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# Ecological footprint in the cotton supply chain: The consumers' view

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**Abstract.** The ecological footprint estimates the impact of individuals in nature as they maintain their lifestyle. It can be used as an indicator of environmental sustainability applied to individual lifestyles, regions, and nations. This study aimed to assess the ecological footprint and the awareness of sustainability of consumers based mostly on their choice of consumption of cotton clothing. The estimation was based on the answers to an online questionnaire containing questions related to the subject lifestyle. The ecological footprint was calculated, and the results were analyzed using data mining, considering the cross-validation using 10% of the samples to obtain a decision. The results show that the better the index of the ecological footprint, the greater the awareness of the issue by the consumer.

**Keywords:** Textile Supply Chain, Sustainability, Cotton Clothing.

## Introduction

The environmental impacts caused by human activities and the level of consumption of natural and industrialized resources are environmental concerns amongst the countries, governments, academia, companies, and citizens. Climate change is a consequence of the consumer lifestyle, and it represents a threat to the natural environment [1, 2]. Carbon footprint assessment (CFA) is an important approach for the control and management of noxious gasses - NG [3]. Sustainability indicators have been the item of study in several areas, with the objective of operationalizing sustainable development [2]. It is necessary to monitor consumption of natural resources in the various segments of production that meet the human needs of survival, and thus presenting proposals that can absorb the impacts and residues generated by such consumption To evaluate sustainability information. The Ecological Footprint (EF) method [6] was developed to estimate how much of the material is being used and waste generated by individuals, cities, countries, and worldwide, which draws attention to the unsustainable lifestyle that has spread since technological advances accelerated the consumption of natural resources. The model was quickly applied worldwide as a tool to assess sustainable development [6]. The methodology can be used on several levels for organizations, individuals, families, regions, national and worldwide [7].

Cotton is an agribusiness product, and it is accountable for increasing the impact of the pollution. In Brazil, agriculture is responsible for 33% of the total emissions in 2014, and part of it comes from cotton production [1]. However, consumers are not conscious that by wearing clothes made of cotton they are harming the environment. Cotton processing integrates the fashion chain, known as one of the most polluting supply chains [8]. Scientific studies are scarce in the areas of ecological footprint in textile chains, specifically the use of cotton to make yarns for making fabrics. This study aims to show the consumer's view on sustainability, having as a parameter the Ecological Footprint, adapted for the consumption of cotton clothes.

## 1 Literature Review

Global climate change has been discussed lately in worldwide meetings since the Brundtland Report by the World Commission on Environment and Development (WCED) in 1987. In that meeting it was defined the expression 'sustainable development,' summarized as the capacity to use natural resources to the extent in which nature can recompose itself, making the planet habitable to the next generations [9]. In 1992, with the achievement of Eco-92 in Brazil, the governments of all parts of the world committed themselves to reduce the emission of noxious gasses (NG), and consequently the carbon footprint.

Agriculture, which includes cotton production, is one of the factors that elevate NG emissions. Brazil is self-sufficient in the manufacture of cotton, which is the fundamental raw material for the textile chain, with revenues of near US\$ 4 billion in 2016, with the projection of producing 1,443.1 thousand tons in the 2016/2017 harvests [7]. Brazil is the world fifth largest producer of fiber, following India, China, USA, and Pakistan. The country also represents the last complete textile chain of the West, from fiber production and cotton planting to fashion shows, and going through spinning, weaving, processing, and retailing [10]. In 2016, the textile and confection production chain earned US\$ 31 billion, which represented 8% of Brazilian GDP, with around 32 thousand formal companies. Textile production stood at 2 million tons, ranking fifth amongst world producers. The Brazilian garment industry, the fourth in the world production, produced about 7 billion pieces, including clothing, accessories, bedding table and bath linen. It represents 17% of jobs with 1.5 million direct employees, and nearly 8 million indirect employees, being the second largest employer in the manufacturing industry. Brazil is the world second largest producer and third largest consumer of denim [10].

