



Forest-based employment research: Taking stock and looking ahead

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ABSTRACT

The labour market in the forest-based sector sits at the intersection of three pressing challenges: demographic changes, deficits regarding *decent* work, and climate vulnerability. These challenges are further exacerbated by the demands of intensified resource use and global conservation pledges. Given the diversity of labour markets in the forest-based sector worldwide, policy strategies to tackle long-standing challenges can vary by context. A state-of-the-art overview of forest-based employment research is thus a prerequisite for advancing knowledge and informing policy decisions. The Special Issue on “Forest-based employment research: Taking stock and looking ahead” addresses this need. This introductory commentary provides an overview of key thematic areas of research in forest-based employment and examines in detail the main topics of the 29 articles included in this collection, which showcase current perspectives on the forest-sector workforce from multiple angles. Based on these articles, seven overarching themes of contemporary research on forest-based employment have been identified: i) education, training, and skills development; ii) employment creation and its development; iii) gender equity, diversity, and inclusion in employment contexts; iv) employment in social sustainability and bioeconomy transition contexts; v) occupational safety, health, and ergonomics (OSHE); vi) institutional and policy frameworks shaping forest-sector employment; and vii) distress-driven employment. These themes reflect both well-established research areas, such as OSHE, and emerging ones including employment in relation to social sustainability and bioeconomy transitions. The commentary concludes with key findings that highlight emerging challenges and potential pathways for policy and practice, followed by setting future priorities for research on forest-based employment.

1. Introduction

“Forestry is not about trees; it is about people. And it is about trees only insofar as they serve people's needs”. The note by Westoby (1987) reflects our understanding of forest-based employment research and sets the scene for this collection. Managing forests requires consideration for people, including those employed in the sector.

Forests and other tree-based systems are indispensable for sustaining livelihoods across the globe (Razafindratsima et al., 2021). They play a vital role in national economies and sustainable development by generating employment, creating social and economic value, and maintaining ecosystem services (FAO, 2025). The forest sector is also central to the transition to a sustainable bioeconomy, supplying renewable biological resources and bio-based products that contribute to societal well-being (Jonsson et al., 2021a). Accordingly, forests feature on various policy agendas addressing climate change mitigation, biodiversity conservation, and the provision of renewable materials in a circular bioeconomy (Jonsson et al., 2021; Lawrence et al., 2022; Moomaw et al., 2020). However, efforts to advance the sustainable and resilient forest sector have traditionally focused on biodiversity

conservation and habitat protection, as well as the provision of wood resources (Priebe et al., 2024). Recent international policy has similarly prioritised the global environmental benefits of forests, often overlooking their socio-economic contributions (Djenontin et al., 2024). Research on forest-based value creation has likewise focused primarily on economic dimensions, despite some notable community-based approaches (Rusanen et al., 2024). As a result, the societal aspects and human dimension have often remained marginal in policy and scientific debates (Priebe et al., 2024), highlighting the need for greater attention, particularly to people employed in this sector.

Forest-based employment spans a continuum from extraction, conservation and manufacturing jobs to household-level economic activities and represents one of the key socioeconomic benefits derived from forests and their associated value chains (Lippe et al., 2022). The forest sector employed at least 42 million people worldwide as their main jobs in 2022, accounting for approximately 1.2% of the global labour force (Lippe et al., 2026). While this proportion may appear relatively small, it does matter given the sector's broader social and economic implications, especially in rural areas where income-generating opportunities are often limited (Arce, 2019). At the same time, the growing complexity of

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sustainable forest management itself is intricately linked to labour and workforce dynamics, as highlighted by Doimo et al. (2024) and Priebe et al. (2024). In particular, Lewark (2022) synthesised decades of research on forest work science in tropical forests, demonstrating that the sustainability of forest management depends not only on ecological and economic performance, but also on people and their work, which are fundamental components. Thus, achieving sustainable transformation and meeting environmental commitments hinges on a sufficient labour supply and an appropriately skilled and fairly treated workforce to address competing demands at multiple levels (Kniivilä et al., 2024; Lewark, 2022; United Nations Economic Commission for Europe, 2025). Although increasing demand for forest products and commitments towards restoring millions of hectares of degraded and deforested areas are likely to create new employment opportunities, the workforce faces mounting challenges that vary substantially across countries and regions (Kniivilä et al., 2024). This disparity underscores a critical gap between policy ambitions and labour market realities.

Particularly in developed economies, the forest sector struggles with skilled labour shortages and retention challenges, as younger generations increasingly move away from forestry careers in favour of urban employment opportunities (Belval et al., 2024; Lee and Kim, 2026; Owuor et al., 2021; Šporčić et al., 2023). Further challenges arise from an ageing workforce and an insufficient number of new entrants to replace retiring workers, raising concerns about knowledge transfer and long-term workforce sustainability (Korhonen et al., 2024a; Kurokawa, 2023; UNECE and FAO, 2020). In developing economies, conversely, different but equally pressing challenges predominate as informal employment is widespread, and workers lack access to social protection, fair wages, safe working conditions and relevant training (Cui et al., 2022; ILO, 2019; Lippe et al., 2023; Runacres, 2021; Ssanyu and Mubiru, 2021). Across socioeconomic regions, mechanisation and technological change are transforming job profiles, reducing demand for manual labour while creating new requirements for technical and digital skills (Bettinger and Merry, 2017; Kniivilä et al., 2024). Despite some improvements over the past decades, job quality in the forest sector remains a challenge (FAO et al., 2023; Owuor et al., 2021). Simultaneously, gender inequality and gaps in diversity remain pervasive (Baruah and Biskupski-Mujanovic, 2023; Korhonen et al., 2024b; Sjölie et al., 2024; Ville et al., 2023). Women are often excluded from formal forest-based employment or not genuinely included in decision-making despite their substantial contributions (Cui et al., 2022; ILO, 2019; Ota et al., 2024). Climate change adds another layer of complexity, increasing health risks associated with extreme weather conditions (Achuthan et al., 2020; Kniivilä et al., 2024; Lewark, 2022). While the multifunctionality of forests underpins healthy economies and societies, the forest sector labour market sits at the intersection of three pressing issues: demographic shifts, decent work deficits, and climate vulnerability, which can be exacerbated by demands of sustainable resource use intensification and global conservation pledges.

Given the distinct labour markets in the forest-based sector worldwide, policy strategies to tackle the long-standing challenges can vary by context. As part of social science research on forests, a curated body of forest-based employment literature is thus a prerequisite for advancing knowledge and informing policy. This Special Issue (SI) responds to this need by compiling current perspectives on the forest-sector workforce from multiple angles, thereby consolidating these diverse insights into a single, thematically aligned platform. Specifically, the SI aims to answer what we collectively understand about forest-sector employment and identify the key research priorities for moving forward. The 29 articles in this collection bring together academics, researchers, and practitioners, offering new empirical and conceptual insights into the current state of forest-based employment and its development across economies and regions. Taking stock of relevant studies from various geographic and analytical levels further offers a lens for recognising knowledge gaps and future trends in this field of research.

This commentary opens with an overview of the key thematic

research areas over the past decade. Subsequently, we delve into the focus and scope of the contributions to this SI. We then draw key implications from those studies and assess potential research priorities for forest-based employment from a forward-looking perspective.

2. Previous research on forest-based employment: thematic areas 2015–2024

This section maps the key thematic areas of forest-based employment research preceding this SI. It thus provides for a rough baseline on the state of the art on key thematic areas in the field of forest work sciences and forest-based employment. This brief overview is synthesised from a SCOPUS search using a set of search strings and terms related to employment in the forest sector, along with an additional review of the journal *Forest Policy and Economics* (see further details in the Supplementary Material). The search encompasses all peer-reviewed and book contributions published in English between 2015 and 2024. This time span was selected to capture the most recent developments in research on forest work sciences and forest-based employment prior to the collection of the Special Issue. The screening of titles, keywords, and abstracts was conducted to include only publications relevant to forest-based employment. Following this process, and after removing duplicates, a total of 355 publications were retained for mapping research themes. The key thematic contributions of research on forest-based employment over the past decade are centred around the themes illustrated in Fig. 1.

