

Chapter 2

Definitions and Terminology: What Is Continuous Cover Forestry in Fennoscandia?



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Abstract

- Definitions of continuous cover forestry (CCF) vary among countries, and are often a political compromise.
- We offer a common definition of CCF for this book, which can be found in a text box below.
- The three silvicultural systems included in CCF are described briefly.
- Conversion to CCF will be an important activity in the near future, but approaches to and experiences of conversion to CCF are largely lacking in Fennoscandia.
- Methods need to be developed for how to assess the suitability of forest stands for CCF or conversion to CCF.
- Bad practices and experiences with selective cutting in Fennoscandia before 1950 have led to a loss of experience and willingness to apply CCF.
- Climate adaptation will make it necessary to modify CCF approaches in the region, especially given the limited number of shade-tolerant species.

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2.1 Definitions and Terminology

In this chapter, we define the terms essential for this book, i.e., continuous cover forestry (CCF), conversion to CCF, and other related terms. We also give a brief overview of the silvicultural systems included in CCF in our region. The context for these definitions and terms will be presented in Sect. 2.2. Clear definitions of terms are essential for communication, especially when using technical terms, which are often abbreviations of complex concepts. Terminology also varies between countries, and the English terminology is often not well known.

2.1.1 Continuous Cover Forestry

CCF has been defined in many different contexts, and definitions vary. It has never been a scientific concept, and does not have its origin in research or academic textbooks. When CCF is defined in the context of forest policy at different levels, these definitions are typically not very detailed or operational (e.g., Vitkova et al. 2014; Hertog et al. 2022; Egan et al. 1999). Silvicultural textbooks and scientific literature rarely offer a clear definition of CCF. Frequently, equivalent terms in national languages are used, which sometimes overlap with CCF as it is defined here. Some of these terms are reviewed below.

Based on the terms and definitions currently used in Fennoscandia, *we define CCF* as the group of silvicultural systems that maintain a continuous forest cover. CCF is not defined by the occurrence of specific stand structures over a fixed period, nor by individual silvicultural interventions, e.g., regeneration cuts. However, the silvicultural systems included lead to variations in stand structures within certain limits. The terminology of silvicultural systems and definition of the term silvicultural system draws upon Matthews (1989).

Silvicultural systems that are, or can be, used in Fennoscandia to maintain a continuous cover are the *selection system*, the *shelterwood system*, and the *group system*. The shelterwood and group systems also belong to the *rotation forest management* paradigm, while the selection system does not (Table 2.1). The rotation forest management includes silvicultural systems designed for more or less even-aged stands, where all trees are harvested more or less at the same time, i.e., at the end of the rotation. The use of shelterwood and group systems can only be considered as CCF if a continuous minimum forest cover is maintained and is an explicit aim. In that sense, a fast complete release of an established regeneration in the shelterwood system or large, many, or frequent gaps in the group system do not

Table 2.1 Summary of terms used for silvicultural systems

Management paradigm	Silvicultural system	Individual cuttings	Continuous cover forestry
Selection management	Selection system	Selection cutting	Yes
Rotation forest management/rotation forestry	Group system	Gap cutting, gap extension	When continuous cover is the aim and maintained
	Shelterwood system	Preparatory cutting, shelterwood cutting(s), shelter removal	When continuous cover is the aim and maintained
	Clearcutting system	Clearcutting, seed tree cutting, seed tree removal	No

maintain a forest cover. These practices of the shelterwood and group system are therefore outside what we define as CCF.

What is CCF in Fennoscandia?

- We define *CCF* as the group of silvicultural systems that maintain a continuous forest cover.
- We refrain from including a detailed definition of a *minimum forest cover* in terms of density, height, homogeneity, and continuity of the cover in our definition of CCF. An overview of definitions for a minimum forest cover in the three countries is given.
- *Silvicultural systems* that are, or can be, used in Fennoscandia to maintain a continuous cover are the *selection system*, the *shelterwood system*, and the *group system*.
- Only the long-term application of one of these silvicultural systems qualifies as CCF.
- *Conversion to CCF* is not included as CCF in our definition. However, conversion will be an important activity in the near future for forest owners who wish to apply CCF.

CCF is defined here as an application of a silvicultural system over at least one rotation, for the silvicultural systems where the term rotation still applies, or over an equivalent period for the selection system. Individual cuts only qualify as CCF if they are part of a silvicultural system and its long-term application. For example, an individual selective cut is only CCF if it is part of the selection system; the same applies for gap cuttings and the group system, and for shelter cuts or late thinnings and the shelterwood system.

Our definition of CCF only includes the practice of the silvicultural systems in stands that possess and maintain these systems’ typical structures. Conversion to

CCF is not included in this definition. However, in Finland and many other political contexts, conversion to CCF is also included under this umbrella (Äijälä et al. 2019; Valkonen 2020).

CCF is most often thought of as being connected to *natural regeneration*. However, it can also be practised in combination with or purely based on artificial regeneration methods.

None of the CCF methods are strictly limited to *shade-tolerant species*, but the methods were originally developed for them (Schütz 2001; Burschel and Huss 1997). The current call in Fennoscandia to apply CCF to intolerant species such as Scots pine or mixed forests containing shade-intolerant species makes modifications to the original prescriptions necessary.

When discussing CCF, it is frequently necessary to specify the opposite, i.e., summarise silvicultural systems, or certain practices of silvicultural systems, which do not meet our definition of CCF, under a common term. Such terms exist in our national languages and for the national definitions of CCF, e.g., *åpne hogster* in Norwegian and *hyggesskogsbruk* in Swedish. These terms summarise the traditional practice during the last 70 years and include the clearcutting system and the seed tree system. We do not introduce a common definition in English for non-CCF methods in this book, and instead refer to them as *traditional management* or give details about which silvicultural methods have been addressed in the studies.

2.1.1.1 Minimum Density and Continuity of Forest Cover

We refrain from giving a detailed definition of a *minimum forest cover* in terms of density, height, homogeneity, and continuity of the cover in our definition of CCF. However, such definitions are understandably necessary to implement forest policies, legislation, and management prescriptions. In this context, the first attempts to define CCF more specifically, including minimum forest cover specifications, have been made in Fennoscandia.

In Norway, *lukkede hogster* (closed cuts) means that at least 150 trees/ha are left after a regeneration cut or that gap size is less than 0.2 ha. In addition to the selection system, the shelterwood system, and the group system, it is also customary to include *fjellskoghogst* (mountain forest selection cutting), a method combining the group and selection systems, in this term. The term *lukkede hogster* has been in use in silvicultural textbooks for decades. This definition is not legally binding, except for the Norwegian PEFC standard (revision 2023), which uses the limits shown above for stand density and gap size.