The sector seeks differentiated products that use less non-renewable resources such as water and reduce energy consumption and chemical aggression in the handling of goods [1, 11]. The consumption of abundant water and effluents are a major problem in the sector. Effluent components use the common chemical dyes found in the textile industry [2], during the production phases iron, pre-ironing, bleaching, dyeing, stamping, washing and softening.

The developers of the ecological footprint concept in the early 1990s [6] at the University of British Columbia, Canada, presented the footprint as the land surface

area needed to maintain natural resource consumption levels and to house the residues of this consumption. In the next step, a tool was built up to spread the concept worldwide, and individuals, companies, and organizations can calculate the carbon footprint. Each inhabitant of the planet, on average, has a carbon footprint of four tons per year [11]. In the United States, the production is 20 tons per person per year. In Europe, the UK has 20 tons and France, six. Governments and businesses are also aware of the world's carbon footprints [12].

The Global Footprint Network points to the availability of 1.8 hectares of productive land for each inhabitant, but the average has been on 2.2 ha, which makes it impossible for the land to replenish what has been consumed over a year. That points to Brazil in 59<sup>th</sup> place in the list of countries that consume more natural resources than the planet is capable of replenishing. The Brazilian ecological footprint presents the index of 3.1 ecological footprints per capita (GHA, global hectares) in 2012 [13]. The emission of greenhouse gasses (mainly carbon dioxide - CO<sub>2</sub>) into the atmosphere is measured for obtaining the Ecological Footprint. It is also evaluated the presence of pollutants in the air, water, and soil.

Countries have responded to the Global Footprint effort. Switzerland has adopted the indicator as the basis for sustainability; Some European countries, such as Germany, Austria, France, Finland, Belgium, Scotland, and Wales, are reviewing their environmental accounting and presenting footprint initiatives. Canada, Ecuador and the United Arab Emirates work with the entity to reach a common denominator [9, 13]. Amongst the factors related to consumers' daily habits, the carbon footprint measurement analyzes various issues. They also include age, address location and size of household, monthly energy costs (water, light, gas), the quantity of household trash and their recycling habits, buying habits, what kind of food they consume and how they are produced, whether they travel a lot, and what modes of transportation they favor.

## 2 Materials and Methods

The Global Footprint Network has created a tool for citizens to measure their indicator, which has been used globally. In it, data on habits such as meat consumption, light spending at home, distance traveled by car per day, and some plane trips in the year, among others, is collected and can be performed on various websites [14]. In Brazil, the assessment can be made answering an online questionnaire.

Sustainability assessment tools still require adaptations for the various business chains. In this first phase of the methodology, a standard questionnaire was developed including questions about the consumption of clothes, and also questions related to the level of knowledge about sustainability by the consumer. Questions were designed aiming to evaluate the Ecological Footprint (EF) [14].

The sample was chosen based on the size of the Brazilian population (nearly 200 million inhabitants). The sampling error adopted was 10%, and the estimated sample size was 97 participants applying Eq. 1 [15] that was rounded to a minimum of 100 participants.

$$n = \frac{N Z^2 p(1-p)}{(N-1)\varepsilon^2 + Z^2 p(1-p)} \quad (1)$$

$n$  = sample;  $N$  = population of each region;  $Z$  = confidence interval (95%);  $p$  = homogeneity degree (split 50/50);  $\varepsilon$  = sample error (10%).

The online questionnaire, developed using the Google Docs was distributed using the internet tools (e-mails and social media networks) obtained 209 answers, and all were employed in the analysis.

To determine the carbon footprint of each participant the scores of each subject was calculated. Each question had 2 to 5 alternatives, and each alternative was given value as described in Table 1. Subjects with a total of points from 50 to 70 had a good footprint. A total of points from 35 to 49 had a moderate footprint, and a total of points less than 35 had a bad footprint. For the analysis, the data were processed in the machine learning software WEKA® (3.5), using the algorithm J48, considering cross-validation with samples of 10% (10-fold cross-validation).

