A REVIEW ON LIFE CYCLE ASSESSMENT OF COTTON DENIM JEANS: COMPARATIVE ANALYSIS ON CONVENTIONAL AND ORGANIC APPROACH

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Abstract: Cotton denim jeans are widely known to be among the dirtiest textiles available in the market. Denim jeans consume a significant amount of water, chemicals, and energy during their entire existence, from cultivation to disposal. This literature review examines the environmental impacts of denim production across four important phases: cotton cultivation, raw material processing, finishing, and disposal using conventional and organic methods. The environmental impact is classified into four areas using the life cycle assessment software openLCA 2.0.2. The four impact categories are: global warming, water consumption, freshwater ecotoxicity, and ozone formation in terrestrial ecosystems. Cotton cultivation makes use of a disproportionate number of chemicals (around 25 percent of the world's insecticides). Denim fabric manufacturing consumes 34, 38, 23, and 5 percent of total energy throughout the spinning, chemical process, weaving phase, and other operations, respectively. Besides, consumer use phase is the most resource consumed phase. People frequently discard or burn clothes, contributing to vast amounts of waste and harming the environment by emitting greenhouse gases. Cotton cultivation and conventional raw material processing produce the highest greenhouse emissions and use the most energy. Organic approaches emit 12 percent fewer emissions than conventional approaches. The conventional approach has a bigger environmental impact.

Keywords: *Life cycle assessment, Denim pant, resource consumption, sustainable approach.*

Abbreviations

AP	acidification potential
BCF	billion cubic feet
CFP	Carbon Footprint
EP	eutrophication potential
GHG	Greenhouse gas
GWP	global warming potential
ISO	International Organization for Standardization
LCA	Life cycle Assessment
VFD	variable frequency drive

1. INTRODUCTION

Textiles encompass a wide range of aspects, including fibers, yarns, fabric processing, and clothes. All of which undergo examination throughout their lives. Cotton textiles are the fourth most stressful industry worldwide, following food, housing, and transportation [1]. Cotton textiles' life cycle begins with farming and harvesting. After that, we process it by ginning, spinning, weaving, dying, cutting, and sewing before it reaches customers and is disposed of. This review summarized and analyzed previous research findings to provide relevant information for determining the phase that has a significant impact on environment. They discovered that the post-consumer phase had little impact on the environment, but the manufacturing and consumption stages had the most negative consequences [2]. The production of denim jeans has a substantial environmental impact. Denim jeans are becoming increasingly popular. A denim jean has an impact throughout its life cycle, from cradle to grave. The International Organization for Standardization (ISO) 14040:2006 and ISO 14044:2006 make extensive use of life cycle assessment (LCA), an effective tool for evaluating the environmental impact of textile goods [3]. Similarly, LCA is a rigorous process for identifying the environmental consequences of a product over the course of its entire life cycle [4]. Numerous LCA studies look at how textile goods influence the environment. Researchers conducted studies on the use of environmental life cycle analysis (e-LCA) in the global supply chain. Cotton cultivation has the most significant impact on water use, accounting for 2.6% of global water consumption and causing drought [5]. Pesticide use has a negative environmental impact; it accounts for 11% of global consumption, and nearly half of that is in poor countries [6]. Another study found that producing one pair of denim jeans takes up 12 square meters of land, 3781 liters of water, and 33.4 kilograms of CO_2 [7]. Denim jeans production alone accounts for 1% of global greenhouse gas emissions, with washing and drying methods resulting in 24.6 kg CO_2-eq/piece of emissions [8, 9]. The use of energy-intensive resources such as fertilizers, seeds, herbicides, diesel fuel, and power throughout the processing phases contributes to cotton farming's greenhouse gas (GHG) emissions [10]. The textile industry's global water consumption exceeds 80 billion cubic meters, according to the European Parliament. This produces 1,715 million metric tons of CO_2 equivalent emissions and over 95 million metric tons of textile waste [11]. Chen et al. [12] found that the most common effect categories in their LCA analysis of cotton textiles were global warming potential (GWP), eutrophication potential (EP), acidification potential (AP), and water usage. Kazan et al. [13] investigated alternative manufacturing methods and LCA for cotton-woven clothing. Using recovered cotton fibers as a raw material reduced acidification, eutrophication, abiotic depletion, and global warming by 90 percent, 96 percent, 69 percent, and 47 percent, respectively. This eliminates the negative environmental effects of cotton farming. Organic cotton farming and renewable energy sources replaced traditional methods, lowering the risk of eutrophication, acidification, and global warming by 48 percent, 52 percent, and 70 percent, respectively. Similarly, LCA has revealed that the most significant effects of textile and clothing manufacture are the intensity of water resource usage, chemical use, absence of treatment methods, energy consumption, wastewater discharges, and the carbon intensity of electricity [14]. An analysis of the carbon footprint (CFP) of textile products manufactured in China reveals the representation of GHG emissions throughout the apparel supply chain and the product's lifecycle. According to a baseline model, spinning is the second-largest contributor to CFP (at 30.35 percent from the consumer usage phase) due to high electricity demand [15]. To investigate the environmental impact of Swedish clothing consumption, researchers focused on jeans. They used climatic effect, energy consumption, and water shortage indicators, as well as the influence of land use on soil quality, freshwater ecotoxicity, and human toxicity [16]. As a result, early research focused on the environmental impact of textile goods in various regions. A global supply network facilitates multiple stages of denim jeans manufacture, such as cotton farming, material production, and consumer use, all of which take place in different parts of the world. Globally, rather than in a single region, we carry out cotton farming, material production, consumer use, and so on. The current study emphasizes the importance of resources such as fuel, energy, and water in the five stages of denim jeans manufacturing, which include cotton cultivation, yarn, fabric, jeans production, and final disposal. We identified the literature reviews using two criteria: life cycle assessment and the resources used in the denim jeans supply chain. This study examines the scientific literature and case studies to organize the present body of information about the following questions:

