Silva Fennica vol. 57 no. 3 article id 23053
Category: discussion article
https://doi.org/10.14214/sf.23053

SILVA FENNICA

http://www.silvafennica.fi
ISSN-L 0037-5330 | ISSN 2242-4075 (Online)
The Finnish Society of Forest Science

Back Tomas Ersson[1], Linnea Hansson[2], Jussi Manner[2], Per Sandström[3] and Johan Sonesson[2]

Forest management in northern Fennoscandia: the need for solutions that mitigate conflicts during forest regeneration and increase the use of continuous cover forestry

Ersson B.T., Hansson L., Manner J., Sandström P., Sonesson J. (2023). Forest management in northern Fennoscandia: the need for solutions that mitigate conflicts during forest regeneration and increase the use of continuous cover forestry. Silva Fennica vol. 57 no. 3 article id 23053. 11 p. https://doi.org/10.14214/sf.23053

Highlights

- In Sápmi, increased use of continuous cover forestry (CCF) can reduce the frequent conflicts between forest industry and reindeer herding communities.
- Nordic forestry needs to develop new technical solutions for gentle and lichen-adapted mechanical site preparation during CCF in Sápmi.
- Such site preparation technology will promote pioneer tree species' germination and growth, and increase the forest industry's acceptance of CCF.

Abstract

Today, conflicts often occur in northern Fennoscandia (also known as Sápmi) between forestry and reindeer husbandry. Continuous cover forestry (CCF) is requested by both reindeer herding communities and the general public and is becoming more common, but the forest industry criticizes CCF for lower wood production. Mechanical site preparation (MSP) increases regeneration success and, thus, increases wood production in CCF. To reduce the conflict between forestry and reindeer husbandry, MSP in Sápmi should destroy as little ground lichen as possible. Today, there are no solutions for gentle and lichen-adapted MSP in CCF. Thus, there is a strong need to develop and test new technical solutions that increase regeneration success in a lichen-adapted way during CCF in Sápmi. We suggest that MSP solutions be developed which are gentle, work selectively and function in shelterwoods, gap cuts, and selection cutting stands. We envision that these solutions could fill the gap between the desired adaptivity on the part of the reindeer herding communities and the desired efficiency on the part of the forest industry. Such MSP technology would contribute to increased acceptance of CCF in the forest industry, higher biodiversity, and considerably reduce the conflict between forestry and reindeer herding communities.

Keywords indigenous rights; mechanical site preparation; natural resources conflict; reforestation; reindeer husbandry; Sámi; Sápmi
Addresses [1]Swedish University of Agricultural Sciences (SLU), School of Forest Management, SE-739 21 Skinnskatteberg, Sweden; [2]The Forestry Research Institute of Sweden (Skogforsk), Uppsala Science Park, SE-751 83 Uppsala, Sweden; [3]Swedish University of Agricultural Sciences (SLU), Department of Forest Resource Management, SE-901 83 Umeå, Sweden
E-mail back.tomas.ersson@slu.se
Received 12 September 2023 **Revised** 17 October 2023 **Accepted** 23 October 2023

1 Background: the conflict between forest industry and reindeer husbandry

The conflict between the forest industry and reindeer husbandry in northern Fennoscandia (specifically the Sámi homelands, hereafter referred to as Sápmi) has been ongoing since the introduction of industrial forestry during the 1950s (Sandström 2015), or even earlier (Turunen et al. 2020). The conflict, continually escalating, revolves around how the forestland best be used to fulfil the needs of both parties, and resources are constantly being invested to solve the issue (Widmark 2018; Berg 2022; Roos et al. 2022; Rikkonen et al. 2023). In addition to the needs advocated by reindeer herding communities, societal actors and market forces are now pushing for change within Nordic forestry, with a shift away from clearcutting and towards continuous cover forestry (CCF) as an important ingredient (Appelqvist et al. 2021). To meet both the demand for less clearcutting and the strong desire of reindeer herding communities to safeguard and improve conditions on the last lichen-rich forestlands, there is a great need for new, lichen-friendly yet efficient methods and equipment for mechanical site preparation (MSP) during CCF.

2 Reindeer husbandry and silviculture

Reindeer (*Rangifer tarandus* L.) is recognized as a keystone species in the mountain and boreal landscapes of the reindeer husbandry area of northern Fennoscandia (Fig. 1), as well as elsewhere in Eurasia (Vors and Boyce 2009). Reindeer are important for biodiversity for several reasons. Reindeer grazing keeps mountain landscapes open, and by trampling and fertilising through their dung, reindeer create opportunities for non-competitive plant species to thrive (Tunón and Sjaggo 2012). The importance of reindeer husbandry is pinpointed in the Swedish environmental goal “Magnificent mountain landscapes” (Naturvårdsverket 2019), which specifically addresses the necessity of grazing-based landscapes. However, since the critical bottleneck in reindeer husbandry is winter grazing in the forest landscape (Sandström et al. 2016), this environmental goal ties directly into the need of transforming current forestry practices in northern Fennoscandia.

