

		Income (€)		
Enterprises in Galicia		**2002**	**2003**	**Rate change**
1	INDIPUNT, S.L.	108,887,959	121,538,735	11.62%
2	ADOLFO DOMINGUEZ, S.A.	108,661,215	111,445,122	2.56%
3	SOCIEDAD TEXTIL LONIA, S.A.	65,458,230	84,689,511	29.38%
4	DENLLO, S.A.	59,144,970	71,754,631	21.32%
5	CARAMELO, S.A.	70,231,324	71,062,860	1.18%
6	GLENCARE, S.A.	49,864,237	67,448,559	35.26%
7	STEAR, S.A.	52,177,220	62,368,324	19.53%
8	KETTERING, S.A.	51,765,239	53,384,858	3.13%
9	ZINTURA, S.A.	49,263,790	49,942,639	1.38%
10	CONFECCIONES FIOS, S.A.	45,055,948	46,951,264	4.21%
11	CONFECCIONES SAMLOR, S.A.	44,558,016	45,482,300	2,07%
12	TRISKO, S.A.	39,312,677	39,872,447	1.42%
13	HAMPTON, S.A.	24,435,043	32,219,532	31.86%
14	ROBERTO VERINO DIFUSION, S.A.	30,049,085	29,654,136	-1.31%
15	CHOOLET, S.A.	29,530,237	27,529,624	-6.77%
16	SIRCIO, S.A.	24,142,187	27,181,542	12.59%
17	CONFECCIONES GOA, S.A.	22,922,776	26,536,385	15.76%
18	NIKOLE, S.A.	24,945,428	26,032,533	4.36%
19	OYSHO ESPAÑA, S.A.	21,364,225	—	—
20	FLORENTINO COLECCION, S.L.	20,185,845	20,609,685	2.10%
Enterprises in Spain				
1	INDUSTRIAS Y CONFECCIONES, S.A.	446,081,317	459,713,269	3.06%
2	CORTEFIEL, S.A.	289,793,997	—	—
3	LEVI STRAUSS DE ESPAÑA, S.A.	149,165,759	125,176,806	-16.08%
4	INDIPUNT, S.L.	108,887,959	121,538,735	11.62%
5	ADOLFO DOMINGUEZ, S.A.	108,661,215	111,445,122	2.56%

Table 3
Enterprises classification depending on the income (Ardán, 2005).

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)

Figure 1
Distribution of textile enterprises in Galicia as percentage of contribution per province (IGE, 2004).

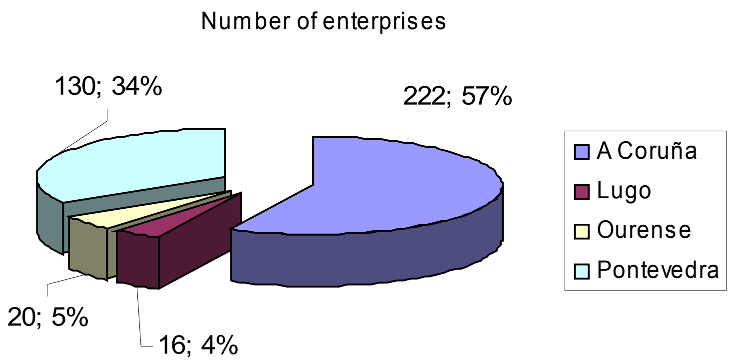

Figure 2
Geographical situation of the main locations where the textile sector enterprises are established in Galicia.