RQ 1: Have there been any comparative studies on the use of environmental life cycle analysis, or e-LCA, for denim jeans made using conventional and organic methods?

RQ 2: What resources are utilized to prepare cotton fiber in both conventional and organic approach?

RQ 3: Which phases of the denim jeans life cycle evaluation contribute to an environmental burden?

RQ 4: Can we compare the environmental consequences of a traditional and organic approach to software assessment?

To address these questions, we organize the paper as follows: Section 2 analyses the environmental life cycle assessment for the worldwide supply chain of denim trousers. Section 3 highlights the major phases in denim production. Section 4 identifies the phase with the maximum resource consumption. Section 5 contains the concept of sustainable denim jeans production. Section 6 highlights the comparison of conventional and organic approach of denim jeans production. Finally, section 7 closes the discussion.

2. ENVIRONMENTAL LIFE CYCLE ASSESSMENT (E-LCA) FOR THE WORLDWIDE DENIM JEANS PRODUCTION CHAIN

2.1 Explain e-LCA

LCA is a way to look at environmental factors and possible effects in the life cycle, from getting the raw materials to production, use, and finally throwing it. A product's entire life cycle is outlined, including the extraction of raw materials, the creation of materials, the manufacturing process, and the use of the product, its disposal and all intermediary transportation. The Life cycle assessment framework is described in four phases as seen in Figure 3. The assessment is based on the goal and scope, inventory analysis, impact assessment and interpretation of results [17].

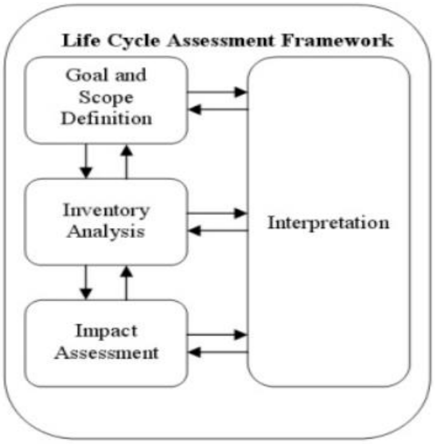

Fig1. The Life Cycle Assessment Framework [18].

2.1.1 Goal and Scope

The first phase of the LCA begins with the goal and scope which sets the context of the study. The goal and scope can be defined as, “the functional unit”, which defines what precisely is being studied and quantifies the service delivered by the product system [18].

2.1.2 Inventory Analysis

The Life Cycle Inventory Analysis focuses on inventory flows to and from nature. The inventory flows are the inputs of water, energy, and raw materials and the outputs into the air, land, and water [19].