However, the number of trees alone does not specify a forest cover, nor the duration of the cover. Assuming tree dimensions in a shelterwood system of DBH = 32 cm, 150 trees/ha would translate to 12 m²/ha basal area, which likely comprises a forest cover in that situation. The current practice of *mountain forest selection cutting* often leaves much more open stands (Granhus et al. 2020).

In Sweden, the Forestry Act (§5 and §10) defines a minimum stand density (standing volume as a function of basal-area-weighted mean height) that does not

trigger an obligation for active regeneration efforts. These density thresholds define a minimum forest cover for CCF. Current definitions of CCF-related terms provide detailed definitions (Appelqvist et al. 2021). The Swedish definition of *hyggesfritt skogsbruk* (clearcut-free forestry) has its baseline in the statutory restriction in harvesting level at a given height, which distinguishes a thinning from a cutting that requires regeneration, the “§5 curve” (illustrated in Appelqvist et al. 2021, page 7, <https://www.skogsstyrelsen.se/globalassets/om-oss/rapporter/rapporter-20222021202020192018/rapport-2021-8-hyggesfritt-skogsbruk%2D%2D-skogsstyrelsens-definition.pdf>). However, this only applies until regeneration is established. In shelterwood cutting, the stand volume can be reduced to half the standing volume defined in the §5 curve after a satisfying regeneration is established. The number of seedlings needed for this is defined in the Forestry Act, and ranges from 1000 to 1500 /ha depending on site quality. When the regeneration reaches 2.5 m, the remaining shelterwood can be reduced to 25 trees/ha above 10 m height in coniferous stands and 5 trees/ha above 10 m in noble broadleaf stands (e.g., beech). In gap cutting, gap size is limited to 0.25 ha, and additional gaps that reduce the standing volume below the §5 curve can be created after a satisfying regeneration is established and reaches 2.5 m height.

In Finnish legislation, CCF is defined by cutting methods, with the explicit inclusion of only selection and gap cutting. Minimum post-harvest stand basal area limits are defined for harvest entries in the Forest Act. They vary by latitude (lower limits in the north) and soil fertility (lower limits where fertility is lower). The values range from 5 m²/ha on xeric and subxeric sites in northern Lapland to 10 m²/ha on mesic sites in southern Finland. In the widely recognised Finnish best practices (Äijälä et al. 2019), the recommended minimum basal areas are generally 2–3 m²/ha greater than the statutory limits. The motivation is to provide a buffer in the event of post-harvest damage and mortality, and also to safeguard a high level of volume production.

2.1.1.2 Conversion to CCF

Conversion is a distinct change in silvicultural system, stand structure, and/or tree species composition. *Transformation* indicates a smaller or more gradual change in silvicultural system, stand structure, and/or tree species composition. This definition has been used in Central Europe for many decades and is also reflected in Hasenauer (2004). Shifting from the clearcutting and seed tree system to CCF, as currently intended in many places in Fennoscandia, falls under the term conversion.

Given the current rarity of CCF in Fennoscandia, conversion to CCF will be an important activity in the coming decades. A time horizon of many decades is the compound consequence of only individual properties or stands being converted, only a part of the forest stands being readily suitable for conversion, and the time horizon of many decades for a conversion of specific stands. Knowledge about conversion is therefore currently much more relevant than detailed prescriptions for the silvicultural systems included in CCF in conditions after conversion.

Special silvicultural treatments to convert to CCF are only necessary for some silvicultural systems and stand conditions (see Sect. 2.1.2.2 for further details). In some cases, silvicultural systems under CCF can be applied without conversion, for example the shelterwood system in previously thinned stands or the group system. In these cases, the first regeneration cut might mark the shift to CCF.

2.1.1.3 Other Terms

Uneven-aged management is used as a more general term in many contexts. Some of the silvicultural systems included in our definition of CCF, e.g., the shelterwood system, might only generate a limited range of age variation for longer periods of stand development.

The term *multi-storeyed* (*flersjiktet*) is frequently used in the context of CCF and related terms. Our definition of CCF is wider in that it does not set up a certain stand structure as an objective, but accommodates variation in stand structures according to the dynamics of the silvicultural systems involved.

Mountain forest selection cutting (*fjellskoghogst*) is practiced in Norway and Sweden, often reducing standing volume intensively at large cutting intervals (Granhus et al. 2020). Even though the current practice might not fulfil criteria for a minimum forest cover, a modified practice that maintains a larger standing volume and acknowledges the very long regeneration times on these sites might be classified as CCF.

National terms only partly overlap with our definition of CCF.

In Norway, *lukkede hogster* (closed cuts) only provides a very simple and hardly operational classification of silvicultural systems.

In Sweden, *hyggesfritt skogsbruk* (clearcut-free forestry) is mainly a negative definition that excludes clearcutting (Appelqvist et al. 2021). However, the detailed definitions supply a coherent definition of CCF. *Naturkultur* (Liberich) is a proposal for an individual tree-based management system (Hagner et al. 2001), where performance at stand level is uncertain and not documented, but currently being tested in a series of field trials (Goude et al. 2022).

In Finland, *jatkuvapeitteinen metsänkasvatus* (continuous cover forest management), or *jatkuva kasvatus* (continuous cover silviculture), is wider than our definition of CCF, because it also includes methods for conversion to CCF and some overlap with two-storey stands (Äijälä et al. 2019).

In the same way that CCF is most often a political concept, many other terms have been coined to describe forest management systems that follow a certain philosophy or political agreement. Most prominently, *close-to-nature forestry* has been promoted in Europe for decades (Brang et al. 2014). More recently, the EU has introduced the term *closeR-to-nature forest management* and asked researchers to define it (Larsen et al. 2022; European_Commission 2023). In North America, *forest ecosystem management* and *ecological forestry* have been promoted as alternatives to traditional forest management in recent decades. Egan et al. (1999) discuss

the lack of clarity of these terms and their relationship to other basic concepts of forest management, i.e., sustainability and multiple use.

Retention forestry (Gustafsson et al. 2020) is a concept closely linked to the clearcutting system. However, in leaving single trees and groups of trees, retention forestry can generate stand structures that might facilitate conversion to CCF in the future. Retention will also be necessary in most CCF methods.

Natural disturbance-based forest management (Kuuluvainen et al. 2021) promotes a philosophy that asks forest management to mimic natural disturbances. Harvesting with single-tree selection and small gaps would reflect small-scale natural disturbances, while larger gaps would represent intermediate disturbances, and larger clearcuts large-scale disturbances, respectively. A much greater volume of retained trees, snags, and coarse woody debris would be characteristics for such management (Koivula et al. 2014). In contrast to this philosophy, the silvicultural systems included in our definition of CCF do not explicitly intend to mimic natural disturbances. They might briefly generate stand structures that also can be found in forests under natural dynamics (Rouvinen and Kuuluvainen 2005). However, systematic target diameter harvest in the selection system or a homogeneous shelter in the shelterwood system do not have equivalents in natural forest dynamics.