In the culture of the Sámi – Europe’s only indigenous people – reindeer husbandry is an essential part and has been practiced in Sápmi for millennia. Ground lichen (*Cladonia* spp. P.Browne) is the crucial winter food source for reindeer and may constitute up to 50–80% of their diet during winters (Heggberget et al. 2002). However, traditional MSP during forest regeneration can have a significant negative impact on ground lichen, leading to decreased reindeer lichen cover (Roturier and Roué 2009). The amount of forestland rich in ground lichen has declined with 71% from 1955 to 2016 (Sandström et al. 2016), and it continues to decrease.

In general, the priority of the forest industry – which is also a large landowner in Sápmi – is maximizing wood production with little consideration for maintaining and improving lichen cover for the reindeer herding communities. Consequently, during reforestation, the focus of MSP is generally on ensuring seed germination and satisfactory seedling survival and growth (Bergsten and Sahlén 2013; Karlsson et al. 2017). Hence, MSP increases wood production by shortening the regeneration phase (Örlander and Gemmel 1989; Fries 1993). However, traditional MSP like disc-trenching disturbs a large proportion of the ground surface area, often >50% of a clearcut (Mattsson 2002). This extensive soil disturbance negatively affects the ecosystem and ground lichen. Moreover, even-aged forestry is currently the dominating forest management system in Sápmi (Kuuluvainen et al. 2012). Young, dense and homogeneous stands and clearcuts fragment the forest landscape and reduce the contiguous areas of old forests, which are the best habitats for arboreal lichens (*Bryoria* spp. Brodo & D.Hawksw. and/or *Alectoria* spp. Ach.) (Horstkotte et al. 2011; Sandström et al. 2016).