2.1.3 Impact Assessment

After the inventory analysis, follows the impact assessment that is called life cycle impact assessment (LCIA). This phase focuses on taking the results of the inputs and outputs and strategically categorizes them. Data is organized into a flowchart of the processes that represent the input and output flows [20]. These impact categories are broadly divided into two major divisions. One is impact category that is also called as midpoint category and another is damage category alternatively known as endpoint category. Midpoint methods are problem oriented approach. They are based on cause-effect chain relationship [21]. There are several LCIA methodologies in these categories naming CML, CED, ILCD 2011, USEtox, ReCiPe etc. There are some renowned LCA tools or software for the presentation of the impact in two categories following the specific methods. The name of the software’s is openLCA, GaBi, SimaPro etc.

2.1. Interpretation

The interpretation of the study aids in ensuring the validity of the study. It is important to review the results by identifying key data elements that had a large significance to the study and the environment.

Here the goal of the study is to calculate the environmental impact created by denim jeans. So the functional unit is one pair of denim jeans. The below figure shows the phases of a denim jeans from raw material to disposal phase.

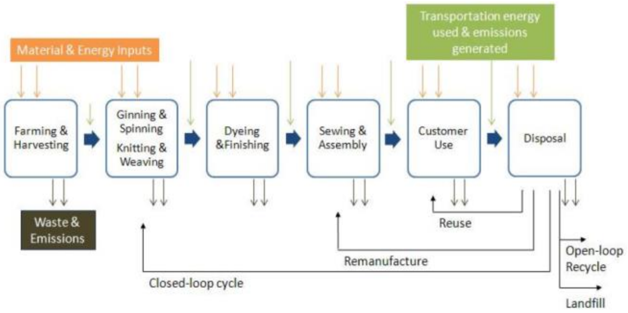

Fig 2: LCA of Denim Jeans made from Cotton Fiber [22].

Here energy, chemical and water is considered as input resource and effect is assessed in ReCiPe (2016) midpoint impact method. openLCA software is used for the interpretation of the data. Here the impact is assessed in four major categories naming global warming, freshwater ecotoxicity, water consumption, ozone formation in terrestrial ecosystem.

2.2 Using e-LCA for Denim Apparel

Numerous large-scale LCA studies on textiles and clothing are available in the literature. Environmental issues arise due to the substantial resource usage involved in the production of cotton, a common fabric used in denim jeans. The LCA illustrates how cotton affects the environment in terms of energy, land, and water consumption. Fidan et al. [23] investigated how organic cotton jeans influenced the environment. However, much research is required to accurately measure the transmission of effects from one phase of the life cycle to the next [24]. The life cycle of textile fibers, specifically cotton, was studied in order to provide guidance for future studies in the textile sector of Brazil. In order to lessen the negative effects and achieve sustainability, the authors concluded that managing socio-environmental effects over a product's lifespan requires the adoption of best practices and collaborative efforts among a variety of stakeholders within the textile industry [25]. Another study proposed measures to reduce China's carbon footprint in cotton production. Fertiliser efficiency, electricity utilization, and quality development are all viable measures for lowering carbon emissions in China's cotton processing [26]. Researchers examined the utility balance and greenhouse gas emissions related to Turkish cotton production. Cotton production resulted in a total CO_2 emissions of 6,482.36 kg per hectare. This amount included the following: 1.6 percent (104.94 kg CO_2-eqha-1) from chemicals, 1.6 percent (81.85 kg CO_2-eqha-1) from equipment, 0.8 percent (5.18 kg CO_2-eqha-1) from potassium, 47.94 percent (3 107.60 kg CO_2-eqha-1) from electricity input, 16.29 percent (1 055.67 kg CO_2-eqha-1) from irrigation water, 14.82 percent (960.50 kg CO_2-eqha-1) from diesel fuel, and 3.07 percent (199.14 kg CO_2-eqha-1) from seed [27]. Some academics proposed a cleaner development approach for the denim and textile industries to combat greenhouse gas emissions that contribute to climate change. This would require providing recovered fabrics and implementing sustainable business procedures [28]. Similarly, researchers identified technological limitations in Bangladeshi denim washing facilities. The authors suggested that Bangladeshi denim washing facilities use more ecologically friendly processes to reduce their detrimental impact on the environment [29].

