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Wood Waste Utilization in the Forest Industry: Innovations for Sustainable Management

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

The forestry sector produces considerable quantities of wood waste throughout the processes of harvesting, processing, and manufacturing. This waste poses a significant environmental challenge, leading to greenhouse gas emissions, the accumulation of waste in landfills, and the depletion of resources. The investigation data was collected in literature review and case studies of the related

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field. This study aims to analyse the challenges and opportunities related to the utilization of wood waste, emphasizing innovative technologies and strategies for sustainable management. We analyse both current and emerging uses of wood waste, such as bioenergy generation, composite materials, wood-derived chemicals, and soil enhancements. The study identifies integrated biorefineries and technological innovation as critical pathways for enhancing wood waste value.

Keywords: Wood waste; sustainable forestry; bioenergy; composite materials; forest industry; resource management.

1. INTRODUCTION

Worldwide, the forestry sector is crucial in supplying timber, paper, and various other important wood products. Nevertheless, this sector also produces considerable quantities of wood waste, which is generally characterized as the residues and by-products generated during forestry operations, timber processing, and manufacturing activities (such as logging slash, sawdust, bark, and discarded timber (Chandra et al., 2021). Historically, a large portion of this wood waste has been incinerated, disposed of in landfills, or merely allowed to decompose, leading to a loss of economic value and considerable environmental consequences (Carpio et al., 2013).

“Wood waste is a group of waste that includes surplus wood products from a variety of sources, such as the construction industry, private homes, railway construction, and wood packaging and packaging” (Van Benthem et al., 2007; Bhardwaj et al., 2023; Pandey,2022). A secondary source of raw materials for energy production and the development of various new potential products, including chemicals, biofuels, and other lignocellulosic materials, can be found in this kind of waste (Packalen et al., 2017). Both lipophilic and hydrophilic extractives, for example, can be found in wood bark and converted into high-value goods like pharmaceuticals and cosmetic chemicals (Routa et al., 2017; Tiwari et al., 2024). Similarly, Yang et al., (2014) discovered that bio-oil derived from waste wood resources serves as an effective extender and modifier for petroleum asphalt binders in asphalt pavement. The generation of biofuels and wood-based composites represents additional high-value applications for wood waste (Dionco-Adetayo, 2001). Additionally, reducing wood waste can help the timber industry meet the growing demand for wood while reducing its environmental impact without putting the world's forests at further risk (Eshun et al., 2012; Chandra et al., 2024; Davids et al., 2017). Therefore, minimising, recovering, and increasing the use of wood waste produced during the harvesting and processing of wood should be the main goals of the strategy for forest-based industries.

Wood waste and byproducts from wood-based industries can be used to make a variety of useful industrial products (Demirbas, 2001; Lykidis and Grigoriou, 2008; Darro et al., 2022; Bhardwaj et al., 2024). According to Saal et al. (2019), sawmills gather one tonne of sawdust, shavings, slabs and edgings for every 1000 board feet of lumber produced; approximately 75% of this seemingly worthless material is made up of wood, and 25% is bark. This substance can be used for both energy-related and non-energy-related purposes (FAO, 2002). Combustion, cogeneration, and the production of pellets and briquettes are approaches that generate energy from wood waste, while non-energy uses include cementboards, composite boards, surfacing products, and composting (Murphy et al., 2007; Kumar et al., 2024; Limanpure and Kumar, 2018). Several value-added opportunities for turning wood waste into other useful products have been found by numerous research studies. For example, a study carried out in Finland found a number of developing markets for wood-based goods, such as chemicals, textiles, biofuels, and substitues for plastic (Cai et al., 2013). The majority of the chips and offcuts from wood-based businesses are used as firewood by nearby communities and at commercial sawmills to generate steam for kiln dryers, according to research conducted in Zimbabwe (Charis et al., 2019; Kumar et al., 2022a,b Aashutosh et al., 2024). Furthermore, a Japanese study found that furniture manufacturers produced 15 million cubic meters of wood waste, of which more than 90% was recycled into fuel and wood-based panels (Hiramatsu et al., 2002). Moreover, it was discovered that underutilised wood from the quickly growing Paulownia (Paulownia fortuniei) species satisfied the EN 300 Type 1 (1997) minimum value requirements for general-purpose orientated strand board (OSB) for use in arid environments (Salari et al., 2013).