A total of 14 questions is related to the lifestyle of the subjects, with emphasis on means of transportation, diet, energy consumption and production and disposal of garbage. The results present an idea of the individual's lifestyle, which was submitted to the table of weights available in [16] (see Table 1).

**Table 1.** Weight attribution for each alternative and the question related to the carbon footprint.

Alternatives	Questions													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
A	5	5	5	5	5	5	5	1	1	1	5	1	5	4
B	5	5	1	4	4	2	4	4	2	5	4	3	4	0
C	4	4	-	3	2	0	2	5	4	5	2	5	3	5
D	1	3	-	1	1	-	1	5	5	2	1	-	1	-
E	0	1	-	-	0	-	-	-	-	-	-	-	0	-

Source: [16].

### 3 Results and Discussion

Table 2 presents the profile of the participants in the research. The majority of the subjects are between 26 and 60 years of age, female, with a minimum of college education and monthly income between US\$ 550.00 and US\$ 2,750.00. Although the questionnaire was largely distributed in the social media 95% was answered by subjects living in São Paulo State, which is the wealthier and most developed state of the federation, establishing a limitation to the research.

**Table 2.** Summarized description of the profile of the subjects who responded to the questionnaire

<b>Age</b>	25 (6.1%)	26-40 (43.3%)	41-60 (44.3%)	>60 (6.1%)	
<b>Gender</b>	Male (27.4%)		Female (72.6%)		
<b>Educa- tion</b>	Primary Education (0.9%)	Secondary Edu- cation (9.4%)	High Educ. In- complete (8.0%)	High Educ. Incomplete (35.8%)	Post-grad. (45.8%)
<b>Monthly Income</b>	Up to US\$ 550.00 (14.2%)	From US\$ 550.01 to US\$ 1,162.50 (34.4%)	From US\$ 1,162.51 to US\$ 2,750.00 (34.0%)	From US\$ 2,750.01 to US\$ 5,500.00 (13.7%)	≥ US\$ 5,500.01 (3.8%)

Amongst the answers, 74% of respondents believe that it is important to buy products from companies that are sustainable and 21% believe that it is indifferent to choose companies for this purpose. Almost 60% of the respondents could not say if the company from which they made their purchase is sustainable, and 30% stated that the business is not sustainable. More than half (56.6%) of the participants were not able to answer if the garment they wear contributed to the pollution or the sustainability of the planet. More than a third (33.6%) realizes that clothing contributes to pollution and 10.1% for the sustainability of the world. Near 70% of the respondents do not know how the industrial production of fabrics for the manufacture of clothes is done, 23.9% know, and they care about it. The total 5.6% does not know or do not care about this information. The values used for the income were adopted by the Brazilian criteria of socioeconomics scale [17]. The values were converted from Real to US Dollar (conversion rate=R\$ 3.20 to US\$ 1.00). Analyzing the data we found that these parameters, however, were not associated with the individual's ecological footprint, since they were not selected by the J48 algorithm to determine the model (see Fig. 1).

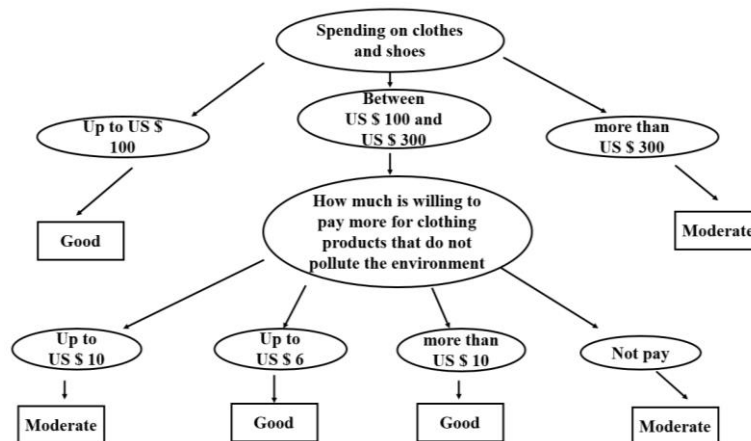
**Fig. 1.** Decision tree for the ecological footprint of the obtained answers.

