

# Sustainable Paper Making: A Comprehensive Review

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## ABSTRACT

Handmade paper making, an ancient craft, holds significant promise for a sustainable future. It utilizes diverse cellulosic materials, including recycled paper, agricultural residues like banana fibres, anara fibres, corn husks, hemp, etc and even invasive aquatic plants like water hyacinth, water lettuce and animal residues like cow dung, elephant dung and linen fibres. These alternatives address the environmental burden of conventional paper production, which relies heavily on deforestation and pollution-intensive processes. Studies have demonstrated the viability of various non-wood sources, showcasing their suitability for producing handmade paper with acceptable strength and quality. Compared to machine-made paper, handmade production significantly reduces water and energy consumption, along with air and water pollution. It supports environmental sustainability by using recycled and renewable resources, minimizing waste, and reducing the reliance on forests. Economically, it creates employment, particularly in rural communities, fostering entrepreneurship and preserving traditional skills. Culturally, it safeguards heritage by continuing age-old paper-making techniques. Socially, it can empower marginalized groups and contribute to their livelihoods. The growing demand for eco-friendly products creates market opportunities for handmade paper, which can be crafted into a wide array of items, from stationery to decorative pieces.

The growing demand for handmade paper highlights the need to explore a wide range of sustainable raw material sources. To unlock the full potential of this eco-friendly and culturally significant industry, it is essential to raise public and governmental awareness of its value. Strategic support—through policy initiatives, skill development programs, and improved access to resources—will play a key role in driving the industry's growth. By addressing these critical areas, the handmade paper sector can evolve into a thriving model of sustainable development and heritage preservation.

**KEYWORDS:** Sustainable, Handmade Paper, Eco-friendly, Zero waste

## INTRODUCTION

The history of paper spans over two millennia and is closely intertwined with the development of human communication and civilization. Paper as we know it today originated in ancient China, where it was invented by Cai Lun in 105 CE during the Han Dynasty. Cai Lun's method used natural materials such as mulberry bark, hemp, old rags, and fishnets, which were soaked, beaten into pulp, and pressed into thin sheets—an innovation that dramatically improved upon earlier writing materials like bamboo, wood, and silk. From China, papermaking techniques spread to Korea and Japan by the 7th century, where they were further refined. By the 8th century, the knowledge reached the Islamic world, especially after the Battle of Talas in 751 CE, when captured Chinese papermakers introduced the craft in Samarkand. The Islamic Golden Age saw technological improvements and the rise of paper mills in Baghdad, Damascus, and Cairo, making paper more widely accessible [1].

By the 12th century, papermaking had reached Europe through Spain and Italy, and the Moors had introduced it. The first mills were established in Xàtiva and Fabriano. The invention of Gutenberg's printing press in the 15th century dramatically increased demand for paper, fueling the expansion of the industry [2].

In the 18th century, the development of the wood pulp-based paper industry in Europe aimed to cater to diverse paper needs and maximise profits, often at the expense of traditional paper production methods. However, this modern papermaking practice took a toll on the environment by consuming significant natural resources such as water and trees, the primary source of wood pulp, and generating pollution through the use of harsh chemicals [3]; [4].

Paper has played a crucial role in human civilization for centuries, serving as a medium for communication, creativity and commerce. However, its production has raised serious environmental concerns. A large number of trees are felled daily to satisfy the increasing demand for paper, leading to deforestation and a decline in biodiversity. Moreover, papermaking methods are associated with high levels of water and energy consumption, as well as the release of harmful chemicals, which result in environmental degradation [5].

The paper industry heavily relies on forests for its raw materials. In the last two centuries, roughly six million square kilometres of the Earth's forests have been depleted [6];[7]. Around 40% of timber resources are exclusively directed towards paper manufacturing. As reported by the Ecology Global Network, global paper consumption has surged by more than 400% over the last four decades [5]. Presently, paper industries worldwide collectively consume nearly 4 billion trees, amounting to roughly 35% of the total trees harvested globally. This exploitation of forests has pushed the Earth's limits, resulting in the loss of six million square kilometres of forest in less than two centuries [8]. This contributes significantly to deforestation and puts species living in forested areas at risk.

Environmental pollution is undeniably one of the most critical challenges facing the world today, escalating annually and causing severe and lasting damage to the planet. Processes like Kraft pulping, bleaching with chlorine and chlorine-based compounds, and high energy and water consumption levels in paper mills result in significant emissions of CO<sub>x</sub>, SO<sub>x</sub>, NO<sub>x</sub> into the air, as well as the release of Dioxins and Furans in effluents, leading to air and water pollution [9]; [10]; [11]. Paper making, especially in conventional, large-scale industrial settings, can lead to significant noise pollution. The machinery used in pulp and paper mills, such as grinders, digesters, dryers, and large rollers, operates at high decibel levels, often exceeding safe limits for prolonged human exposure. Therefore, they significantly contribute to environmental pollution.

