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BEST 402
Dec 19, 2024

Tracing the Threads: An Environmental Breakdown of Jeans

Abstract

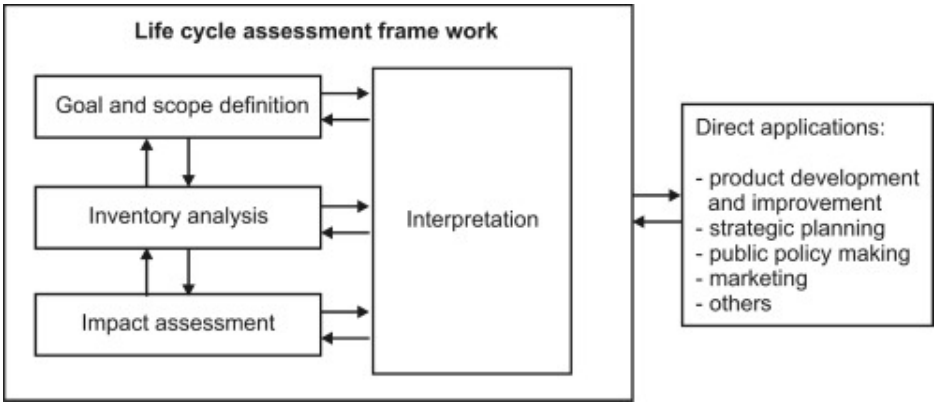
As common as jeans are, they have a significant environmental footprint. This LCA examined the environmental impacts of climate change (kg CO2-e) and water use (litres), of a pair of 100% cotton, medium-sized stonewashed jeans that weigh 0.340 kg to determine areas that are most detrimental and factors that can be improved on. The LCA covered a cradle-to-use system boundary that included the cultivation of raw materials, raw material extraction, manufacturing process, and distribution for use. It was found that 1498 litres of water were used while emitting 28.69 kg of CO2.

Introduction

Jeans are one of the most popular and common pieces of clothing that almost anyone at any age owns. Someone at any point in their life will likely own a pair of jeans. However, it wasn't always like this. Back in the 18th century, only the wealthy were able to afford these textile fibres and had hardly any concern about the impacts they would have on the environment. Since the mid-19th century, the production and consumption of textile fabrics have increased and have now become integral in everyday life. Processes to cultivate cotton, harvest, dyeing, weaving, and manufacturing are all resource intensive. Because it's so common, it can often be overlooked how damaging it can be to the environment. Cotton itself is an environmentally friendly fibre but the insecticides and pesticides needed to procure account for 25% and 12% of global use respectively (Periyasamy et al, 2017).

Using a life cycle assessment (LCA) technique has become more widespread as governments and societies become more aware of the dangers of climate change and our current projection. Creating an LCA is important as it helps industries determine areas most detrimental to the environment through factors such as carbon emissions, water consumption, land use, and other chemicals produced. In this LCA, jeans were chosen as they are quite abundant and nearly everyone owns at least one pair with many individuals owning an average of 7 in the United States (Periyasamy et al, 2017). The LCA will follow the ISO 14040 guidelines seen in Figure 1. To start, we need to define the goal and scope of this report. This report will examine the cradle-to-use system boundary while pinpointing the most destructive areas for the environment and giving my recommendations for decreasing their impact. Along with this, the functional unit will be a pair of 100% cotton, medium-sized stonewashed jeans that weigh 0.340 kg (Periyasamy et al, 2017).

Figure 1. ISO 14040 guidelines. (Muralikrishna & Manickam, 2017).



