

A Comparative Life Cycle Assessment of Conventional and Organic Cotton in Denim Fabric

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Textile Industry

- ❑ Today's textile industry is one of the largest greenhouse gas (GHG) sources in the world .
- ❑ GHG emissions from textiles production was more than those of all international flights and maritime shipping combined in 2015 [1,3].
- ❑ The main source of these emissions is that **the raw materials** and **auxiliary materials** used in production harm both the health of people in the supply chain as well as the environment.
- ❑ **Cotton**, which accounts for more than 82% of the global fiber consumption, is the most widely used natural fiber [4].
- ❑ Conventional cotton cultivation has high **water and energy consumption, use of fertilizers and pesticides**, and **land use** that can harm the environment and human health [5-7].
- ❑ Since conventional cotton has significant environmental and health-related damages, alternative sustainable methods are obtaining more attention every day in the denim industry.
- ❑ **Organic cotton production** is one of these methods with its strict regulations and limits [6,8].

Organic Cotton

- ❑ **Organic cotton** cultivation is gaining importance day by day due to the environmental pollution caused by conventional cotton cultivation.
- ❑ 11% of the **pesticides** used in the world are used only in conventional cotton cultivation [25].
- ❑ Therefore, organic cotton cultivation reduces or eliminates the use of chemicals, which greatly reduces harmful environmental impacts [6].
- ❑ Because organic cotton cultivation is carried out without banned chemicals such as **synthetic fertilizers, herbicides, insecticides, growth agents** [26].
- ❑ In addition, the organic productions are certified with various standards (GOTS, OCS), and the chain of custody is provided throughout the entire supply chain [27].



Life Cycle Assessment

- ❑ **Life Cycle Assessment (LCA)** is a comprehensive and systematic tool used to determine the possible environmental impacts of a product, service, or process [10].
- ❑ According to this methodology standardized by **ISO 14040 and 14044**, the LCA consists of four steps for operation [11,12].
- ❑ These steps are:
 - ❑ the definition of purpose and scope,
 - ❑ life cycle inventory analysis (LCI),
 - ❑ life cycle impact assessment (LCIA),
 - ❑ interpretation.



Literature Review



- ❑ **Baydar et al.** (2015), **Khan et al.** (2018), **Sipperly et al.** (2019), and **Kazan et al.** (2020) conducted LCA Studies for cotton t-shirt: produced from conventional and organic cotton.
- ❑ According to the LCA results, organic cotton t-shirt had better results than conventional cotton t-shirt.

- ❑ **Rosa et al.** (2019), **Avadi et al.** (2020), and **Shah et al.** (2018) conducted LCA Studies for conventional and organic cotton cultivation systems.
- ❑ According to the LCA results, organic cotton had better results than conventional cotton cultivation.



Objective of the Study



- ❑ Although LCA is a very useful tool for determining environmental impacts, LCA studies in the field of sustainable textiles are limited in the literature.
- ❑ Current studies focused either solely on the impacts **of cotton farming systems** [8,13,14], or various textile products produced using **different cotton fibers such as conventional, recycled, etc.** [15-18].
- ❑ A few studies are examining the contribution of organic cotton use to the environmental impact of the product, and to our knowledge, there is no such study for denim.
- ❑ Consequently, cotton as the main raw material of **denim fabric**, it is important to examine its environmental impacts [9].
- ❑ To reduce the environmental impacts in the denim industry, the use of **organic cotton** instead of **conventional cotton** needs to be evaluated.
- ❑ **To fill this gap in the literature, this study investigated the environmental impacts of two denim fabrics with the same production processes when the raw material is organic and conventional cotton.**

Denim Production

- ❑ Denim fabric production is a complex system that includes many processes such as spinning, finishing, etc.
- ❑ A graphical representation of denim production with upstream, core and downstream processes is given in Figure 1.