Wood is utilized in the construction of both large and small structures globally (Ramage et al., 2017; Manninen et al., 2015). A significant portion of land in Nepal is designated for forests and shrublands (DFRS, 2015). The use of timber in the nation plays a crucial role in the building of residential homes, commercial and industrial facilities, livestock shelters, and furniture (Kanel et al., 2012). The timber demand was recorded at 3.37 million m3 in 2011, increased to 3.75 million m3 in 2020, and is projected to reach 4.80 million m3 by 2030 (Kanel et al., 2012). Despite the growing demand due to population growth, wood remains underutilized or mismanaged in developing nations like Nepal, primarily due to outdated sawmill technology and untrained personnel. Industries based on forest resources have the potential to enhance themanagement of natural resources while providing income and job opportunities (Acharya and Acharya, 2007; Pandit et al., 2009; Kumar et al., 2023). The various sectors that utilize wood produce substantial amounts of wood waste, which requires effective management, repurposing, marketing, or disposal (Owoyemi et al., 2016). However, the main challenges stem from a lack of incentives for utilizing wood waste, inadequate information regarding the economic advantages of wood waste utilization, poor enforcement of environmental regulations, and the absence of policies for managing wood waste.

2. WOOD WASTE FROM FOREST INDUSTRIES

The extraction of logs and the manufacturing of completed goods are just two of the steps involved in the production of timber products, all of which have the potential to pollute the environment by contaminating the land, the air, and the water. About half of wood is turned into useful products, with the other half being categorised as waste (Zeng et al., 2013; Vaishnav et al., 2025). Planer shavings, peeler log cores, bark, slabs, sawdust, chips, coarse residues, and end trimmings are a few types of wood waste generated during primary industrial processes (see Table 1). In order to reduce environmental effects without endangering the world forest, it is imperative that wood waste be used effectively. oduces about 207,000 tonnes of waste wood every year from packaging, of which about 31,000 tonnes are recovered per year. The remaining 176,000 tonnes are used for energy. The Wood Recyclers Association 2021 (https://woodrecyclers.org/) estimates that 1.3 million of the 4.5 million tonnes of wood waste produced in the UK are recycled. Sweden contributes more than 10% of the global forest industry, which includes swan timber and pulp and paper products, despite having only 1% of the world's total forest cover (Kumar et al., 2021).

Table 1. Wood sources and their various residues

Source	Types of residues
Forest operation	Branches, stumps, low graded and decayed wood,needles, leaves, roots, slashings and sawdust
Sawmilling	Bark, split wood, sawdust, planer shavings, trimmings, sander dust
Plywood production	Bark, core, veneer clippings,sawdust and waste, panel trim, sander dust
Particleboard production	Bark, panel trim, screening fines, sawdust, sander dust

3. WOOD WASTE UTILIZATION

“Wood waste can be minimized by improving the efficiency of primary wood utilization and by employing raw wood materials obtained from sustainably managed forests, thus preventing additional damage to the world’s forests” (Magin, 2001; Kumar et al., 2022a,b). There exist numerous potential applications that offer opportunities for the effective utilization of a considerable amount of wood waste produced from harvesting to processing. Eshun et al. (2011) “propose five distinct strategies for the utilization of wood waste, which include technological innovation, sound operational practices, recycling, reuse, and recovery, as well as a combination of technological innovation, sound operational practices, and recycling (Fig. 1). Although technological innovations entail significant costs, they can reduce wood waste generation from plywood manufacturing by 6%, from veneer production by 9%, and from furniture component production by 19%” (Shin et al., 2008). Loehnertz et al. (1994) found that “certain sawmills in tropical regions, such as Venezuela (60–70%) and Malaysia (54.5%), successfully recovered sawn wood of commercial dimensions”. According to Lykidis and Grigoriou (2008), “wood waste has the potential to be a resource for producing various materials through reformation or the development of new products. In Zimbabwe, the majority of offcuts and chips from wood-based industries are utilized at commercial sawmills to generate steam for kiln dryers and are also used as firewood by local communities. Similarly, Japanese furniture manufacturers produced 15 million cubic meters of wood waste, of which 90% is recycled for the production of wood-based panels and fuel". As noted by Bruns (2017), "Australia has effectively harnessed wood waste on a large scale, generating annual revenue of approximately 7.3 million Euros. Various building materials and engineered wood products, such as plywood, laminated veneer lumber, and glued-laminated lumber particleboard, are produced from wood waste. This indicates that the utilization of wood waste for the creation of new products is a financially viable strategy. Several techniques are employed for the utilization of wood waste".

