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Research Article

Females as forest machine operators

Heli Kymäläinen[a], **Aida Tuupanen**[a], **Simo Jaakkola**[b], **and Kalle Kärhä**[a]

[a]School of Forest Sciences, University of Eastern Finland, P.O. Box 111, FI-80101 Joensuu, Finland; [b]The Trade Association of Finnish Forestry and Earth Moving Contractors (Koneyrittäjät ry), Sitrantie 7, FI-00420 Helsinki, Finland

Corresponding author: **Heli Kymäläinen** (email: heli.kymalainen@uef.fi)

Abstract

Globally, the scarcity of skilled forest machine operators, combined with growing demand for sustainable wood raw materials, has made labor availability a critical challenge. This study examined the participation of females in forest machine operations in Finland through interviews with female operators and with a survey of forest contractors. Our results showed that females remain markedly underrepresented in the forest workforce, accounting for only 1.6%–2.0% of operators in 2024. Female operators expressed high satisfaction with their career choice, while contractors generally supported the idea of employing females and recognized gender equality as vital for sectoral development. Yet, barriers persist. Both groups highlighted limited encouragement in schools, insufficient knowledge about the profession, and misconceptions about the work. Female operators reported prejudice, belittlement, and difficulties in balancing long shifts with family life. Contractors emphasized the challenges related to parental leave, particularly in small firms with scarce resources. Key solutions included strengthening school outreach programs when students decide on their occupational education, targeted visits to forest companies, and increasing the media visibility of female operators. Both operators and contractors stressed the importance of presenting forestry work realistically yet positively, emphasizing the independence of the work, the advanced technology used, and a connection to nature. Expanding females' participation is not only an issue of equality but is also essential to secure the future labor supply and competitiveness in the forestry sector.

Key words: contractor, employment, Finland, forest sector, gender equality, timber harvesting

Introduction

Globally, sustainable wood raw materials are increasingly needed (Johnston et al. 2023), but an effective, safe, and sustainable supply chain is difficult to achieve without skilled forest machine operators. The cut-to-length (CTL) timber harvesting method, which is used in approximately 37% of global forest operations (Lundbäck et al. 2021), utilizes modern high-tech machinery and requires proficient operators. However, studies to date have revealed both a global scarcity and the uncertain availability of professional forest machine operators in the field (Häggström and Lindroos 2016; Pagnussat et al. 2019; Lautanen et al. 2020; He et al. 2021; Vaughan et al. 2022; Šporčić et al. 2023; Conrad and Blinn 2024).

The CTL harvesting work is dominated by cognitive workload, with continuous observation and problem-solving skills, and an understanding of the complex forest environment and its characteristics (Gellerstedt 2002; Häggström et al. 2015; Malinen et al. 2018). In addition to cognitive load, prolonged sitting periods in the cabin of the harvester, machine vibration, and noise lead to physical strain in the work (Häggström 2015; Poje et al. 2019). Moreover, forest machine work is often carried out in remote areas, which can require long commutes by the operators. As the work is organized in shifts, daylight hours and temperature can vary considerably, especially in the Nordic countries, where operations continue regardless of season (Kymäläinen et al. 2021).

Forest machine operator education can vary considerably between countries and range from informal education to formal education. In Finland, vocational 3-year education is available, although not all student places are always filled (Metsäkoulutus 2024, 2025; Lautanen and Karhu 2025). Furthermore, the education of forest machine operators requires substantial resources, yet many leave the field soon after graduation or during the early career years (Lautanen et al. 2020). Up to 25% of graduates shift to another profession, often due to the high performance demands in their field, such as productivity and a complex work environment (Malinen et al. 2018; Lautanen et al. 2020). In Finland alone, a minimum of 250 new forest machine operators are needed annually to ensure sufficient labor availability for timber harvesting operations (Strandström and Poikela 2025).

Machine operations are dominated by males. In the Nordic countries, only 1%–4% of forest machine operators are female, and these numbers are only slowly rising (Vennesland et al. 2020). In Finland, 5% of machine operator graduates in 2022 were female, and forestry was seen as one of the most atypical career choices for female students (Kilpeläinen and Lautanen 2023). For all applicants, the biggest moti-

vational factors for a career in forest operations were the independence of the work, the perception that it was responsible work in natural surroundings, and an interest in operating heavy machinery (Kilpeläinen et al. 2022). However, accurate information on timber harvesting work and its possibilities for females is often lacking, which has led to misunderstandings and misinterpretations about the profession (Mäntyniemi et al. 2019; Korhonen et al. 2020). This has resulted in vague perceptions of forest machine work, thereby making it easier for gender assumptions and stereotypes to take hold (Lahtinen 2019; Mäntyniemi et al. 2019). For example, a study conducted in Sweden (Johansson and Ringblom 2017) pointed out that in the forest sector generally, there is a perception that females should be very "thick-skinned" and understand rough humor to be able to succeed in the male-dominated business. These narrow and stereotypical views have also been detected among machine educators in the field (Mäntyniemi et al. 2019).

Research (e.g., Barney 1991; Frink et al. 2003; Campbell and Mínguez-Vera 2008; Ellemers and Rink 2016; Tsou and Yang 2019) has shown that diversity in the workplace fosters creativity, problem-solving, better decision-making, openness to change, and can enhance both financial performance and company value. A broader range of perspectives improves problem-solving and typically leads to better decision-making. In contrast, a workforce that is too homogenous can create a rigid "mold" where everyone is expected to fit (Johansson et al. 2020). Those who do not fit this mold, or who have different interests, may face discrimination and feelings of exclusion in the workplace (Johansson et al. 2020).

In the future, population decline in many countries will reduce the number of people entering the workforce. As the availability of labor diminishes, competition for skilled employees will become increasingly intense. As such, a narrow idea of the "ideal" forest machine operator can damage a company's reputation and limit its ability to attract talent. Therefore, building a more gender-neutral image would benefit the entire forestry industry. Greater diversity would likely increase interest in the field and broaden the pool of potential employees (Korhonen et al. 2020). Currently, females make up only a small fraction of forest machine operators, which means that the sector is effectively recruiting from just half the population. To modernize its image, the industry should promote a vision of both females and males working in clean, high-tech machine cabins, which would help the profession appeal to a broader and more varied group of potential employees (Kilpeläinen et al. 2022).

