ForestEcoSecurity - Management methods and technology for young boreal forests for adaptation to sustainable forest management goals in a changing climate

Literature review

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Aurora region forestry objectives, their target measures and the current state of the forests

The novelty of this literature review is to take the young forest management problems of Nordic Boreal Forestry (NBF) and change them into opportunities. Focusing on young forest management, we summarize the national Interreg Aurora region forestry objectives, their target measures and current state of the forests. Based on the NBF area study results published in the 2000s, we review the current young stand management systems by dividing them in practical implementation categories: I) digital tools for pre-planning of cutting areas, II) mechanized harvesting work methods and technologies, III) monitoring of wood procurement resourcing, and IV) transfer of research and development knowledge to practitioners and forest owners. Finally, we analyze the strengths and weaknesses of the systems to assess the roadmap for further development.

Background

The Interreg Aurora region, particularly Finnish Lapland and Norrbotten in Sweden, focuses on enhancing climate resilience within its forestry sector. Since 2024, Finland's North Karelia and Kainuu have also been part of the Aurora program area. An important focus area is combining sustainable use of forest raw material resources for the industries with initiatives to promote advanced technology.

Despite the overall Aurora region forestry promotion strategy, the NBF's problems are the growing area of poor condition young forests and their unexploited raw material. One of the reasons for neglecting young forests is the forest owners' low willingness to manage young forests and sell small-diameter wood because the management is costly and the revenue from sales is very scarce. The changing structure of forest owners has significantly increased the importance of ecological and social values for their forests. In the traditional rotation forestry (RF) management method, dominating in NBF, mixed forest formed of coniferous and deciduous trees usually develops by natural regeneration by planting or sowing after clear-cutting. Next, during the first 10-20 years, the development of the young forest is strongly influenced by its management intensity, in other words, what tree species and how densely they are grown. However, RF pre-commercial thinning (PCT) and first commercial thinning do not always create enough post-stands with higher biodiversity. For forest owners and forestry companies, it could be possible to find improvements to the problems of young forests by cross-border synthesizing the best Nordic Boreal Forestry (NBF) management strategies.

Selection of the studies

In total, 46 articles were selected and analyzed by using an integrative literature review method [47, 48]. The selection criteria for the articles were: the research is Nordic, main author employed at a Swedish or Finnish organization, the article was published in the 2000s, the article is sufficient to meet the practical implementation categories, and the article is based on empirical material or simulations.

I) Digital tools for pre-planning of cutting areas

Several studies from the 2020s have shown that digital methods have potential in recording and predicting forest inventory attributes or terrain features [49-54]. Remote sensing methods (RSM) are increasingly used to obtain forest structure information covering large areas [6]. Methods to use tree stem information recorded by harvesters along operative logging in RSM-based prediction of forest inventory attributes have also been developed [5]. Drone-mapping using deep learning algorithms could tackle the challenges of traditional young forest inventory methods which are expensive, time consuming and lacking in spatial resolution. However, there is still a lack of practical and affordable applications [1, 2, 3].

II) Mechanized harvesting work methods and technologies

Work methods

Forest work methods refer to the different ways in which forest management is carried out with the most suitable technology.

Currently, the most used and cost-effective working method in early cleaning for seedling stands is motor-manual clearance using a brush saw. Compared to motor-manual work with a brush saw, the cost competitiveness of using mechanized clearing machines is still low in young forests. However, mechanical uprooting of non-crop deciduous trees around the conifer seedings has proven to be a promising method because it can eliminate the need of additional pre-clearence work up to the first commercial thinning [25].

For first thinning stands, two mechanized harvesting systems from stump to the roadside landing, including cutting and forwarding, are used: the traditional two-machine (harvester and forwarder) system and the harwarder system, i.e., the same machine performs both cutting and forest haulage to the roadside landing. The two-machine system is most common because of its flexibility. One of the strengths of harwarder method is the lower relocations costs compared to the two-machine system. Because of this, the harwarder system is more competitive than the two-machine system in low-removal harvesting sites [19, 22, 24, 29].

The results strongly indicate that the key work phase of wood procurement in small-diameter stands is smooth harvester's crane and head movements in felling, accumulating, processing, and piling the trees [20, 21, 23, 28]. The good quality and location of roundwood (small timber and pulpwood) and biomass (small whole trees and tops and branches) bunches along the strip road are a prerequisite for efficient loading into the forwarder's loading space [31, 34].