Occupational safety, health, and ergonomics (OSHE) emerge as a predominant theme in research on forest-based employment. Studies frequently evaluate the physical workload and musculoskeletal symptoms experienced by workers (Eroğlu et al., 2015; Okuda et al., 2023; Tsioras et al., 2022). Existing research also continuously documents a high rate of fatal and non-fatal occupational accidents (Akay et al., 2023; Ghaffariyan, 2016; Nowakowska and Pajęcki, 2024). Furthermore, research highlights exposure to heat stress, knowledge and precautionary behaviour (Achuthan et al., 2020; Permatasari et al., 2024; Rother et al., 2020; Yovi et al., 2023), biological hazards (Olivieri et al., 2023; Ricciardi et al., 2021), and chemical and physical hazards, such as wood dust, noise, and hand-arm vibration from machinery (Borz et al., 2024; Dimou et al., 2020; Neri et al., 2016; Tas and Akay, 2022). Beyond physical strain, research examines cognitive fatigue resulting from long hours, fast-paced work, and limited breaks, which significantly contribute to workplace incidents (Hinze et al., 2021; König et al., 2023). Job insecurity, production pressures, and isolation also negatively impact the mental health and overall subjective well-being of forestry professionals (Arman et al., 2022; Lotfalian et al., 2017).

The **employment creation and its development** thematic area constitutes a significant proportion of the literature. This strand of research explores several aspects, ranging from the forest's contributions to employment (Gore et al., 2023; Jolley et al., 2020; Li et al., 2019; Ng'andwe et al., 2015; Rahman et al., 2024; Toth et al., 2019) and trends (Apsalyamova et al., 2017; Whiteman et al., 2015) to challenges such as the workforce demographic shifts and labour migration (Daheur, 2024; Erkan Bugday and Özden, 2017; Kurokawa, 2023), labour shortages and retention (Belval et al., 2024; Jurjonas et al., 2023; Mihály and Földes, 2023; Šporčić et al., 2024). The impacts of socio-economic conditions and shocks, such as the COVID-19 pandemic, on forest-based employment and enterprises have been examined (Bourassa-Viau et al., 2022; Chizmar et al., 2024; Jayasundara et al., 2024; Laudari et al., 2021; Munyemana et al., 2024). Furthermore, there is a growing body of literature addressing forest-sector employment within the broader context of the bioeconomy transition and social sustainability (Clement et al., 2024; Langridge and White, 2024; Perunova and Zimmermannová, 2022; Robert et al., 2020).

The **socio-economic importance of non-timber forest products (NTFPs)**, particularly in the employment context, is often embedded in studies of rural household livelihoods and NTFP commercialisation.

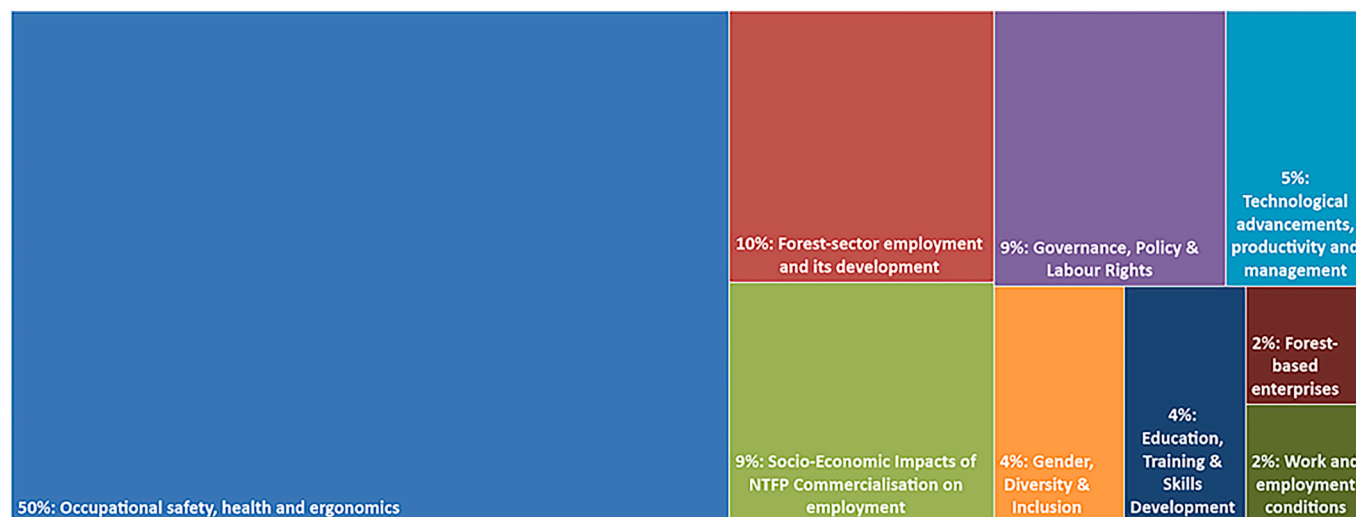


Fig. 1. Key thematic areas of forest-based employment research in the Scopus database and Forest Policy and Economics journal referring to peer-reviewed and book contributions in English between 2015 and 2024.

Note: NTFPs denote non-timber forest products.

Under this theme, scholars discussed NTFPs as a source of job creation (Asamoah et al., 2024; Astutik et al., 2023; Awono et al., 2016; Hazari et al., 2023; Pant, 2015; Tambe et al., 2020) and as a critical buffer that absorbs displaced workers during economic or climatic instability (Mulungu, 2024). Studies further address the structure of NTFPs employment, which is frequently stratified by gender. Women dominate low-paid harvesting and retail processing but remain underrepresented in higher-value wholesale or processing nodes, reinforcing existing social inequalities (Asamoah et al., 2024; Carter and Smith, 2017; Hazari et al., 2024). Despite its social and economic importance, scholars also delve into the aspects of life-threatening physical risks of NTFP collectors (Dunphy et al., 2024) and the prevalence of child labour, especially in highly impoverished forest-proximate communities (Zubair et al., 2019).

The next theme highlights how **institutional and policy frameworks**, including organisational arrangements, shape the forest-sector workforce and employment conditions. Research within this theme addresses multiple dimensions of employment, including job creation and labour absorption through forest community initiatives, forest protection programs, forest-product trade policies, and investment in locally controlled forestry (Eric McConnell et al., 2019; Eric McConnell and Altizer, 2019; Kang et al., 2021; Macqueen and de Marsh, 2015; Yu et al., 2024). A further focus concerns labour market transitions and employment reallocation resulting from environmental policies, such as logging bans, ecological restoration programs, and economic shifts that alter labour allocation or create new roles (Chen et al., 2022; Gazal and Arano, 2021; Geng et al., 2021; Li et al., 2021; Zhu et al., 2022). Studies also explore governance structures and organisational dynamics, particularly within public forestry institutions, highlighting tensions between social employment objectives, operational efficiency, and community participation (Fagarazzi et al., 2021; Piabuo, 2022). Another key strand investigates labour rights, including wage enforcement for migrant workers, the implementation of occupational health and safety regulations, and the role of certification standards in promoting worker protection, training, and fair wages (Bruzeliuss and Seeleib-Kaiser, 2023; Di Lallo et al., 2016; Inanç and Ağyürek, 2019; Sen and Genç, 2018; Sen and Genç, 2017; Sen and Güngör, 2019).

Technological advancements, productivity and management have also received scholarly attention. This theme focuses on advanced mechanisation and automation to offset rising labour costs (Bont et al., 2024; Kaakkurivaara and Stampfer, 2018) or to improve worker efficiency (Kaakkurivaara and Stampfer, 2018; Khoza et al., 2024), while

reducing physical strain and proactively monitoring workers' safety and health (Hinze et al., 2022; Knobloch et al., 2024). In connection with complex technologies and workforce development, attention has been directed towards research on **education, training, and skills development**. Bettinger et al. (2016) and Bettinger and Merry (2017) assess the importance of technology knowledge and skills for forestry jobs. Several studies emphasise how to design effective training programs and training personnel (Kirillov et al., 2022; Lingua et al., 2019; Soucy et al., 2016; Tsioras, 2017; Tsioras, 2015), and identify best practices to advance innovation in forest education (Rodríguez-Piñeros et al., 2020). At the same time, research on workforce capacity underscores a mismatch between educational outcomes and labour market requirements (Kirillov et al., 2022; Topuzi et al., 2021). Another critical strand that has garnered scholarly attention concerns how forestry education is perceived, accessed, and improved to attract diverse and sufficient participation (Arevalo et al., 2012; Larasatie et al., 2024; Oluwajuwon et al., 2023), and what explains student motivations for forest-related education and career pathways for nature and biodiversity conservation (Owuor et al., 2023).