3.1 Wood Waste as a Source of Energy

Wood waste produced by furniture manufacturing facilities is utilized for energy conversion. Research has shown that the lumber, plywood, pulp, and paper industries incinerate their wood by-products in large furnaces and boilers, supplying 60% of the energy necessary for factory operations (Bruns, 2017). In the United Kingdom, around 10 million tons of waste wood are repurposed each year for energy generation (Steierer, 2007). Canada exports 1 million tons of wood pellets made from waste to Europe, which serve as a raw material for power plants as substitutes for fossil fuels (Edo et al., 2016). Wood pellets, which are essentially compressed sawdust, can be used as fuel, thus reducing the pressure on forest resources. Goetzl (2015) reports a rising trend in the industrial use of wood pellets for electricity generation and in industrial and commercial applications in developed countries. Currently, many developing nations are also producing wood briquettes, which are regarded as a more efficient energy source than conventional firewood (Asresu, 2017). Charis et al. (2019) observed that from 2013 to 2017, modified 'smokeless' briquettes were manufactured in Zimbabwe using innovative densification techniques. In Peru, wood waste from the timber sector has been found to be an excellent fuel alternative for 55.81% of families in the region (Sánchez et al., 2014).

3.2 Using Wood Waste to Create Engineered Wood Products

Engineered wood products are created from small wood pieces that are adhered together using various adhesives. The use of wood waste in the manufacturing of engineered wood products aids in mitigating climate change by reducing the need for additional tree harvesting and fostering ongoing carbon storage (Hill et al., 2015). Examples of engineered wood products include oriented strand board, particleboard, Medium Density Fiberboard (MDF), glue-laminated timber, laminated lumber, and others (Williamson, 2002). Structural wood panels, such as plywood and oriented strand board, are made by laminating various wood-based materials to improve the strength, stiffness, and stability of the panels (Stark et al., 2010). Generally, these panels are not designed to bear loads; instead, they are frequently utilized in interior applications as substitutes for solid wood. According to Braghiroli et al., (2020), planer shavings make up more than half of the wood components in particleboard manufactured in the United States, followed by other mill byproducts such as sawdust and wood chips. A variety of resins, including Amino-formaldehyde and Melamine, are used for their cost-effectiveness and water-resistant qualities. Medium-density boards (MDF) are employed for high-quality items such as stereo cabinets, moldings, and table and furniture tops with profiled edges. Due to its smooth surface and edge finishing properties, MDF is an excellent substrate for wood veneer, vinyl films, and heat transfer foils (Stark et al., 2010). In 2013 and 2014, Italy recycled 95% of waste wood to produce particleboard, while Germany and the United Kingdom accounted for 34% and 53%, respectively (Garcia and Hora, 2017). Despite these benefits, the production of engineered wood products incurs significant costs in terms of time, money, and energy.

3.3 Wood Chips for Mulch

Mulches are layers placed on the soil surface to aid in weed management, protect roots from temperature fluctuations, reduce water loss from the soil, and improve aesthetic value. Wood chips, rich in lignin, tannins, and a variety of complex compounds, supply nutrients and gradually retain significant amounts of water (Chalker-Scott, 2007). As a result, developed countries recognize wood chip mulches as an eco-friendly choice for gardens and green spaces.

3.4 Wood Chips for Animal Bedding

Bedding materials encompass any substances that provide comfort to animals in their enclosures. They can alleviate negative environmental impacts in livestock facilities and improve animal comfort by absorbing excess moisture and reducing ammonia (NH3) emissions (Ahn et al., 2020). Furthermore, wood chips utilized for animal bedding are practical, cost-effective, and absorbent, fostering a clean, warm, and dust-free environment (Panivivat et al., 2004). The bedding can also be combined with cattle dung to create compost manure.