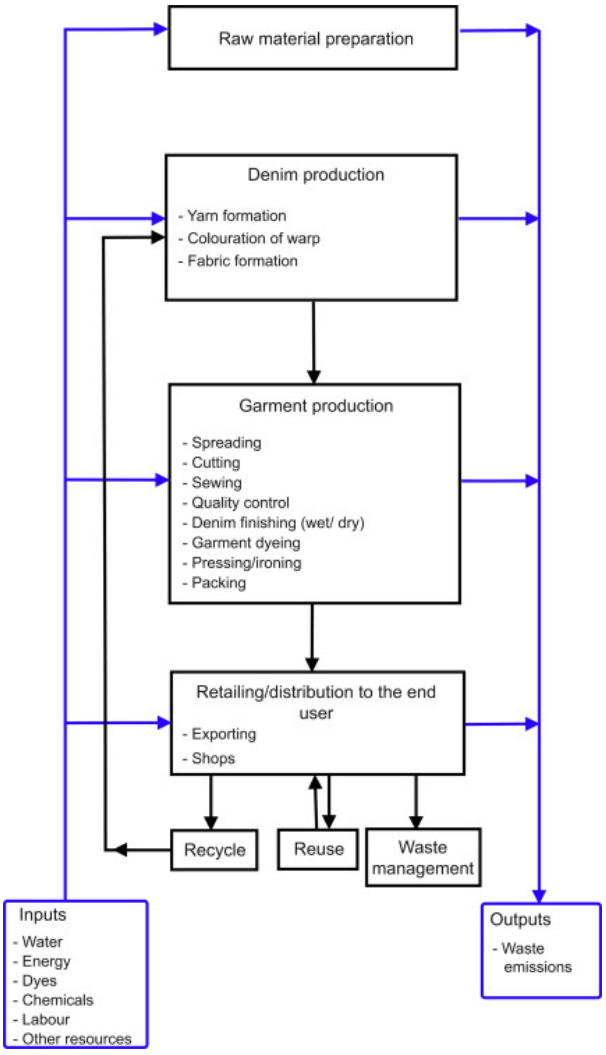
Research questions:

1. What are the environmental impacts of producing a pair of 100% cotton, medium-sized stonewashed jeans that weigh 0.340 kg, measured through climate change (kg CO2-e) and water use (litres)?
2. How much of the impact is through consumer use and what kind of actions can be taken to reduce these impacts?

Methodology

Breaking down the entire production process will help with modelling. It can be broken down into four main sections: cultivation of raw materials, raw material extraction, manufacturing, and distribution for use (Muralikrishna & Manickam, 2017). Figure 2 represents this breakdown. The environmental impacts will be calculated throughout all four sections and added together.

Figure 2. Production process breakdown with inputs and outputs (Periyasamy et al, 2017).



The data collection will come from a variety of academic literature done around denim jean LCAs. This mostly includes five reports that were done by Dr, Farooq et al (2022) who examined from a cradle-to-gate approach of 100% cotton jeans, Cundubey & Azgin (2024) who examined from a cradle-to-grave approach of 1-meter long denim fabrics, Levi Strauss (2015) examined from a cradle-to-cradle approach of their Levi 501 jeans, Periyasamy et al (2017) who examined from a cradle-to-grave approach of a 340 g Levi's women jeans, and Hedman (2018) who examined from a cradle-to-grate approach of medium-sized jean manufactured by Nudie Jeans. The inventory of these reports was taken into account when noting down all the different factors along with online databases. This includes inputs like the cotton cultivated, yarn and

fabric production, dyes, chemicals, auxiliaries, and electricity (Farooq et al, 2022). OpenLCA was used to model this lifecycle and its impacts while using Ecoinvent and ELCD databases for values.

Most of the data was taken from Hedman (2018) as they had a very detailed list of all the inputs and outputs due to having worked with Nudie Jeans and provided the inventory data. The comparison will most closely follow along with their report. The assumption for this LCA is that the average size of Nudie Jeans is similar to Levi's medium-sized jeans weighing around 340g. Along with this, I'm assuming the practices aren't too dissimilar in terms of cultivation, treatment, dyes, and chemicals used. Aside from the jeans, I'm assuming that a majority of the energy consumed is electricity produced from hydro as Sweden (the headquarters for Nudies Jean) primarily uses hydro (IEA, 2024). Additionally, the water consumption through consumer use is from individuals who do laundry weekly with warm water.

To answer the first research question, I will input the inventory data I've been able to collect into OpenLCA to determine the impacts of climate change and water consumption while highlighting the largest producing inputs. For the second question, I will create a pie chart to accurately represent the breakdown of water usage throughout the cradle-to-use system boundary to figure out how much of the water consumption is through the laundry. Once this is complete, I will change my assumption of consumers doing laundry to biweekly to see how much that alters the pie chart and the overall carbon emissions.