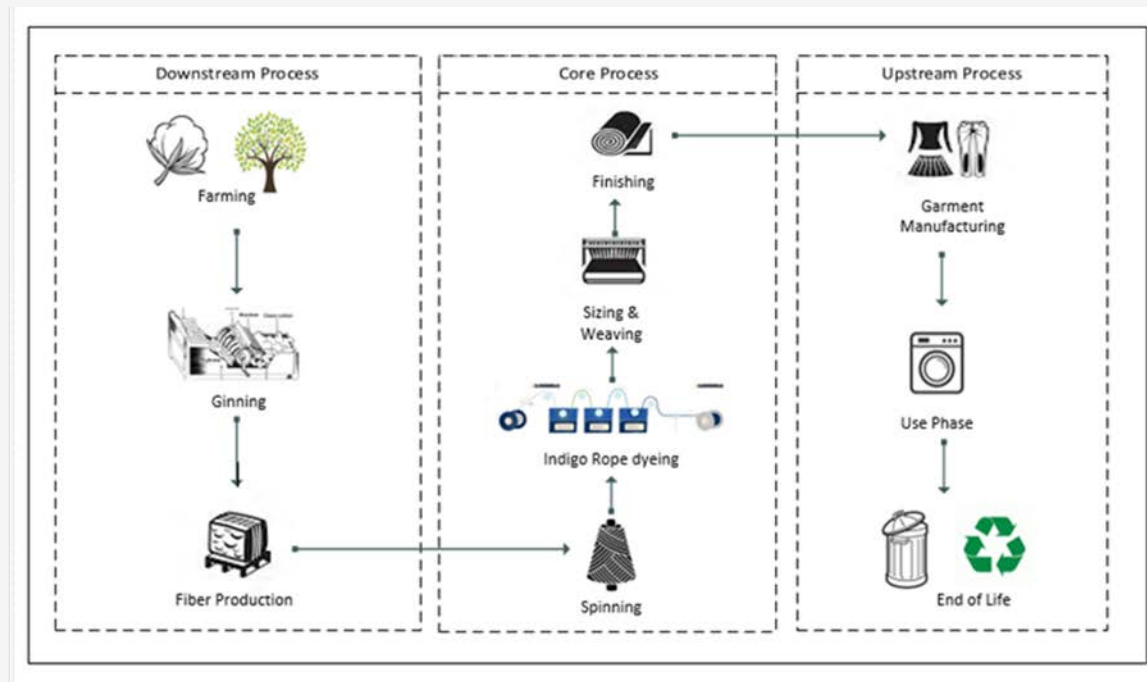


Figure 1. Flow diagram of the denim production process

LCA Steps

1-Goal and Scope Definition

- ❑ The goal of this study was to analyze the potential environmental impacts of 1 m² denim fabric produced in a textile company located in Turkey.
- ❑ The functional unit was determined 1 m² denim fabric.
- ❑ LCA was conducted with a cradle-to-gate approach.
- ❑ System boundaries were selected downstream and core processes with the addition of product delivery to an average customer.
- ❑ To determine how the organic and conventional cotton concerns the environmental impacts, two denim fabrics were selected:
 - ❑made of 100% organic cotton
 - ❑made of 100% conventional cotton.

LCA Steps

2- Life Cycle Inventory Analyses

- ❑ The LCA methodology requires a large amount of data from primary or secondary sources.
- ❑ In this study, primary data was process-specific and obtained from a denim mill located in Turkey. For the remaining process, **the Ecoinvent V3.0 database** was used as secondary data [28].
- ❑ Data for the **production of organic cotton** were obtained and used for Turkey.

LCA Steps

3- Life Cycle Impact Assessment

- ❑ Comparison of denim fabric produced with two different raw materials with LCA was implemented as a cradle to gate perspective with SimaPro software [29].
- ❑ **The CML** was selected as the LCA method and a total of 11 environmental impact potentials were investigated [30].
- ❑ These potentials are **abiotic depletion (ADP), abiotic depletion fossil fuels (ADP*), global warming (GWP), ozone layer depletion (ODP), human toxicity (HTP), fresh aquatic ecotoxicity (FAEP), marine aquatic ecotoxicity (MAEP), terrestrial ecotoxicity (TEP), photochemical oxidation (PCOP), acidification (AP), and eutrophication (EP).**

LCA Results

- ❑ The results LCA for comparing two denim fabrics with CML Method are given in Figure 2.
- ❑ According to LCA results conducted using the CML-IA method, it was observed that the denim fabric produced with organic cotton has lower environmental impacts than the conventional cotton in all environmental impacts considered.