3.5 Chemical Utilization of Wood Waste

Wood waste and byproducts serve as a promising source for a wide array of green chemicals. A typical softwood, such as spruce or fir, comprises approximately 67% carbohydrates, 27% lignin, and 6% extractives. In a similar vein, hardwoods like maple are made up of about 73% carbohydrates, 22% lignin, and 5% extractives (Pavlovich and Paylovna, 2020). Studies suggest that the sulfite pulping process can only utilize half of the wood for pulp production, while the other half, which is not usable, consists of nearly equal proportions of carbohydrates and lignin (Li et al., 2015). The carbohydrate fraction of wood includes two categories of materials: alpha-cellulose and hemicellulose. Alpha-cellulose, which makes up 50% of wood, is resistant to mild chemical treatments and is formed from glucose polymers. Hemicellulose, on the other hand, is composed of simple sugars such as pentoses and hexoses, uranic acids, and acetylated compounds. The optimal utilization of wood residues is realized by converting them into fiber for the production of paper and paperboard. The chemical processing of wood residues may involve multiple stages, with economic factors presenting considerable challenges. Generally, wood residues are hydrolyzed using acid to yield simple sugars and lignin. Research indicates that lignin can be utilized for a variety of commercial purposes, including battery storage, tanning agents, adhesives, road construction, and dispersing agents in cement.

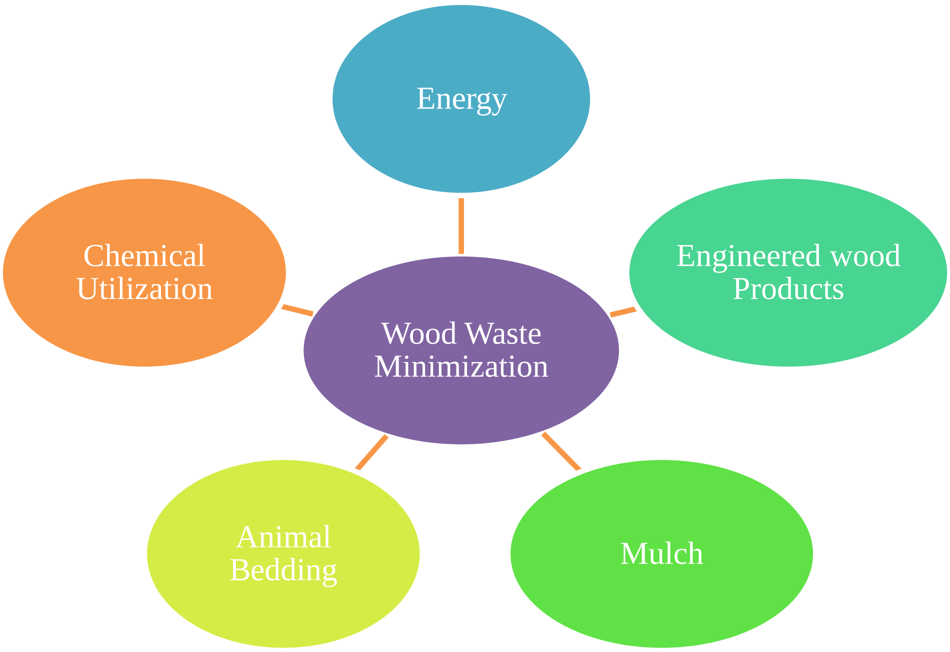

Fig. 1. Minimization of wood waste

4. CHALLENGES TO WOOD WASTE UTILIZATION

Despite the many advantages, various obstacles impede the broad adoption of wood waste utilization:

4.1 Collection and Transportation Costs

The scattered nature of forest residues, along with the relatively low economic value of wood waste, can render collection and transportation financially challenging (Soni et al., 2025).

4.2 Variability in Feedstock Quality

The diversity of wood waste, which includes differences in species, moisture levels, contaminants, and particle sizes, can influence the efficiency and effectiveness of specific processing technologies (Soni et al., 2025).

4.3 Technological Barriers

Certain advanced technologies for converting wood waste, such as gasification and pyrolysis, remain in development and necessitate furtheroptimization (Soni et al., 2025).

4.4 Lack of Awareness and Information

A limited understanding among stakeholders regarding the potential uses of wood waste and the technologies available can obstruct its adoption (Soni et al., 2025).