Results & discussion

In terms of jean production, fabric manufacturing was found to have the largest impact compared to cotton cultivation and jean production while consumer use ended up having the largest impact on the whole system. The majority of the impact comes from the amount of water

needed to produce it. This makes sense as it was a similar finding to Levi Strauss (2015) which had fabric production as 9 kg CO2-e while I found it to be roughly 6.75 kg CO2-e. Fabric production is when dyes, acids, bases, and elastane are introduced would have negative impacts on the environment. The total climate change impact was determined to be 28.69 kg CO2-e and is a little less than 33.4 kg CO2-e found from Levi. The differences can mostly be seen in fabric production and consumer use as the difference is a little more than 2 kg CO2-e. The differences in consumer use could be due to the consideration of more advanced laundry machines as the LCA done by Levi was nearly a decade ago. Most new homes come with a washing and drying machine that is typically more efficient (Murshida, 2024). Other than that, regional variations such as the amount of renewable energy primarily consumed and consumer care through different drying and washing temperatures could have attributed to the results. The fabric production had differences as well. Again, regional variations would play a factor as a majority of the energy in my LCA was through renewable means while Levi's was primarily focused on the United States as that's where their headquarters are (Muralikrishna & Manickam, 2017). Manufacturing processes would also have more energy-efficient machines. However, even with these differences the overall trend was similar, and I was expecting to have a lower climate change impact as technology and practices would naturally advance.

Figure 3. Climate change of 0.340 kg medium-sized, 100% cotton jeans.

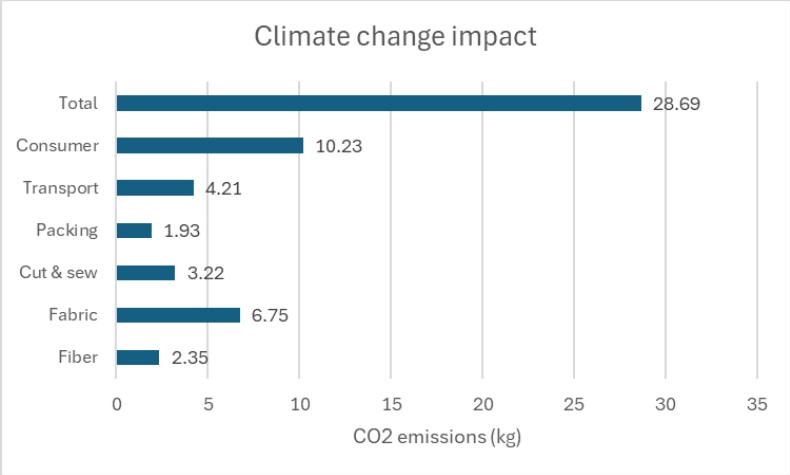
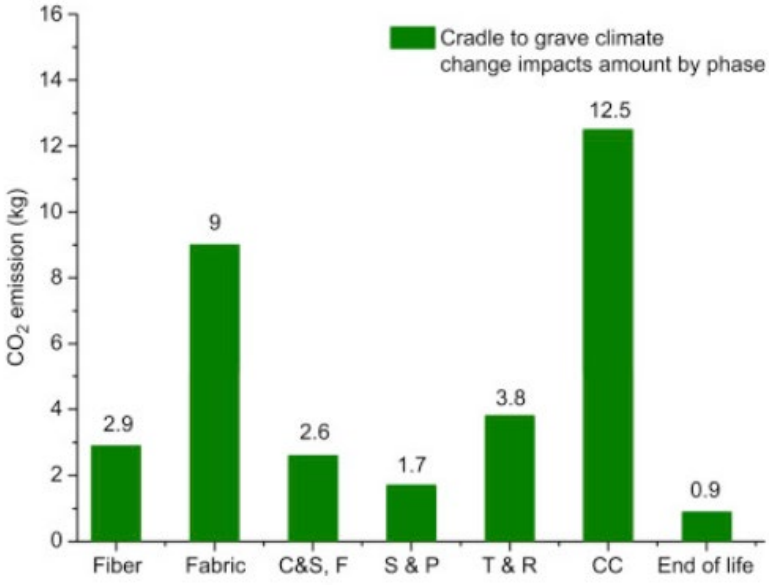
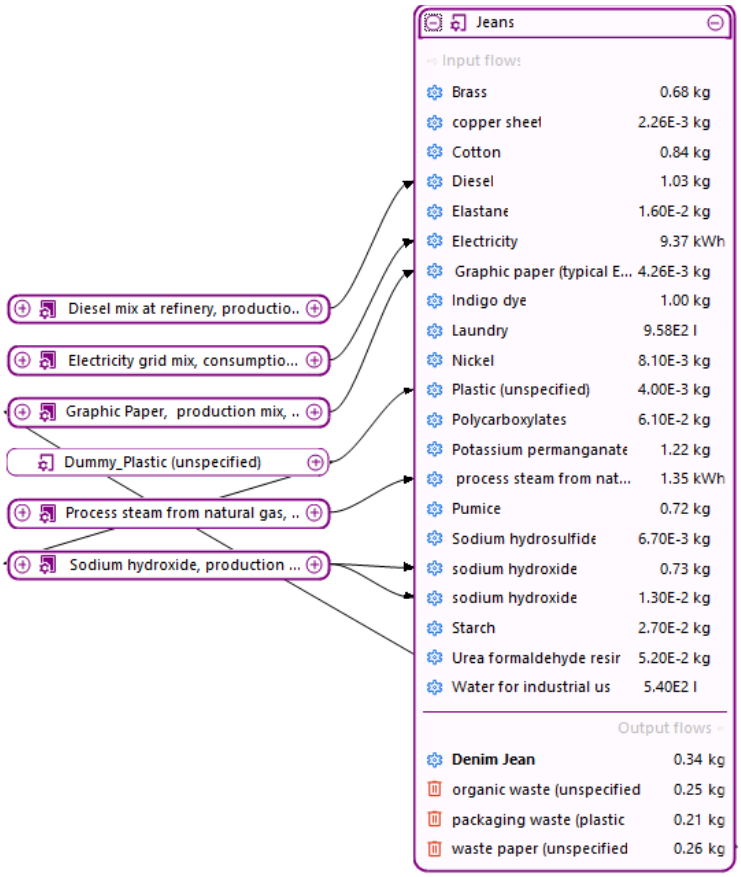