2.1.2 Methods of Continuous Cover Forestry

In this section, to give a more detailed definition of CCF likely to be practised in Fennoscandia, we briefly describe the silvicultural systems and conversion methods involved. Due to the current lack of practice of these methods, the description will largely rely on silviculture textbooks from Central Europe and experiences from a limited number of experiments in Fennoscandia. We also address necessary modifications to current forest management in Fennoscandia due to adaptation to climate change.

2.1.2.1 Silvicultural Systems under CCF

The following descriptions of the three silvicultural systems are only intended as a definition of these CCF methods. Detailed research results from the region that describe regeneration, genetic effects, growth and yield, pathogens and pests, and wood quality will be reviewed in later chapters. In contrast to the simple, standardised instructions currently practised in the context of the dominant clearcutting and seed tree system, silvicultural prescriptions for CCF methods will be much more complex and detailed, and require more intensive status descriptions and monitoring by professional managers and forest owners.

Other silvicultural systems relevant in this context include combined systems, such as irregular shelterwood. They are not described in detail here.

2.1.2.1.1 The Selection System

The selection system is based on the harvest of individual trees and the continuous maintenance of a multi-layered stand structure. It has been practised for centuries, mostly by farmers in different regions of Europe. Around 150 years ago it was developed into a more systematic management system, often accompanied by detailed inventories controlling stand structure and stand density (Schütz 2001; Lundqvist et al. 2014). Given the continuously high stand density, the selection system is best suited for shade-tolerant species, e.g., Norway spruce in Fennoscandia. However, trials with less shade-tolerant species, e.g., Scots pine, have been set up. To guarantee continuous ingrowth of less shade-tolerant species, stand density has to be reduced, which limits productivity.

An alternative approach to maintaining presence of these species is to create larger openings in a group selection system. The group selection system systematically opens small gaps, either in addition to or combined with single tree harvesting, to allow regeneration of groups of trees. In addition to allowing regeneration of less shade-tolerant species, groups of young trees are an advantage for species that require conspecific competition to form a straight trunk, such as most broadleaved species.

The multi-layered structure in stands managed by the selection system is characterised by a falling diameter distribution. This diameter distribution indicates that trees of all size classes are to be found in a stand, and is often thought of as indicating a vertical structure with multiple canopy layers. However, these stands are also richly structured horizontally, with small openings and dense groups (Figs. 2.1 and 2.2). Quantifying a 3D stand structure or diameter distributions in practical forest management probably exceeds the resources available in forest management in Fennoscandia. Simplifications for these stand structure requirements have therefore been proposed (Lundqvist et al. 2014).

To maintain the multi-storeyed stand structure, a stand density that guarantees high productivity and sufficient ingrowth must be preserved over time. Cutting intervals and amounts need to be adapted to this. Individual tree selection is most often guided by principles of target diameter harvest, but might also include elements of stand tending.

The selection system should not be misunderstood as directly copying natural disturbance dynamics. It is an intensive management system that maintains a certain phase of stand dynamics. Given the harvesting of mostly the largest trees and the low target diameters in Fennoscandia, large living and dead trees will not automatically be present in stands managed according to this system. To provide habitats for organisms adapted to these structures, the selection system must also apply retention principles and leave large trees of various species. This also applies to the shelterwood and group systems.

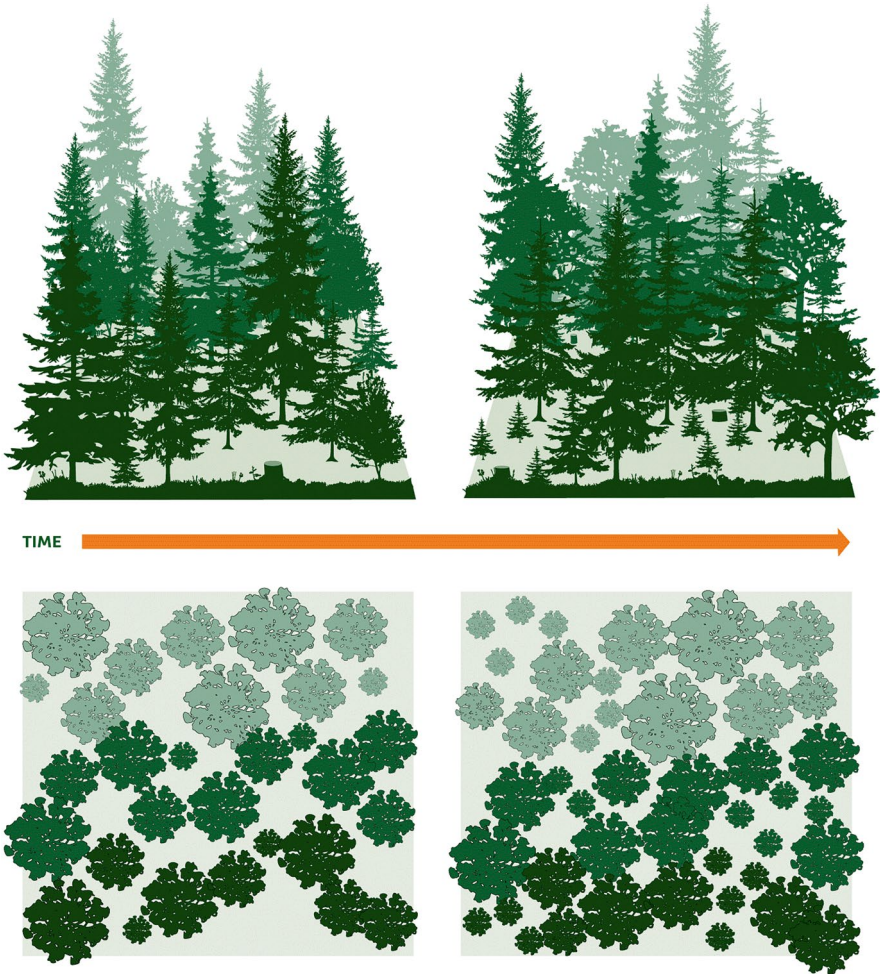


Fig. 2.1 A stand managed with the selection system at two points in time. Even though the structure of the stand has changed due to tree growth and removals, the visual impression is near constant

2.1.2.1.2 The Shelterwood System

The shelterwood system has been practised on small areas in Fennoscandia in recent decades, both in Norway spruce and in Scots pine (Fig. 2.3). Starting with stands that have been regularly thinned during their lifetime, and therefore consisting of individual trees with long crowns and high individual-tree stability, the first preparatory cuts initiate a series of cuts that maintain a shelter over many decades. This initiates regeneration at rather high density, distributed homogeneously over the entire area (Figs. 2.4 and 2.5). The last shelter trees should not be removed before