Consequently, the overarching aim of this study was to determine how the proportion of females in forest machine work could be increased. The study explored the factors that motivate females to pursue a career in forest machine operations, and potential barriers to seeking a career, entering the profession, and working in the field. In addition, we investigated the attitudes of timber harvesting contractors toward female operators and gathered information on how many contractors had employed female operators.

Materials and methods

This study was conducted following the Responsible Conduct of Research guidelines and Ethical Review principles of the Finnish Advisory Board on Research Integrity (Keiski et al. 2023). All the study participants and respondents gave informed consent before participating in the study.

Interviews with female operators

This study conducted 16 semi-structured interviews (Appendix A) with females who had experience working as CTL machine operators in Finland. Participants were recruited in January 2024 through the Trade Association of Finnish Forestry and Earth Moving Contractors (Koneyrittäjät ry), which represents approximately 2000 companies, of which about 1000 report active operations in the forest sector. An email invitation was distributed to member companies, requesting that female operators be informed of the study and encouraged to participate on a voluntary basis. Additional recruitment was undertaken via announcements in the Facebook group *Metsäkoneenkuljettajat* ("*Forest machine operators*", circa 12 000 members at the time, including machine operators and people interested in forest operations) and through articles published in *Koneyrittäjä* Magazine (Tuupanen 2024) and *KL-Uutiset*, the member bulletin of Koneyrittäjät ry. A reminder email was distributed to member companies of Koneyrittäjät ry in March 2024 to reach further potential participants.

At the time of the interviews, 12 participants were employed as forest machine operators. To ensure an adequate sample size, four participants who were no longer in the role but had recent work experience and relevant training were also included in the study. The participants' experience in forest machine operations ranged from 1 to 20 years (mean 6.3 years). Nine participants primarily operated forwarders, five operated harvesters, and two reported working with both types of machines, depending on company needs. Participants were employed in forest machine companies of various sizes (Fig. 1), and the sample group represented all regions of Finland: one participant from southern Finland, one from eastern Finland, seven from western Finland, and seven from northern Finland.

Interviews with the female operators comprised both open-ended items and closed-ended questions rated on a five-point Likert-type scale. The semi-structured interview underwent testing before implementation. Respondents were able to provide verbal comments and clarifications with regard to the numerical ratings. The interviews were conducted between January and March 2024. Ten interviews were carried out by telephone, and six via Microsoft Teams.

The interviews were analyzed through themed content analysis, which divided the data into four themes: *(1) the factors that influence those seeking the profession and the profession's image, (2) employment and equality, (3) resistance and criticism, and (4) career choice and future.* Themes were partly derived from the interview structure and questions to represent and align the different career stages, which ranged from initial interest in the profession to active employment in the sector. In addition, the thematic areas were further reflected in the con-

Fig. 1. Number of forest machines in the companies represented by the study participants.

tractors' (open-ended) responses. Interview features, which included numerical data, were also analyzed by mean values, graphs, and diagrams, although no statistical evaluation was carried out due to the qualitative nature of the data and the small sample size.

Survey of timber harvesting contractors

The perspectives of harvesting contractors with regard to females as operators and the potential to increase their participation in the sector were examined through an electronic Webropol questionnaire. The survey investigated contractors' willingness and activity in hiring female operators, their views of the capability of females to perform forest machine work, and their perceptions of the barriers that limit females' entry into the profession, as well as possible measures to support greater female participation. In contrast to the interviews, the survey method was expected to yield a broader dataset. Furthermore, the anonymity of the questionnaire was considered advantageous to elicit more candid responses with regard to the entrepreneurs' attitudes toward female operators and their recruitment.

The questionnaire (Appendix B) comprised a series of statements and factors rated on a five-point Likert-type scale, supplemented by an open-ended section at the end for additional comments. The questionnaire was distributed only after the completion of interviews with female operators, which allowed issues raised in the interviews to be accounted for in the design of the entrepreneur questionnaire. Furthermore, the questionnaire underwent an expert review by Koneyrittäjät ry and was tested before distribution.

The questionnaire was emailed to all member companies of Koneyrittäjät ry engaged in forest machine contracting on 12 April 2024, and was available until 2nd May 2024, which included a time extension to increase the response rate. In total, the questionnaire was sent to 792 contractors, and 87 valid responses were received, yielding a response rate of 11%. The entrepreneurial experience of the respondents ranged from 2 to 58 years (mean: 21.7 years), and ages ranged from 26 to 82 years (mean: 49.9 years). On average, the entrepreneurs employed 10 machine operators, and the number of employees correlated strongly with the number of machines owned by the company (Fig. 1). Geographically, 9% of respondents operated primarily in southern Finland, 29% in eastern Finland, 38% in western Finland, and 24% in northern Finland.

The survey data were statistically analyzed by the nonparametric Mann–Whitney U test and the Kruskal–Wallis test with a significance level of $\alpha = 0.05$. The hypothesis was that all the contractors would give similar responses. Statistical differences were analyzed through seven variables: (1) age of the contractor, (2) company's operational region, (3) duration of the entrepreneurial career, (4) number of forest machines in the company, (5) number of hired machine operators, (6) number of hired female machine operators, and (7) number of previously hired female operators.

Nonresponse analysis

To assess potential bias due to the nonresponse of contractors, we conducted a nonresponse analysis using member data from Koneyrittäjät ry. A sample of 80 contractors was randomly selected from the pool to which the original questionnaire had been sent. The nonresponse sample contractors were contacted by phone, and we conducted a brief interview with questions related to female operators (Appendix C). A total of 51 confidential responses were collected for the nonresponse analysis, and the data were analyzed using the Mann–Whitney U test. The outcome of the nonresponse analysis was consistent with the survey results and, therefore, did not affect the interpretation of the findings. The specific results can be found in the Appendix D and a more detailed reflection on the nonresponse analysis is provided in the "Discussion" section.

Results

Factors influencing those seeking the profession and the profession's image

For the interviewed female operators, career choice in timber harvesting was strongly influenced by family, relatives, and close friends (Fig. 2). Many had family members in the sector—fathers' professions and encouragement were partic-

Fig. 2. Importance of factors that influence the decision of female operators to enter the profession (importance scale: 1 = no influence at all, 5 = strong influence).

