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Potential of Jute Products as a Substitute for Plastic in Bangladesh from Life Cycle Perspective

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Abstract

The global movement towards sustainability and the urgency to address plastic pollution have prompted the exploration of alternative materials and their environmental effects. Replacing plastic with jute offers a more sustainable solution due to its lower persistence in the environment. Life Cycle Assessment (LCA) serves as a valuable tool in evaluating the environmental performance of different options, facilitating the selection of more sustainable alternatives. The objective of this research is to outline the essential prerequisites for conducting a thorough Life Cycle Assessment (LCA) of jute products within the context of Bangladesh. The paper also emphasizes the need for adherence to guidelines and standards to ensure rigorous and consistent LCA practices, focusing on key areas such as jute cultivation, processing methods, end-of-life treatment, and the allocation of multifunctional process impacts. This paper demonstrates that jute has superior environmental performance with a 92% terrestrial ecotoxicity impact compared to plastic based on database comparison rather than actual LCA for the same functional unit, whereas it has a 59% freshwater aquatic ecotoxicity impact. Considering that comprehensive LCA for jute products is a relatively new field of research in Bangladesh, this paper provides a conceptual framework for future LCA studies of jute products to identify the hotspots or domains of notable environmental influence associated with jute products.

Keywords: *Jute; Plastic; LCA; Substitution Potential; Environmental impacts*

1 Introduction

Plastic pollution has emerged as a pressing environmental issue worldwide, prompting the search for sustainable alternatives. Plastic is now considered to be an international concern as one of the main causes of marine pollution, demanding immediate actions to reduce its use (Evans et al., 2020; World Bank, 2021; Xanthos & Walker, 2017). The natural fiber jute, which comes from the Corchorus plant, offers itself as a suitable substitute for plastic due to its renewable nature, biodegradability, and adaptability(Amin & Begum, 1996; Dayan et al., 2022). Bangladesh, being a major global producer of jute, holds a unique position to explore the viability of jute products as an alternative to plastic (Ahmed, 2020; Mourshed et al., 2017; Sheheli& Roy, 2015). Extensive literature suggests that jute offers numerous environmental advantages over plastic(Asim et al., 2022; Stafford et al., 2022a). However, an in-depth investigation using Life Cycle Assessment (LCA) is necessary in order to fully understand the environmental implications of using jute as a plastic alternative. LCA provides a systematic and holistic approach to evaluate the environmental impacts associated with a product throughout its entire life cycle, from raw material extraction to end-of-life disposal (Bisinella et al., 2018). While jute has generally been accepted as an environmentally friendly material, a thorough LCA analysis allows to delve deeper into the specific factors that influence its environmental performance. By applying LCA methodology to the comparison of jute and plastic, insights are gained into the specific stages of their life cycles where one material may have a greater environmental impact than the other. The environmental performance of jute may be optimized, and its potential as an environmentally friendly substitute for plastic may be further increased, through the integration

of LCA results alongside appropriate practices (Gautam et al., 2020). The impact assessment for jute LCA would provide valuable insights into the environmental consequences of jute products, allowing for a comprehensive understanding of their potential impacts across different impact categories. Decision-makers are able to understand the trade-offs and choose their use by assessing and comparing the environmental performance of jute products to those made of plastic (Hossain et al., 2021). Through impact assessment, potential areas for improvement and strategies to minimize the environmental impacts of jute products can be identified. This knowledge can guide the development of more sustainable practices, promote the adoption of cleaner technologies, and drive innovation in the jute industry. Impact assessment plays a critical role in assessing and quantifying the environmental impacts associated with the life cycle of jute products. By considering a range of impact categories, LCA assessment helps to identify environmental hotspots, prioritize improvement measures, and support the sustainable development of jute as a viable alternative to plastic.
The goal of the study is to identify the appropriate requirements for conducting a comprehensive LCA of jute products in Bangladesh, in order to assess their environmental impacts. Comprehensive and consistent guidelines for performing LCAs on jute products are also thoroughly discussed, aiming to enhance the comprehension of the environmental effects of these products. Hence, this paper will serve as a framework for future research in this area by focusing on key areas such as feedstock sourcing, processing methods, end-of-life treatment, and allocation of multifunctional process impacts of alternative products.