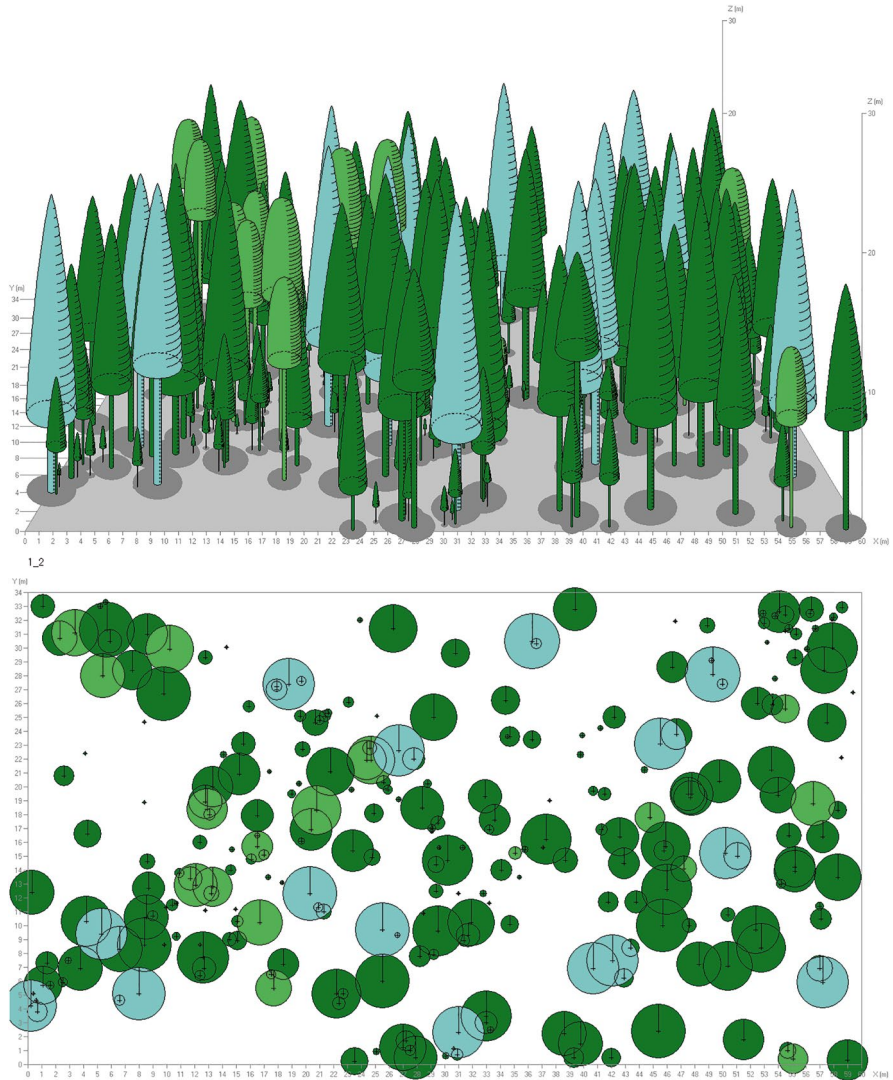


Fig. 2.2 Stand structure and cut instructions for a sample plot in Norway managed with the selection system. Dark green = spruce, light green = birch. Spruce trees to be removed during the next selection cut are shown in light blue. The planned cut will remove approximately 100 m³/ha of the standing volume of 255 m³/ha

the entire area is regenerated and covered by small trees with a minimum height to be established, i.e., at least 50 cm (Fig. 2.5). This variant of the system produces a stand in the next generation with an age variation of up to 30 years, which most often develops into a rather homogeneous stand structure despite the large age range. In a contemporary Finnish variant for pine (Fig. 2.4), some of the overstorey



Fig. 2.3 Advance regeneration of Scots pine under a shelter in Løiten Almenning, Norway. Photo: Andreas Brunner

trees are retained throughout the rotation to promote ecosystem services and production of high-quality timber (Äijälä et al. 2019; Valkonen 2020). Wind damage is common in this system during the shelter phase, but varies greatly according to stand and meteorological conditions (Hånell and Ottosson-Löfvenius 1994).

2.1.2.1.3 The Group System

In the group system, stands are opened up by creating a series of gaps. Gap size, number, and placement, chronological gap sequence, and gap extension can vary widely in this system (Figs. 2.6 and 2.7). Gaps might also be initiated as shelter groups. After initiating the regeneration process with gaps, the remaining parts of the stand might also be harvested at once or with other patterns. However, gap extension is a common prescription in this system. The irregular shelterwood system also creates gaps as part of the regeneration process. Gap size and sequence have to be adapted to the shade tolerance of the species targeted in the next generation. There are no long-term examples of the practical application of group systems in Fennoscandia, and in Central Europe a description of the full regeneration period is also lacking (Brunner et al. 2004).

In Fennoscandia, the group system is often proposed for shade-intolerant species such as Scots pine. The minimum gap size for natural regeneration of Scots pine and birch species is not known, but might vary greatly depending on site conditions and along latitudinal gradients.

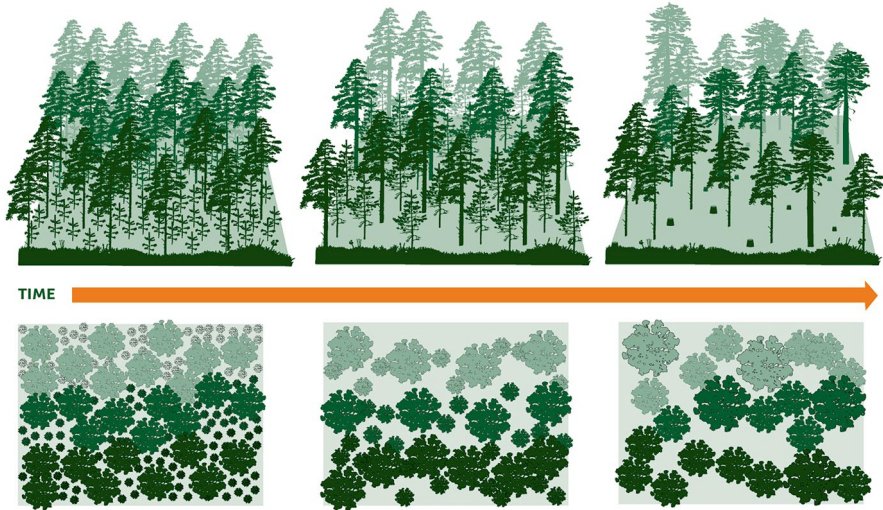


Fig. 2.4 A Scots pine stand managed with the shelterwood system at three points in time. This variant of the shelterwood system keeps a dense shelter over an extended period, until the next generation has reached heights that approach the heights of the shelter trees

2.1.2.2 Methods for Conversion to CCF

Conversion to CCF is most challenging in the case of conversion to the selection system, because it requires developing multi-layered stand structures. This can only be accomplished over a period of many decades, involving natural regeneration processes and requiring sufficient individual tree stability and remaining lifetime of the adult trees (Schütz 2001). This section therefore focuses mainly on this task.