Gender equity, diversity, and inclusion (GEDI) in employment contexts address the trajectory of women's ascent into leadership roles within the forest sector, the strategies used to retain them, and the organisational benefits of diverse management (Hartshorn et al., 2023), including adverse effects that can be harmful for women's livelihoods if they are not genuinely included in decision-making (Ota et al., 2024). Research by Strelnyk et al. (2024) also highlighted the experiences of women who were marginalised in forest research discourse and fieldwork, as well as difficulties in reconciling their roles as wives, mothers and academics. Further relevant focuses under this theme are intersectional barriers faced by indigenous women in natural resource industries (Baruah and Biskupski-Mujanovic, 2023) and the quantitative tracking of diversity and data insufficiencies (Korhonen et al., 2024b). The bright side of studies explored rural women transitioning from agriculture to forest-based industries (Ling et al., 2024) and how mechanisation or technologies equalise physically demanding work (Zhu et al., 2020), as well as opportunities for young women with unprecedented opportunities for paid work in forestry and personal freedom (Östlund et al., 2020).

A further identified theme is associated with the thematic areas of **forest-based enterprises**, in which literature examines their contribution to job creation and enterprise formalisation (Anane et al., 2023; Dumenu et al., 2023). Another focus is on how community forest

enterprises structure their workforce and balance their social responsibility principles with operational efficiency (Butler and Current, 2022; Cherchyk et al., 2023; Engbring and Hajjar, 2021; Humphries et al., 2020). Other relevant themes include job quality, such as healthcare access (Boal et al., 2022), precarious wage (Runacres, 2021; Toupin et al., 2007), as well as experiences of workplace violence (Cvenkel, 2020a, 2020b), labour informality (Dumenu et al., 2023; Lippe et al., 2023) and forest-sector employment data (Korhonen et al., 2024b; Lippe et al., 2021; Morales Olmos, 2022).

The evidence from the reviewed studies over the past decade indicates a growing body of research on forest-sector employment spanning a broad spectrum of thematic concentrations. Nonetheless, several dimensions remain underexplored or fragmented, underscoring significant room for comprehensive, interdisciplinary research in this field, given global commitments to sustainability transformation and demographic shifts.

3. Advancing the state of the art on forest-based employment: thematic contributions to this special issue

The 29 articles in this SI respond to the literature gaps by covering a diverse array of economic activities in forests and tree-based systems, including forestry, wood and non-wood forest products, mangroves, and rubber plantations. Geographical coverage spans across continents, including Africa, Asia, Europe, North America, and South America, as well as two cross-country studies (Fig. 2) and one global study. Methodologically, most studies in this collection are empirical, alongside two systematic literature reviews and two commentaries. Together, seven overarching thematic areas can be discerned (Fig. 3). While the previously discussed themes remain relevant, there is a clear evolutionary shift in this field of research. The current SI thus reflects a deeper engagement with education, training, and skill development; GEDI in

employment contexts, forest-sector employment in contexts of social sustainability and bioeconomy transition; and the realities of distress-driven informal labour.

3.1. Theme 1: Education, training, and skills development

The following six studies collectively provide evidence-based findings for reversing workforce demographic challenges and bridging the labour supply and demand within the rapidly transforming forest and natural resources sector.

Chamlagain et al. (2025) investigate the preparedness perceptions of university students entering the US forest and related natural resources workforce (FNR). Employing survey data and perceived fit theory, findings reveal a disconnect between Generation Z students, who rated their highest competency development as “analysis, synthesis, and critical skills,” and Generation X recruiters, who placed significantly greater importance on “responsibility and perseverance” competency. Notably, the study revealed a paradoxical negative correlation between lifelong learning competencies and perceived preparedness, suggesting that as students learn more, they increasingly realise how much more they need to know, which diminishes their feeling of readiness. Crucially, the data showed that women, individuals with other gender identities, and students of colour felt significantly less prepared to enter the workforce compared to their peers. The authors attribute this disparity to a pervasive lack of a “sense of belonging” and potential imposter syndrome within a historically white, male-dominated sector. Leaders of the FNR program could facilitate chances for students to articulate their experiences of belonging through mentorship or networking based on shared social identities or life stages.

Owuor et al. (2025) examine the alignment between the skills of recent forest science graduates and the evolving demands of the global forest sector by comparing employers' and graduates' perceptions across five countries. Drawing on the Work-Readiness Integrated Competence Model, the study reveals that while employers are satisfied with graduates' traditional, job-specific technical skills, they anticipate a significant shift towards emerging aspects of the job, specific dimensions such as restoration, climate change and carbon sequestration. Both employers and graduates agree that non-technical competencies, specifically meta-skills like communication and IT, alongside intellectual and personality resources such as problem-solving and self-management, will become increasingly critical for future workforce readiness. Furthermore, graduates reported that current curricula should sufficiently address topics related to forest policy, legislation, and economics. Universities may adapt their academic programs through closer, systematic cooperation with employers to ensure future foresters are equipped to manage the changing societal expectations.

Wan et al. (2025) analysed the complex causal relationships between forestry, scientific, and technological talents aggregation and five factors within the talent ecosystem across 87 forestry enterprises in China's key state-owned forest areas. The study concludes that high talent concentration is achieved through the synergistic interaction of economic conditions, scientific and technological quality, work opportunities, living security, and infrastructure, which form five equivalent successful configuration pathways. Conversely, low scientific and technological quality, combined with poor living security, act as the primary barriers inhibiting talent attraction. As the aggregation and cultivation of forestry scientific and technological talent are critically important for achieving ecological protection and combating an ageing workforce and the shortage of skilled forestry management, policymakers must accelerate comprehensive improvements to the talent ecosystem, such as redefining forestry talent, improving labour relations, and developing new forestry technologies. Authorities should prioritise enhancing scientific/technological quality and living security by leveraging internal workforce potential and attracting external talent through green industries like forest therapy and tourism. Promoting balanced, tailored development strategies customised to each enterprise's unique

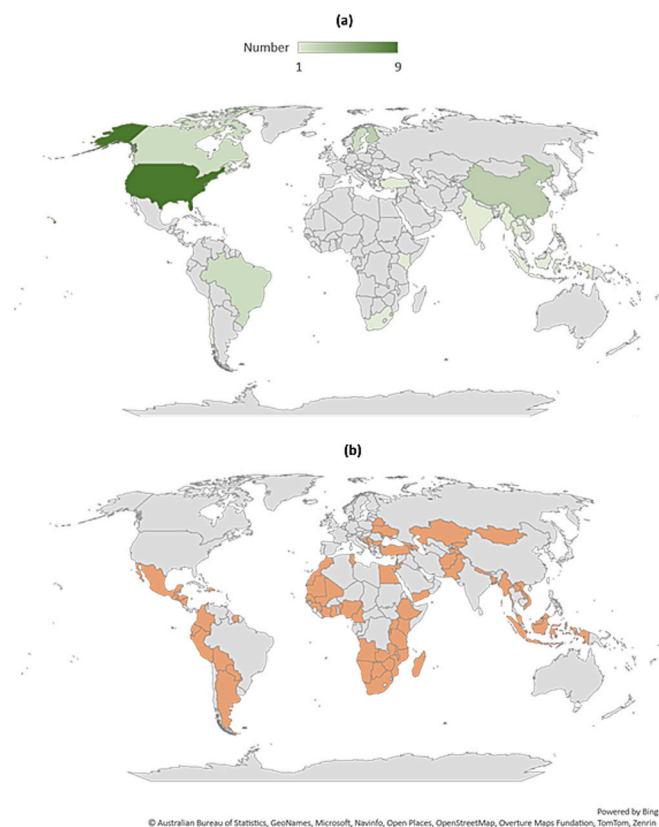


Fig. 2. a) country coverage in 28 articles and b) country coverage in one article focusing on countries across a developing and emerging economy context.