2 Methodological Framework for LCA of Jute Products

The subsequent sections describe the methodological details, outlining the key steps and considerations for conducting the LCA of jute products in accordance with DIN EN ISO 14044(ISO 14044, 2006). Jute LCA generally considers factors such as cultivation practices, processing methods, transportation, and waste management (see figure 1). The methodology encompasses goal and scope definition, system boundaries, data collection, impact assessment, interpretation, and comparison. In the beginning, the identification of potential data sources for collecting LCA data is crucial. Using accurate and reliable data for each life cycle stage of jute products ensures a comprehensive and precise assessment of their environmental impacts. It supports decision-making, promotes transparency, and facilitates the development of more sustainable and environmentally friendly jute products. Criteria and indicators are to be established to assess variations in environmental impacts across various life cycle stages and impact categories.

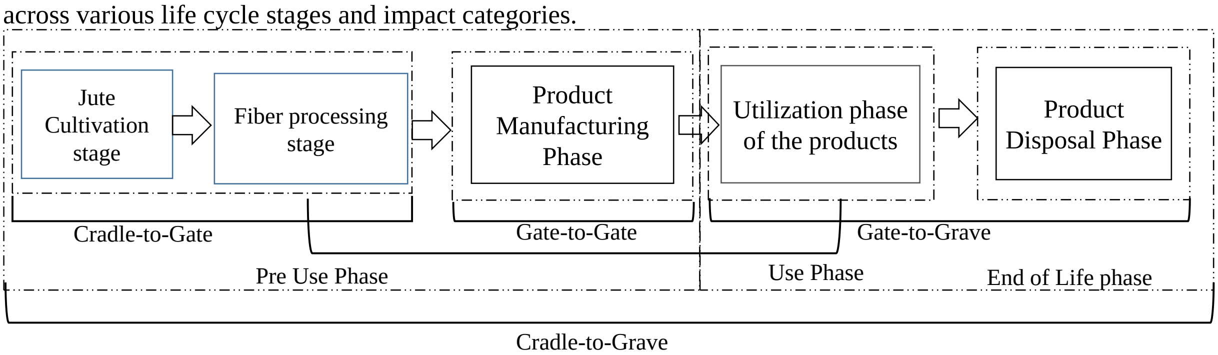

Figure 1. Phases involved in Life Cycle Assessments (LCA) of jute products.

2.1 Goal and Scope Definition: LCA of Jute Products

LCA of jute products involves establishing the purpose and boundaries of the assessment. This phase sets the foundation for conducting a comprehensive and meaningful analysis of the environmental impacts associated with jute products throughout their life cycle considering the specific context of Bangladesh. The scope of the LCA study outlines the system boundaries, functional unit, and life cycle stages to be considered. It defines the jute product under assessment, including its specific applications, such as packaging, textiles, or construction materials. The scope also determines the spatial and temporal boundaries, as well as any cut-off criteria for excluding certain life cycle stages or environmental impacts. A clear and focused analysis is ensured, enabling accurate comparisons and informed decision-making regarding the potential use of jute products as a sustainable alternative to plastic by defining the goal and scope of the LCA.