Figure 1 presents the decision tree for the ecological footprint with 70.75% of accuracy. It is observed that in the present study, the parameter that is most related to the ecological footprint of the individual was the expenditure on clothes and shoes, followed by how much the individual is willing to pay for garments that pollute less the environment. According to the generated decision tree, persons who have bought clothes and shoes up to US\$ 100.00 in the year are individuals who present a good footprint. The other hand, subjects who have spent over US\$ 300.00 annually have a moderate footprint. When evaluating the people who spent between US\$ 100.00 and US\$ 300.00, we need to search for how much they are willing to pay extra for clothing products that do not pollute the environment. Those who are not prepared to pay anything or pay up to US\$ 3.00 in the price of goods present a moderate footprint. Those willing to pay up to US\$ 6.00 or US\$ 10.00 or more show a good footprint.

The findings from the questionnaire were limited to São Paulo state population (95% of the responses were from São Paulo residents) characteristics, and it does not represent Brazilian society. The total answers were from women with a high degree of education, which also adds a limitation to the results.

In the Brazilian textile sector, suppliers seek to use some environmental indicators as a parameter in their cleaner production [10] that might be used to evaluate the consumer perception on this matter. The ecological footprint was employed by [18] to assess the environmental impact in a garment industry, dividing the data into three broad categories energy, resources, and waste. The results showed that the main contribution to the reduction of the footprint was the class of resources due to the high value associated with the cloth. The energy consumed was the second and the waste, the third. After this analysis, the final results were divided by the production rates for comparison by other areas. In the present study, it was found the same trend of the consumer worries regarding the energy and wastes.

When studying the Chinese textile chain [19] used the carbon footprint calculation system in a manufacturer of pure cotton shirts and found the average throughout the life cycle of the product in the country. According to the authors, the carbon footprint of global production, including agriculture and industry, accounts for more than 90% of the world's total carbon footprint, 96% of which is indirectly absorbed by the use of energy and materials. Thus, tissue production and its consumption refer to a highly polluting sector. Consumers need to be concerned with reducing the carbon footprint and thus contribute to the planet's sustainability. The carbon emissions are directly linked to personal habits (more walking or using public transportation than driving cars, saving energy resources, investing in an alternative source of energy among others) [12]. When comparing the data in the current study, it was observed that the consumer's lifestyle directly influence the ecological footprint, even when the consumer does not present the related consciousness.

Measurement has been applied to assess the impact of individual lifestyles, regions, nations and even worldwide on the planet's sustainability. A report with ecological data Footprints is annually available [11]. Other studies have been carried out for the EF of regions and cities all over the world, such as [20], who calculated the footprint in the town of Rio Claro, Brazil. Other authors calculated EF from cities, for instance Barcelona [21]. The continuation of the present study will be the calculation of the ecological footprint in the whole textile supply chain.

## 4 Final remarks

Cotton production and the textile manufacturing process is one of the most polluting supply chains. The present study is the first initiative to assess the ecological footprint in the cotton chain and the Brazilian textile industry. The approach adopted in the research was to understand the perception of the consumer about sustainability in this cotton supply chain. One of the findings was that about 60% did not know if the supplier of the clothes they wear is sustainable. The same index was repeated regarding the issue on the clothes contributing to the pollution or for the sustainability of the planet.

It was also observed that the better the index of the ecological footprint, the more awareness for the subject the researched individual demonstrates since they have a willingness to pay more to get products that are less aggressive to the environment.

Although there are already manufacturing processes and ecologically correct raw materials (sustainable fibers, such as organic and colored cotton), awareness about the subject is still small. A detected limitation of the present study was that more than 70% of the answers were provided by women.

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