Application of the shelterwood and group systems often only requires stands that are sufficiently thinned during earlier stand development to consist of trees that are individually highly stable. No further conversion is necessary, as regeneration is initiated during the regeneration cuts in these systems.

Conversion to the selection system will be an important topic in the context of CCF for many forest managers in Fennoscandia in the coming decades. Forest management practices in Fennoscandia since 1950 have created stand structures that are difficult to convert to CCF. These are even-aged monospecific stands, often dense and unthinned (e.g., in Norway) and therefore with very low individual tree stability and basically no other option than clearcutting in older stands. However, in younger stands, lower risk of wind damage permits creation of openings, initiating recruitment, and generating multi-layered stands over the subsequent decades.

Approaches for conversion to the selection system have only been developed and tried for a few decades in other regions, e.g., Central Europe and western North America. The first empirical results are available, but development and testing are still taking place. For boreal forests and Fennoscandia, approaches and trials are

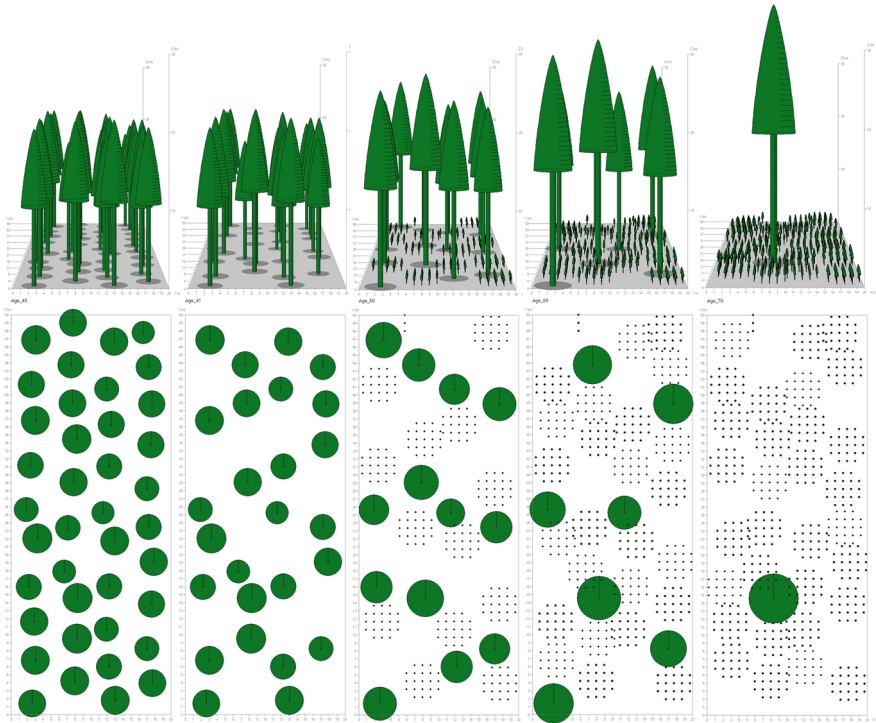


Fig. 2.5 Time series of the shelterwood phase in a shelterwood system. After the preparatory cut at age 40 (subfigure 2), two shelterwood cuts at ages 50 and 60 (subfigs. 3 and 4) create an open shelter that allows advance regeneration. The shelter is removed at age 70 (subfig. 5) when the advance regeneration has reached a height of at least 50 cm. By age 70 the regeneration established after the first shelterwood cut has reached a height of about 2 m

very scarce and still need substantial work for development or adaptation. Practices from other regions that have been tried in Fennoscandia are *target diameter harvest* and *variable-density thinning*, which are described in more detail below.

Conversion scenarios have been studied with growth models, which often show lower growth during the conversion period (Reventlow et al. 2021; Hilmers et al. 2020; Hanewinkel and Pretzsch 2000; Brunner et al. 2006). Reduced growth is caused by reducing the stand density to initiate recruitment. The exact reduction in stand growth is uncertain, because growth models are often not designed for these stand structures (Drössler et al. 2014; Brunner et al. 2006), or because they use rough assumptions for the establishment and growth of seedlings and saplings (Drössler et al. 2014; Reventlow et al. 2021; Hanewinkel and Pretzsch 2000; Hilmers et al. 2020). In some scenario studies, the conversion method is described in insufficient detail, so cannot be adapted to other forest types (Reventlow et al. 2021; Hanewinkel and Pretzsch 2000; Drössler et al. 2014; Hilmers et al. 2020). None of the simulators include risks for windthrow or other risks that reduce