4.5 Policy and Regulatory Barriers

Insufficient policy frameworks, absence of financial incentives, and complicated regulatory requirements can deter investment in wood waste utilization initiatives (Soni et al., 2025).

4.6 Market Competition

Products derived from wood waste frequently encounter competition from less expensive alternatives that are based on fossil fuels or virgin materials.

5. INNOVATIONS AND STRATEGIES FOR SUSTAINABLE MANAGEMENT

Addressing these challenges necessitates a comprehensive strategy that emphasizes technological innovation, supportive policies, and collaborative partnerships (Bargah et al., 2024). Below are several essential strategies:

5.1 Enhanced Harvesting Techniques

Adopting more effective harvesting practices that reduce waste generation and aid in the collection of residues.

5.2 Pre-Processing and Standardization

Creating economical pre-processing methods to enhance the consistency and quality of wood waste feedstock. This may involve chipping, grinding, drying, and screening procedures.

5.3 Technological Advancements

Allocating resources to research and development aimed at increasing the efficiency and cost-effectiveness of wood waste conversion technologies, including gasification, pyrolysis, and enzymatic hydrolysis.

5.4 Integrated Biorefineries

Establishing integrated biorefineries capable of transforming wood waste into various high-value products, such as bioenergy, chemicals, and materials.

5.5 Life Cycle Assessment (LCA)

Performing LCAs to assess the environmental impacts of wood waste utilization technologies and confirm that they provide real sustainability advantages.

5.6 Policy and Regulatory Support

Enacting policies that encourage wood waste utilization, such as feed-in tariffs for bioenergy, tax incentives for incorporating woodwaste in manufacturing, and regulations that limit the landfilling ofwood waste.

5.7 Public Awareness and Education

Raising public awareness regarding the advantages of wood waste utilization and the availability of products derived from wood waste.

5.8 Collaborative Partnerships

Encouraging cooperation among forest owners, processors, researchers, policymakers, and consumers to create and execute sustainable wood waste management strategies.

5.9 Development of Robust Supply Chains

Creating dependable and efficient supply chains for the collection, processing, and distribution of wood waste.

5.10 Digitalization and Data Analytics

Utilizing digital technologies, such as sensors and data analytics, to enhance the efficiency of wood waste collection, processing, and utilization.

6. CONCLUSION

Wood waste represents a significant underutilized resource with the potential to contribute to a more sustainable and resilient forest industry. By adopting innovative technologies and strategies, we can transform wood waste from a disposal problem into a valuable resource that contributes to renewable energy production, bio-based materials, and a circular economy. Overcoming the challenges associated with wood waste utilization will require a collaborative effort from forest owners, processors, researchers, and consumers. By investing in research and development, implementing supportive policies, and fostering public awareness, we can unlock the full potential of wood waste and create a more sustainable future for the forest industry and the environment. The transition towards a more circular and bio-based economy necessitates a paradigm shift in how we view and manage wood waste, recognizing its inherent value and promoting its responsible utilization.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author hereby declares that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during writing or editing of manuscripts.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

Aashutosh, K. M., Bhardwaj, A.K., Kumar, R., Chandra, K.K., Kumari, C., & Pandey, S.K. (2024). Impact of Urban Xenobiotics on Mycorrhizal Associations in Urban Plants.*Nature Environment & Pollution Technology, 23*(4), 1-15.

Acharya, K., & Acharya, S. (2007) Small wood-based enterprises in community forestry: contributing to poverty reduction in Nepal. *RAP Publ 9*, 102–113

Ahn, G.C., Jang, S.S., Lee, K.Y., Baek, Y.C., Oh, Y.K., & Park, K.K. (2020) Characteristics of sawdust, wood shavings and their mixture from different pine species as bedding materials for Hanwoo cattle. *Asian-Australas J Anim Sci 33*, 856–865

Asresu, A.T. (2017) Biomass briquetting: opportunities for the transformation of traditional biomass energy in Ethiopia. *J Energy Technol Policy 7*, 2224–3232

Bargah, A.S., Kumar, R., Khandekar, H., &Vaishnaw, A.K. (2024). A Status of Different Non Wood Forest Products in Chhattisgarh, India. *International Journal of Plant & Soil Science*, *36* (11), 23-40. https://doi.org/10.9734/ijpss/2024/v36i115118.