2.2 Inventory analysis for the LCA of jute product

Inventory analysis provides a comprehensive inventory of the environmental impacts resulting from the production, use, and disposal of jute products. The goal of inventory analysis is to compile and quantify the relevant data related to resource consumption, energy use, emissions to air and water, waste generation, and other environmental indicators. It involves gathering data from various sources, including primary data collected from jute farms, manufacturing facilities, and factory personnels as well as secondary data obtained from existing databases, industry reports, and scientific literature. The actual functional unit definition will depend on the specific jute product being assessed and the goals of the LCA study. The functional unit is essential for enabling comparability, relevance, goal-oriented analysis, communication, and data normalization in LCA studies. It ensures that the assessment focuses on the specific function or service of the product or system, facilitating informed decision-making towards more sustainable solutions. When selecting the functional unit for jute products, the specific quantity or service provided by the product have to be considered (i. e., as seen in Figure 2). Factors such as physical dimensions (e.g., area, volume), duration of use, or the equivalent function compared to alternatives are to be taken into account. It has to be ensured the functional unit is meaningful, relevant, and aligns with the goals of the life cycle assessment.

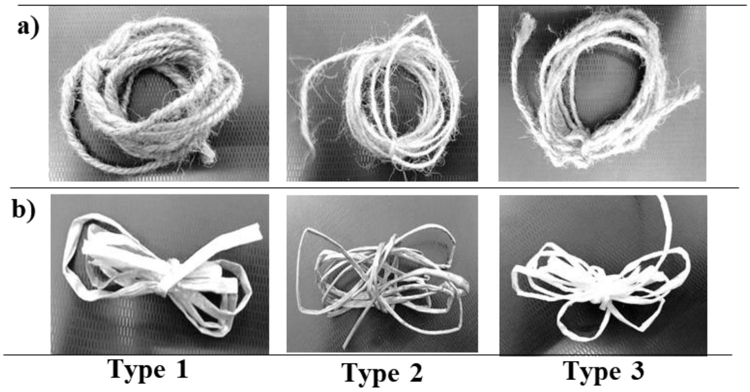

Figure 2. The functional unit specification (average mass/meter) to compare jute and plastic products, (a) Jute rope: Average weight per length (g/m) = 1.95g/m, (b) Plastic rope: Average Weight per length(g/m)= 0.055g/m

Jute fiber processing encompasses multiple essential stages. Initially, jute plants are collected and their stems retted to extract fibers. After retting, these fibers are separated from the stalks, washed, and dried. The processing depicted in figure 3 focuses on the fiber processing phase and the manufacturing phase beginning with transportation and carding. The fibers undergo carding to arrange them and eliminate impurities. Subsequently, the carded fibers are twisted into yarns, which can undergo additional processes for specific applications like weaving, knitting, or rope production. Lastly, the finished jute products are subjected to finishing treatments, such as bleaching or dyeing, before being ready for use.

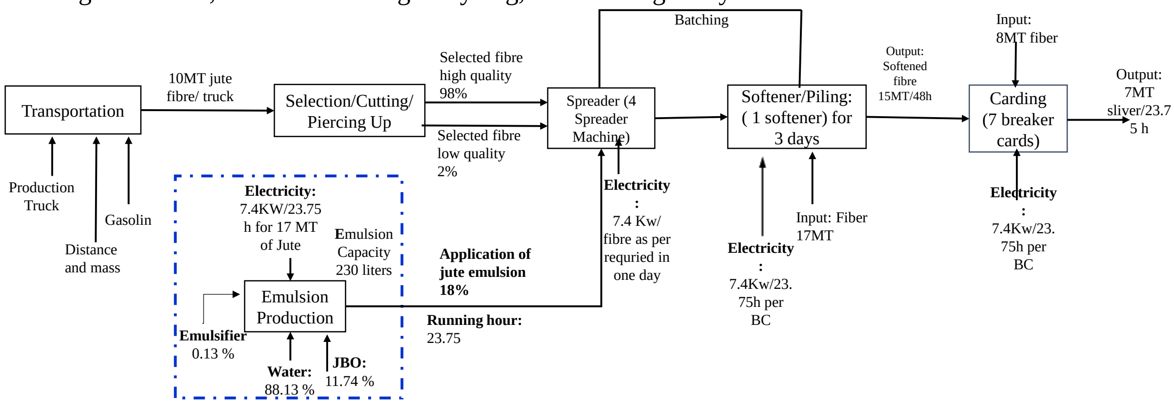

Figure 3. Sequential jute fiber processing starting with transportation and progressing to carding.