The unchecked depletion of natural resources has placed humanity in a precarious position. Researchers, governments, and citizens worldwide are actively seeking ways to promote sustainable production and consumption, aiming to achieve economic, environmental, and social benefits. Due to the restricted supply of forest-derived materials, the growing need for paper, and a heightened focus on environmental sustainability, paper industries are compelled to find alternative sources [12, 13]. In response, the handmade paper industry has emerged as a promising sustainable alternative, utilizing non-wood raw materials and eco-friendly practices to meet the growing demand for paper while reducing environmental impact.

The handmade paper industry is vital for several reasons. It supports environmental sustainability by using recycled materials and requiring 50% less energy and 75% less water compared to machine-made paper. Additionally, it produces 90% less water pollution and 70% fewer air pollutants [14]. Economically, the industry provides employment opportunities, particularly in rural areas, fostering entrepreneurship and helping preserve traditional skills. Culturally, it sustains heritage by keeping centuries-old papermaking techniques alive. Socially, it empowers marginalized communities, contributing to their economic well-being and self-reliance. The resulting handmade paper products, known for their texture, durability, and uniqueness, are often favoured for specialized uses such as stationery, gift wraps, art, and archival documents.

Handmade paper is a thin, fibrous sheet produced from a diluted suspension of cellulose fibres. This mixture is poured or filtered through a mesh screen, where the fibres interlock as the water drains away, leaving behind a woven layer that solidifies into paper as it dries [15]. It has emerged as a significant component of cultural heritage and contemporary industry, embodying a unique intersection between traditional craftsmanship and modern consumer demands. This conventional craft not only embodies cultural heritage but also aligns with modern sustainability goals.

However, with the growing demand for handmade paper, the industry now faces challenges related to the availability of conventional raw materials such as cotton rags and recycled paper. These traditional sources are becoming limited or inconsistent, prompting concerns about long-term sustainability. To address this issue and support the continued growth of the handmade paper sector, it is essential to explore alternative raw materials [15];[16]. Agricultural residues, invasive plant species, textile waste, and even animal waste like cow and elephant dung have emerged as viable options. These sustainable alternatives not only reduce dependency on conventional resources but also align with circular economy principles, further reinforcing the industry's positive environmental and social impact.

The following studies highlight the work of various researchers who developed handmade paper using different types of waste materials:

**Bidin et al. (2015)** investigated the potential of five aquatic plant species (*Cyperus digitatus*, *C. halpan*, *C. rotundus*, *Scirpus grossus*, and *Typha angustifolia*) to produce handmade paper. Handmade paper sheets created from these aquatic plants displayed adequate tensile strength, breaking length, and low moisture content, indicating their feasibility for diverse paper products [17].

**Kumar et al. (2015)** examined the use of banana and Ankara fibres for handmade paper and paperboard production [18].

**Pandita et al. (2015)** studied the use of non-wood lignocellulosic materials (*Lantana camara*, *Parthenium hysterophorus* and *Eichhornia crassipes*) and agricultural wastes (bagasse, rice straw, and wheat straw) for making handmade paper in different blends. Among the combinations tested, the blend of rice straw and *Lantana camara* produced superior-quality paper suitable for various paper products [19].

**Ganie et al. (2017)** examined the potential of *Amaranthus hybridus* stalks for making handmade paper. The resulting 60 gsm paper sheets exhibited promising strength properties, including tensile, tear, burst, and double-fold strength [20].

**Arafat et al. (2018)** investigated the potential of using banana as a raw material for handmade paper. The study evaluated both Extracted Banana Fibre (EBF) and Waste Banana Fibre (WBF), finding that although WBF exhibited lower tensile, burst, and tear indices compared to EBF, it still met the standards for handmade paper production [21].

**Yadav et al. (2019)** explored the use of flower waste for handmade paper production. While the resulting paper was not ideal for writing, it proved suitable for packaging, art, and craft applications. The study also noted that its strength could be improved by blending it with other temple waste materials, such as paper or coconut husk [22].

**Islam et al. (2021)** assessed the potential of Water Hyacinth for handmade paper production. Its pulp was evaluated following TAPPI standards for both bleached and unbleached variants. Results showed that bleached handmade sheets demonstrated enhanced tensile index, tear index and brightness, emphasizing the positive impact of bleaching on Water Hyacinth [23].