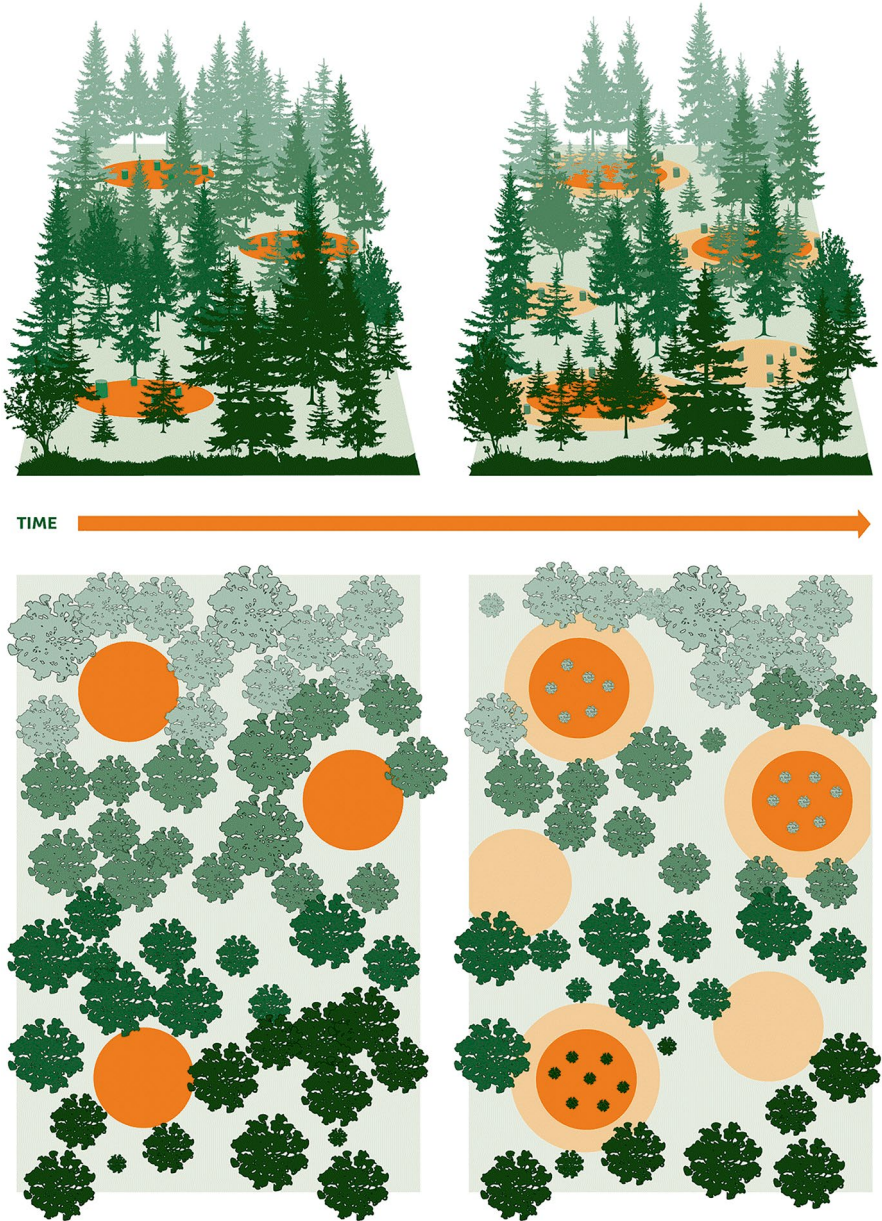


Fig. 2.6 A stand managed with the group system at two points in time. Here, the group system is applied in a stand with large variation in tree heights. Gap cuttings remove only a few trees per gap, creating small openings in the beginning, which are slightly extended in later cuts. This example is therefore close to the group selection system

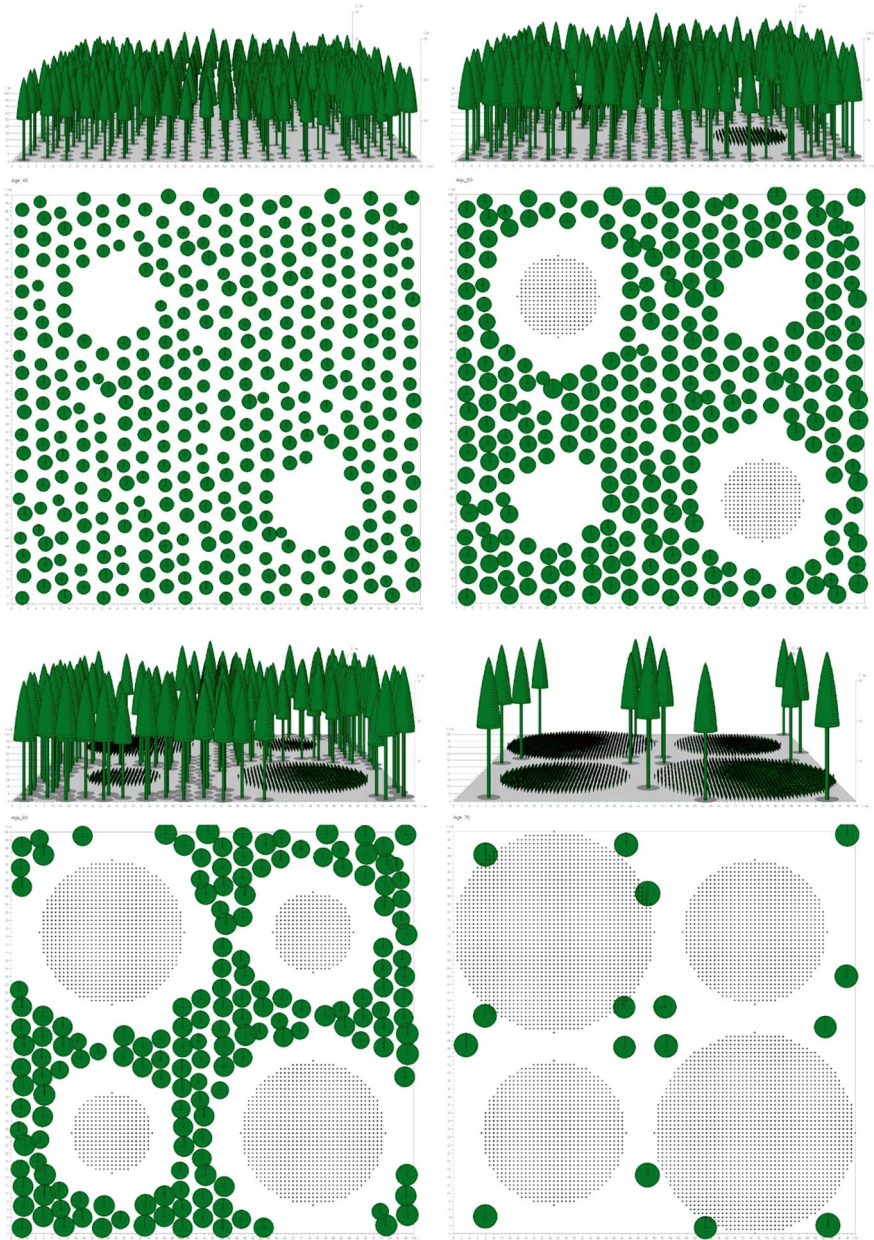


Fig. 2.7 Time series of the gap cutting phase in the group system. The first two gaps with a diameter of 20 m are created at age 40 (subfigure 1) in this even-aged 1-ha stand with little variation in tree heights. These gaps are extended to a diameter of 35 m at age 50 (subfig. 2), when new gaps are also created. All gaps are further extended at age 60 (subfig. 3) and the remaining stand is removed at age 70 (subfig. 4), when the advance regeneration has reached a height of at least 50 cm. The regeneration established after the first gap cuts will now have reached a height of about 2 m

production, depending on treatment. Stand simulators are therefore unlikely to contribute to the design of conversion methods in the near future.

Target diameter harvest has been proposed and tried as a method for converting even-aged Norway spruce stands to the selection system (Sterba 2004; Sterba and Zingg 2001; Reininger 1987). Results so far indicate that the stands have developed towards a multi-layered structure and survived major storm events. In southern Germany, beech has been managed with target diameter harvest; however, this is unlikely to produce multi-layered structures due to the high shade-tolerance of this species (Brunner et al. 2004). Inspired by the practice in Central Europe, experiments with target diameter harvest have been set up in Sweden (Drössler et al. 2015).

