Evaluating Environmental Impact of Different Fibers Utilizing a Lifecycle Assessment (LCA) Approach

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Introduction. The fashion industry and its operating supply chains are the world's third-largest polluters preceding the food and construction industries (Boston Consulting Group, 2021). There were 208 million pounds of textile waste generated in 2019, among which only 14.7% was recycled (Fashion Intelligence, 2021). It was estimated that the textile industry is responsible for approximately 10% of global greenhouse emissions because of its lengthy supply chains and energy-intensive production processes. The accelerating environmental detriment is calling on the textile industry to take immediate actions for sustainable development (Chi et al., 2021).

Literature Review and Rationale. The type of fiber utilized for apparel products has different sources, production requirements, and yields different environmental impacts across the product's lifecycle. While cotton is one of the most consumer-preferred fibers and holds the largest market share size, it is also one of the most resource-intensive fibers in terms of water, land, energy, and chemical use. Polyester is another increasingly favored fiber, especially in the last few decades. Polyester production creates significant environmental burdens, with a 65.52% impact in the climate change potential category (Moazzem et al., 2021). Due to advanced technology and increasing consumer demand, blending textiles have become increasingly popular. One of the most popular blends on the market is the cotton-polyester blend. This blended fiber has many advantages, such as increased performance, easier dyeing, and quicker drying rates. However, the nature of blended fibers makes it difficult to separate and recycle when it reaches the end-of-life phase of its lifecycle.

Alternative textile fibers are being considered to reduce the environmental impact. One of the alternative fibers is hemp. Compared to cotton, hemp requires 50% less water and land (La Rosa & Grammatikos, 2019). It can be grown without using harmful chemicals such as herbicides and pesticides and can be used to create long-lasting, renewable, and sustainable textile applications (La Rosa & Grammatikos, 2019). Other alternative textile fibers include recycled polyester and recycled cotton; however, both fibers have minimal utilization rates. In particular, recycled polyester only accounted for approximately 13% of the market share in 2018 (Textile Exchange, 2022).

Limited studies have been conducted to quantify the environmental impact of different fibers at each stage of the product lifecycle. Addressing this gap, this research intends to investigate different fibers (100% conventional cotton, 50%/50% cotton and recycled polyester, 100% recycled cotton, and 100% hemp) and compare their environmental impact using a Life Cycle Assessment (LCA) approach. LCA provides a standardized framework for quantifying the potential environmental impact of a product (EPA, 2021). It can be applied to different textile fibers or products throughout their lifecycle stages including raw material extraction, fiber processing, textile and/or apparel manufacturing, distribution, consumer use, and end of life (Muthukumarana et al., 2018). This research lends meaningful insight to both marketers and academics regarding the environmental impacts behind textile production and where to start in improving the current processes for a more sustainable future.

Methodology. The tools and framework of LCA will be adopted in this study to gather quantitative data to evaluate the environmental sustainability of four different fiber blends: 100% conventional cotton, 50%/50% cotton and recycled polyester, 100% recycled cotton, and 100% hemp. The functional unit will be 1,000 kg of each selected fiber while utilizing a cradle-to-gate system boundary cut-off, ending the assessment after the garment manufacturing stage. Focusing the system boundary on a cradle-to-gate analysis allows for more data analysis and visualization on the production side of the value chain, typically where most of the impacts are created. The analysis will rely on previous LCA studies of textile and apparel products and the Evoinvent 3.8 database. Data collection will be performed according to the ReCiPe 2016 Life Cycle Inventory Assessment methodology on the SimaPro software platform. Table 1 presents each impact category within the ReCiPe 2016 framework. This methodology is selected because it is one of the most used impact assessment methods for its ability to accurately quantify the effects of production processes into numerical environmental scores and its inclusion of many impact categories (Wu & Su, 2020).

Table 1. ReCiPe 2016 Impact Categories (Huijbregts et al., 2017)

Water related categories	*Air related categories*	*Human Health related categories*	*Land related categories*	*Fossil Fuel/Global Warming categories*
Water Consumption	Fine Particulate matter (PM2.5) formation	Human Carcinogenic Toxicity	Terrestrial Ecotoxicity	Global Warming (also called climate change)
Freshwater Eutrophication	Ozone Formation, Terrestrial ecosystems	Human non-carcinogenic toxicity	Mineral Resource scarcity	Fossil Resource Scarcity
Marine Eutrophication	Ozone Formation, Human Health		Land Use	

Freshwater Ecotoxicity	Stratospheric Ozone Depletion		Terrestrial Acidification	
Marine Ecotoxicity	Ionizing Radiation			

Conclusion. This research aims to quantify the potential environmental impact of the four most used fibers in the apparel and textile industry. This study will help quantify the environmental impacts of different fibers at each stage of the product life cycle, which will help consumers make more sustainable consumption decisions. It will also aid companies in creating more environmentally friendly apparel and textile products utilizing more sustainable production processes.

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