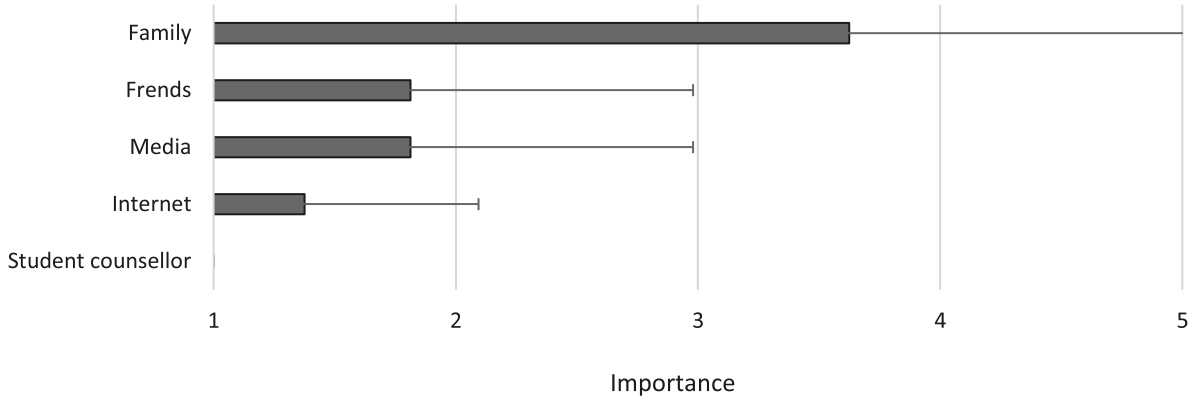
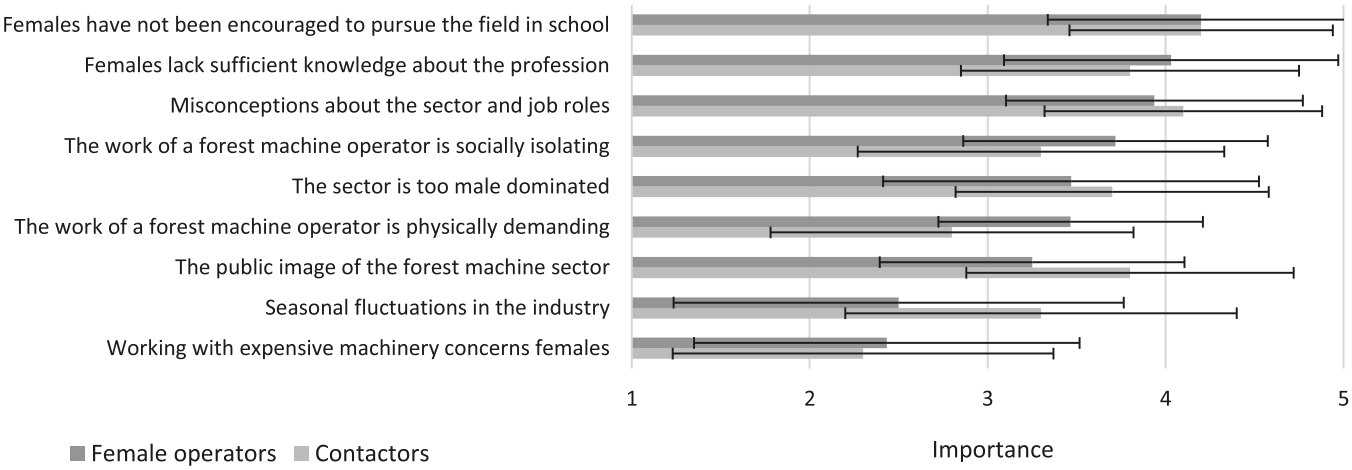


Fig. 3. Female operators' and contractors' assessments of the factors that influence females to seek careers as forest machine operators (importance scale: 1 = not important at all, 5 = very important).



ularly emphasized—along with early exposure to heavy machinery and forest work. Many interviewees shared a prior interest in heavy equipment, having operated excavators, trucks, or tractors before entering the forest sector. Regardless of the background influence, all the interviewees sought careers that offered independence, a close connection to nature, and the opportunity to witness their own handiwork. A high employment rate encouraged them to enter the field and provided a decisive factor in cases when the individual was considering two different career paths.

However, the profession suffers from a persistent image that it is not a suitable career option for females, thus creating barriers for females. Lack of information and guidance was indicated in both the female operators' and contractors' answers (Fig. 3). According to the female operators, the forest machine sector is rarely seen as an option by school-aged girls, who are typically expected to choose the care or service sectors. Females interested in machinery often turn to truck driving, as forest machine operations are seldom considered. Seasonal fluctuations were seen as a greater barrier by contractors than by female operators. Working with expensive machinery was rated least significant, except in small companies (<3 machines, <4 employees; $\alpha = 0.05$) in which a single machine investment can play a notable role in the contractor's finances. Contractors' open responses also identified employer bias, co-worker discrimination, irregular hours, and work-life balance challenges.

Employment and equality

Of the 87 contractors who responded to the survey, 13% reported employing at least 1 female forest machine operator (as of the start of 2024), and 27% of the respondents had employed female operator(s) before 2024. When the estimated overall workforce in forest machine operations in Finland and seasonal fluctuations were taken into account, our result indicated that approximately 1.6%–2.0% of all operators in 2024 were female. Nearly all respondents agreed (67%) or somewhat agreed (29%) that they would hire a female as an operator (Fig. 4). Most also considered females competent and that the occupation was suitable for them (58% agreed, 29% somewhat agreed). Contractors with more than 12 operators, as well as those who had previously employed females, were significantly more likely ($\alpha = 0.05$) to state that females are

Fig. 4. Willingness of the contractors to hire a female operator.