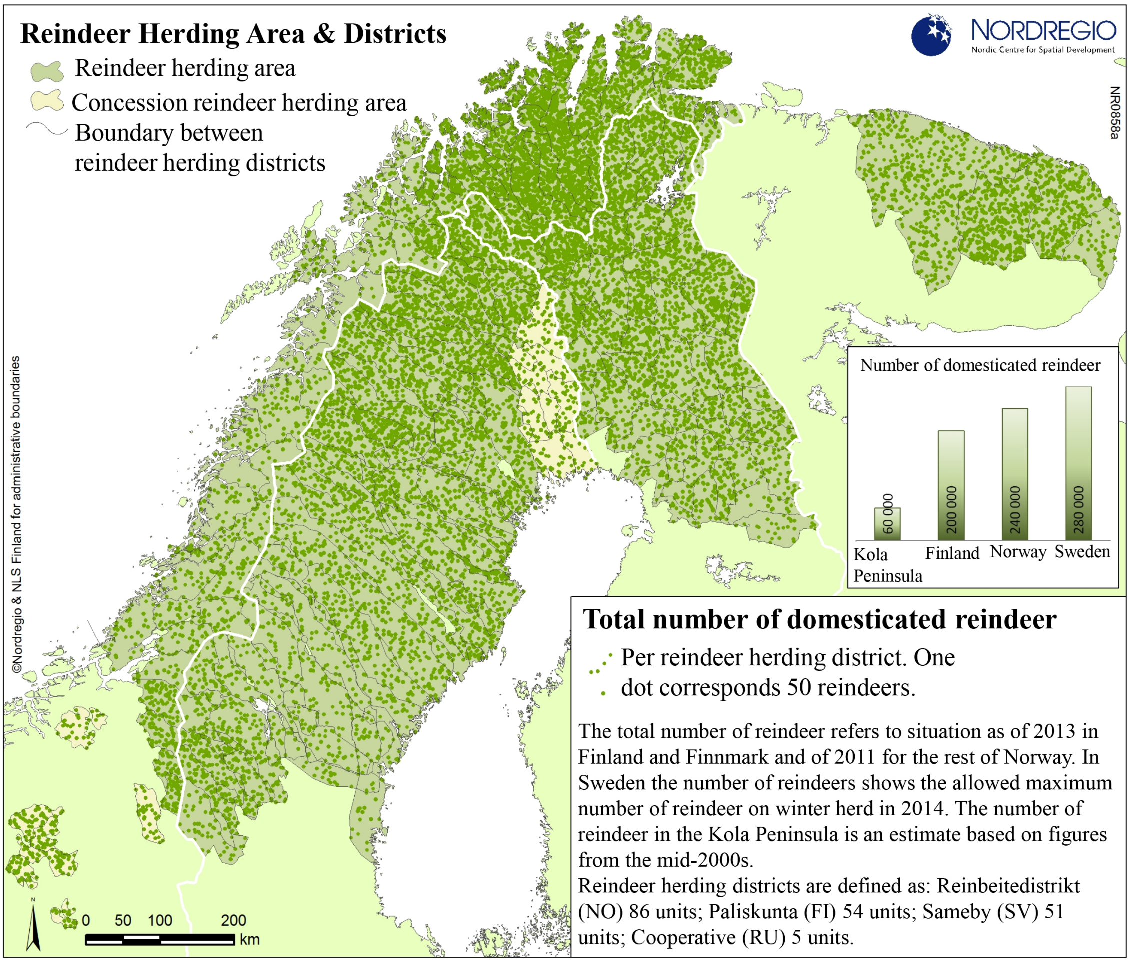

Fig. 1. Reindeer husbandry areas (in darker grey or yellow with green dots) in the Nordic countries and Russia (Fennoscandia). Illustration: Johanna Roto, Nordregio 2015.

3 The conflict is solvable

The conflict between the forest industry and reindeer herding communities has been ongoing for decades. The lack of incentives to turn current silvicultural practices more "reindeer friendly" has been the main reason for this persistence (Horstkotte and Djupström 2021). Nevertheless, researchers have argued that it is technically possible to adapt forest management practices to better suit the needs of reindeer herding communities (Roturier and Bergsten 2009; Eggers et al. 2023). In addition, society's increasing awareness of the forests' social and environmental values is forcing the Swedish forest industry to slowly adapt its forest practices (cf. Holopainen et al. 2014; Toppinen et al. 2019; Toppinen et al. 2020). In general, CCF is better than even-aged forestry at protecting several of the social and environmental values of forests (Peura et al. 2018; Diaz-Yanez et al. 2020; Eyvindson et al. 2021). CCF is thus gaining acceptance in the Nordics, although the forest industry keeps criticizing CCF's lower wood production (Lundqvist 2017; Sonesson et al. 2017; Hynynen at al. 2019).

Today, CCF in Sápmi encompasses three general types of management methods (Appelqvist et al. 2021): shelterwoods, gap cutting, and selection cutting. Berg et al. (2015) evaluated forest management recommendations made by the National Union of Swedish Sami (SSR 2009). These recommendations include gentle site preparation and increased use of CCF because these management practices benefit both reindeer husbandry and the growth of ground and arboreal lichens. Hence, there is a need to actively promote research and technical development of gentle MSP, which in turn increases the forest industry's acceptance and implementation of CCF. Gentle MSP is congruent with the concept of Lean forestry (Rautio et al. 2023), a concept which is in many ways desirable from several economic, ecological and societal points-of-view.

4 The need for MSP development

In northern Fennoscandia, site preparation is necessary for successful and rapid reforestation, both by natural and artificial means (Sikström et al. 2020). But for MSP to be compatible with sustainable forest management and reindeer husbandry, soil preparation must not be too heavy, deep, nor be done indiscriminately (Roturier 2009). In addition, the MSP should destroy as little ground lichen as possible (Fig. 2). In order to be cost-efficient (and thus appealing to the forest industry) and relevant in CCF, MSP must be able to be carried out: 1) fast; 2) without significant damage to remaining trees; and 3) on small areas (and/or on few hectares) without expensive relocation costs making MSP unprofitable.

Wildfire is the main natural determinant of successional stages of ground vegetation in boreal forests, and most northern Fennoscandia forests have been affected by recurrent fires (Zackrisson 1977; Niklasson and Granström 2000). However, during the last century, these forests have been subjected to fire suppression, which has dramatically reduced fire's impact on vegetation (Östlund et al. 1997). This absence of fire has resulted in an increase of feathermosses and dwarf shrubs (Wardle et al. 2004). Tree seedling establishment and growth is better in reindeer lichens than in feather mosses (Steijlen et al. 1995). Thus, there is a greater need for site preparation on microsites dominated by mosses than on lichen-rich sites and patches.

Fig. 2. A) Conventional, large-scale mechanical site preparation (MSP) has eradicated the ground lichen; B) gentle, lichen-adapted MSP has sustained the ground lichen cover, hence providing a food source for reindeer year-round. Photo: Sven Adler, SLU.

Site preparation became common in the early 1950s (Frölén 2019), and ever since then, forest management in Sweden has focused on cultivating conifers on clearcuts. Thus, site preparation development has traditionally been geared towards operating on large clearcuts, and there are currently no technical solutions for gently and cost-efficiently performing site preparation during CCF in Sápmi.