3. MAJOR PHASES IN DENIM JEANS PRODUCTION

3.1 Cotton Cultivation Phase

Cotton cultivation encompasses multiple critical stages, including fiber development, pesticide and fertiliser application, energy consumption, water usage, and product transportation [30]. Conventional cotton farming necessitates a significant amount of space, energy, and water, as well as a heavy reliance on pesticides and fertilizers. Cotton agriculture accounts for approximately 2.6 percent of global water usage and 11 percent of global pesticide consumption. Overuse of pesticides and water can raise production costs while also having a negative impact on the environment, such as soil degradation, water pollution, and greenhouse gas emissions [31, 32, 33]. The production of cotton has been known to have a negative environmental impact due to the use of chemicals and excessive water consumption. The key areas of focus are as follows:

Use of pesticides: Cotton is one of the most hazardous crops in the world, accounting for 12 percent of all pesticides and 25 percent of all insecticides used globally. Pesticide use has detrimental effects on the human health and environment [34].

Use of water: The fact that 7–29 tons of water are needed to produce one kg of raw cotton is quite worrying. Therefore, the process of producing cotton uses a lot of water, creating detrimental impact on the environment [35].

Use of Energy: Textile production's environmental impact, including cotton, water, and energy consumption, is a global concern. While researchers have thoroughly investigated the influence of cotton textiles, they have paid less attention to denim fabric production, particularly the utilization of alternative energy sources [36]. For conventional cotton cultivation, the carbon footprint (kg CO2e/kg) and energy footprint (MJ/kg) are 4.43 and 30.89 respectively [37]

3.2 Raw Material Processing Phase

Because modern machinery operates for longer hours in less-than-ideal circumstances, the textile industry consumes more electricity and spends more money on energy. The spinning process, which uses the most energy, consumes 58 percent of it [38]. The spinning and winding processes use approximately 80 percent of the energy consumed per kilogram of a single yarn [39]. You can make denim fabric from either rotor spun or ring spun yarns [40, 41]. The spinning step of the denim fabric production process consumes 34 percent of the total energy, followed by the chemical process (38 percent), weaving (23 percent), and miscellaneous processes (5 percent). Water heating and drying are among the most energy-intensive steps of fabric manufacturing. The amount of water used in textile production is often closely connected to the amount of fuel used in mills [42]. In the denim jeans production, both automated and conventional cutting technologies are used concurrently during manufacturing. Because denim is thicker than other apparel fabrics, handling and sewing denim fabric requires the use of heavy-duty and standard sewing machines. Machines that use both lock and chain stitches are used to finish a denim item of clothing. The daily energy usage of a typical sewing machine with a variable frequency drive (VFD) was 15.9 kW, while the machine without a VFD was 8.7 kW [43].

3.2.1 Denim washing

Washing is an artistic procedure that removes colorants and sizes substances to create a distinct appearance [44, 45]. There is also a demand for various types of faded or colored jeans. Typically, these variations appear after washing. Washing is one of the most important procedures in creating stunning denim jeans [46]. The production and cleaning of jeans commonly involve the use of water and energy [47]. Traditional washing processes, which are neither environmentally friendly nor sustainable, include acid washing, enzyme washing, spray treatments, and stone enzyme washing using strong bleaching chemicals such as potassium permanganate and sodium hypochlorite [48, 49].

3.4 Consumer Use Phase and End of Life/Disposal

The consumer phase of the life cycle refers to the actions a consumer takes while considering, purchasing, using, and maintaining a product [50]. According to the literature survey, consumers wear their jeans an average of 8.2 times before cleaning them [51]. Consumers discard denim clothes in landfills after using them for a year due to excessive washing frequency, which can reach twice a week [52]. According to statistics, users in the United Kingdom and France use 1647.7 liters of water, while those in the United States and China use 2543 liters [53]. When compared to other countries, the United States uses the most water for a pair of jeans over the duration of their existence, owing largely to its high per capita consumption of denim and the culture of washing after every wear [54]. To evaluate the environmental impact of washing, examine the amount of chemicals used during the consumer phase, such as detergent and softener. According to Saouter and Van Hoof [55], a typical washing machine is a front-loading device that utilises 75 liters of aqueous solution per 8 kilograms of clothing and 2.25 deciliters of laundry soap. It is impossible to disregard the environmental impact of using a washing machine and dryer, especially in terms of energy usage. We expect a typical dryer to require 0.95 kilowatt-hours of power to dry one kilogram of cotton. According to McQueen et al. [56], garments frequently end up in landfills, where they contribute to massive amounts of waste, or are burned, generating greenhouse gases and badly hurting the environment. To transport waste from cities to landfills, a 21-ton truck or lorry with an average journey distance of 80 km is required. The distance varies per country. This approach requires a lot of fuel [57].