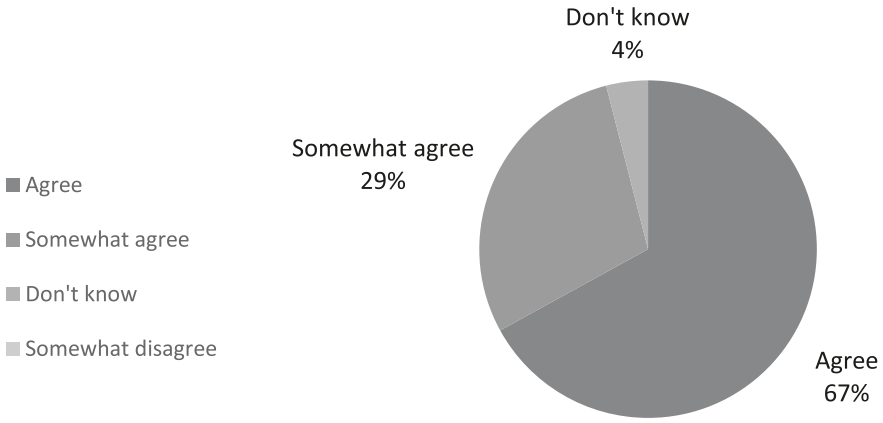
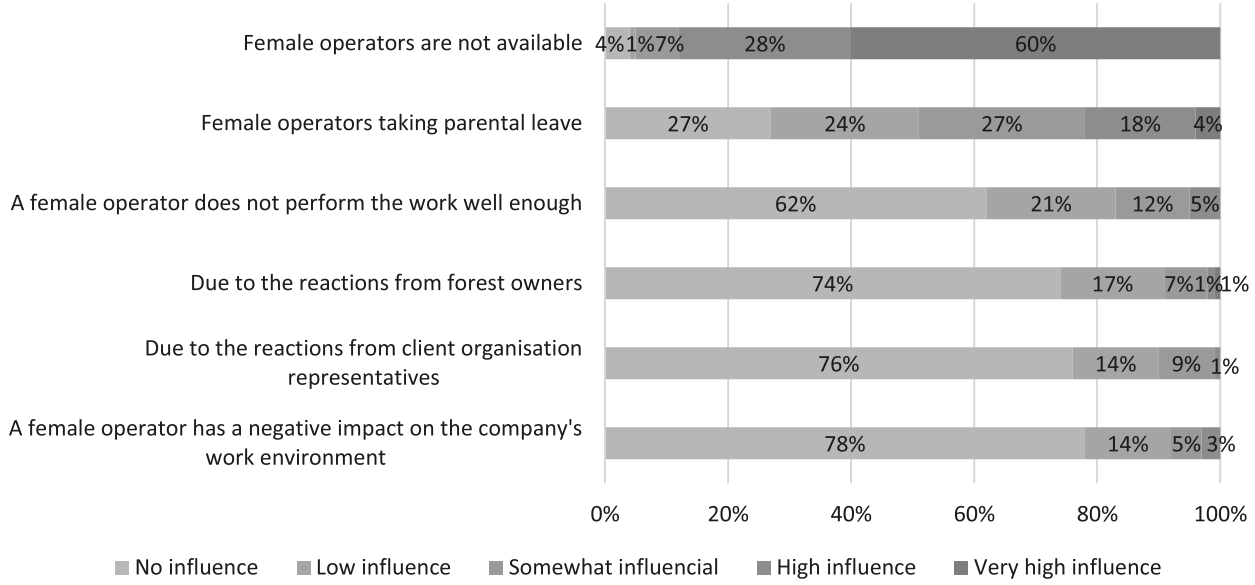


Fig. 5. Employers' assessments on the factors that determine whether to employ female operators.



skilled operators, compared with those who had never employed female operators.

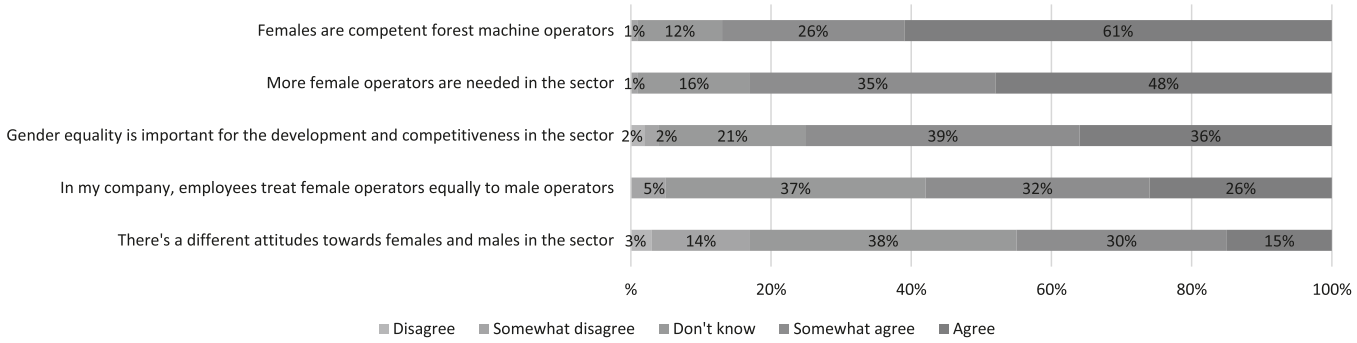
The main reason identified by respondents for not employing female operators was their unavailability: 60% rated this as highly influential and 28% as somewhat influential (Fig. 5). By contrast, concern about negative impacts on the workplace environment was minimal, with 78% in the survey reporting no influence. Interestingly, contractors with 15–29 years of experience rated impacts on the work environment as more influential ($\alpha = 0.05$) than those with shorter careers.

When the factors that influence employers' hiring decisions were considered, opinions on the impact of parental leave on hiring decisions were the most divided (Fig. 5): 22% of respondents reported that the risk of parental leave had a great or considerable influence on their decision not to hire females, 27% said it had some influence, 24% reported little influence, and 27% stated that it had no influence. By contrast, concerns about females' ability to perform the work were minimal: 62% reported no influence and 21% little influence, though 17% indicated at least some or considerable influence. Reactions from forest owners and client organizations were also largely insignificant: 74% of forest owners reported no influence, while 76% of client representatives reported no influence. However, entrepreneurs over 55 years of age were statistically more likely ($\alpha = 0.05$) than younger respondents to view that forest owners' reactions as affecting hiring decisions, since the operators are often executing the work in family-owned forests.

The question about gender equality in the forest machine sector had a divided rating. Several interviewees stressed that inequality was not limited to gender, as male workers also experienced unequal treatment, depending on the company. Overall, females viewed the sector as neither particularly poor nor excellent in terms of equality, but comparable to many other professions in terms of challenges. Gender equality assessment was rather similar across the contractors' responses.