The figure 3 also provides information on electricity consumption and input data for various machines involved in jute yarn production. It indicates the electricity consumed, number of machines, running hours, total electricity usage, input quantities, and total input for each machine, highlighting the energy and material inputs involved in the production process. End-of-life treatment for jute products plays a vital role in achieving their overall sustainability and minimizing environmental impacts. It becomes possible to effectively tackle the environmental repercussions linked to their discarding through deliberate assessment of choices for the disposal of jute products, including recycling, composting, landfilling, or energy retrieval(Stafford et al., 2022b). Recycling jute products can help conserve resources and reduce waste generation, while composting offers a natural and eco-friendly way to return jute to the soil. Jute product disposal options (recycling, composting, landfill, energy recovery) impact resource conservation and pollution, while LCA guides eco-friendly choices for a circular economy with jute.

3 Impacts Assessment

Life Cycle Assessment (LCA) considers a wide range of environmental impacts, including global warming potential, ozone depletion potential, acidification potential, eutrophication potential, photochemical ozone creation potential, human and ecotoxicity potential, freshwater and marine ecotoxicity potential, terrestrial ecotoxicity potential, abiotic resource depletion, depletion of fossil and renewable energy reserves, land use, water consumption, particulate matter formation potential, resource use, and waste generation (ISO 14044, 2006). These impacts provide a comprehensive assessment of the environmental burdens associated with a product or system throughout its life cycle, enabling the identification of areas for improvement and the promotion of more sustainable alternatives.

3.1 Environmental Impacts Assessment from LCA

The environmental impact of jute fiber and plastic granule production was evaluated using the Ecoinvent 3.8 database and OpenLCA software, considering the same functional unit of yearly per capita production for grocery bags (Stafford et al., 2022b). In order to facilitate comparison, the maximum result for each indicator is set to 100 %, and the results of the other variants are presented in relation to this maximum value. The analysis (as seen in figure 4) reveals that production of jute fiber exhibits negative impacts in certain cases, indicating areas where improvements are needed. This study highlights the substantial differences focusing on 11 distinct impact categories from the total of 18 assessed. Jute outperforms plastic in terms of environmental impact, showcasing an impressive 92% reduction in terrestrial ecotoxicity impact and a noteworthy 59% rise in freshwater aquatic ecotoxicity impact. Impacts of plastic impact is 50% lower than that of jute in terms of abiotic depletion. Additionally, plastic shows less than 10% impact compared to jute in terms of acidification and eutrophication. Furthermore, jute exhibits a 50% lower impact than plastic in ozone layer depletion and human toxicity categories.