The most successful harvesters' working technique for dense small-diameter stands when roundwood is the main target product is the use of multi-tree harvesting head [41] that is able to fell, delimb, buck and pile up several trees during the same crane cycle [20]. If the only product is biomass, multi-tree handling felling- and bunching heads are more suitable. Depending on the marked conditions, the benefits of multi-tree handling can be reinforced by the following methods:

- Integrated harvesting where small-diameter energy wood and thicker pulp wood are harvested at the same time by using the two-pile method [23].
- In boom-corridor thinning, trees are harvested in narrow corridors which enables the harvester head to move more smoothly and faster [21, 30, 36].
- Bundling the trees during cutting makes the logging-chain from stump to the end use place more efficient (forwarding, truck transport [33, 35, 45, 46].

Technologies

In the 21st century, the machines and equipment for young forest management work have been under multifaced development. The early cleaning devices are based on traditional saw chains, circular saw discs, rotation cone-shaped shears, uprooting technology or devices with biological fungus sprouting methods against deciduous trees. These devices can be mounted on forest machines of different models and sizes equipped with a crane. However, the acquisition, maintenance and use of the machinery still requires relative high investments compared to using manual and motor manual tools and work methods. Moreover, the boom tip control to maximize the flexible movements of clearing device should be developed [37, 38, 40, 44].

Multi-tree harvesting heads are now available in the market and in a large number of models. Some of the models are simple felling heads [39, 40, 43]. Harwarder heads perform both cutting and loading so that one machine is able to conduct cutting and forwarding [42]. One important development target for dense small-diameter stands is boom tip controlled harvester heads capable of continuous felling and accumulation of trees in one crane cycle [32].

III) Monitoring of wood procurement resourcing

The control of work resourcing before and after work in early cleaning [4, 7, 15, 26, 27] and logging [9, 12, 13, 14] has been developed as an important part of forest management and wood procurement. Monitoring the work quality requires that after the management procedure, the forest is profitable in terms of timber yield and the biodiversity is at a sufficient level [8, 10, 11]. In general, current methods prioritize wood production over other values.

IV) Transfer of research and development knowledge to practical implementers and forest owners

The challenge of putting new research and development knowledge into practice is how entrepreneurs and forest owners find new valuable information e.g., informative courses, slides and brochures [16, 17, 18]. Important for forest sector companies, educational organizations and research and development projects is how this could be enhanced, and how the new knowledge could be marketed.

Future development steps

Digital tools need to be developed to support pre-planning of implementation of Nordic juvenile and first thinning stands management. With this development, forest regeneration practices and stand structure of the young forests should be considered: 1) artificial regeneration, 2) natural regeneration, 3) managed stands, 4) unmanaged stands. In this way, the tools and methods developed will improve pre-planning of the implementation and the quality and profitability of the young forest biomass.

We compiled in this literature review the current management methods and technology for young boreal forests. Based on the results, the following advances in pre-planning and implementation play an important role in improving the profitability of young Nordic forests:

- Digital pre-planning tools based on remote sensing systems in targeting cutting areas: information in the logging machine's tree-specific production files (HPR-data) is connected to remote sensing data from the same stand to test the possibilities of remote sensing.
- Drone, 360 degrees cameras, LIDAR data for harvesting planning: determine the working environment of young forests based on stand structure (tree diameter and length, stand density), undergrowth properties and terrain properties.
- Virtual reality technologies for harvesting planning: real time operator decision support technologies.
- Silvicultural methods and technologies: describe work methods and suitable technologies for young dense forests; and develop a harvester working location based, thinning models.
- Monitoring resourcing and profitability: calculation platform of integrated biomass and roundwood harvesting for contractor.

- Data transfer network: through the cooperation between research, forest professionals and teaching, a network model of data transfer to ensure the transfer of new research and development data to practical forestry.

NBF has common forest types, common problems, and common goals. Due to slightly different market situations in each country, we perform silvicultural actions slightly differently. This diversity of national harvesting systems, work methods and technologies is the strength of cooperation. The possibility is to learn from each other and learn together, and then jointly take new steps forward.

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