Half of the interviewees felt gender had affected job opportunities: for most negatively, but for a few positively, as

Fig. 6. Contractors' responses with regard to the competence and equality of female forest machine operators.



being female helped them stand out. Some employers were seen to prefer males due to assumptions about family responsibilities. Others emphasized that job-seeking in the sector was challenging for all candidates, regardless of gender, and that employers were often cautious toward any new operator. Work-family balance was identified as a major challenge, particularly with long shifts, the overtime culture, and childcare responsibilities. Female operators emphasized the need for greater flexibility and understanding from employers.

Most contractors agreed that more females were needed in the sector: 48% strongly agreed and 35% somewhat agreed (Fig. 6). Approximately 75% of the contractors also considered that gender equality is important for the industry's development and competitiveness. Contractors' views were more divided on whether males and females were treated differently in the sector, and on whether (male) co-workers' attitudes toward female operators were comparable to their attitudes toward other colleagues.

In the open responses, many contractors emphasized that gender was irrelevant to competence and highlighted genuine interest, willingness to learn, and overall professionalism as key qualities. Several respondents stressed the general shortage of skilled operators regardless of gender, while others described females as diligent and reliable employees.

Resistance and criticism

When pursuing a career as a forest machine operator, most interviewees reported encountering skepticism, questioning, or at least surprise from outsiders. In addition, student counsellors and teachers at the comprehensive school level often discouraged the choice of machine operator as a profession. One participant also described facing very negative attitudes even in vocational school while already enrolled in the program.

Most interviewees reported experiencing belittlement and prejudice as female operators in the forest machine sector. Females often felt scrutinized, subjected to coarse humor or inappropriate remarks, and compelled to prove their competence continuously. Several noted that earning credibility required considerably more effort than for their male counterparts. Some emphasized that older male colleagues tended to question their suitability for the profession, while some reported assumptions that they should instead work as forwarder operators. The experiences of the female operators and the attitudes of the employers varied considerably. Some females reported skepticism, especially in smaller firms or with older male entrepreneurs, though attitudes often improved once competence was demonstrated. In addition, positive feedback was frequently related to females' perceived precision and care with machinery.

Gender-related biases were most frequently encountered from forest owners and co-workers. While responses varied, gaining trust and credibility with the forest owners was often described as difficult, with some cases of inappropriate behavior reported. Others, however, valued the precision and care demonstrated by female operators. Attitudes among co-workers were generally positive, although new employees were sometimes described as harboring initial prejudices. Almost all interviewees had encountered surprise from both colleagues and forest owners; however, in most cases, this was expressed as positive curiosity. Representatives of client organizations (e.g., forest companies) were almost universally reported to react favorably toward female operators.

Career choice and future

Overall, interviewees were highly satisfied with their career choice (Fig. 7), and commitment to remain in the profession over the next 5 years was also strong. Some forwarder operators expressed interest in learning harvester operations, and three participants aspired to become entrepreneurs. Interviewees highlighted many positive aspects of the work and stressed that forest machine operation is equally suitable for females, and they could see no reason why they could not succeed in the field.

Both female operators and contractors identified better school outreach programs and increased media visibility—especially featuring female operators—as the most effective ways to attract females to the profession (Fig. 8). Interviewees emphasized realistic yet positive marketing and preferred school visits to actual worksites over classroom presentations alone. Improving wages and the sector's image were also seen as important, although opinions on current pay levels were mixed. Female-specific training divided views: some saw it as unnecessary segregation, while others supported targeted information sessions and recruitment events featuring female operators with opportunities to explore the machinery.

Fig. 7. Female operators' level of satisfaction with their career choice.

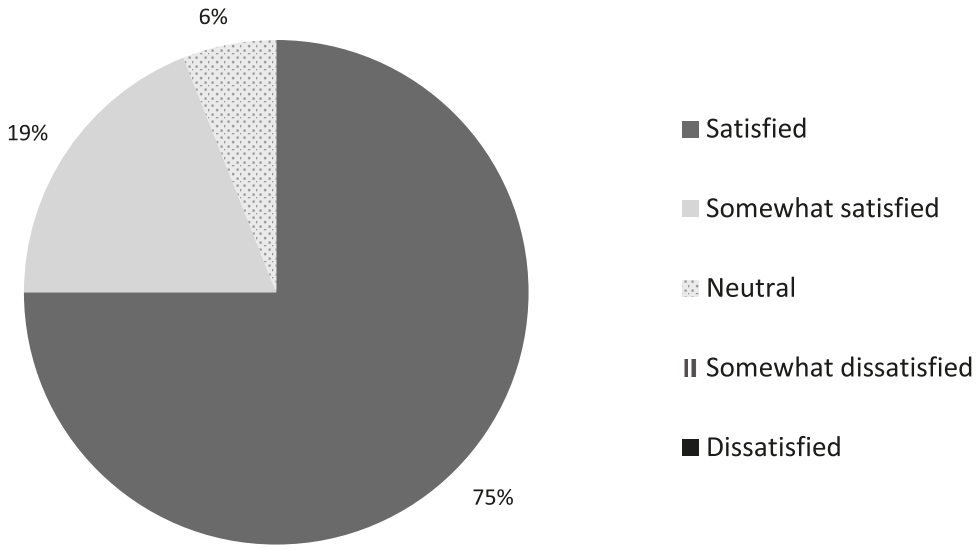
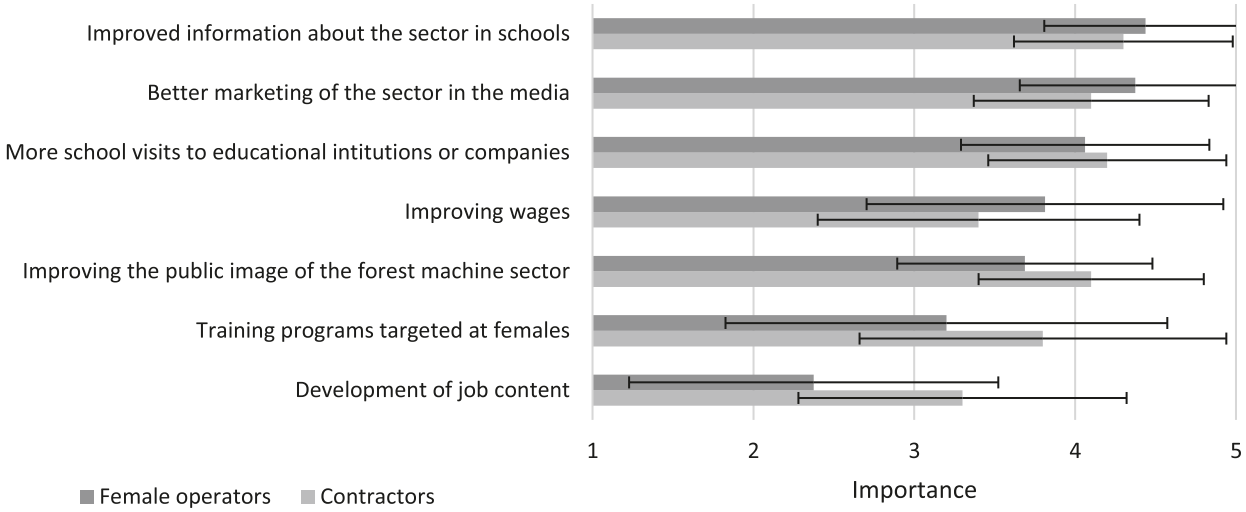