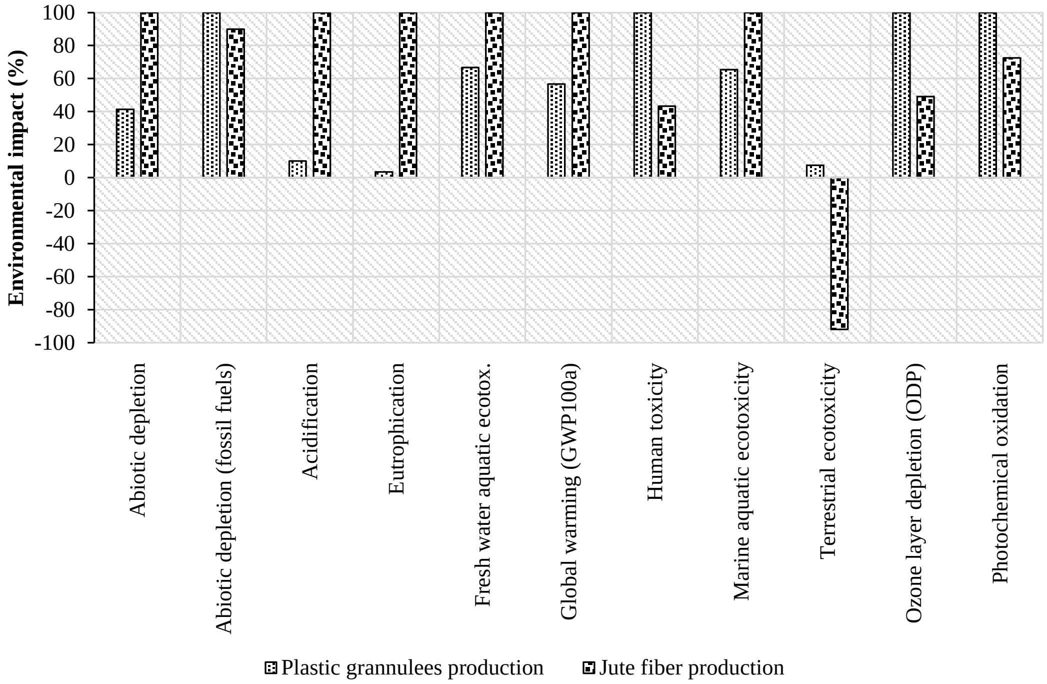

Figure 4. Results of different environmental impacts category for the same functional unit (annual per capita raw material)

The negative environmental impacts associated with jute products can be minimized, making them a more sustainable alternative to plastic by addressing the areas of improvement. Optimizing agricultural practices such as water management, pesticide and fertilizer use, and crop rotation can help minimize the negative environmental impacts associated with jute cultivation. Implementing sustainable farming techniques, such as organic farming or integrated pest management, can reduce the use of synthetic inputs and minimize the associated environmental risks. Improvements in processing methods can contribute to reducing the environmental footprint of jute products. Implementing cleaner production techniques, such as using energy-efficient machinery and optimizing resource consumption, can lead to lower energy and water consumption, as well as reduced emissions and waste generation. Proper management of jute product waste at the end of its life cycle is essential for reducing environmental impacts. Promoting recycling and composting of jute products can help minimize landfilling and the associated methane emissions. Developing appropriate infrastructure and waste management systems to facilitate the collection, separation, and recycling of jute products can significantly enhance their environmental performance. Evaluating and improving the packaging and transportation practices associated with jute products can help reduce their environmental impacts. Using eco-friendly packaging materials and optimizing logistics to minimize transportation distances and emissions can contribute to overall sustainability. Material Substitution: Identifying opportunities to substitute certain materials or components of jute products with more sustainable alternatives can further improve their environmental performance. This could involve exploring bio-based alternatives, recyclable materials, or renewable energy sources in the production process.

4 Further Risks and Challenges

The application of jute as a potential alternative to plastic holds promise in addressing environmental concerns (see table 1). Even though the LCA outcomes offer encouraging signs of its sustainability, it's vital to undertake additional exploration and careful thought before reaching conclusive judgments. While jute holds promise as a sustainable choice, addressing factors such as strength, resistance to moisture, biodegradability, cost-effectiveness, and the continuous requirement for research and innovation is imperative. Jute can contribute to reducing plastic waste and promoting sustainability in appropriate applications by addressing these issues.