4. MAXIMUM RESOURCE CONSUMPTION PHASE

It's concerning to note that the consumer care phase consumes 23 percent of the water used during the production of a pair of jeans. This strongly implies that, among all phases, the consumption phase may have the greatest environmental impact [58]. To put things into perspective, one typical home used a 2.2 kW washing machine twice a week, with an average cycle consumption of 1.24 kWh. As a result, their average moving consumption was 2.48 kWh [59]. Due to the humid and muggy weather, 22 of the 35 families surveyed used the washing machine every day; only four households stored their clothes in a laundry basket for more than two days [60]. It is critical to recognize that the consumer stage of the denim lifecycle is responsible for the majority of energy consumption and greenhouse gas emissions. This includes cleaning, drying, ironing, and driving in jeans [61]. Laundry contributes to water pollution by distributing microfibers and textile chemicals, as well as harmful compounds from detergents, solvents, and softeners into rivers. According to the Carbon Trust, annual CO_2 emissions from clothing use, particularly from laundry, drying, ironing, and dry cleaning, account for a significant share of garment consumption phase emissions [62].

5. CONCEPT OF SUSTAINABLE DENIM JEANS PRODUCTION

Within the textile industry, sustainability refers to the production of textiles in a manner that minimizes waste, upholds ethical production practices, conserves resources, employs eco-friendly materials to minimize environmental impact, uses less energy and water, recycles, and reuses materials [63]. Three pillars support the idea of sustainability: social, environmental, and economic. Since they are all interrelated and dependent on one another, attaining true sustainability will require addressing and balancing them all [64]. In addition to meeting the world's need for fiber, sustainable production should protect natural resources and the environment while preserving cotton farming businesses' financial stability. A production system's sustainability is called into doubt if it necessitates large land and cost increases without demonstrable advantages to sustainability [65]. The sustainability in the denim jeans production can be ensured in the following organic approach:

5.1 Organic cotton Cultivation Phase

The production of organic cotton requires the use of environmentally friendly and sustainable farming practices. The genetically modified organisms is strictly prohibited, and the use of chemical pesticides as fertiliser is closely monitored [66]. Organic cotton requires less water consumption, referencing 182 L/kg lint, whereas conventional cotton substantial water estimated 2,120 L/kg lint [67]. On average, 5.8 MJ of energy are needed worldwide to manufacture 1 kilograms of organic cotton [68]. According to Cotton Inc. [69] the potential energy demand (PED) for conventional cotton is approximately 15 MJ/kg lint cotton. As a result, the PED (non-renewable) decreased by 62 percent. Because mineral fertilizers are made from petroleum and have a high PED content, avoiding their use lowers the global warming potential (GWP).

5.2 Raw Material (Organic Cotton) Processing Phase

About 70 percent of the total energy used to create a pair of jeans is expended during the transformation of fibers into yarn, yarn into fabric, and fabric into apparel. The production of jeans is a laborious process that calls for specialist tools and machinery, in addition to complex abilities and a high degree of inventiveness and expertise. To build a sustainable environment, the use of natural colors should be promoted. Promote the use of several additional dyes and eco-friendly mordents to generate a variety of hues on denim [70].

5.2.1 Denim Washing

It's high time that denim washing began using all-natural products. Natural soap nut was used as a de-sizing agent because of its high detergency. Sunlight exposure has the ability to lighten many substances. Both lemon and tamarind have been used as natural bleaching agents when exposed to sunlight. Denim fabrics washed with tamarind and lemon performed better than the calcium hypochlorite sample and were essentially equal to the enzyme sample in all tests. As an outcome, it may be highlighted that lemon and tamarind offer considerable potential as natural ingredients in denim wash [70].