Bhardwaj, A.K., Chandra, K.K., & Kumar, R. (2023). Mycorrhizal inoculation under water stress conditions and its influence on the benefit of host microbe symbiosis of *Terminalia arjuna* species. *Bulletin of the National Research Centre, 47*(89), 1-13.https://doi.org/10.1186/s42269-023-01048-3

Bhardwaj, A.K., Chandra, K.K., Kumar, R. (2024). Inoculants of Arbuscular Mycorrhizal Fungi Influence Growth and Biomass of *Terminalia arjuna* under Amendment and AnamendmentEntisol. *Mycobiology, 52* (3), 183-190.

Braghiroli, F.L., Passarini, L. (2020).Valorization of biomass residues from forest operations and wood manufacturing presents a wide range of sustainable and innovative possibilities. *Curr For Rep., 6*, 172–183

Bruns, A. (2017). Tweeting to save the furniture: the 2013 Australian election campaign on Twitter. *Media Int Aust., 162*:49–64

Cai, Z., Rudie, A.W., Stark, N.M., Sabo, R.C., Ralph, S.A. (2013) New products and product categories in the global forest sector. The global forest sector: changes, practices, and prospects. CRC Press, Boca Raton, pp 129–150

Carpio, M., Zamorano, M., Costa, M. (2013). Impact of using biomass boilers on the energy rating and CO_2 emissions of Iberian Peninsula residential buildings. *Energy Build, 66*:732–744

Chalker-Scott, L. (2007). Impact of mulches on landscape plants and the environment—a review. *J Environ Hortic., 25*:239–249

Chandra, K.K., Kumar R.,&Baretha, G. (2021). Vandalism: A Review for Potential

Solutions. Tree Benefits in Urban Environment and Incidences of Tree. (Eds. Bhadouria R., Singh P., Upadhyay S., Tripathi S.), John Wiley & Sons, Inc., Hoboken, NJ, USA.

Chandra, K.K., Kumar, R., Dixit, B., Nayak,P.P., Bhardwaj, A.K., &Pandey, S.K. (2024). Analyzing the Contribution of Moringa oleifera (Lam.) to the CO Stock and Other Advantages for Urban Residents. *International Journal of Plant & Soil Science, 36* (10), 305-317.

Charis, G., Danha, G., Muzenda, E. (2019). A review of timber waste utilization: challenges and opportunities in Zimbabwe. *Procedia Manuf, 35*:419–429

Darro, H., Swamy, S. L., Kumar, R., & Bhardwaj, A. K. (2022). Comparison of Physico-chemical Properties of Soils under different forest types in dry tropical Forest rcosystem in Achanakmar-Amarkantak Biosphere Reserve, India. *Eco. Env. & Cons. 28*, S163-S169*.*

Davids, W.G., Willey, N., Lopez-Anido, R., Shaler, S., Gardner, D., Edgar, R., Tajvidi, M. (2017). Structural performance of hybrid SPFs-LSL cross-laminated timber panels. *Constr Build Mater., 149*, 156–163

Demirbas, A. (2009). Reuse of wood wastes for energy generation. *Energy Sources A, 31*, 1687–1693

DFRS, (2015). State of Nepal's forests, Forest Resource Assessment (FRA) Nepal. Department of Forest Research and Survey (DFRS), Kathmandu

Dionco-Adetayo, E.A. (2001). Utilization of wood wastes in Nigeria: a feasibility overview. Technovation 21, 55–60.

Edo, M., Björn, E., Persson, P.E., Jansson, S. (2016). Assessment of chemical and material contamination in waste wood fuels—a case study ranging over nine years. *Waste Manag, 49*, 311–319

Eshun, J.F., Potting, J., &Leemans, R. (2012). Wood waste minimization in the timber sector of Ghana: a systems approach to reduce environmental impact. *J Clean Prod., 26*, 67–78

Eshun, J.F., Potting, J.,& Leemans, R. (2011). LCA of the timber sector in Ghana: preliminary life cycle impact assessment (LCIA). *Int J Life Cycle Assess,16*, 625–638

FAO, (2002). An overview of forest products statistics in south and southeast Asia. In: Ma, Q., Broadhead, J.S., (eds) Information and analysis for sustainable forest management: linking national and international efforts in south and southeast Asia. Bangkok, Thailand, pp 136–150

Garcia, C.A.,& Hora, G. (2017) State-of-the-art of waste wood supply chain in Germany and selected European countries. *Waste Manag., 70*:189–197

Goetzl, A. (2015). Developments in the global trade of wood pellets. US International Trade Commission, Washington.