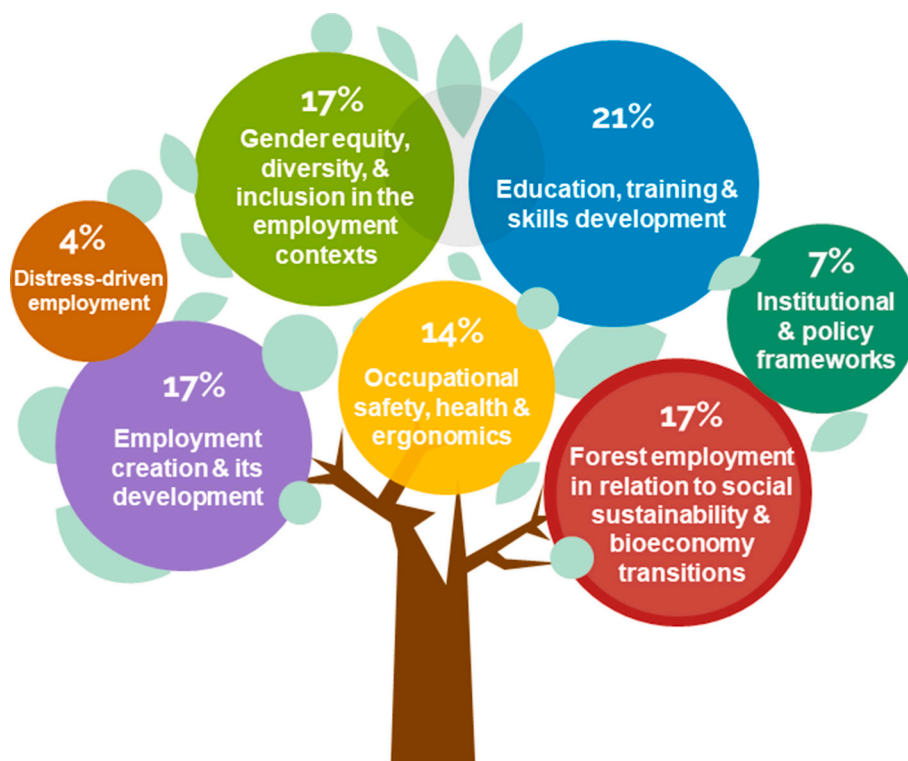


Fig. 3. Identified themes across the 29 studies curated in this Special Issue.
Source: Authors' own illustration using the Tree ppt template from [slideegg.com](https://www.slideegg.com)

geographic location, resource endowments, and economic status is further recommended.

[Lucena et al. \(2025\)](#) explore the perceived learning outcomes of a group of forest engineering students who were exposed to Problem-Based Learning (PBL) and the challenges of implementing PBL at a public university in Brazil. The findings highlight both the significant educational benefits of this method and the structural barriers to its integration. The survey results reveal that participants experienced significant, interconnected growth in technical knowledge, field experience, teamwork, and entrepreneurial capabilities such as project management and marketing. Students attributed these positive learning outcomes to immersive, hands-on field experiences, collaborative problem-solving, and peer mentorship. Despite these positive outcomes, students and researchers identified several critical challenges and areas for improvement in implementing PBL in a public university setting, including inadequate faculty training in PBL methodologies combined with insufficient financial and departmental support.

[Suryawan et al. \(2025\)](#) investigate the skills and socio-economic factors that influence local community engagement in green-blue jobs within the context of mangrove conservation in Bali, Indonesia. By surveying 500 respondents and utilising exploratory factor analysis, the authors identify three core competency models necessary for preparing communities for green-blue jobs: feasibility and stakeholder engagement; market, financing, and business development; and institutional and gender-inclusive capacity building. Involving local communities through participatory processes and equipping them with market analysis skills significantly boosts their willingness to engage in green-blue job opportunities. Furthermore, socio-demographic characteristics, including age, education, marital status, and income, play a critical role in shaping these participation outcomes. Building practical competencies, addressing structural inequalities, and tailoring interventions to local socioeconomic contexts are critical to advancing inclusive and effective mangrove conservation and sustainable green-blue employment.

Employing the knowledge, attitudes and practices framework, [Ritter](#)

[et al. \(2025\)](#) explore how forestry and natural resources (FNR) professionals across academic, government, and industry sectors perceive and utilise AI technologies. Findings indicate that while participants broadly recognise AI's potential to save time, manage heavy workloads, and supplement an increasingly strained and shrinking workforce, widespread adoption faces critical socio-technological barriers. Key obstacles identified by professionals include severe "data debt" stemming from poor data collection and stewardship, cultural resistance from experienced management, interpersonal agency competition, known as "friendly fire", and inconsistent academic policies regarding students' use of AI. The authors conclude that integrating AI effectively into the FNR sector demands a human-centric approach that ensures AI functions as a supportive tool rather than a labour replacement, alongside proactive cross-sector collaboration to establish transparent, explainable models and standardised, ethical policies.

3.2. Theme 2: Employment creation and its development

Five studies offer new empirical insights into the contributions of forests and forest products to employment using existing large-scale databases, such as IMPLAN data and the Labour Force Survey in the U.S and India. These provide a comprehensive, macro-level view of the forest sector's total economic contribution and employment transformation.

Utilising IMPLAN input-output modelling across four major geographic regions, [Poudel and Dahal \(2025\)](#) assess the economic performance of the U.S. forest products industry in 2022, comparing it with pre-COVID-19 conditions. Findings indicate that the forest products industry demonstrated significant resilience and positive economic performance. Despite a marginal 0.27% decline in direct jobs, the sector experienced substantial growth in gross output and labour income, alongside a 14.46% increase in total value-added. However, the pandemic's impact was uneven across subsectors. Capital-intensive areas such as sawmills, paper mills, and paperboard container manufacturing saw massive gains in value added, whereas sectors such as pulp mills,

stationery products, and wood office furniture manufacturing experienced declines. The study underscores the industry's critical role as an economic driver, while highlighting the need for targeted support and intervention to aid the recovery of the small-scale sectors.

Crandall et al. (2025) scrutinise how industrial geographies of the timber sector in the U.S. Pacific Northwest have shifted over the past 50 years with attention to outcomes in rural areas. Analysing decades of harvest, employment, and mill capacity data in the 1990s Northwest Forest Plan and broader industry consolidation, the authors identified a growing spatial division. While timber extraction remains heavily concentrated in rural areas, processing infrastructure and manufacturing jobs have increasingly agglomerated in urban and urbanising counties, favouring larger mills closer to private timberlands and major transportation networks. Consequently, rural counties have suffered the steepest declines in harvest volumes and mill numbers, yet they remain disproportionately economically dependent on the forestry sector. Spatial reconfigurations are driven as much by capitalist political economy as by environmental regulations, raising significant questions about the feasibility of the social contract and the adequacy of the workforce and infrastructure required to support restoration, climate change adaptation and wildfire-risk-reduction activities on federal forestlands.

Lamsal et al. (2025) evaluate the far-reaching economic consequences of sawmill entries and exits in the state of Michigan, US, between 2019 and 2023. Utilising employment data from the Michigan Department of Natural Resources and a Social Accounting Matrix (SAM) with IMPLAN input-output modelling, the authors found that a net loss of 273 direct sawmill jobs triggered a much larger cumulative economic decline, resulting in the loss of approximately 820 total jobs and 211.5 USD million in economic output. Nearly two-thirds of job losses occurred outside the mills, indicating that sawmills serve as critical economic anchors in rural, forest-dependent regions. These closures heavily impacted labour-intensive upstream sectors, such as commercial logging and transportation, as well as downstream and service sectors, including wholesale trade, real estate, and healthcare. The study offers a framework for anticipating and mitigating the cascading effects of industrial changes. It highlights the need for coordinated efforts, such as workforce retraining, investments in value-added processing and integration with local supplier networks to enhance economic resilience.