5.4 Consumer Use and Disposal Phase

Consumers are responsible for a surprisingly large portion of jeans' environmental impact. Careful washing and maintenance can lessen the environmental impact of denim while also extending the garment's lifespan. Out of habit, we frequently soak our jeans in water for too long. Participants in a 2012 study wore the same pair of dirty jeans for three months without any negative effects. Stains and odors can be easily removed with only some airing out and spot cleaning. Through years of use, everyone eventually acquires a unique patina. Experts advise against machine-washing jeans. Jeans will last longer if you wash them in cold water and dry them on a line. Chip Bergh, president of the company, has revealed that he never washes his jeans and instead cleans them by hand or with a spot cleaner. Denim may lose its color in the washing machine because of the excessive water level. Jeans that have been stretched from wear may be returned to their original size with several washings. Longevity and durability are concepts that the denim industry is eager to adopt. While Levi Strauss stresses the importance of having a meaningful relationship with one's wardrobe, Nudie provides a denim repair service. The recycling of denim after it has been worn is a serious problem. Several consumers still dispose of their denim as municipal solid waste, despite the availability of collection services (curbside collection, textile waste bins) in several nations. This waste is either buried underground or incinerated. The jeans turn damp and smelly when mixed with other waste, and high-end recycling is no longer a possibility. Denim donations often go to textile recyclers. Jeans that can still be worn are sorted by hand, with a focus on branded jeans, and then donated to thrift stores or exported to developing nations. Efforts are being made in a number of nations to boost textile material collections (especially jeans). To encourage people to sort their textiles and donate them to charity and clothing banks, authorities are collaborating with nonprofits and commercial textile waste collectors [70]. It is important to take steps to reduce energy consumption in mechanical processes. Regularly servicing spare parts like spark plugs, lubrication oil, and various filters helps cut down on energy use. The energy potential of gas is infinite. Suggest installing an EGB (exhaust gas boiler) to mitigate high-grade heat [71]. In order to cut down on energy costs, the dying process requires the installation of active economizers to preheat water in the boiler [72].

6. COMPARISON OF CONVENTIONAL AND ORGANIC APPROACH OF DENIM JEANS

6.1 GHG emission through LCA of Denim Jeans in Conventional and Organic Approach

From the above all of the data of LCA of denim jeans, the summarization of GHG emission for cotton fiber in conventional & modern processes is shown in figure 3

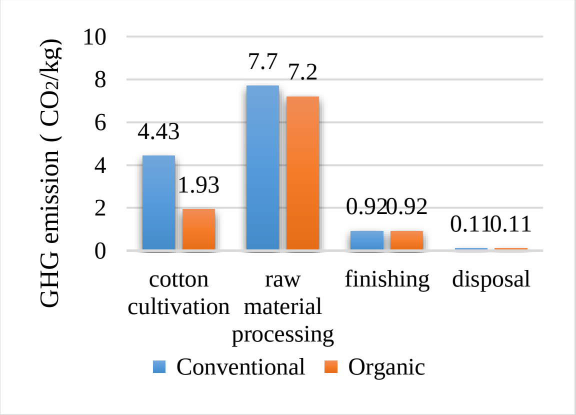

Fig 3: Comparison of GHG emission in LCA of denim jeans in Conventional Approach and Organic Approach [Data source: 37,56,71]

So it is apparent from the above figure that cotton produced conventionally generates higher greenhouse gases. Cotton cultivation and raw material processing have had the most significant impact of the four phases.

6.2 Energy Consumption through LCA of Denim Jeans in Conventional and Organic Approach

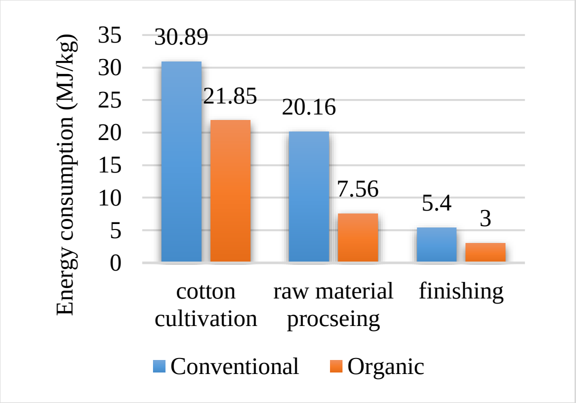

Fig 4: Comparison of Energy Consumption in LCA of denim jeans in Conventional Approach and Organic Approach [Data Source: 37, 52, 63]

The graphic above depicts energy usage in four important stages of the denim jeans' life cycle. The disposal phase is classified as landfill. The graph does not depict the disposal phase due to data limitations. The conventional approach consumes more energy than the organic approach. In the consumer usage phase, sunshine is considered as a method of drying denim jeans. So the energy consumption value is assumed to be zero.