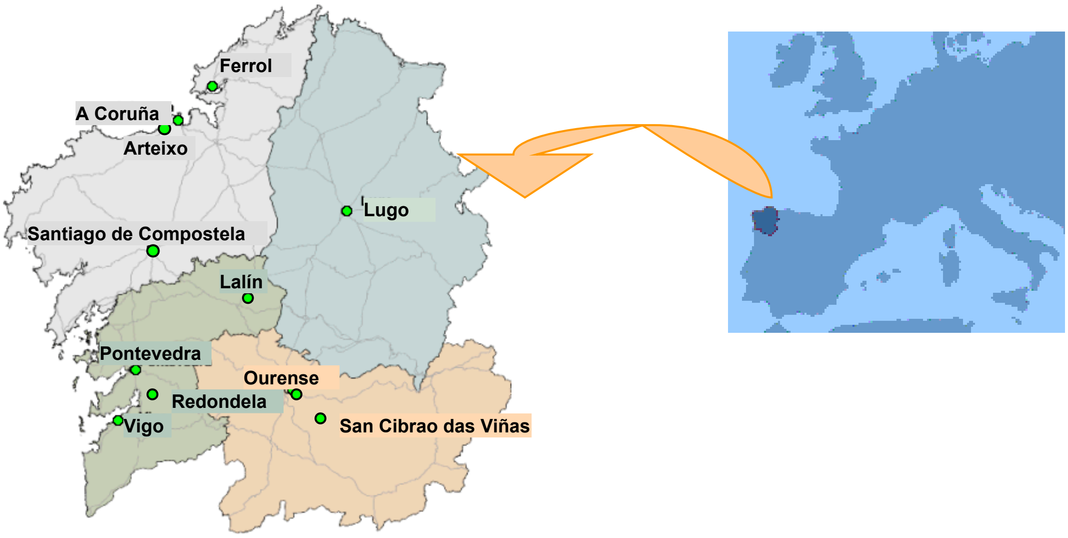

Figure 3
Dressmaking factory process flowsheet.

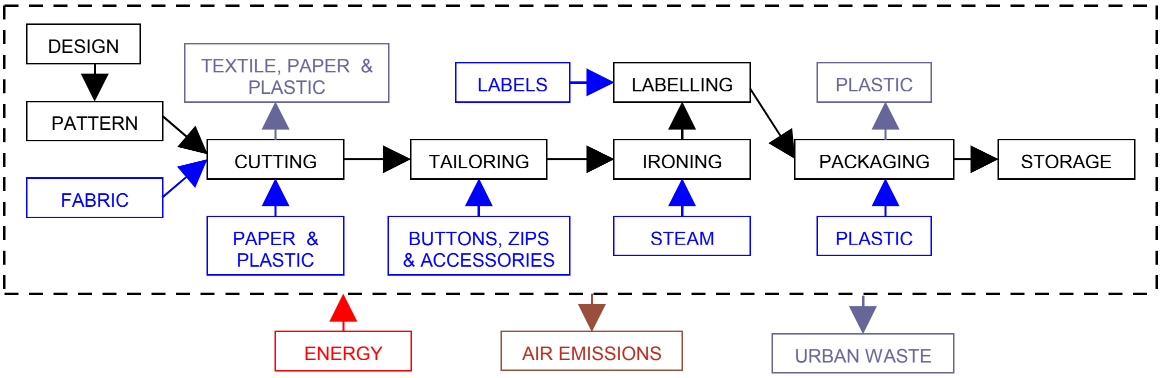

Table 4
Categories included in the estimate of the Ecological Footprint.

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

Table 5
Equivalence factors (F_j) used to normalize and homogenize the different kinds of land (Wackernagel *et al*, 2005).

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

Table 6. 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 & cardboard (kg)	(*)5,867	(*)5,740	6,971	7,173
		Plastic (kg)	(*)32,153	(*)31,459	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 (l)	61,924	35,470	19,547	34,054
	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 (t)	(*)0.575	(*)0.330	(*)0.182	(*)0.316
		NO_x (t)	18.194	3.542	3.554	6.086
		CO (t)	11.529	11.502	3.652	4.623
		CO_2 (t)	261.901	184.975	196.896	262.527
	Urban or assimilable waste	Textile (kg)	81,765	83,353	104,632	119,065
		Paper & cardboard (kg)	(*)5,867	(*)5,740	6,971	7,173
		Plastic (kg)	(*)605	(*)592	660	740
		Urban waste	-	-	-	-
	Hazardous waste	Paint (kg)	-	-	-	1.185
		Batteries (kg)	1.492	14.967	4.825	2.378
		Fluorescent lamp (kg)	11.114	5.443	13.669	6.817
		Ofimatic waste (kg)	-	3.402	3.586	92.265
		Oil filters (kg)	60.719	11.566	7.706	4.756
		Mineral oil (kg)	104.430	115.658	100.823	-
		Contaminated containers (kg)	0.746	1.565	4.594	3.171

(*)Estimated values.