IMPLAN data also provide valuable insights into the economic importance of non-timber forest products (NTFPs). Thapa et al. (2025) assess the potential economic impacts of establishing a commercial maple syrup industry in the state of Kentucky, U.S and explore the viability of expanding production beyond traditional north-eastern and midwestern regions. Utilising IMPLAN input-output modelling, the authors evaluated the direct, indirect, and induced economic ripple effects across low, medium, and high production scenarios, assuming a projected producer price of 9.48 USD per litre. The findings reveal that at its highest potential production level, a Kentucky maple syrup industry could support up to 1356 jobs, contribute 11.5 USD million in value-added, and generate 25.1 USD million in total economic output. Even at the lowest projected capacity, the industry could create 336 jobs and 6.2 USD million in total output. While the analysis suggests the nascent industry might initially require government subsidies, evidenced by negative direct tax contributions, the overall tax revenue impact would ultimately be positive due to robust indirect and induced economic activities. Non-timber forest product could thus serve as a valuable niche for diversifying Kentucky's rural economy, providing viable supplementary income for woodland owners, and fostering long-term agricultural resilience.

Using unit-level data from the Periodic Labour Force Survey (PLFS) from 2017 to 2023, Sharma and Thoudam (2025) examine recent employment trends in India's forestry and logging sector. The findings reveal consistent employment growth in the sector, characterised by a massive surge in the number of female workers entering segments such as gathering firewood and tendu leaves, as well as growing and

maintaining nurseries. Overall, the sector is characterised by a high degree of informality, with approximately 80% of jobs classified as self-employed or casual labour. Employment in the Indian forestry sector is determined by strong economic fundamentals, social expenditure, rural unemployment, rural illiteracy rate and poverty. In this case, forestry employment must be more than a mere safety net or gap fillers, but rather needs to serve as a 'sunrise sector'. Specifically, there is an urgent need to shift towards the structural transformation of forest employment by investing in afforestation and silviculture. Furthermore, fuel questions have to be addressed, with a time-bound shift from firewood to clean fuel. Extending robust social security measures to informal workers and improving market access of NTFPs will help realise the full potential of the forestry sector in generating sustainable and productive employment.

3.3. Theme 3: Gender Equity, Diversity, and Inclusion (GEDI) in employment contexts

Four studies on this theme highlight that the forest sector remains highly gender-segregated, with a gap between high-level policy commitments and on-the-ground reality. Despite these barriers, areas of progress and successful interventions, such as growing grassroots awareness and collaborative action, as well as targeted economic empowerment and capacity building, are highlighted across studies.

Korhonen et al. (2025) provide novel insights into current perceptions of and future aspirations for the inclusion of women in the forest and natural resource sector. Employing a World Café-style participatory workshop at the 2022 Women's Forest Congress, responses and reflections from 60 women, predominantly from the US and Canada, were gathered and analysed through the cultural dimension theory. The analysis identified 17 community-desired areas of change, with justice, equity, diversity, inclusion, and access (JEDIA), and work policy emerging as the most critical and interconnected themes driving cultural transformation. Participants highlighted systemic barriers, such as unequal power dynamics, inadequate safety measures, and a persistently masculine work culture, while calling for actionable improvements, including open communication across all organisational levels, prioritisation of holistic health and well-being, and strict accountability in leadership and hiring practices. Fostering a genuinely inclusive forest sector requires systematic, multi-level organisational efforts that go beyond merely achieving diverse representation to actively dismantle exclusionary norms and ensure equitable, as well as decent work conditions for all.

Colonna et al. (2025) explore practical strategies to promote gender equality and women's economic empowerment in Southeast Asia's small-scale wood-processing sector. Drawing on field experiences from the European Forest Institute's Forest Smallholders Project (2018–2023) across Lao PDR, Myanmar, Thailand, and Viet Nam, the authors outline three effective strategies targeted at micro, small, and medium enterprises. These strategies include conducting targeted capacity-building through technical training and tailored mentoring, enhancing public engagement to amplify women's voices and foster cross-sector collaboration, and developing inclusive value chains, such as upcycling reclaimed timber and wood waste, to create leadership opportunities for women. The study indicates that while all three approaches successfully improve women's access to decent work in this traditionally male-dominated industry, their scalability heavily depends on local contexts, resource availability, and the active engagement of local authorities and nationally relevant partners. Combining gender sensitisation with technical skills development, leadership training, and tangible economic opportunities is more likely to be a transformative pathway to narrowing gender gaps in rural forest-based economies.

Boakye-Danquah et al. (2025) explore Canada's progress in building a diverse and equitable forestry labour force by using proxies to examine employment opportunities and the representation of three equity-denied groups: women, Indigenous Peoples, and immigrants. The findings

reveal that progress remains extremely slow, uneven, and highly segmented. Despite high-level commitments to equity, diversity and inclusion (EDI), federal forest sector documents demonstrated little attention to these issues, aside from promoting opportunities for Indigenous workers, reflecting a broader lack of standardised EDI goals. Employment data corroborates these structural deficits: although women's participation increased slightly to 19% by 2021, they remain heavily segregated into administrative roles and face a persistent gender wage gap. Meanwhile, Indigenous workers are heavily concentrated in lower-paying, seasonal logging jobs, and immigrants are drastically underrepresented compared to the national workforce average, primarily occupying non-management manufacturing roles. The slow and uneven progress towards EDI suggests that the social goals are less prioritised, promoted or resourced. Advancing EDI in forestry requires broader ethical motivations, clear employment targets, improved intersectional data collection, and the mandate of transparent public reporting.

Andersson and Johansson (2025) investigate the change in the gendered division of labour and working experiences within the Swedish forestry sector, a decade after the launch of a national gender equality strategy. By comparing survey responses from 860 higher-education forestry graduates with data from 2011, the authors found that while overall gender segregation has slightly declined, significant vertical and horizontal segregation persists. Although women are attaining middle-management positions more quickly and their representation in forestry companies has increased, they remain largely concentrated in environmental and advisory roles, while men continue to dominate executive leadership and operational areas such as harvesting. Disparities remain deeply entrenched, with women leaving the sector at higher rates than men and reporting disproportionately high levels of gender-based discrimination and harassment. The findings suggest that future gender equality initiatives must move beyond merely increasing women's numerical representation and instead focus on deep cultural and structural reforms to dismantle the masculine norms that perpetuate workplace vulnerability and inequality.

Yurdakul Erol and Şahin (2026) discuss how international forestry and environmental frameworks alongside national gender equality and employment policy agendas shape women's employment within Türkiye's forest governance. The findings reveal a misalignment between international and national gender equality agendas, reflecting limited integration of gender mainstreaming into core forest policy, particularly regarding formal employment, leadership, and institutional transformation. Achieving meaningful gender equality in forestry requires embedding gender mainstreaming and women's empowerment in core forest policy instruments such as work-life balance initiatives and professional education. Furthermore, there is a need to institutionalise gender-responsive governance, particularly in leadership and decision-making, to promote the coherent integration of forestry, gender equality, and employment policies, and to address power imbalances for long-term institutional transformation. Structural reforms and alignment across institutional frameworks and governance mechanisms can ensure the effective translation of policy commitments into employment systems.

3.4. Theme 4: Forest-sector employment in contexts of social sustainability and bioeconomy transition

The four contributions under this theme address the critical shortfall of social sustainability and decent work within the forest sector's transition to a green economy. Three country cases alongside a global review study highlight a significant discrepancy that, while the forest sector heavily promotes its environmental and economic sustainability, the fundamental rights, safety, and well-being of its workforce are systematically overlooked or marginalised.

Alvear-Vega and Astudillo-Molina (2025) identify the social determinants that influence employment in Chile's forestry sector,

following the social dimensions of the environmental, social, and corporate governance (ESG) framework. To avoid bias from companies, the analysis is based on data from the 2022 National Socioeconomic Characterisation Survey (CASEN). Findings reveal a highly vulnerable workforce; those most likely to work in the forestry industry are predominantly male, possess lower educational levels, are often of indigenous descent, and belong to the lowest income quintiles. Furthermore, these workers are disproportionately likely to work under task-specific or fixed-term contracts for external companies, rely on public health insurance, lack internet access, and experience health and nutrition problems due to severe financial constraints. The lived reality of Chilean forestry workers falls drastically short of established ESG standards, highlighting an urgent need for companies to implement genuine social improvements to ensure equitable, decent working conditions for this marginalised labour force.