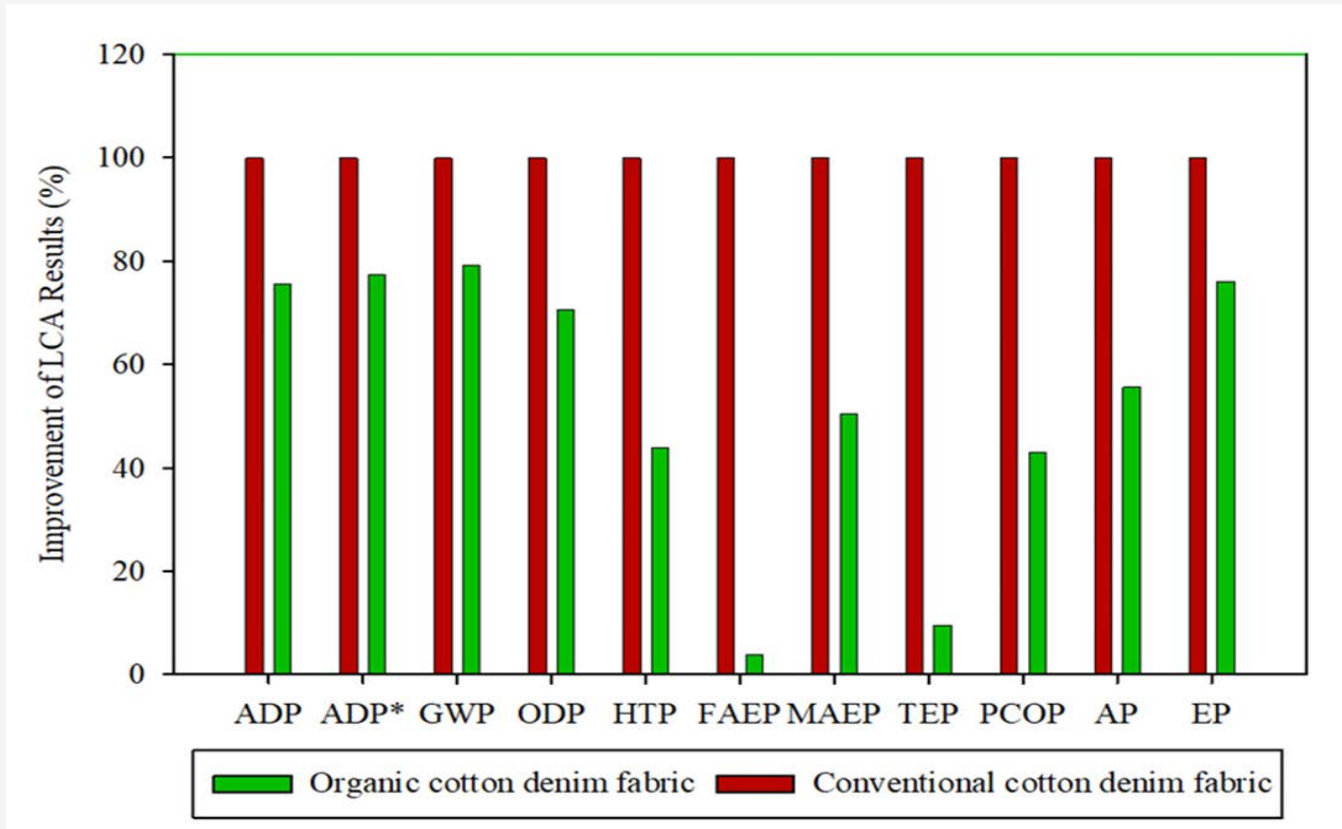


Figure 2. Comparison of LCA Results for two denim fabrics

LCA Results

- ❑ The lowest reduction was achieved in **GWP** with 21%.
- ❑ Baydar et al. (2015) found that **GWP** gain was realized as 22% with the use of organic cotton in their work [19].
- ❑ Sipperly et al. (2019), **GWP** improvement was obtained approximately 15% with organic cotton t-shirts [21].
- ❑ It was clear that using organic cotton as a raw material contributes to the **GWP** of the product, regardless of whether the product is denim or a T-shirt.
- ❑ The main reasons for the **GWP** of cotton cultivation are fertilizer and pesticide use with 57% and application of N fertilizer to land with 22% [19].
- ❑ It is expected for **GWP** to decrease as the use of fertilizers and pesticides is limited or forbidden in organic cotton.
- ❑ Through to substituting conventional cotton with organic cotton, the highest improvement was achieved in the **FAEP** with a 96% improvement.

LCA Results

- ❑ **EP** of the denim fabric had an improvement of approximately 24%.
- ❑ Sipperly et al. (2019) showed in their study that the **EP** value of organic cotton was 46% less than conventional cotton.
- ❑ Nitrate emissions and agricultural chemicals are the main drivers of **EP** in cotton cultivation.
- ❑ **AP** decreased by 44% with the use of organic cotton in denim fabric.
- ❑ Kazan et al. (2020) showed that a T-shirt using organic cotton and consuming renewable energy decreased **AP** 52% [23].
- ❑ Similarly, La Rosa et al. (2019) showed that organic cotton has 80% more **AP** than conventional cotton [7].