Table 1. Issues concerning the adaptation of jute as a plastic alternative necessitate more investigation

Related Issues	Description	Potential Impact	Some Mitigation Strategies
Market Acceptance (Islam & Xiaoying, 2016)	Consumer preferences and acceptance of jute-based alternatives in the market.	Limited demand and market penetration for jute substitutes.	- Market research should be conducted to understand consumer preferences and identify potential target markets.
Cost-effectiveness (Akter et al., 2020)	The cost-effectiveness and competitive pricing of jute-based substitutes compared to plastic alternatives need to be evaluated, considering factors such as production costs, market pricing, and consumer affordability.	- Higher production costs may make jute substitutes less competitive in the market.	- Cost optimization strategies should be implemented, and efforts should be made to explore economies of scale and offer competitive pricing for jute products
Supply Chain Challenges (Ahmed, 2020)	Ensuring a consistent and efficient supply chain for jute production, processing, and distribution.	Inconsistent jute supply may lead to production delays or insufficient quantities.	-Sustainable jute cultivation practices should be promoted to ensure a stable and reliable supply.
Environmental Impacts (M. S. Islam & Ahmed, 2012)	Assessing the overall environmental impact of jute cultivation, processing, and disposal.	Potential environmental challenges associated with jute production and waste management.	To implement sustainable jute farming practices, promote proper waste management and recycling of jute products.
Policy and Regulations	Adherence to relevant policies, regulations, and standards governing the use of jute as a plastic substitute.	Non-compliance with regulations may hinder the adoption of jute substitutes.	-To advocate for supportive policies, incentives, and regulations that promote the use of jute as a sustainable alternative to plastics.
Technological Advancements (Sheheli & Roy, 2015b)	The technological capabilities and infrastructure for jute processing and manufacturing may pose limitations in terms of efficiency, quality, and cost-effectiveness	Outdated technology and lack of modern machinery may hinder production capabilities.	-To invest in research and development to enhance jute processing techniques, explore new applications, and improve the overall quality of jute products.

5 Conclusion

This paper presented the prerequisites for a thorough LCA of jute products and stressed the significance of performing additional research in Bangladesh in this area. While a detailed LCA was not conducted as part of this study, the outlined steps and considerations serve as a valuable foundation for future LCA studies on jute products. are outlined as follows:

1. LCA framework offers insights into jute's sustainability, covering goal definition, system boundaries, data collection, impact assessment, and interpretation.
2. Comparison of jute products to plastic alternatives reveals substantial differences. Jute boasts a remarkable 92% reduction in terrestrial ecotoxicity impact and a noteworthy 59% rise in freshwater aquatic ecotoxicity impact.

3. The environmental impacts of jute fiber and plastic granule production were assessed using the Ecoinvent 3.8 database and OpenLCA software. Results indicate specific areas in jute production that require improvement.
4. Plastic displays lower impacts than jute in abiotic depletion, acidification, eutrophication, ozone layer depletion, and human toxicity.

Additionally, this study advocates for further research in the field of jute LCA to bridge existing knowledge gaps and enhance the understanding of jute's environmental performance. By considering the recommendations provided and building upon the methodology discussed, future LCA studies can contribute to a more comprehensive understanding of jute products' environmental impacts, ultimately supporting the transition towards a more sustainable and plastic-free future.

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References

Ahmed, S. (2020). An Approach to Design a Sustainable Supply Chain: Future Non-government Investment in Jute Industry in Bangladesh. Supply Chain Insider. https://www.academia.edu/44796428/An_Approach_to_Design_a_Sustainable_Supply_Chain_Future_Non_government_Investment_in_Jute_Industry_in_Bangladesh.

Akter, S., Sadekin, M. N., & Islam, N. (2020). Jute and Jute Products of Bangladesh: Contributions and Challenges. Asian Business Review, Vol. 10, No. 03, pp. 143–152. https://doi.org/10.18034/abr.v10i3.480.

Amin, M. N., & Begum, M. (1996). A Method for the Preparation of a Jute-batching Emulsion by Using Castor Oil. Journal of the Textile Institute, Vol.87, No.3, pp.432–437. https://doi.org/10.1080/00405009608631344

Asim, Z., Shamsi, I. R. Al, Wahaj, M., Raza, A., Abul Hasan, S., Siddiqui, S. A., Aladresi, A., Sorooshian, S., & Seng Teck, T. (2022). Significance of Sustainable Packaging: A Case-Study from a Supply Chain Perspective. Applied System Innovation, Vol. 5, No. 06, pp. 1-18. https://doi.org/10.3390/asi5060117.