Luhás and Mikkilä (2025) explore the role of social sustainability in the forest-based bioeconomy, using Finland as a case study, through a narrative literature review and qualitative content analysis of peer-reviewed publications. Findings indicate that social sustainability exerts both supportive and conflicting effects on the forest-based bioeconomy, particularly regarding employment, welfare, and power dynamics. Policies frequently focus on future temporal scales and span various geographic levels (from local to global); there remains a significant gap between policy goals and tangible, verifiable implementation. Furthermore, the sector faces persistent challenges, including gender inequality, limited stakeholder dialogue, and a lack of comprehensive data. *"While social sustainability is recognised as an important component in the forest-based bioeconomy, there remains a significant gap between policies and tangible implementation."* To address these issues and bridge the implementation gap, the study highlights the development of standardised assessment tools, including measurable indicators, the refinement of terminology to build shared understanding, and the fostering of highly inclusive, participatory policy-making processes.

Olofsson (2025) assesses the discrepancies between Sweden's public commitments to a socially sustainable just transition and the exploitative realities within its forestry sector. By analysing the National Forest Programme and interviewing 21 industry stakeholders, findings reveal that the sustainable transition efforts in Sweden prioritise economic output and ecological goals while making essential seasonal migrant workers practically invisible in policy. Although these migrant workers perform critical manual silvicultural tasks like planting and clearing, they face severe structural disempowerment. Complex subcontracting chains, language barriers, and a lack of regulatory enforcement systematically exclude migrants from exercising fundamental labour rights, such as receiving sick pay and adhering to legal working hours. To achieve a truly sustainable and just transition, migrant workers need to be treated as a viable option on a policy level. *"Sweden needs labour migration, but on fair and just terms"*.

The study by Munthali et al. (2025) highlight the Malawi Green Corps (MGC) project as the transformative potential of green jobs in addressing youth unemployment and forest degradation in low-income countries. By engaging over 2000 youth in environmental restoration activities such as forest and soil conservation, the initiative significantly boosted participants' annual incomes and increased their participation in business enterprises, demonstrating the potential of green jobs to provide decent and meaningful employment for youth. The MGC project successfully equipped youth with the skills and capital to transition to more profitable livelihoods, rather than simply increasing livelihood options. However, the impact on overall poverty reduction was not statistically significant, reflecting the persistent working poverty and vulnerability of youth labour in the region. While targeted, short-term green job interventions can effectively provide decent work and stimulate youth entrepreneurship, achieving sustainable poverty alleviation requires long-term investment and the integration of these green jobs into broader, ongoing national programs, such as graduate internships and environmental restoration programs.

Through a systematic literature review, [Da Silva and Schweinle \(2025\)](#) investigate the characteristics and promotion of green jobs within the global forest sector, analysing 50 publications to determine whether these roles meet both environmental sustainability and social equity standards. The authors found that while the sector is generating new forest-related opportunities with greener shades, none of the identified literature fully satisfied the International Labour Organisation's criteria for decent work. Significant deficits in employment quality persist, most notably a high prevalence of labour informality, inadequate earnings, and unsafe working conditions. Although incentives such as continuous training programs and forest certification schemes have shown potential to improve labour conditions, the review highlights a critical lack of standardised methodologies for systematically assessing job quality. In conclusion, realising the true potential of green forest jobs requires establishing clear assessment metrics, rigorous data collection on employment quality, and targeted policies that balance environmental goals with workers' fundamental rights and safety.

3.5. Theme 5: Occupational Safety, Health, and Ergonomics (OSHE)

Four papers addressing this dimension offer emerging perspectives that link OSHE to mechanisation, reforestation and climate vulnerability. At the same time, workload remains a central concern, as forest work continues to impose high physical and mental demands.

[Zenir et al. \(2025\)](#) explore the evolving health, safety, and financial concerns of commercial loggers in the north-eastern United States by analysing semi-structured qualitative interviews with 29 industry participants. Findings reveal that participants expressed concerns about health risks associated with prolonged use of machinery, particularly weight gain and cardiovascular concerns. Furthermore, loggers report experiencing severe mental stress driven by the high financial burdens of purchasing and maintaining expensive mechanised equipment, especially since timber prices have failed to keep pace with rising operational costs. Frustration over untrained amateur loggers whose unsafe practices cause injuries and damage the profession's credibility was reported. Sustaining the logging workforce thus requires comprehensive occupational support, including accessible health insurance, stress-management resources, lifestyle interventions to prevent weight-related illnesses, and tailored safety training programs.

[Catling et al. \(2025\)](#) narrate the collaborative, iterative approach to developing and implementing health, safety, security, and environment (HSSE) risk mitigation strategies in a community-based reforestation-for-carbon initiative in the Philippines. By analysing incident reports and utilising collaborative risk assessments over a three-year period, the authors found that despite dedicating 3.14% of the project's expenditures to safety training, health insurance, and protective equipment, changing established cultural norms to build a shared safety culture proved difficult. Notably, of the 95 reported incidents, which were primarily related to illnesses, weather exposure, and vehicular accidents, the vast majority were reported by project staff rather than local community workers, indicating a significant underreporting issue driven by existing behavioural norms for outdoor labour. Fostering a robust safety culture thus requires collaborative, iterative HSSE design and implementation, with workers and organisations involved at all levels of the project structure. Voluntary carbon standards can contribute by explicitly requiring and rewarding HSSE investments during certification to ensure the protection of community workers.

[Lewark and Karmann \(2025\)](#) highlight the urgent need for forest work science to address rapidly deteriorating working conditions caused by the climate crisis, particularly the severe threats posed by extreme heat to outdoor workers. While foundational knowledge about heat stress and dehydration already exists, the authors identify a critical gap in applied research specifically targeting the climate crisis's impact on forestry workers, particularly compared with studies in other outdoor sectors. To protect the health, safety, and social sustainability of this vulnerable workforce, the study calls for an urgent review and

adaptation of the discipline's research priorities. The authors emphasise the necessity of cross-disciplinary collaboration, such as integrating insights from occupational medicine and rural sociology, and stress the importance of implementing science-based evidence through practical interventions, including adjusted work hours and updated forest management certification standards.

[Kallioniemi et al. \(2025\)](#) investigate the physical and mental workload of wood harvesting and transportation professionals in Finland, including loggers, truck drivers, and officers, using a 2019 survey of 1282 participants. Forests harvesting and transportation professionals reported heavy workloads, including stress, mental load, and long working hours. Especially the average of 44.9 working hours per week, significantly exceeding the broader European average. Key drivers of stress included poor recovery from work, lack of autonomy over personal matters, financial concerns, and specific professional statuses. Furthermore, common physical and operational hazards included prolonged sitting, repetitive movements, working alone, vibration, and cold drafts. Higher-educated workers, officers, employers, and the small minority of female workers were identified as particularly vulnerable to stress and mental load. To ensure the long-term social sustainability of this vital bioeconomy sector, the authors emphasise the urgent need for stakeholder collaboration to improve stress management, enhance peer support networks, and implement targeted grassroots interventions to alleviate administrative and operational burdens on small forestry enterprises.

3.6. Theme 6: Institutional and policy frameworks shaping forest-sector employment

Institutional and forest policy frameworks have played a role in shaping employment in the sector. Two studies in this collection offer new empirical insights into a country-specific case and into cross-economy comparisons.

[Dang et al. \(2025\)](#) examine the employment impacts of the National Forest City Construction (NFCC) initiative by applying a staggered difference-in-differences approach across an extensive panel dataset of 289 prefectures in China from 2002 to 2019. The findings reveal that the NFCC significantly boosted local job markets, resulting in an average 7.08% increase in employment within participating prefectures compared to non-adopting regions. Three primary mechanisms driving this growth are stimulating the operational performance of forest-related industries, improving the ecological environment to generate indirect job opportunities, and upgrading local infrastructure. Crucially, the policy's benefits extended far beyond traditional primary sector forestry jobs; it actively drove structural transformation by creating jobs in the manufacturing and tertiary sectors, particularly among private enterprises and self-employed workers in forest-rich regions. Targeted investments in vocational training to equip workers with the skills needed for the emerging green economy can maximise the long-term benefits of such policies, while improving workers' well-being.