Variable-density thinning (VDT) has been developed and practised as an approach for conversion of young even-aged conifer stands in Washington and Oregon during the last 30 years (O'Hara et al. 2012; O'Hara et al. 2010; Brodie and Harrington 2020; Harrington et al. 2005; Carey 2003, 2006; Puettmann et al. 2016; Willis et al. 2018; Comfort et al. 2010; Dodson et al. 2012). VDT results in varying stand density after thinning, from the extremes of openings (*gaps*) to unthinned patches (*skips*), with thinning intensity varying within the thinned matrix between those extremes. Designs are adapted to the objective of the conversion and often planned in detail and marked in the stand before operations. In a simulation study for Finland, Pukkala et al. (2011a) designed a VDT that only harvests four different patches at different times. VDT has been adapted to tree species and thinning practice with harvesters in Norway (Brunner 2024), and a series of trials is currently under way in Norway. Disturbances like wind or snow damage in young stands might also generate stand structures with variable density that can be used to convert to the selection system (Knoke and Plusczyk 2001).

A different concept for conversion of young spruce stands involving heavy but homogeneous thinnings has been tried in Sweden (Drössler et al. 2014), but the results have been contradictory and the treatment plan was modified in the trial (Goude et al. 2022).

In Finland, the approach to conversion is rather pragmatic, given the lack of practical experience and research. The general idea is to initiate regeneration through shelterwood or gap cutting to gradually establish the understorey that may later be used to develop structural complexity (Äijälä et al. 2019; Valkonen 2020). An alternative pathway suggested by (Pukkala et al. 2011b) would be to conduct a shelterwood cutting with very low density in the remaining overstorey. An abundant regeneration of pioneer species could be expected to emerge quite rapidly. The subsequent emergence of an understorey of shade-tolerant species like spruce would pave the way to a structurally complex, mixed-species stand. Another suggested method is *all-aged forestry* (Pukkala 2018), where treatments are tuned to the specific situation, without any strict regimes or methodologies.

In Finland, *thinning from above* is promoted as a conversion method towards the selection system (Pukkala et al. 2014). Thinning from above is applied as the first step towards more complex stand structures, and advance regeneration, undergrowth, and trees of the lower canopy layers are considered valuable assets, and retained and protected in the thinning operation. Originally a thinning method,

thinning from above has been tested in experiments in the region and is frequently discussed among researchers (Karlsson and Norell 2005; Nilsson et al. 2010; Hynynen and Kukkola 1989; Mielikäinen and Valkonen 1991). Even though the method resembles target diameter harvesting at an early stage of stand development, it creates homogeneous stand structures in the same way as thinning from below, and is therefore unlikely to convert homogeneous young stands into multi-storeyed stands suitable for the selection system.

Another approach to semi-continuous cover management with conversion connotations is currently practised in Finland with two-storeyed management of pine as an example. The purpose is to initiate the conversion of an even-aged stand towards greater structural complexity. A greater degree of cover is initially maintained, but not at a level required for CCF throughout the rotation. An even-aged mature pine stand is regenerated with the seed tree or shelterwood method. As the new generation emerges, the overstorey is thinned, but a small number of large overstorey pines is retained throughout the next rotation to retain a degree of continuity in large trees. This benefits biodiversity, amenity, and other ecosystem services, and enables the production of very high-quality timber (Valkonen 2020; Äijälä et al. 2019); see Chap. 9, Wood properties and quality. The more or less spatially uneven natural regeneration and the competitive effects of the overstorey trees tend to establish and maintain a degree of structural complexity in the lower storey, which can be enhanced in the precommercial and commercial thinnings during the management cycle, or reduced if that is preferred.

2.1.2.3 Suitability of Stands for Application of and Conversion to CCF

Before initiating application of or conversion to CCF, forest managers need to evaluate whether stands are suitable for these specific methods. Criteria will vary between the silvicultural systems and conversion methods, and no complete list has been developed for any of the methods so far. The criteria addressed here therefore only highlight some of the most important aspects. The criteria have varying importance for the final decision, numerical risk assessments are often difficult for individual requirements, and risk aversion of the forest owner is an important factor when compiling all individual requirements into a final suitability assessment for a given stand.

The most important criterion is a site-adapted species mixture, both now and in future climates. Given that Norway spruce can often be found on sites that are naturally stocked with Scots pine, this considerably limits conversion attempts. Shade-tolerant species are not an absolute prerequisite for CCF, but Scots pine and other light-demanding species, either in pure stands or in mixtures, necessitate modifications to the CCF and conversion methods.

The speed of regeneration is significant for the progress of the conversion work. Frequently, lack of regeneration within short periods is misinterpreted as a site effect, i.e., that only certain vegetation types would permit natural regeneration. Forest managers in Fennoscandia have little experience of natural regeneration in

CCF and therefore often have unrealistic expectations about the speed of regeneration. In subalpine environments, the speed of regeneration is so slow (for example, due to infrequent seed years) that recruitment does not occur within acceptable times for commercial forest management.

During the conversion period it is essential to create individual tree stability by thinning in young stands. Dominant height can be used as an indicator for storm risk, and thinnings should be started at a dominant height of 10–12 m. Crown thinning favours stability of dominant trees more than the commonly practiced thinning from below by removing the dominant competitors of the dominant crop trees. Crown length can be used as an indicator for individual tree stability. The shelterwood system is riskier than the group system and the selection system. Releasing large trees to create a shelter comes with a certain risk, emphasising the need for sufficient thinning history and preparatory cuts. Individual trees damaged by wind or snow in multi-storeyed stands might be acceptable because these types of damage increase variability, compared to when entire stands or a shelter are damaged by the same agents.

The low target diameters in Fennoscandia of only about 40 cm DBH require that conversion efforts begin early. The dominant trees in the stand need to be retained long enough to supply the necessary seed and shelter for the development of a multi-storeyed stand.

Root rot susceptibility is an important limitation, and needs to be assessed before decisions on or conversion to CCF. Browsing can effectively prevent natural regeneration and limit the application of CCF. Saplings are at browsing height for a longer period under a shelter or in small openings in CCF systems. This problem is greatest for moose browsing on Scots pine but might also apply to other species admixed in spruce-dominated stands, including selection and gap systems (Komonen et al. 2020).

2.2 Context for CCF Definitions and Terms

2.2.1 Ecological and Geographical Context

Managed boreal forests in Fennoscandia are dominated by few and native species, mainly Norway spruce and Scots pine. Reluctance to use exotic species (e.g., an almost total ban in Norway, and strict restrictions in Finland and Sweden) means that CCF must use these two species as the main stand components, which is particularly critical, as only one of these species (Norway spruce) is moderately shade tolerant. Further, site conditions, especially shallow soils, permit only Scots pine in many places. Norway spruce often occurs naturally on peat or other waterlogged sites with low stability due to limited rooting space. The low stability of Norway spruce on those sites presents a challenge to CCF.