Hill, C., Norton, A., Kutnar, A. (2015). Environmental impacts of wood composites and legislative obligations. In: Wood composites. Woodhead Publishing, Sawston, pp 311–333.

Hiramatsu, Y., Tsunetsugu, Y., Karube, M., Tonosaki, M., Fujii, T. (2002). Present state of wood waste recycling and a new process for converting wood waste into reusable wood materials. *Mater Trans., 43*, 332–339.

Kanel, K.R., Shrestha, K., Tuladhar, A.R., &Regmi,M.R.(2012) A study on the demand and supply of wood products in different regions of Nepal. Nepal Foresters Association, Babarmahal, Kathmandu, Nepal.

Kumar, A., Adamopoulos, S., Jones, D., &Amiandamhen, S.O. (2021). Forest biomass availability and utilization potential in sweden: a review. *Waste Biomass Valoriz, 12*, 65–80

Kumar, R., Bhardwaj, A. K., Chandra, K. K., Dixit, B., & Singh, A.K. (2024). Diverse role of mycorrhiza in plant growth and development: Review.*Solovyov Studies ISPU,72*(2), 37-61.

Kumar, R., Bhardwaj, A. K.,& Chandra, K. K. (2023). Effects of arbuscular mycorrhizal fungi on the germination of *Terminalia arjuna* plants grown in fly ash under nursery conditions. Forestist, 74, 142-146. DOI:10.5152/forestist.2023.23015

Kumar, R., Bhardwaj, A.K., & Chandra, K.K. (2022a). A Review on Agroforestry Practices for Improving Socioeconomic and Environmental Status. *Indian Forester, 148*(5), 474-478.

Kumar, R., Ramchandra, Bhardwaj, A.K. & Chandra, K.K. (2022b). Impacts of varying nitrogen levels on leaf length of onion varieties under poplar based agroforestry system.*The Indian Forestor, 148*(12), 1241-1244.

Li, J., Zhang, H., Duan, C., Liu, Y., Ni, Y. (2015). Enhancing hemicelluloses removal from a softwood sulfite pulp. *Bioresour Technol., 192*:11–16.

Limanpure, Y., & Kumar, R. (2018). Effect of Different Levels of Inorganic Fertilizers on the Growth and Yield of Barley (*Hordeumvulgare .L)* Under Teak (*Tectonagrandis*) Based Agrisilviculture System. *Trends in Biosciences, 11*(6), 881-886.

Loehnertz, S.P., Cooz, I.V.,& Guerrero, J. (1994). Sawing Hardwoods in Five Tropical Countries. Res. Note FPL-RN-0262. United States Department of Agriculture, Forest Services, Forest Products Laboratory, Madison, USA

Lykidis, C. & Grigoriou, A. (2008). Hydrothermal recycling of waste and performance of the recycled wooden particleboards. *Waste Manag., 28*, 57–63.

Magin, G. (2001). An introduction to wood waste in the UK. Fauna & Flora International, Cambridge, United Kingdom.

Manninen, K., Judl, J.,&Myllymaa, T. (2015). Life cycle environmental impacts of different construction wood waste and wood packaging waste processing methods. Ministry of the Environment – Environment Protection Department, Helsinki, Finland.

Murphy, J.A., Smith, P.M., &Wiedenbeck, J. (2007). Wood residue utilization in Pennsylvania: 1988 vs. 2003. *For Prod J., 57*, 101–106

Owoyemi, J.M., Zakariya, H.O.,&Elegbede, I.O. (2016). Sustainable wood waste management in Nigeria. *Environ Socio-Econ Stud., 4*, 1–9

Packalen, T., Kärkkäinen, L., Toppinen, A. (2017). The future operating environment of the Finnish sawmill industry in an era of climate change mitigation policies. *For Policy Econ., 82*, 30–40

Pandey, S. (2022). Wood waste utilization and associated product development from under-utilized low-quality wood and its prospects in Nepal. SN Applied Sciences, 4(6), 168.