Fig. 8. Female operators' and contractors' viewpoints on how to increase females' interest toward the sector (importance scale: 1 = Not important at all, 5 = very important).



The contractors largely agreed that school outreach programs, company visits, and improving the sector's image and marketing would be effective in increasing the interest of females. Smaller companies (<3 machines or <4 operators) and those with no female operators rated wage improvements as significantly more important ($\alpha = 0.05$–0.01). Both groups considered changes to job content as the least important factor.

Interviewees emphasized that employees should not be judged by gender and that forestry work should not be divided into "men's" and "women's" jobs. They hoped for greater recognition from employers, especially among the older generation, and for more opportunities for females to prove themselves without prejudice or belittlement. Many believed that attitudes had already improved and would continue to do so as the number of female operators increases in the future.

Discussion

Data and methods

This study examined ways to increase the proportion of female operators in forest machine operations. The study explored barriers, motivations, and experiences in the field through semi-structured interviews with female operators. Using an online survey, we also investigated the attitudes of harvesting contractors toward female operators and the attitudes of contractors to employing female operators. In addition, a nonresponse analysis was carried out to further evaluate the contractors' results.

Our dual focus, which included both female operators and employers, provides a more comprehensive understanding of the phenomenon. To ensure the quality of the results, this study applied a mixed-methods approach. For the qualitative interviews, a semi-structured interview guide was used, con-

sistent interview procedures were maintained, and research triangulation was utilized during the analysis. However, finding a sufficient number of female participants proved challenging, requiring several rounds of phone calls, and the final sample included some operators who had already left the sector. Consequently, this may have introduced potential bias, which also may have occurred with the wording in some of the semi-structured interview questions.

For the contractors' quantitative survey, content validity was ensured by designing items based on themes identified in the interviews, from the expert review by Koneyrittäjät ry, and by testing before distribution. The contractors' nonresponse analysis showed no significant differences in the key questions between the survey data and the nonresponse data (Appendix D), which would indicate that the survey responses were sufficiently representative. One background variable (number of employees) did differ significantly between the groups. The nonresponse data included a higher proportion of small companies than the survey data. In small companies, where employment opportunities are more limited, responding to surveys on employment-related topics may not be viewed as equally relevant as in larger companies. This likely contributed to a higher response rating from larger firms in the original survey. The nonresponse data collection further revealed that many small companies outsource services to other firms to avoid the financial risks of machine investments or human resources responsibilities. As a result, companies may remain small in terms of employees.

Discussion of results

The interviewed female operators cited similar reasons for entering the profession as reported in earlier studies among (male) forest operators (e.g., Rutkowska and Adamowicz 2018; Kymäläinen et al. 2021; Kilpeläinen et al. 2022): a desire for independent work, appreciation of the forest environment, and interest in machinery. Family influence, especially fathers' encouragement or professions that involve machinery, was frequently mentioned by the respondents. Support from their immediate circle, together with favorable employment prospects, was consistent with prior findings that have linked labor market opportunities to gender-atypical choices (Mastekaasa and Smeby 2008; Durante et al. 2012; Leaper et al. 2012; Hardie 2015).

In 2024, 13% of contractors employed at least one female operator, which corresponds to only 1.6%–2.0% of all operators in Finland. This aligns with previous findings, although the expected upward trend has not materialized (Vennesland et al. 2020; Kilpeläinen and Lautanen 2023). In 2022, only 5% of machine operator graduates were female (Kilpeläinen and Lautanen 2023), which would indicate that there has not been strong pressure from females to enter the sector. Moreover, females have not been employed in the industry as well as males after graduation (Kilpeläinen and Lautanen 2024). Beyond the scarcity of females in the labor market, contractors cited parental leave as a reason for hesitancy, noting that females in Finland typically take longer leave periods than males (Carnicelli et al. 2024; Salonen and Koivisto 2024; Lütolf 2025). Research has shown that finding replacement is more difficult in small companies that have limited staff numbers and little prior experience with parental leave (Österbacka and Räsänen 2024). In Finland, where most harvesting contractors are small male-dominant enterprises, these challenges are particularly relevant (Mäkilä et al. 2024). Female operators reported difficulties in balancing work and family life, particularly due to long work hours, shift schedules, and a lack of flexibility for childcare needs. The male-dominated workplace and the absence of peers in similar life situations further limited support and discouraged family-friendly decisions (Maume 2006; Österbacka and Räsänen 2024; Riemma et al. 2025).

Contractors recognized the need to increase female participation and viewed gender equality as important for development of the sector. While most considered forest machine operations suitable for females, those with prior experience employing females or with larger workforces (>12 employees) were significantly more likely to regard them as skilled operators. Female operators, however, reported gender bias, noting that their opportunities were sometimes limited because the contractors did not take them seriously—a pattern also observed in previous studies (Bardekjian et al. 2019; Johansson et al. 2020; Sjølie et al. 2024; Proctor et al. 2025).