Bisinella, V., Albizzati, P., Federica, Astrup, T., Fruergaard, & Damgaard, A. (2018). General rights Life Cycle Assessment of grocery carrier bags, pp. 1-144. https://www2.mst.dk/Udgiv/publications/2018/02/978-87-93614-73-4.pdf.

Dayan, M., Rahman, M., Ferdush, J., Kaysar, M., & Uddin, M. D. (2022). Effect of Harvesting Time on the Fiber Yield and Characterization of Jute Fiber. Journal of Natural Fibers, Vol. 19, No. 15, pp. 12334-12445. https://doi.org/10.1080/15440478.2022.2060405.

Evans, D. M., Parsons, R., Jackson, P., Greenwood, S., & Ryan, A. (2020). Understanding plastic packaging: The co-evolution of materials and society. Global Environmental Change, Vol. 65, No. 102166, pp. 1-18. https://doi.org/10.1016/j.gloenvcha.2020.102166.

Hossain, S., Rahman, M. A., Chowdhury, M. A., & Mohonta, S. K. (2021). Plastic pollution in Bangladesh: A review on current status emphasizing the impacts on environment and public health. In Environmental Engineering Research. Korean Society of Environmental Engineers, Vol. 26, No. 06, pp. 1-22. https://doi.org/10.4491/eer.2020.535.

Islam, M. M., & Xiaoying, J. (2016). Customer’s Perception towards Buying Eco-Friendly Diversified Jute Products: An Empirical Investigation in Dhaka City, Bangladesh. Journal of Marketing and Consumer Research, Vol. 24, No. 2016, pp. 34-40.

Islam, M. S., & Ahmed, K. (2012). The Impacts of Jute on Environment: An Analytical Review of Bangladesh. Journal of Environment and Earth Science, Vol. 2, No. 05, pp. 24-32.

ISO 14044. (2006). ISO 14044 Environmental management-Life cycle assessment-Requirements and guidelines Management environnemental-Analyse du cycle de vie-Exigences et lignes directrices.

Jute Ecolabel Annexures to Life Cycle Assessment Study Annexure 1: Data Collection Format for Primary Data Collection from Different Jute Mills/ Jute Manufacturing Units ecolabel, The Golden Natural Fibre. (2006). www.jute.com/.

Mourshed, M., Masud, M. H., Rashid, F., & Joardder, M. U. H. (2017). Towards the effective plastic waste management in Bangladesh: a review. Environmental Science and Pollution Research, Springer Verlag, Vol. 24, No. 35, pp. 27021–27046. https://doi.org/10.1007/s11356-017-0429-9

Sheheli, S., & Roy, B. (2015a). Constraints and opportunities of raw jute production: a household level analysis in Bangladesh. Progressive Agriculture, Vol. 25, No. 2014, pp. 38–46. https://doi.org/10.3329/pa.v25i0.24070.

Stafford, W., Russo, V., & Nahman, A. (2022a). A comparative cradle-to-grave life cycle assessment of single-use plastic shopping bags and various alternatives available in South Africa. International Journal of Life Cycle Assessment, Vol. 27, No. 9–11, pp. 1213–1227. https://doi.org/10.1007/s11367-022-02085-2

World Bank. (2021). Towards a multi-sectoral action plan for sustainable plastic management in Bangladesh. www.worldbank.org.

Xanthos, D., & Walker, T. R. (2017). International policies to reduce plastic marine pollution from single-use plastics (plastic bags and microbeads): A review. Marine Pollution Bulletin, Vol. 118, No. 1–2, pp. 17–26. https://doi.org/10.1016/j.marpolbul.2017.02.048.