Pandit, B.H., Albano, A.,& Kumar, C. (2009). Community-based forest enterprises in Nepal: an analysis of their role in increasing income benefits to the poor. *Small-Scale For., 8*, 447–462

Panivivat, R., Kegley, E.B., Pennington, J.A., Kellogg, D.W.,& Krumpelman, S.L. (2004). Growth performance and health of dairy calves bedded with different types of materials. *J Dairy Sci., 87*, 3736–3745

Pavlovich, P.N.,& Pavlovna, P.G. (2020). Utilization of wood chemical production waste in wood composite materials technology. *Int J Eng Res Technol., 13*, 4843–4845

Ramage, M.H., Burridge, H.,& Busse-Wicher, M. (2017). The wood from the trees: the use of timber in construction. *Renew Sustain Energy Rev., 68*, 333–359

Routa, J., Anttila, P., &Asikainen, A. (2017). Wood extractives of Finnish pine, spruce and birch—availability and optimal sources of compounds: a literature review. Luonnonvarakeskus, Luke.

Saal, U., Weimar, H.,&Mantau, U. (2019). Wood processing residues. Advances in biochemical engineering/biotechnology. Springer, Cham, pp 27–41

Salari, A., Tabarsa, T., Khazaeian, A.,&Saraeian, A. (2013). Improving some of applied properties of oriented strand board (OSB) made from underutilized low quality paulownia (*Paulownia fortunie*) wood employing nano-SiO_2. *Ind Crops Prod, 42*, 1–9

Sánchez, E.A., Pasache, M.B.,& García, M.E. (2014). Development of briquettes from waste wood (sawdust) for use in low-income households in Piura, Peru. In: Proceedings of the world congress on engineering.

Shin, D., Curtis, M., Huisingh, D., Zwetsloot, G.I. (2008). Development of a sustainability policy model for promoting cleaner production: a knowledge integration approach. *J Clean Prod., 16*, 1823–1837.

Soni, P., Kumar, R., Singh B., Sahu, C., Netam, G., Chetan, S., Mogale, P., Raman, C., Khandekar, H., Bargah, A.S.,& Vaishnav, A.K. (2025). Exploring Certification Pathways for Non-Wood Forest Products: A Study of Opportunities and Challenges. *Journal of Scientific Research and Reports,31* (7), 103-11. https://doi.org/10.9734/jsrr/2025/v31i73232.

Stark, N.M., Cai, Z. & Carll, C. (2010). Wood-based composite materials: panel products, glued-laminated timber, structural composite lumber, and wood-nonwood composite materials. U.S. Department of Agriculture, Forest Service, Forest Products Laboratory, Madison.

Steierer, F. (2007). Wood energy in Europe and North America: a new estimate of volumes and flows. *World Sustain Energy Days, 1*, 1–14

Tiwari, R.K.S., Chandra, K.K., Kumar, R., Bhardwaj, A.K., Pandey, S.K., & Dixit, B. (2024).Microbial Biopesticides: An Ecofriendly Plant Protection Measures. *Environment and Ecology, 42* (4), 1590-1598.

Vaishnav, A.K., Kumar, R., Khandekar, H., &Bargah, A.S. (2025). Sericulture: A Dynamic Contribution of the Indian Nation. *International Journal of Agriculture Sciences*, *17*(1), 13317-13321

Van Benthem, M., Leek, N., Mantau, U. & Weimar, H. (2007). Markets for recovered wood in Europe; case studies for the Netherlands and Germany based on the BioXchange project. In: Proceedings of 3rd European COST E31 Conference. p 1–12.

Williamson, T.G. (2002). APA engineered wood handbook. McGraw-Hill, New York, USA.

Yang, X., You, Z., Dai, Q.,& Mills-Beale, J. (2014). Mechanical performance of asphalt mixtures modified by bio-oils derived from waste wood resources. *Constr Build Mater, 51*, 424–431

Zeng, N., King, A.W., Zaitchik, B., Wullschleger, S.D., Gregg, J., Wang, S., Kirk-Davidoff, D. (2013). Carbon sequestration via wood harvest and storage: an assessment of its harvest potential. *Clim Change, 118*, 245–257

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