Most female operators experienced curiosity, prejudice, and belittlement during studies and at work. They often had to prove their competence and credibility, with prejudices most frequently encountered with co-workers and forest owners. In strongly gendered work cultures, individuals who represent the minority gender often report that their competence or authority is questioned (Baublyte et al. 2019). While this study focused on females' experiences in working life, Mäntyniemi et al. (2019) found that similar experiences of prejudice and undervaluation often start during training and when seeking internships in the forest sector.

Both contractors and female operators agreed on the main barriers to females entering the sector: lack of encouragement at school, limited knowledge about the profession, and misconceptions about the work. Female operators' experiences of opposition from guidance counsellors reinforced this finding. Contractors also emphasized the industry's negative image, consistent with earlier research that showed that perceptions of forestry as outdated, male-dominated, and overly physical deter young people from entering the sector (Murto et al. 2018; Korhonen et al. 2020; Kilpeläinen et al. 2022).

Suggested measures to increase females' interest were also largely similar. Both groups highlighted the need for more information in schools, better awareness among teachers and counsellors, and improvements to the industry's image through marketing, which could present the positive but realistic aspects of the work. School and company visits were considered effective, targeted specifically at females. Previous studies support these findings (Ferry 2006; Mäntyniemi et al. 2019; Sáinz et al. 2020; Säkkinen 2023), stressing that showcasing female role models in media and outreach programs is crucial to demonstrate the success of females in the field. In Finland, the forest sector has gained increased media visibility and has been linked to rural lifestyles through

radio advertisements, television programs, and social media campaigns (e.g., Metsäliiga, Savotta, Savolife), although these efforts have not concentrated specifically on females in the field.

Conclusions

The aim of this study was to investigate how the proportion of females in forest machine operations could be increased in the future. The study conducted interviews with female operators and undertook a survey of contractors. Our results show that females remain highly underrepresented in the forest workforce, comprising only 1.6%–2.0% of operators in 2024. Key barriers include limited encouragement in schools, lack of information, misconceptions about the work, gender stereotypes, and a negative industry image. Female operators reported prejudice, while contractors—though generally willing to employ females—cited parental leave and labor scarcity as challenges. Suggested measures to encourage females to enter the field included stronger school outreach programs, greater media visibility of female operators, and targeted visits to worksites. Enhancing flexibility in the work and inclusivity is essential to attract and retain a more gender diverse workforce.

The forest machine sector faces a critical need to modernize its image and practices to attract and retain skilled labor. Expanding female participation is not only an issue of equality but also of ensuring long-term labor availability and competitiveness in the industry. By investing in school-level outreach, promoting diverse role models, and addressing structural barriers, such as work-life balance, the sector can build a more inclusive and sustainable workforce.

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Data availability

Data generated or analyzed during this study are not available due to the nature of this research and the personal information that the data contain.

Author information

Author ORCIDs

Heli Kymäläinen https://orcid.org/0000-0002-2676-4100

Author contributions

Conceptualization: AT, SJ, KK
Data curation: HK, AT, SJ, KK
Formal analysis: HK, AT
Funding acquisition: KK, SJ
Investigation: HK, AT, SJ
Methodology: HK, AT, KK
Project administration: KK, SJ
Resources: KK, SJ
Supervision: KK, SJ
Validation: HK, KK
Visualization: HK
Writing – original draft: HK, SJ, KK
Writing – review & editing: HK, KK

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The authors declare there are no competing interests.

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Appendix A. Interview questionnaire for female forest machine operators

1. How many years have you worked as a forest machine operator? _____
2. In which region do you primarily work?
   - ☐ Southern Finland (Uusimaa, Kanta-Häme, Päijät-Häme, Kymenlaakso, South Karelia)
   - ☐ Eastern Finland (South Savo, North Savo, North Karelia)
   - ☐ Western Finland (Åland, Southwest Finland, Satakunta, Pirkanmaa, Central Finland, Ostrobothnia, Central Ostrobothnia, South Ostrobothnia)
   - ☐ Northern Finland (Kainuu, North Ostrobothnia, Lapland)
3. Do you mainly operate:
   - ☐ Harvesters
   - ☐ Forwarders
   - ☐ Both
4. How many forest machines does the company you work for operate in total?
   - ☐ Less than 3
   - ☐ 3–7
   - ☐ 8–13
   - ☐ 14–20
   - ☐ More than 20
5. Did you study to become a forest machine operator directly after school or later as an adult student? _____
6. What influenced your decision to become a forest machine operator? Rate each factor on a scale of 1–5.
   (1 = No influence … 5 = Very strong influence)
   Study counselor: 1 2 3 4 5
   Family: 1 2 3 4 5
   Friends: 1 2 3 4 5
   Educational institutions' websites: 1 2 3 4 5
   Media: 1 2 3 4 5
   Other (specify): _____
7. Did any of the above try to persuade you to choose another profession instead? _____
8. Why were you interested in becoming a forest machine operator? _____
9. Are you satisfied with your choice of profession? (1 = Not at all … 5 = Very satisfied)
   1 2 3 4 5

10. How likely are you to work as a forest machine operator in 5 years time? (1 = Not at all … 5 = Very likely)
    1 2 3 4 5
11. Are you interested in becoming a forest machine entrepreneur in the future?
    ☐ Yes ☐ No
12. Has your gender affected your employment opportunities?
    ☐ Yes, how? _____
    ☐ No
13. Have you encountered gender-related prejudice at work? (1 = Not at all … 5 = Very much)
    Employer: 1 2 3 4 5
    Co-workers: 1 2 3 4 5
    Client representatives: 1 2 3 4 5
    Forest owners: 1 2 3 4 5
    Others (specify): _____
14. Is there a difference in how females and males are treated in the sector?
    ☐ Yes, how? _____
    ☐ No
15. What do you consider the greatest challenge in your work? _____
16. How do you perceive gender equality in the sector? (1 = Very poor … 5 = Very good)
    1 2 3 4 5
17. How should the sector change in the future from a female perspective? _____
18. What factors may influence why females do not apply as operators? (1 = Not at all … 5 = Very significant)
    Expensive machinery: 1 2 3 4 5
    Work is isolating: 1 2 3 4 5
    Lack of knowledge: 1 2 3 4 5
    Male-dominated sector: 1 2 3 4 5
    Physically demanding: 1 2 3 4 5
    Not encouraged in schools: 1 2 3 4 5
    Seasonal fluctuations: 1 2 3 4 5
    Misconceptions: 1 2 3 4 5
    Poor image: 1 2 3 4 5
    Other (specify): _____
19. How could females be encouraged to pursue the profession? (1 = Not at all … 5 = Very significant)
    Better media marketing: 1 2 3 4 5
    More school information: 1 2 3 4 5
    School/company visits: 1 2 3 4 5
    Female-targeted training: 1 2 3 4 5
    Better wages: 1 2 3 4 5
    Improved image: 1 2 3 4 5
    Job content development: 1 2 3 4 5
    Other (specify): _____
20. Additional comments: _____