Figure 4. Climate change of alternative LCA done on Levi's denim 501 jeans (Periyasamy et al, 2017).



One of the biggest points of concern is water consumption. The water consumption was nearly 1500 litres through the consumer consumption (laundry) and total water usage from the industrial process which can be seen in Figure 3.

Figure 5. Model graph of a single pair of denim jeans



There were some major differences between my findings and the findings of Pereyasamy & Militky. Specifically the breakdown of water consumption. Within my LCA I gathered data that suggested 958 litres of water would be used by the consumer and 540 litres would be used during the cultivation and manufacturing process (Levi Strauss, 2015) (Hedman, 2018). Pereyasamy & Militky (2017) found that 860 litres would be used by the consumer while a staggering 2912 litres would be consumed during cultivation and manufacturing. Out of the 2912 litres used, 2565 were used for cultivation which makes me think that the cultivation process used from Heldman's data had a different time frame compared to the other. Additionally, the use of pesticides and insecticides could be another factor. Using pesticides and insecticides can lead to soil degradation which would hinder the plant's ability to retain water properly. The

reason for this huge difference is probably due to the amount of rainfall received during the cultivation period. A lot less water would need to be consumed if it's naturally raining more often and I'm assuming that the LCA done by Pereyasamy & Militky was in relatively dry conditions.

Figure 6. Water consumption breakdown of 0.340 kg medium-sized, 100% cotton jeans.

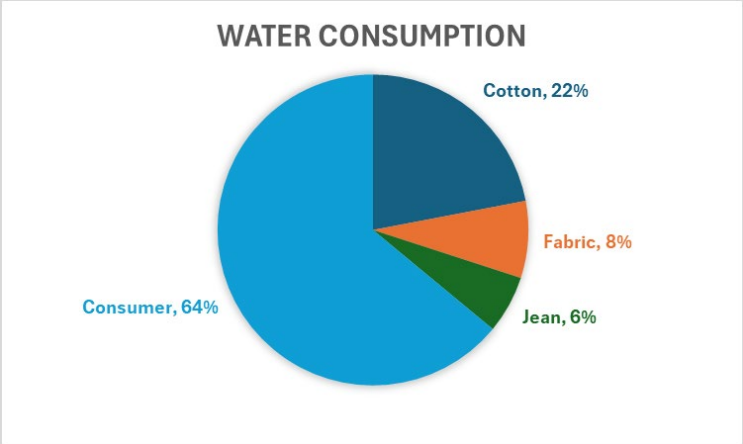
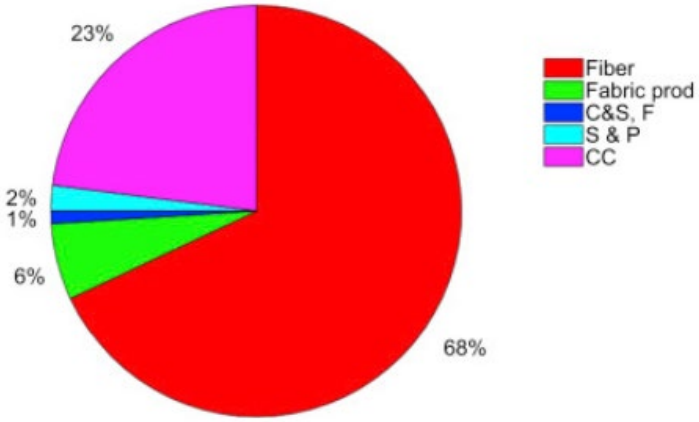