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IJRTI

**Table No. 1: Alternative sources of raw materials for Handmade Paper Production**

S.NO.	RAW MATERIAL	AUTHOR	YEAR	REFERENCE
1.	Species of Aquatic Plant Weeds ( <i>Cyperus digitatus</i> , <i>C. halpan</i> , <i>C. rotundus</i> , <i>Scirpus grossus</i> , and <i>Typha angustifolia</i> )	Bidin <i>et al.</i>	2015	[17]
2.	<i>Musa sapientum</i> (Banana) and <i>Calotropis procera</i> (Ankara)	Kumar <i>et al.</i>	2015	[18]
3.	<i>Lantana camara</i> , <i>Parthenium hysterophorus</i> and <i>Eichhornia crassipes</i> (blended with Bagasse, Rice straw, and Wheat straw)	Pandita <i>et al.</i>	2015	[19]
4.	<i>Amaranthus hybridus</i> stalks	Ganie <i>et al.</i>	2017	[20]
5.	<i>Musa sapientum</i> (Banana)	Arafat <i>et al.</i>	2018	[21]
6.	<i>Rosa rubiginosa</i> (Rose) and <i>Tagetes erecta</i> (Marigold Flowers )	Yadav <i>et al.</i>	2019	[22]
7.	<i>Eichhornia crassipes</i> (Water Hyacinth )	Islam <i>et al.</i>	2021	[23]

In addition to academic research, several innovative companies also ventured into sustainable papermaking by producing handmade paper from unconventional waste materials such as cow dung and elephant dung. One such initiative was *Haathi Chhap*, a Rajasthan company that produces handmade paper from elephant dung [24]. Similarly, *Gaukriti*, a Rajasthan-based company, creates handmade paper and eco-products using cow dung. The initiative was rooted in traditional Indian practices and aligned with the principles of zero waste and the circular economy [25]. Another notable initiative in the handmade paper industry was Athulya Paper Studio, based in Auroville, India. The studio focuses on producing handmade paper using waste such as cotton rags from the garment industry as its primary raw material, turning textile waste into high-quality, aesthetically appealing paper products [26].

## CONCLUSION

The handmade paper industry stands as a vital bridge between cultural heritage and contemporary sustainability. While the industrialised wood pulp-based paper industry has undeniably met the escalating global demand for paper, its environmental repercussions, including deforestation and pollution, are undeniable and unsustainable. In stark

contrast, handmade paper production offers a compelling alternative, utilizing renewable and recycled resources, reducing energy and water consumption, and minimizing environmental impact.

The exploration of diverse non-wood fibres, such as agricultural residues, aquatic plants, and even temple waste, presents a promising avenue for addressing the raw material challenges faced by the handmade paper industry. These studies demonstrate the feasibility of producing high-quality handmade paper from various readily available and often underutilized resources. The utilization of these materials not only mitigates the reliance on forest resources but also contributes to waste management and creates economic opportunities, particularly in rural communities.

By embracing sustainable practices and exploring innovative raw material sources, the handmade paper industry can continue to thrive, providing unique, high-quality products while minimizing its environmental footprint. As the global focus shifts towards sustainable production and consumption, the handmade paper industry serves as a model for harmonizing economic, environmental, and social benefits. By supporting this industry, we invest in a future where tradition and sustainability coexist, contributing to a healthier planet and a more equitable society.