6.3 Percentage Rate of Decrease in Organic Approach over Conventional Approach

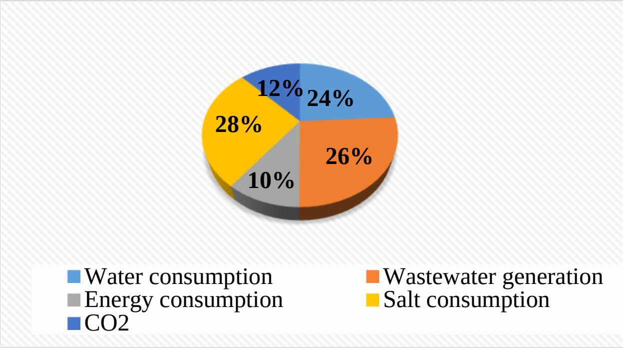

Fig 5: Percentage Rate of Decrease in Organic Approach Over Conventional Approach in a Turkish Facility [Data Source: 73]

The accompanying figure clearly shows that sustainable production reduces energy use. As a result, greenhouse gas emissions are lowered by 12 percent. So, ecologically friendly technology consumes 28 percent less salt, 10 percent less energy, 26 percent less wastewater generation and 24 percent less use of water, resulting in huge resource savings. Implementing sustainable methods will enable the sustainability of the resource [74].

6.4 Life cycle Interpretation

The aggregated results from the Life Cycle Impact Assessment phase have been presented in Life Cycle Interpretation. Results for each environmental impact category are described for a pair of jeans. The life cycle of the denim jeans is divided in four phases naming cotton cultivation, weaving, finishing and disposal. The ecoinvent 3.8 (cut-off) database is used for the analysis The consumer use phase is not considered as database is not available in software. The four major impact categories naming global warming, water consumption, freshwater ecotoxicity, ozone formation in terrestrial ecotoxicity (Cradle-to-grave), have been used to group results. The global database for each phase is used in conventional and organic approach. The When the data is analyzed in openLCA software finishing of woven fabric and disposal phase is considered same for both conventional and organic approach due to the limitation of database.

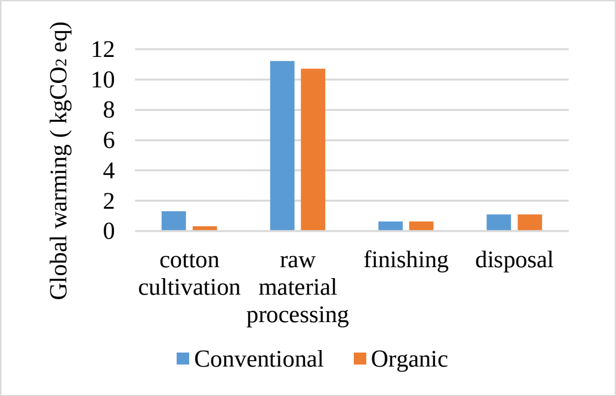

Fig 6: Global warming impact of four life cycle phases to produce a pair of denim jeans

The preceding figure clearly shows that conventional approaches have a greater impact on global warming. The most noticeable influence occurs during the weaving and cultivation phases. During cultivation, GHG emissions are 1.3136 kg CO_2 eq. for conventional and 0.3178 kg CO_2 eq. for organic approaches.

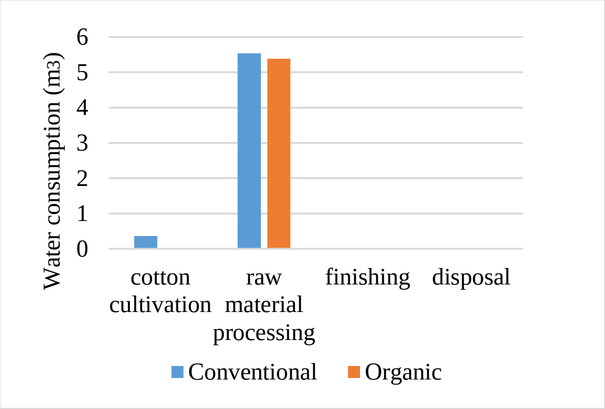

Fig 7: Water consumption impact of four life cycle phases to produce a pair of denim jeans

The production phase of the life cycle significantly adds to water usage. Undoubtedly, the cotton farming phase of the life cycle is the most significant step in the water consumption impact category. In conventional approach 0.3621 m^3/kg water is needed. But in case of organic approach only .0001 m^3/kg water is needed.