However, if we are to site prepare in CCF, it is probably not efficient or even possible to use the common MSP tools of clearcut forestry (such as disc trenchers and continuously advancing mounders). What's more, the market for silvicultural technology is small, and the cost of MSP development is often high. Furthermore, forest companies do not always recognize an immediate return from investments in site preparation, as is often the case with the direct cost-recovery from investments in harvesting-related research and development (R&D).

Examples of previous Swedish attempts at MSP development that were either relatively selective or gentle include: Prekal (Sundblad 2012; Eriksson and Täljeblad 2022); inverting with Kicken (Frölén 2019) and Kovesen (Bergkvist et al. 2018), HuMinMix (Roturier 2009): HuMax 24 (Andersson 2005); additional-added soil ("pytsning", Sörensen et al. 2019); MidiFlex (Wallertz et al. 2018; Persson 2020); KarlOskar (Sundblad 2009; Wallertz et al. 2018) and drag implements (e.g. shark finned barrels, Edlund 2018). However, these MSP devices were either inefficient and/or expensive and thus never got past the trial stage or disappeared from the market, or are non-selective, ungentle, and/or unsuitable for CCF. Hence, MSP development tailored to CCF is necessary.

MSP is needed to solve this three-faceted problem (Fig. 3), but the existing MSP tools/solutions are inadequate. Thus, technical development is necessary; and with this discussion article, we wish to propose an approach to address this developmental requirement.

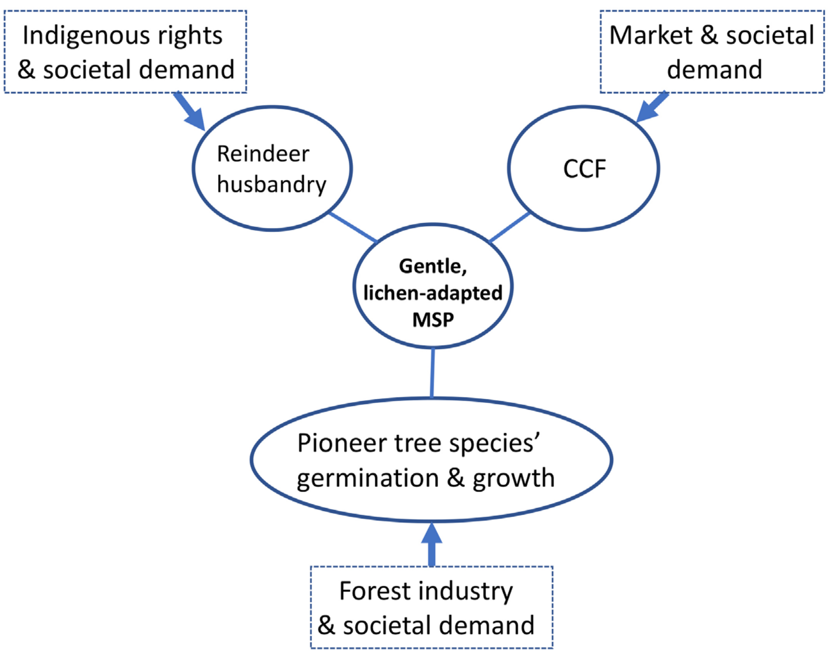

Fig. 3. Combining i) reindeer husbandry needs, ii) societal demand for Continuous Cover Forestry (CCF) silviculture, and iii) the desire of both forest industry and society for volume growth of pioneer tree species requires the development of technology for gentle, lichen-adapted mechanical site preparation (MSP).

5 Proposed MSP solutions

We argue that forest owners in Sápmi need to transition to silvicultural systems that reduce the ongoing conflict between the forest industry and reindeer husbandry. This transition will be expedited if Nordic forestry develops cost-efficient technologies for lichen-friendly site preparation tailored to CCF in Sápmi.

Specifically, we propose that Nordic forestry develop solutions for gentle MSP by mounting new site preparation devices on: i) harvesters used during section cutting (Fig. 4A); ii) forwarders used during gap cutting (Fig 4B); iii) harvesters and/or forwarders used during shelterwood cutting. We suggest that the forwarder-mounted MSP technology be capable of precision real-time steering of the scarifying head, and detecting the lichen cover via sensors, image analysis and artificial intelligence (AI). Based on past research on MSP in Nordic shelterwoods outside of Sápmi (Fjeld 1994; Suadicani 2003), we postulate that harvester-based MSP technology is more suitable when shelterwoods are dense and/or lichen is abundant, while forwarder-based MSP technology is more suitable when the shelterwood and/or lichen is sparse. Notwithstanding, we believe that any development process must start with the mapping of the specific needs of reindeer herding communities, and the particular site preparation results requested by reindeer husbandry experts.