[Marchand and Zerbo \(2025\)](#) evaluate the impact of log export ban (LEB) adoption on employment in the wood-processing industry by utilising an entropy-balancing approach on survey panel data across 74 developing countries. Findings reveal that LEB policies significantly stimulate local job creation, leading to an approximate 25% increase in total employment within processing firms in adopting countries compared to non-adopters. However, this growth is unevenly distributed as the job surge is heavily concentrated among production-related, permanent, and unskilled workers, with no statistically significant gains in skilled, temporary, or non-production roles. The evidence suggests that while LEB effectively boosts baseline employment by retaining raw materials domestically, trade restrictions alone are insufficient for long-term industrial modernisation. To cultivate a more advanced implementation of LEB policy, additional industrial and employment policies, such as attracting foreign direct investment, facilitating technology transfers, and fostering the development of highly specialised training

programs, should be complemented.

3.7. Theme 7: Distress-driven employment

The last two articles articulate two dimensions of how economic hardship influences employment choices. The first illustrates how past investments and cognitive factors prevent smallholders from diversifying their livelihood options. The second illustrates how distress pushes necessity-driven informal microenterprises.

Min et al. (2026) examine why smallholder rubber farmers in Southwest China remain reluctant to transition to non-farm employment despite persistently low rubber prices. Using three-wave panel data from 612 households collected between 2013 and 2019, the authors reveal that sunk costs, such as irreversible planting investments, and path dependencies, such as accumulated crop-specific skills, significantly inhibit farmers from seeking non-farm work. Crucially, those strong path dependencies actively amplify the negative impact of sunk costs. These lock-in effects are significantly stronger for farmers who are exclusively rubber-dependent, socially isolated, and located in areas with poor transportation. The study concludes that the low off-farm employment of smallholder rubber farmers is an active trap reinforced by the interplay of material and cognitive constraints. To help farmers overcome these livelihood traps, targeted policies that promote livelihood diversification, strengthen community social networks, and improve rural transportation infrastructure are advisable.

Lippe et al. (2025) characterise informality and identify the enabling and inhibiting drivers of business formality among informal wooden furniture microenterprises in Nairobi, Kenya, using a mixed-methods research design. The findings reveal that these businesses operate along a formality continuum with a dualistic structure. The lower-tier microenterprises engaged in marginal activities, while the upper-tier is characterised by growth-oriented microenterprises that achieve significantly higher profits, labour productivity, and adoption of formal practices. The majority enter the informal sector out of necessity. Key factors facilitating the transition to business formality include securing permanent business premises, access to affordable credit, and increased business profitability, while rising timber prices and unofficial financial charges act as major barriers. Effective transition from the informal to the formal economy necessitates tailoring strategies to specific enterprise segments: providing lower-tier enterprises with secure workspaces and credit, offering upper-tier enterprises access to high-value markets, and ensuring social security schemes align with the financial capacities of all entrepreneurs.

4. From evidence to policy, practice and future research

4.1. Key implications for policy and practice

The 29 studies in this SI collection highlight seven overarching implications. Notably, we do not aim to exhaust the topic or draw generalisable conclusions; instead, we seek to highlight emerging challenges and potential pathways for policy and practice.

Firstly, occupational safety and health interventions need to go beyond traditional accident prevention. Studies by Zenir et al. (2025), Catling et al. (2025) and Kallioniemi et al. (2025) support this first implication. Although mechanisation has been shown to improve safety conditions and harvest efficiency, it can shift occupational health and safety risks. Furthermore, outdoor workers are increasingly vulnerable to extreme heat and other weather-related hazards. Interventions need to emphasise ergonomic support, especially for mechanised operators, whereas rest breaks and measures to mitigate heat stress and illness are particularly crucial for workers engaged in manual, labour-intensive work. Making comprehensive health insurance accessible and affordable can improve worker retention and well-being. Recognising physical and psychosocial decency at work and building a safety culture are, first and foremost, the responsibility of the government. However, additional

incentives and institutional instruments, such as compliance requirements for voluntary certification standards, can serve as a substitute for weak enforcement.

Secondly, preparing the forest-sector workforce to meet evolving societal demands and the climate crisis requires more inclusive, practice-oriented education and training systems. Five studies across diverse geographical contexts from Chamlagain et al. (2025), Lucena et al. (2025), Owuor et al. (2025) Ritter et al. (2025) and Wan et al. (2025) provide evidence for the second implication. Higher educational institutions need to systematically incorporate entrepreneurship, leadership skills, soft skills, and emerging socio-environmental topics, such as climate change and restoration, into core programs. This should be combined with investment in active learning environments, such as field trips, interdisciplinary projects, and problem-based learning infrastructure, allowing equitable participation for all students. Formal feedback mechanisms between academia and industry are essential to align education with the sector demand. With the rapid development of AI, curricula should be modernised to teach students the limitations, ethics and proper professional applications of AI, ensuring it acts as a supplementary tool rather than replacing critical thinking.

Thirdly, advancing GEDI within the forest-sector workforce requires coordinated, targeted actions at multiple levels and must go beyond merely increasing the proportion of women or symbolically representing diversity. Studies by Andersson and Johansson (2025), Boakye-Danquah et al. (2025), Colonna et al. (2025), Korhonen et al. (2025) and Yurdakul Erol and Şahin (2026) uphold this implication. Fostering economic empowerment for women and those in vulnerable positions through socially inclusive value chains, equitable financial access, and customised training, alongside engagement with local institutions and sectoral networks, can amplify their voices, enhance their visibility, and strengthen their economic resilience within the sector. Addressing organisational factors and dismantling the sector's traditionally masculine culture are critical to improving retention and inclusion. Above all, GEDI considerations should be embedded in the formulation and implementation of core forest policy instruments, moving beyond mere project-based or voluntary approaches.

Fourthly, well-designed environmental measures such as ecological restoration or logging bans can simultaneously achieve environmental sustainability and decent employment growth (Dang et al., 2025; Munthali et al., 2025; Suryawan et al., 2025). Effective implementation of these policies requires complementary policy actions, including financial incentives and infrastructure investments to attract private capital and create a diverse, skilled workforce for emerging green sectors. Strengthening a skilled workforce to thrive in this green transition requires investing in targeted vocational training and transdisciplinary capacity-building that equips communities with practical competencies while addressing structural inequalities. If environmental measures are initially approached as a project, integrating green jobs into enduring national employment programs can sustain initiatives when project funding cycles end.

Various economic, cognitive, and structural barriers can ensnare workers, smallholders, and informal enterprises in livelihood traps, locking them into low-earning or precarious work. Studies in this collection support the fifth implication that to help these actors escape these traps, decision-makers must support structural transformation away from informal, distress-driven employment (Lippe et al., 2025; Min et al., 2026; Sharma and Thoudam, 2025). Investing in afforestation and silviculture can facilitate structural shifts towards decent employment in the forest sector due to multiplier effects, both in the short and long run. Promoting livelihood diversification through vocational training, strengthening social and economic networks, and investing in rural infrastructure can lower barriers to mobility. Providing informal enterprises with access to affordable credit, secure business premises and expanding social security coverage can elevate them from marginal to more stable and productive businesses, and potentially boost the creation of quality jobs.

The sixth implication recognises the need to implement proactive strategies to mitigate the effects of industrial consolidation and shifting industrial geographies, particularly from rural towards urbanising areas (Crandall et al., 2025; Lamsal et al., 2025). Policies need to target regional supply chains and provide workforce retraining for displaced rural workers. It is also important to note that generating employment need not rely solely on timber extraction. Diversifying local economies through public subsidies and investments in sustainable niche NTFP value chains can foster the economic resilience of rural areas (Lamsal et al., 2025).

Lastly, promoting the forest-based bioeconomy and building a resilient future forest sector without due consideration of socially fair and inclusive practices can blur what is happening on the ground (Alvear-Vega and Astudillo-Molina, 2025; Da Silva and Schweinle, 2025; Luhas and Mikkilä, 2025; Olofsson, 2025). Environmentally beneficial jobs are truly green only if they adhere to decent work standards. In many countries, the forest sector is plagued by labour informality and subordinate inclusion of vulnerable groups, such as migrant workers, whose labour rights and social protection are often circumvented through complex subcontracting chains. Ensuring a genuinely sustainable just transition requires institutionalising participatory policy processes that give local communities and workers in vulnerable positions an active voice in forest governance, design and implementation of work safety standards, while dismantling exploitative structures.