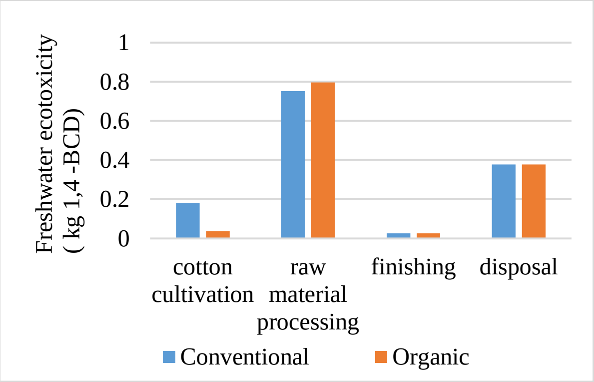

Fig 8: Freshwater ecotoxicity impact of four life cycle phases to produce a pair of denim jeans

The organic technique has the lowest impact on freshwater ecotoxicity during the cotton cultivation phase. In the cotton growing phase, only 0.0373 (kg 1,4-BCD) is generated using an organic approach.

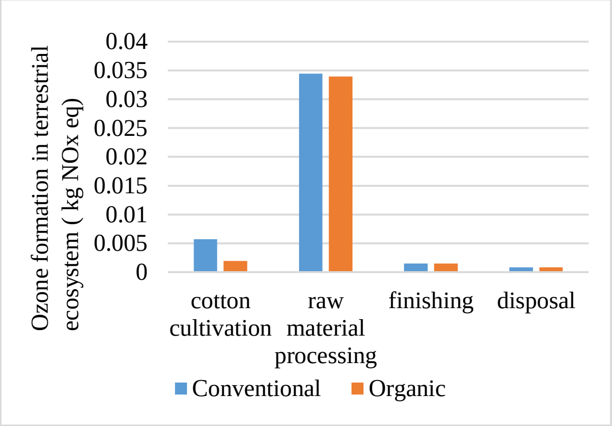

Fig 9: Ozone formation in terrestrial ecosystem impact of four life cycle phases to produce a pair of denim jeans

Finally, it is clearly seen that a comparable impact on ozone generation in terrestrial ecosystems. During the cotton cultivation phase, an organic technique produces a mere 0.0019 kg NOx equivalent.

7. CONCLUSION

This review article looked at the four phases of the denim jeans' life cycle. The phases are named cotton cultivation, raw material processing, finishing, and disposal, with a focus on the use of chemicals, water, and energy. The study discovered that the convention cotton cultivation period utilises the most chemicals and water. The conventional raw material processing phase also requires the most water and energy. Using sustainable methods in textile processing, on the other hand, can reduce water, energy, and salt use according to a Turkish study. The impact assessment scenario also demonstrates that the conventional approach has a greater environmental impact in four categories naming global warming, water consumption, freshwater ecotoxicity and ozone formation in terrestrial ecosystems. Observing all of the categories, it is clear that cotton cultivation and raw material processing have a significant environmental impact in the conventional approach. Organic cotton cultivation can effectively reduce GHG emissions throughout the cotton farming process, as well as during the transition from yarn to final product phases. On the other hand, after production consumers play a vital role. The study also reveals that consumer use phase is the most resource used phase. Based on the literature review, the paper provides recommendations for reducing energy, water and chemical consumption. In farming phase, organic cotton cultivation can reduce resource consumption as well as emission. During the raw material processing phase, the primary recommendations are to use organic cotton, perform routine machine maintenance, install an economizer to warm the feed water supplied to the boiler, eliminate water losses due to manual labor and reduce power consumption. The assessment indicates that following the recommendations can significantly reduce GHG emissions. Therefore, implementing the recommendations for facility sustainability and reducing water, energy and chemical consumption can serve as an excellent model for any global textile facility, especially those that are lagging behind current and sustainable technologies.

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