## REFERENCE

- [1] Hunter, D. (1947). *Papermaking. The History of and the Technique of an Ancient Craft*, Dover, New York.
- [2] Koops, M. (2010). *Historical account of the substances which have been used to describe events, and to convey ideas, from the earliest date, to the invention of paper*. Cambridge University Press.
- [3] Bajpai, P. (2015). Environmental Consequences of Pulp and Paper Manufacture. In: Green Chemistry and Sustainability in Pulp and Paper Industry. Springer, Cham. [https://doi.org/10.1007/978-3-319-18744-0\\_3](https://doi.org/10.1007/978-3-319-18744-0_3)
- [4] Chauhan, S., & Meena, B. L. (2021). Introduction to pulp and paper industry: Global scenario. *Physical Sciences Reviews*, 6(5), 81-109.
- [5] Neelagar R, Yathish R, Srinivasa S, et al. Characterization of paper and pulp properties from weed species. *Journal of Applied Biology & Biotechnology*. 2018;6(06):61–63).
- [6] Kumar, V., Gupta, S., Kalra, J. S., & Patil, P. P. (2021). Improvement in quality of handmade paper materials by recycling of waste papers and PPE kits. *Materials Today: Proceedings*, 46, 11274-11278.
- [7] Teijgeler et al., 2001)(TEIJGELER R., 2001, Handmade paper from India: Kagaj yesterday, today and tomorrow (Conference paper), [https://www.researchgate.net/publication/270273737\\_Handmade\\_paper\\_from\\_India\\_Kagaj\\_yesterday\\_today\\_and\\_tomorrow](https://www.researchgate.net/publication/270273737_Handmade_paper_from_India_Kagaj_yesterday_today_and_tomorrow). DOI: 10.13140/2.1.1499.5522.
- [8] Rani N, Maheshwari RC, Kumar V, et al. Purification of pulp and paper mill effluent through Typha and Canna using constructed wetlands technology. *Journal of Water Reuse and Desalination*. 2011;1(4):237–242.
- [9] Nazhad MM. Recycled fibre quality – A review. *Journal of industrial and engineeringchemistry*. 2005;11(3):314.
- [10][https://www.theworldcounts.com/stories/Environmental\\_Impact\\_of\\_Paper\\_Production](https://www.theworldcounts.com/stories/Environmental_Impact_of_Paper_Production)
- [11] Ince, B. K., Cetecioglu, Z., & Ince, O. (2011). Pollution prevention in the pulp and paper industries. *Environmental Management in Practice*, 5, 224-246.
- [12] Sharma, C.; Kumar, S. Detection of chlorophenolics in effluents from bleaching processes of rice-straw pulp. *J. Environ. Monit.* 1999, 1, 569–572.
- [13] Ali, M.; Sreekrishnan, T.R. Anaerobic treatment of agricultural residue based pulp and paper mill effluents for AOX and COD reduction. *Process Biochem.* 2000, 36, 25–29.).
- [14] Bluecat Paper. 2018b, July 17. *Handmade paper vs machine-made paper*. Retrieved 09 02, 2024, from <https://bluecatpaper.com/handmade-vs-machine-made-papers/>

- [15] Jain, P., & Gupta, C. (2021). A sustainable journey of handmade paper from past to present: a review. *Problemy Ekorozwoju*, 16(2), 234-244.
- [16] Alam, M., Rikta, S. Y., Bahauddin, K. M., Hasnine, T., & Kamal, A. K. I. (2018). Production of ecofriendly handmade paper from wastepaper and other local biomass material. *Acad. J. Environ. Sci*, 6(7), 147-155.
- [17] Bidin, N., Zakaria, M. H., Bujang, J. S., & Abdul Aziz, N. A. (2015). Suitability of aquatic plant fibers for handmade papermaking. *International Journal of Polymer Science*, 2015(1), 165868.
- [18] Kumar, A., Sharma, A. K., Jain, R. K., & Singh, B. P. (2015). The use of banana (*Musa sapientum*) and ankara (*Calotropis procera*) in the handmade paper industries.
- [19] Pandita, S., Kaula, B., & Passey, S. (2015). Use of weeds and agro-based raw materials and their blends for handmade paper making. *DU Journal of Undergraduate Research and Innovation*, 1(3), 169-179.
- [20] Ganie, S. A., Ara, S., Agarwal, M. A., Mehmood, I. M. G., & Mir, S. A. (2017). Papermaking potential of *Amaranthus hybridus* stalks; Sustainable raw material in paper industries. *J. Pharmacogn. Phytochem*, 6(6), 2096-2100.
- [21] Arafat, K., Nayeem, J., Quadery, A. H., Quaiyyum, M. A., & Jahan, M. S. (2018). Handmade paper from waste banana fibre. *Bangladesh Journal of Scientific and Industrial Research*, 53(2), 83-88.
- [22] Yadav, I et al., (2019). *Sustainable utilization of floral waste from some temples of Jaipur Rajasthan* [Doctoral Thesis, IIS (Deemed to be University)]. Shodhganga : a reservoir of Indian theses
- [23] Islam, M. N., Rahman, F., Papri, S. A., Faruk, M. O., Das, A. K., Adhikary, N., ... & Ahsan, M. N. (2021). Water hyacinth (*Eichhornia crassipes* (Mart.) Solms.) as an alternative raw material for the production of bio-compost and handmade paper. *Journal of environmental management*, 294, 113036.
- [24] Parekh, A. (2010, October 21). *Haathi chaap: Elephant poo paper*. The Better India. <https://thebetterindia.com/2051/haathi-chaap-elephant-poo-paper/>
- [25] Dubey, S. (2024, November). *How Gaukriti is Redefining Natural Living with Cow Dung Paper*. Re:Fresh. <https://refreshyourlife.in/blog/how-gaukriti-is-redefining-natural-living-with-cow-dung-paper?srsltid=AfmBOopE3psaK2gXapQYwB145ralm4P9ICWOyMDCo7Od-Kf-kBoIS-dq>
- [26] Srishti Trust. *Athulya-paper-studio*. Retrieved April 16, 2025, from <https://www.srishti-trust.org/athulya-paper-studio>