Our proposed solutions will help to develop site preparation technology that meet the needs of both the forest industry and reindeer herders. By lessening Nordic forestry's negative impact on lichen resources, reindeer husbandry would be strengthened, thereby helping the Nordic countries meet national and international obligations to protect indigenous peoples' rights. Precision MSP technology may even promote lichen growth in the long run if feathermosses and dwarf shrubs are removed during site preparation. Moreover, MSP aids pioneer tree species' regeneration (Grossnickle and Ivetic 2017), which many societal actors including reindeer herding communities wish to see more of in Sápmi (Fig. 3).

Fig. 4. A) Gentle, lichen-adapted mechanical site preparation (MSP) with a harvester in selection cutting; the MSP is performed using a simple scarifier mounted on the harvester head. B) Gentle, lichen-adapted MSP with a forwarder in gap cutting; the MSP is performed using image-based precision steering of the scarifying device to avoid lichen-rich areas. We postulate that the density of lichens and/or shelterwoods dictates whether harvester-based MSP (A) or forwarder-based MSP (B) is most suitable during shelterwood cutting. Drawings: Linnea Hansson, Skogforsk.

Our suggested solutions pertain to several environmental issues related to forestry. When regeneration success is increased, carbon sequestration increases faster after harvest, which helps to mitigate carbon emissions and climate change (Lee et al. 2002). Using precision methods for soil scarification is energy efficient, especially if the MSP is performed using the same machine that is already present during harvesting (von Hofsten and Nordén 2002; Haavikko et al. 2022). Moreover, the risk of soil disturbances decreases if fewer machines (no separate machine for MSP) are used on the site (Labelle et al. 2022). Soil compaction and rutting by forest machinery can increase the methyl-mercury content of fish in nearby streams (Eklöf et al. 2016, 2018) and soil disturbances close to water should be avoided to reach environmental goals like the Swedish national goal "Flourishing lakes and streams". Less soil disturbance is also positive from a recreational point-of-view, e.g. for outdoor tourism and berry picking. In addition, increased regeneration efficiency in CCF is important for increasing the acceptance and implementation of this management system on larger scale in Sweden and other European and boreal countries.

6 Conclusions

Most likely, gentle and CCF-adapted MSP solutions will help to strengthen reindeer husbandry and thereby Sámi rights and cultural traditions. Moreover, such new MSP solutions are critical for cost-efficient, sustainable forest management, which is important if society is to fulfil its environmental goals. Indeed, cost-efficient tools are needed if the forest sector is to willingly increase in Sápmi the forestlands on which CCF is practiced. Silvicultural methods that maintain wood production while simultaneously increasing the social and environmental values of Sápmi forests will also help the Nordic region transition to a bioeconomy, fight climate change, provide employment, protect biodiversity, and reach many other societal goals.

Funding

Funding for this work was provided by Skogforsk and SLU's Faculty of Forest Sciences. Funding for Per Sandström was provided from the Swedish Research Council for Sustainable Development Formas (project no. 2019-431), EU Horizon 2020 project ArcticHubs (grant agreement no. 869580) and the Swedish Environmental Protection Agency´s Research Grant number 2021-00040.

References

Andersson E (2005) Forskningsseminarium skogsbruk – rennäring. [Research seminar forestry – reindeer husbandry]. Report 17/2005, Skogsstyrelsen [The Swedish Forest Agency].

Appelqvist C, Sollander E, Norman J, Forsberg O, Lundmark T (2021) Hyggesfritt skogsbruk – Skogsstyrelsens definition. [Continuous cover forestry –The Swedish Forest Agency's definition]. Report 2021/8, Skogsstyrelsen [The Swedish Forest Agency].

Berg T (2022) Co-existence and conflict in a changing forest landscape – a case study of Maskaure reindeer herding district. Report 9084176, Lund University. http://lup.lub.lu.se/student-papers/record/9084176.

Berg S, Valinger E, Lind T, Suominen T, Tuomasjukka D (2015) Comparison of co-existing forestry and reindeer husbandry value chains in northern Sweden. Silva Fenn 50, article id 1384. https://doi.org/10.14214/sf.1384.

Bergkvist I, Sundblad LG, Hajek J (2018) A comparative study with three different soil preparation machines including scarification, traditional mounding and a centre-mounted device for inverse soil preparation. EFFORTE report D2.2, Natural Resources Institute Finland (Luke).

Bergsten U, Sahlén K (2013) Sådd. [Direct seeding]. Skogsskötselserien No. 5, Skogsstyrelsen [The Swedish Forest Agency].