Figure 7. Alternative denim jean LCA water consumption (Periyasamy et al, 2017)



After changing the consumer water consumption from weekly to biweekly, we get 958 litres and 479 litres respectively. The total water consumption becomes 1019 litres rather than 1498 litres with the consumers now making up 47% of the total consumption. In terms of climate change, the consumer's carbon emissions dropped from 10.23 to 5.32 which brought the total emissions down by 4.91 kg CO2-e seen in Figure 9.

Figure 8. New water consumption from biweekly washes.

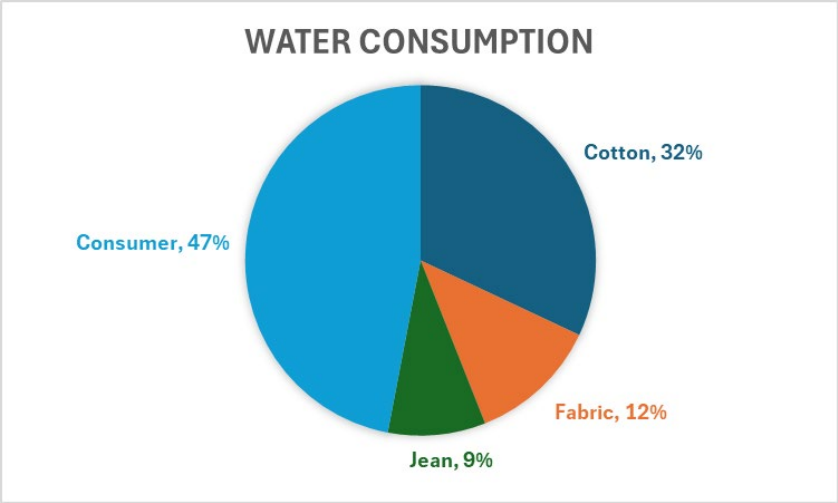
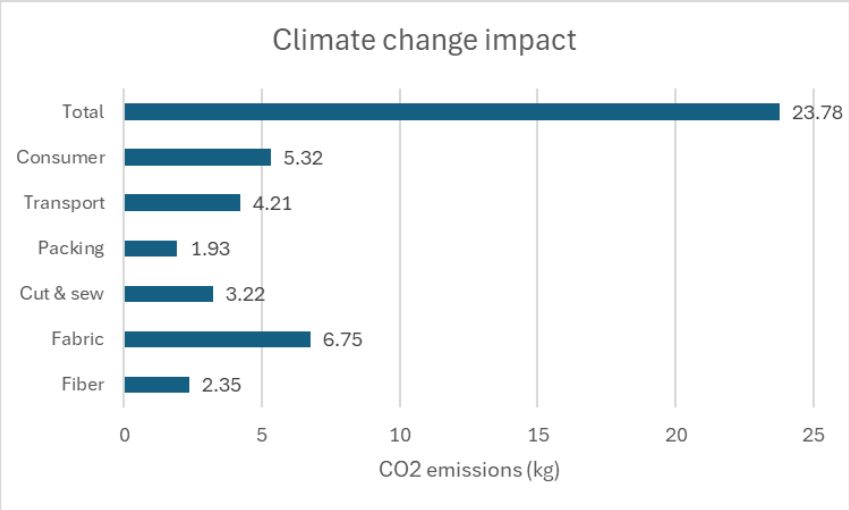


Figure 9. New climate change impacts from biweekly washes.



Conclusion

Overall, the environmental impact was found to be 28.69 kg CO2-e and a total water consumption of 1498 litres. The majority of the climate impacts come from fabric production and consumer use which is backed up by alternative LCAs. These steps require a great deal of water consumption and energy along with the addition of dyes, acids, bases, and elastane which could explain why these processes are the largest. It was found that the majority of water consumption came from consumers with the assumption that washes take place weekly. The total water consumption of the consumer was 958 litres. Future research could focus on a drip

irrigation method to improve water use efficiency. With this practice, water is directly delivered to the roots, reducing the risk of evaporation.

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