4.2. Future priorities in forest-based employment research

Contributions in this collection provide a couple of directions to consider when crafting future research priorities. Many of the articles in this SI explicitly highlight how future research can learn from the methodologies applied or call for replicable or expanded studies to address current limitations. The key areas where future studies can build upon the contributions, among others, are:

- Future studies can **elaborate on existing large-scale databases**, such as IMPLAN data and the Labour Force Survey, by expanding the geographical coverage to better evaluate the economic contribution of forest products and the effects of industrial consolidation, spatial shifts in industry, and idiosyncratic shocks and economic crises across integrated forest economies (Lamsal et al., 2025; Sharma and Thoudam, 2025; Thapa et al., 2025).
- **Moving from static to longitudinal analytical design** is crucial. For instance, Wan et al. (2025) suggests incorporating longitudinal data to track how dynamic changes in regional talent ecosystems affect the aggregation of forestry talent over time. Similarly, longitudinal studies are recommended to understand how community competencies in green-blue jobs in mangrove conservation develop in the long run (Suryawan et al., 2025).
- Studies by Owuor et al. (2025) and Chamlagain et al. (2025) have laid a solid foundation for replicable studies on the **skills required for future forest-sector employment** and **workforce preparedness of forestry students**, respectively. Future studies may replicate these assessments across the same countries, with a much broader representation of interviewed participants, and may also expand the research in a similar fashion to target entirely new countries.
- A study by Korhonen et al. (2025) provides a firm theoretical and methodological basis for understanding the perceived culture within the forest sector and identifying priority areas for change. Comparative studies that replicate the workshop designs across different organisations, geographic locations, and institutional contexts are needed. Specifically, future iterations should adopt an **intersectional approach** that considers overlapping identities.
- The **practitioners' views and lessons from restoration and economic empowerment programs** are essential for bridging the gap between implementation realities and policy frameworks, as presented in this collection (Catling et al., 2025; Colonna et al., 2025).

This type of perspective, published in the scientific literature, is encouraged. Sharing challenges and opportunities encountered during project execution also offers a lens for future research priorities.

The SI, alongside the literature overview presented in Section 2, also points to several avenues for domains that remain understudied or have emerged as priorities.

- In relation to the **climate crisis**, there is a pressing need for empirical research into, for instance, how extreme weather events, heat stress, and high levels of UV radiation directly affect occupational health and alter working conditions among the forest-related workforce (Lewark and Karmann, 2025). It is also crucial to examine how rising temperatures and shifting rainfall patterns may shape the future of employment opportunities at the national, regional, or global scale. Climate change directly influences decisions about adaptation and the choice of forest management strategies, which may, in turn, affect workers who will need to be retrained or reskilled. In that sense, evidence-based research is needed to understand the extent to which education and training systems can meet these emerging needs.
- **Research on GEDI in the context of forest-sector employment** can still expand across several key areas to address knowledge gaps. For example, Colonna et al. (2025) suggest that systematic research is needed to evaluate the effectiveness of local empowerment interventions for promoting gender equality and to identify the enabling conditions required to scale these strategies into systemic policy change. Boakye-Danquah et al. (2025) call for qualitative studies to capture and amplify the lived and employment experiences of migrant and indigenous workers in forestry. Studies that applied advanced modelling approaches are recommended to provide a comprehensive view of how socio-demographic factors and competencies jointly influence workforce participation in emerging green sectors (Suryawan et al., 2025). Furthermore, it is necessary to assess whether evolving environmental regulations create new opportunities for women or inadvertently reinforce existing exclusions (Colonna et al., 2025). Finally, combining policy analysis with legal, institutional, and empirical approaches is recommended to capture regional and institutional variations in how gender equality policies are framed and implemented (Yurdakul Erol and Şahin, 2026).
- While we should replicate and update the older research for occupational safety, health and ergonomics, future forest-sector employment analyses need to **apply a modern lens focused on psychosocial hazards at work caused by actual or superficial problems**. This is particularly relevant as working in the forest sector is intensive and oftentimes stressful, and involves a high degree of risk (Lotfalian et al., 2014). Catling et al. (2025) highlight the need for targeted research to understand the psychosocial factors influencing workers, the most effective incentives to motivate the adoption of best-practice safety protocols, and the safest ways to organise physically demanding tasks in challenging tropical climates. This research domain is particularly needed across geographical regions and countries' economic and development contexts, as it could offer shared lessons on necessary measures to improve working conditions in the sector, especially for developing countries.
- As **generative AI** has become part of forest-related professions, future research may find out whether AI could be utilised to reduce workload and improve well-being at work (Kallioniemi et al., 2025). There is a significant need for continued research into the knowledge, attitudes, practices, and recommendations of forestry and natural resource professionals regarding their engagement with AI technologies (Ritter et al., 2025). In addition, it is worth examining how AI may shape gender equality or further exacerbate inequalities in the forest-related labour market. Future studies should explore

whether new technologies will displace rural manual labour or create new, highly skilled technical opportunities in remote areas, and what this means for inequalities in digital access, technological capabilities and socioeconomic opportunities within forest communities.

- As global priorities shift towards **the transition to a sustainable and circular bioeconomy**, the forest-sector labour market is transforming and expanding more and more into emerging green sectors. Research thus needs to explore **how to effectively integrate the concept of a just transition**, which mandates decent work, safety, and equitable rights into high-level environmental policies (Olofsson, 2025). Furthermore, it is vital to understand how this transition will shape labour demand and the emerging skills required, as well as how it promotes social sustainability by including women, youth, and vulnerable people while ensuring equitable benefits.
- Some dimensions of forest-sector employment research remain understudied and deserve particular attention in scientific and policy debates. These refer to research on **labour informality** (informal workers and informal enterprises), although they account for a significant proportion of the workforce in the forest sector across several economies. Lippe et al. (2025), for example, highlight the need for research into how environmental policies both facilitate and hinder the enterprise formalisation process, and how formalisation, in turn, affects environmental outcomes. Furthermore, research should expand to include studies of **jobs generated in NTFP value chains, the working and employment conditions**, and whether GEDI has been advanced among these workers. Ultimately, it is essential to examine how forest-related policy and regulatory frameworks shape the forest-sector workforce, especially the emerging ones.

Cross-cutting concerns refer to **data and methodological approaches** that facilitate the analysis of multiple dimensions of research on forest-sector employment. Despite recent progress in generating global sex-disaggregated employment data (Lippe et al., 2026), more is needed. For example, research should prioritise developing robust methodologies and standardised indicators to accurately identify what truly constitutes green forest-related jobs (Da Silva and Schweinle, 2025). Data on labour informality, fatal and non-fatal accidents, social security coverage and remuneration are pressing for understanding the forest-sector workforce, as they capture key dimensions of job quality (Lippe et al., 2026). Data for assessing the effectiveness of certification standards on strengthening workers' rights and securing working conditions remains essential (Lewark and Karmann, 2025). There is a growing demand for disaggregated forest-specific labour force data for measuring and tracking equity, diversity and inclusion outcomes over time, especially comparable data across countries (Boakye-Danquah et al., 2025). Enhancing social sustainability in the forest-based bioeconomy necessitates standardised assessment tools, including measurable indicators, and the refinement of terminology to build shared understanding (Luhás and Mikkilä, 2025).

In closing this introductory piece, we emphasise that forest-sector employment and its social dimensions need to be recognised as foundational components of environmental initiatives and policies. Efforts towards sustainable forest management, a transition to a circular bioeconomy, and the fulfilment of environmental pledges, without considering the relevant workforce, may obscure the actual conditions on the ground.

CRediT authorship contribution statement

Rattiya Suddeephong Lippe: Conceptualization, Data curation, Investigation, Methodology, Formal analysis, Visualization, Writing – original draft, Writing – review & editing. **Tatiana Ojeda Luna:** Data curation, Writing – review & editing. **Doris Mutta:** Data curation,

Writing – review & editing. **Jörg Schweinle:** Writing – review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.forpol.2026.103872>.

Data availability

No data was used for the research described in the article.

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