Díaz-Yanez O, Pukkala T, Packalen P, Peltola H (2020) Multifunctional comparison of different management strategies in boreal forests. Forestry 93: 84–95. https://doi.org/10.1093/forestry/cpz053.

Edlund S (2018) Alternativa skötselmetoder i Rånddalen Ett projekt i Härjedalen: Fas 2 – Återväxtåtgärder. [Alternative forest management methods in Rånddalen: a project in Härjedalen, phase 2 – reforestation measures]. Report 2018, Skogsstyrelsen [The Swedish Forest Agency].

Eggers J, Roos U, Lind T, Sandström P (2023) Adapted forest management to improve the potential for reindeer husbandry in Northern Sweden. Ambio. https://doi.org/10.1007/s13280-023-01903-7.

Eklöf K, Lidskog R, Bishop K (2016) Managing Swedish forestry's impact on mercury in fish: defining the impact and mitigation measures. Ambio 45: 163–174. https://doi.org/10.1007/s13280-015-0752-7.

Eklöf K, Bishop K, Bertilsson S, Björn E, Buck M, Skyllberg U, Osman OA, Kronberg RM, Bravo AG (2018) Formation of mercury methylation hotspots as a consequence of forestry operations. Sci Total Environ 613: 1069–1078. https://doi.org/10.1016/j.scitotenv.2017.09.151.

Eriksson B, Täljeblad M (2022) Självföryngring före slutavverkning – Redovisning av projekt PREKAL. [Natural regeneration before final felling – results from the PREKAL project]. Report 1139–2022, Skogforsk.

Eyvindson K, Duflot R, Triviño M, Blattert C, Potterf M, Mönkkönen M (2021) High boreal forest multifunctionality requires continuous cover forestry as a dominant management. Land Use Policy 100, article id 104918. https://doi.org/10.1016/j.landusepol.2020.104918.

Fjeld D (1994) Patch scarification in shelterwood stands of varying stand density. Doctoral Thesis 1994:4, Agricultural University of Norway. ISBN 82-575-0211-1.

Fries C (1993) Development of planted *Pinus sylvestris* and *P. contorta* after soil preparation in a northern climate. Scan J Forest Res 8: 73–80. https://doi.org/10.1080/02827589309382756.

Frölén D (2019) The technical development of mechanical site preparation. Report 2019:6, Swedish University of Agricultural Sciences, Department of Forest Biomaterials and Technology. http://urn.kb.se/resolve?urn=urn:nbn:se:slu:epsilon-s-11127.

Grossnickle SC, Ivetic V (2017) Direct seeding in reforestation – a field performance review. Reforesta 4: 94–142. https://doi.org/10.21750/REFOR.4.07.46.

Haavikko H, Kärhä K, Poikela A, Korvenranta M, Palander T (2022) Fuel consumption, greenhouse gas emissions, and energy efficiency of wood-harvesting operations: a case study of Stora Enso in Finland. Croat J For Eng 43: 79–97. https://doi.org/10.5552/crojfe.2022.1101.

Heggberget TM, Gaare E, Ball JP (2002) Reindeer (*Rangifer tarandus*) and climate change: importance of winter forage. Rangifer 22: 13–31. https://doi.org/10.7557/2.22.1.388.

Holopainen J, Häyrinen L, Toppinen A (2014) Consumer value dimensions for sustainable wood products: results from the Finnish retail sector. Scan J Forest Res 29: 378–385. https://doi.org/10.1080/02827581.2014.925138.

Horstkotte T, Djupström L (2021) Rennäring och skogsnäring i Sverige – delad kunskap för delad markanvändning. [Reindeer husbandry and forestry in Sweden – shared knowledge for shared land use]. Future Forests Report 2021:2, Swedish University of Agricultural Sciences. ISBN 978-91-576-9866-7.

Horstkotte T, Moen J, Lämås T, Helle T (2011) The legacy of logging – estimating arboreal lichen occurrence in a boreal multiple-use landscape on a two century scale. PLoS ONE, 6, article id 28779. https://doi.org/10.1371/journal.pone.0028779.

Hynynen J, Eerikäinen K, Mäkinen H, Valkonen S (2019) Growth response to cuttings in Norway spruce stands under even-aged and uneven-aged management. Forest Ecol Manag 437: 314–323. https://doi.org/10.1016/j.foreco.2018.12.032.

Karlsson C, Sikström U, Örlander G, Hannerz M, Hånell B (2017) Naturlig föryngring av tall och gran. [Natural regeneration of Scots pine and Norway spruce]. Skogsskötselserien No. 4, Skogsstyrelsen [The Swedish Forest Agency].