Appendix B. Survey questionnaire for forest machine contractors

1. How many years have you been working as a forest machine contractor? _____
2. How many forest harvesting machines (harvesters and forwarders) did your company operate at the beginning of 2024?
    ☐ Less than 3
    ☐ 3–7
    ☐ 8–13
    ☐ 14–20
    ☐ More than 20
3. How many forest machine operators were employed in your company at the beginning of 2024? _____
4. How many female forest machine operators were employed in your company at the beginning of 2024? _____
5. How many female forest machine operators have previously been employed in your company? _____
6. What is your age? _____
7. In which region does your company primarily operate?
    ☐ Southern Finland (Uusimaa, Kanta-Häme, Päijät-Häme, Kymenlaakso, South Karelia)
    ☐ Eastern Finland (South Savo, North Savo, North Karelia)

- ☐ Western Finland (Åland, Southwest Finland, Satakunta, Pirkanmaa, Central Finland, Ostrobothnia, Central Ostrobothnia, South Ostrobothnia)
- ☐ Northern Finland (Kainuu, North Ostrobothnia, Lapland)

8. How do you perceive gender equality in the forest machine sector? (1 = Very poor … 5 = Very good)
   1 2 3 4 5
9. What factors may influence why females do not apply to become forest machine operators? (1 = Not at all significant … 5 = Very significant)
   Concerns about expensive machinery: 1 2 3 4 5
   Work is isolating: 1 2 3 4 5
   Lack of knowledge about the profession: 1 2 3 4 5
   Male-dominated sector: 1 2 3 4 5
   Physically demanding work: 1 2 3 4 5
   Lack of encouragement in schools: 1 2 3 4 5
   Seasonal fluctuations: 1 2 3 4 5
   Misconceptions about the sector: 1 2 3 4 5
   Negative public image: 1 2 3 4 5
   Other (specify): _____
10. How could females be encouraged to pursue a career as forest machine operators? (1 = Not at all significant … 5 = Very significant)
    Better media marketing: 1 2 3 4 5
    Improved school information: 1 2 3 4 5
    More school/company visits: 1 2 3 4 5
    Female-targeted training: 1 2 3 4 5
    Better wages: 1 2 3 4 5
    Improved sector image: 1 2 3 4 5
    Job content development: 1 2 3 4 5
    Other (specify): _____
11. What is your opinion of the following statements? (1 = Disagree … 5 = Agree)
    I would hire a female as a forest machine operator: 1 2 3 4 5
    The work of a forest machine operator is suitable for females: 1 2 3 4 5
    Females are skilled forest machine operators: 1 2 3 4 5
    Females and males are treated differently in the sector: 1 2 3 4 5
    My company's employees treat female operators the same as males: 1 2 3 4 5
    More female operators are needed in the sector: 1 2 3 4 5
    Gender equality is important for sector development: 1 2 3 4 5
12. If you have not yet hired female operators, why not? (1 = No influence … 5 = Very strong influence)
    No female operators available: 1 2 3 4 5
    Negative effect on work environment: 1 2 3 4 5
    Parental leave absences: 1 2 3 4 5
    Insufficient work performance: 1 2 3 4 5
    Forest owners' reactions: 1 2 3 4 5
    Client representatives' reactions: 1 2 3 4 5
    Other (specify): _____
13. Additional comments: _____

Appendix C. Interview questionnaire for nonresponse analysis

1. Did you employ any female forest machine operators during 2024?
2. Did you employ any female forest machine operators before 2024?
3. Have you or would you consider employing female operator(s)?
4. In your view, are forest machine operations suitable work for females?
5. Is there any specific reason not to employ female operators?
6. Background information
   a) How many years have you been working as a harvesting contractor?
   b) How many forest machines (harvesters and forwarders) did your company operate at the beginning of 2024?
   c) How many forest machine operators were employed in your company at the beginning of 2024?

Appendix D. Non-response analysis

Question/variable	Contractor survey ($n = 87$)	Nonresponse ($n = 51$)	Test value	Signif.
1. Did you employ any female forest machine operators during 2024? (%)			2139.0	0.823
Yes	13	12		
No	87	88		
2. Did you employ any female forest machine operators before 2024? (%)			2035.0	0.624
Yes	27	22		
No	73	78		
3. Have you or would you consider employing female operator(s)? (%)			2275.5	0.758
Agree	67	71		
Somewhat agree	29	21		
Don't know	4	6		
Somewhat disagree	0	2		
Disagree	0	0		
4. In your view, is forest machine operation suitable work for females? (%)			2587.5	0.053
Agree	58	74		
Somewhat agree	38	22		
Don't know	2	4		
Somewhat disagree	2	0		
Disagree	0	0		
5. Insufficient number of female forest machine operators available for employment. (%)			2269.5	0.108
Agree	60	71		
Somewhat agree	28	25		
Don't know	7	4		
Somewhat disagree	1	0		
Disagree	4	0		
Question/variable	**Contractors' survey ($n = 87$)**	**Nonresponse ($n = 51$)**	**Test value**	**Signif.**
6. Background information				
a) How many years have you worked as a harvesting contractor? (%)			2161.0	0.826
<15	24	28		
15–29	51	41		
>29	25	31		
b) How many forest machines (harvesters and forwarders) did your company operate at the beginning of 2024? (%)			1921.5	0.234
<3	36	47		
3–7	44	37		
8–13	7	8		
14–20	11	4		
>20	2	4		
c) How many forest machine operators were employed in your company at the beginning of 2024? (%)			1667.5	0.015*
<4	35	59		
4–12	41	25		
>12	24	16		

*Significant, $\alpha = 0.05$.