Figure 4
EF estimates considering cotton and synthetic stitch in the jackets design and no recycling of waste.

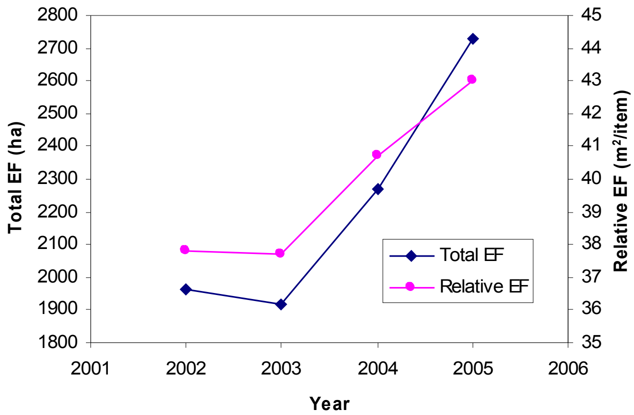

Table 7
Contribution of the considered categories to the final year 2005 EF estimate for synthetic stitch and cotton jackets and no recycling.

Category	**Contribution**
1. 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%
2. 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%
3. Waste	*3.3500%*
Paper and cardboard	0.2855%
Plastic	0.0234%
Textile	3.0411%
Urban waste	0.0000%

Table 8
Contribution of the considered categories to the final year 2005 EF estimate for wool stitch and cotton jackets and no recycling.

Category	Contribution
1. 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%
2. 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%
3. Waste	*2.5447%*
Paper and cardboard	0.2169%
Plastic	0.0178%
Textile	2.3100%
Urban waste	0.0000%

Figure 5
Analysis of the contribution to EF within the energy category.

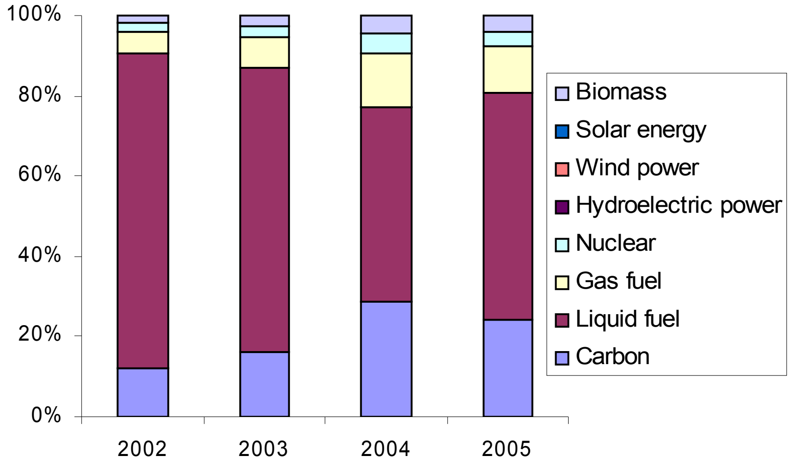

Table 9
EF sensibility to a 10% increase in energy sources, considering no recycling and synthetic stitch (data related to 2005).

EF (ha)	**Initial**	**Δ Electricity**	**Δ Wind Power**	**Δ Propane**	**Δ Gas-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	2,730	2,736	2,730	2,731	2,746
Δ EF (%)	-	0.22	<0.01	0.04	0.59

Table 10
Influence of waste recycling on EF considering synthetic stitch (data related to 2005).

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

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

Table 11
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	1,684.6
2003	35.6	51.5	328.0
2004	37.9	28.4	329.1
2005	50.5	49.4	563.5