Kuuluvainen T, Tahvonen O, Aakala T (2012) Even-aged and uneven-aged forest management in boreal Fennoscandia: a review. Ambio 41: 720–737. https://doi.org/10.1007/s13280-012-0289-y.

Labelle ER, Hansson L, Högbom L, Jourgholami M, Laschi A (2022) Strategies to mitigate the effects of soil physical disturbances caused by forest machinery: a comprehensive review. Curr Forestry Rep 8: 20–37. https://doi.org/10.1007/s40725-021-00155-6.

Lee J, Morrison IK, Leblanc JD, Dumas MT, Cameron DA (2002) Carbon sequestration in trees and regrowth vegetation as affected by clearcut and partial cut harvesting in a second-growth boreal mixedwood. Forest Ecol Manag 169: 83–101. https://doi.org/10.1016/S0378-1127(02)00300-6.

Lundqvist L (2017) Tamm review: selection system reduces long-term volume growth in Fennoscandic uneven-aged Norway spruce forests. Forest Ecol Manag 391: 362–375. https://doi.org/10.1016/j.foreco.2017.02.011.

Mattsson S (2002) Effects of site preparation on stem growth and clear wood properties in boreal *Pinus sylvestris* and *Pinus contorta*. Doctoral Thesis 240, Swedish University of Agricultural Sciences. ISBN 91-576-6324-6.

Naturvårdsverket (2019) Miljömålen – Årlig uppföljning av Sveriges nationella miljömål 2019 – Med fokus på statliga insatser – Reviderad version [Environmental goals – Annual monitoring of Sweden's national environmental goals 2019 – with focus on governmental efforts – revised version]. Report 6890. Naturvårdsverket [The Swedish Environmental Protection Agency]. ISBN 978-91-620-6890-5.

Niklasson M, Granström A (2000) Numbers and sizes of fires: long-term spatially explicit fire history in a Swedish boreal landscape. Ecology 81: 1484–1499. https://doi.org/10.2307/177301.

Örlander G, Gemmel P (1989) Markberedning. [Site preparation – a swedish overview]. Report 1989:03, Sveriges skogsvårdsförbunds tidskrift.

Östlund L, Zackrisson O, Axelsson AL (1997) The history and transformation of a Scandinavian boreal forest landscape since the 19th century. Can J Forest Res 27: 1198–1206. https://doi.org/10.1139/x97-070.

Persson J (2020) Utvärdering av den midjemonterade harven Midiflex markberedningsresultat på fuktiga marker. [Evaluation of the disc trencher MidiFlex's soil preparation results on moist soils]. Report 2020:22, Swedish University of Agricultural Sciences, Skogsmästarskolan. http://urn.kb.se/resolve?urn=urn:nbn:se:slu:epsilon-s-16021.

Peura M, Burgas D, Eyvindson K, Repo A, Mönkkönen M (2018) Continuous cover forestry is a cost-efficient tool to increase multifunctionality of boreal production forests in Fennoscandia. Biol Conser 217: 104–112. https://doi.org/10.1016/j.biocon.2017.10.018.

Rautio P, Lideskog H, Bergsten U, Karlberg M (2023) Lean forestry – a paradigm shift from economies of scale to precise and sustainable use of ecosystem services in forests. Forest Ecol Manag 530, article id 120766. https://doi.org/10.1016/j.foreco.2022.120766.

Rikkonen T, Turunen M, Hallikainen V, Rautio P (2023) Multiple-use forests and reindeer husbandry – case of pendulous lichens in continuous cover forests. Forest Ecol Manag 529, article id 120651. https://doi.org/10.1016/j.foreco.2022.120651.

Roos U, Lidestav G, Sandström S, Sandström P (2022) Samråd: an institutional arrangement in the context of forestry and reindeer husbandry in northern Sweden. Int Forest Rev 24: 441–457. https://doi.org/10.1505/146554822835941878.

Roturier S (2009) Managing reindeer lichen during forest regeneration procedures: linking Sámi herders' knowledge and forestry. Doctoral Thesis 2009:84, Swedish University of Agricultural Sciences. ISBN 978-91-576-7431-9. https://res.slu.se/id/publ/27462.

Roturier S, Bergsten U (2009) Establishment of *Cladonia stellaris* after artificial dispersal in an unfenced forest in northern Sweden. Rangifer 29: 39–49. https://doi.org/10.7557/2.29.1.208.

Roturier S, Roué M (2009) Of forest, snow and lichen: Sámi reindeer herders' knowledge of winter pastures in northern Sweden. For Ecol Manag 258: 1960–1967. https://doi.org/10.1016/j.foreco.2009.07.045.