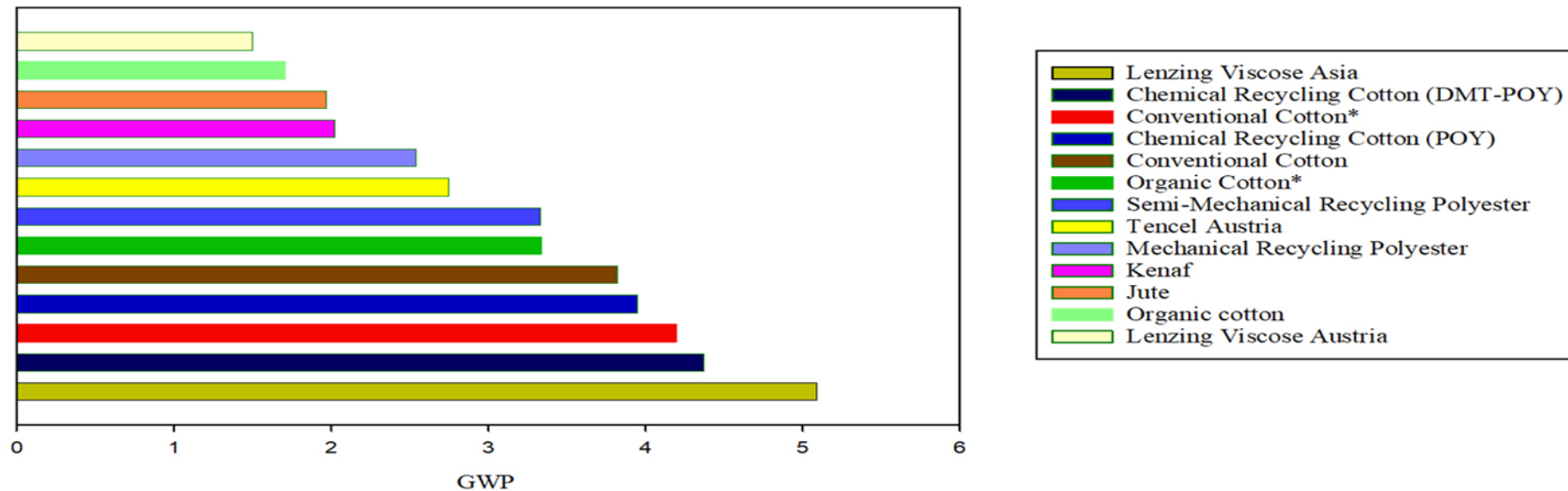
LCA Results

- ❑ **TEP** had a 90% improvement.
- ❑ Similarly, a 57% reduction in **PCOP** and a 56% reduction in **HTP** are achieved.
- ❑ Denim fabric produced from organic raw materials had much better results in terms of all environmental impacts.
- ❑ Therefore, organic cotton is a more sustainable alternative to conventional cotton.

- ❑ As the raw material is the hot spot of denim production and critical to achieving sustainability, it was an interesting research question of how environmental impacts changed with the use of other fibers instead of organic and virgin cotton fibers.

Raw Material Comparison

- ❑ How the environmental impacts of 1 m² denim fabric changed when selected fibers were used for the functional unit of the study is given in Figure 3.
- ❑ According to the results, organic cotton denim fabric had an average environmental impact relative to other fibers studied.
- ❑ However, conventional cotton fiber denim fabric was more sustainable than fibers such as Lenzing viscose Asia and chemical recycled cotton (DMT-POY).



Conclusions

- ❑ Looking for sustainable alternatives is one of the key points for the textile sector because **cotton** is the most important natural fiber used in the **textile industry** worldwide and the hot spot of denim **fabric production**.
- ❑ In this study, the environmental impacts of **conventional and organic cotton denim fabric** production in Turkey have examined using the **LCA** approach.
- ❑ According to the results, denim fabric produced with **organic cotton** has **better** results than denim fabric produced with **conventional cotton** in all environmental impact categories.
- ❑ Significant reductions in environmental impacts were achieved due to the limitation or prohibition of the use of fertilizers and pesticides in organic cotton and other regulations.
- ❑ These results showed that the environmental impacts of denim fabric can be reduced by changing with more sustainable raw material preferences.
- ❑ For further studies, this study can be expanded by adding other sustainable raw material alternatives.

Thank You

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