Sandström P (2015) A toolbox for co-production of knowledge and improved land use dialogues – the perspective of reindeer husbandry. Doctoral Thesis 2015:20, Swedish University of Agricultural Sciences. https://res.slu.se/id/publ/64872.

Sandström P, Cory N, Svensson J, Hedenås H, Jougda L, Borchert N (2016) On the decline of ground lichen forests in the Swedish boreal landscape: implications for reindeer husbandry and sustainable forest management. Ambio 45: 415–429. https://doi.org/10.1007/s13280-015-0759-0.

Sikström U, Hjelm K, Hanssen KH, Saksa T, Wallertz K (2020) Influence of mechanical site preparation on regeneration success of planted conifers in clearcuts in Fennoscandia – a review. Silva Fenn 54, article id 10172. https://doi.org/10.14214/sf.10172.

Sonesson J, Eliasson L, Jacobsson S, Wallgren M, Weslien J, Wilhelmsson L (2017) Hyggesfritt skogsbruk på landskapsnivå. [Continuous-cover silviculture at landscape level]. Report 926–2017, Skogforsk.

Sörensen R, Johansson F, Johannesson T, Eliasson L, Hajek J, Bergkvist I (2019) Utvärdering av markberedningsmetoden ”pytsning”. [Evaluation of the soil preparation method “pytsning”]. Report 1011–2019, Skogforsk.

SSR (2009) Ett renskötselanpassat skogsbruk. [Forest management adapted to reindeer husbandry]. Svenska Samernas Riksförbund [National Union of Swedish Sami].

Steijlen I, Nilsson MC, Zackrisson O (1995) Seed regeneration of Scots pine in boreal forest stands dominated by lichen and feather moss. Can J Forest Res 25: 713–723. https://doi.org/10.1139/x95-079.

Suadicani K (2003) Site preparation and planting in a *Picea abies* shelterwood stand. Scan J Forest Res 18: 247–259. https://doi.org/10.1080/02827581.2003.9728295.

Sundblad LG (2009) Grävmaskinburet aggregat klarar både inversmarkberedning och högläggning. [A new unit available for mechanized inverting]. Report 12–2009, Skogforsk.

Sundblad LG (2012) PREKAL – en nygammal föryngringsmetod. [Traditional regeneration method revived]. Report 46–2012, Skogforsk.

Toppinen A, Mikkilä M, Tuppura A, de Vries G (2019) Sustainability as a driver in forestry related services. In: Hujala T, Toppinen A, Butler BJ (eds) Services in family forestry. World Forests. Springer, Cham, pp 289–306. https://doi.org/10.1007/978-3-030-28999-7_14.

Toppinen A, D'Amato D, T Stern T (2020) Forest-based circular bioeconomy: matching sustainability challenges and novel business opportunities? Forest Policy Econ 110, article id 102041. https://doi.org/10.1016/j.forpol.2019.102041.

Tunón H, Sjaggo BS (2012) Ájddo: reflektioner kring biologisk mångfald i renarnas spår. [Ájddo: reflections on biodiversity in the tracks of the reindeer]. CBM:s skriftserie 68. https://res.slu.se/id/publ/88163.

Turunen MT, Rasmus S, Järvenpää J, Kivinen S (2020) Relations between forestry and reindeer husbandry in northern Finland – perspectives of science and practice. Forest Ecol Manag 457,

article id 117677. https://doi.org/10.1016/j.foreco.2019.117677.
von Hofsten H, Nordén B (2002) Kombinerad risskotare och markberedare. [The forwarder-scarifier – a new dual-purpose machine]. Report 11–2002, Skogforsk.
Vors LS, Boyce MS (2009) Global declines of caribou and reindeer. Glob Change Biol 15: 2626–2633. https://doi.org/10.1111/j.1365-2486.2009.01974.x.
Wallertz K, Björklund N, Hjelm K, Petersson M, Sundblad LG (2018) Comparison of different site preparation techniques: quality of planting spots, seedling growth and pine weevil damage. New Forests 49: 705–722. https://doi.org/10.1007/s11056-018-9634-8.
Wardle DA, Walker LR, Bardgett RD (2004) Ecosystem properties and forest decline in contrasting long-term chronosequences. Science 305: 509–513. https://doi.org/10.1126/science.1098778.
Widmark C (2018) Bargaining costs in a common pool resource situation – the case of reindeer husbandry and forestry in northern Sweden. Can J Forest Res 49: 339–349. https://doi.org/10.1139/cjfr-2018-0265.
Zackrisson O (1977) Influence of forest fires on the North Swedish boreal forest. Oikos 29: 22–32. https://doi.org/10.2307/3543289.

Total of 61 references.