Especially for the southern parts of the boreal region, other species could be considered as part of the mixture in CCF systems, particularly in a future with a

changing climate. Much attention has focused on possibilities and ways to maintain broadleaved species as major stand components. Birch is a commercially valuable species in Finland that could be considered. In the nemoral region in southern Sweden, beech and oak are the most relevant species, but other broadleaved species can also be part of the mixture, e.g., Norway maple.

Simultaneous to the introduction of CCF methods in Fennoscandia, forest management has to adapt forests to the future climate. Brang et al. (2014) show that CCF does not automatically solve all the problems of climate adaptation. For our region, the establishment of mixed-species stands, also involving exotic species, is a major challenge for climate adaptation. CCF methods need to be modified, to prevent them only favouring shade-tolerant species and natural regeneration. Norway spruce is the only naturally occurring shade-tolerant species in the boreal part of the region, which in combination with reluctance to use exotic species is challenging the simultaneous application of CCF and climate adaptation. Norway spruce is already affected by drought periods and bark beetle attacks in the southern part of the region, especially on sites where Scots pine would naturally dominate. The lack of experience regarding climate adaptation and CCF calls for approaches that minimise risks, for example by diversifying species compositions and silvicultural methods. Concepts for addressing these challenges are still lacking, however, and the silvicultural systems presented here in their original form will likely not address the challenges.

Site adaptation of species selection and silvicultural methods is an important prerequisite for CCF. Forest site classification is an essential part of site adaptation, but unfortunately not always practised in Fennoscandia. The only site indicators frequently available are vegetation types and site indices based on dominant height. Due to the low awareness of site adaptation and extensive moose browsing damage on Scots pine, Norway spruce has been planted in large areas on sites more suitable for Scots pine during recent decades. In the context of conversion to CCF and simultaneous climate adaptation, site adaptation needs again to be recognised as an essential principle of forest management. Given the fine-scaled mosaic of site conditions in many forests in Fennoscandia, silvicultural systems presented here will often not be applied on larger areas without modifications.

Knowledge and experience about CCF methods among forestry professionals have never been built up during the last 70 years in the region. Even though the basics of CCF methods have been taught in forestry programmes, the lack of practice has effectively prevented a complete education. Only very few professionals have practised CCF methods and built up the necessary experience. Vitkova et al. (2014) describe a similar situation for Ireland. Vocational education and training about CCF methods has been started during the last decade in response to the growing interest. Mason et al. (2022) compiled knowledge gaps for CCF across Europe, but the group of managers interviewed in this study was heavily biased towards promoters of CCF. Vitkova et al. (2014) describe how political decisions about terminology regarding CCF leave forest managers without clear definitions and knowledge about silvicultural methods, so there is a call for clear definitions and terms.

Applying experiences of CCF from Central Europe to Fennoscandia is challenged by the much less intensive forest management and the much more mechanised forest operations in Fennoscandia. In contrast to Central Europe, trees for removal are not marked by foresters, and selection of trees for removal by harvester operators is hampered by visibility (Kärhä et al. 2021). Individual tree removal by harvesters can cause greater damage to the remaining stand than motor-manual harvesting methods. Diameter premiums are absent in Fennoscandia, and maximum accepted diameters are very low compared to Central Europe, often not exceeding a DBH of 40 cm. The low target diameters in particular are a challenge to the application of traditional CCF, given that regeneration periods and conversion periods need to be shorter than with larger target diameters.

2.2.2 *Historical Context*

Important background for the current definitions of CCF in Fennoscandia is the historical use of CCF, the use of terminology, and the research efforts related to these silvicultural methods.

Since the first humans migrated to Fennoscandia after the last ice age, people have used the forests for their livelihood. Use has varied with geography, time, population density, and available tools. From early on, people cleared forests for agriculture and picked trees for firewood, house building, or other purposes. Over time, domestic use in addition to industrial development of mining, iron works, tar production, shipbuilding, and sawmilling, and timber export led to overexploitation of forest resources (Leikola 1987; Nygaard and Øyen 2020; Aalde 2000), and with that came the need to find systems of managing the forest in more sustainable ways. Early concerns led to attempts to protect resources through specific forestry decrees already in the seventeenth century (Nygaard and Øyen 2020). However, it was not until the first concepts of systematic silviculture came to Fennoscandia in the middle of the nineteenth century that terminology and content of different silvicultural systems were discussed. However, descriptions of silvicultural systems were often vague, and terminology was often not clearly defined or misunderstood (Lundqvist 2017).

Development in Fennoscandia was clearly inspired by developments in Central Europe. According to Pommerening and Murphy (2004) the popularity of CCF has gone in cycles in Europe, with the first wave of interest starting in the latter part of the nineteenth century. They emphasise that long before an accepted term and corresponding definition were agreed, selection systems were practised in parts of the continent.

In all three countries, there have been bad experiences with earlier versions of CCF in the form of exploitive diameter cuttings, leading to heavily degraded forests in the beginning of the twentieth century. We describe the details in the respective countries below. Today, some forest professionals are worried that a return to CCF methods, especially selective cutting as part of the selection system, may cause us

to repeat the mistakes made a hundred years ago. Today's implementation of the selection system must, in a more controlled way, maintain a stand structure and density that leads to sufficient growth and ingrowth to avoid earlier mistakes.

2.2.2.1 Norway

Between around 1500 and 1870, the sawmilling industry in Norway had a high level of activity, and exported large amounts of lumber and timber. In this period, diameter limit cutting (*dimensjonshogst* in Norwegian) was the dominant method. The minimum diameter could vary, but a limit of 20 cm at 1.5 m height was not unusual (Nygaard and Øyen 2020). Although this usually resulted in some sort of continuous cover forest leaving smaller trees, it could also result in clearcuts in areas of more or less even-aged large timber. In addition, smaller timber was used for domestic purposes, not least for firewood. At the same time, providing iron works and mining areas with locally sourced firewood created huge demand for wood, leading to intensive harvests involving clearcuts and sometimes the depletion of larger forest areas, for example around Røros copper mine (Fryjordet 2003).

The lack of regeneration, a low standing volume, and low increment led to the transition to *plukkhogst* (approx. 1900–1940), a selection method where the larger trees were still harvested, but also damaged trees and trees of medium or smaller dimensions (Nygaard and Øyen 2020). In this period, clearcuts were generally considered to be forest degradation, due to negative experiences with excessive harvesting, e.g., around the mining cities. Little focus was put on regeneration and the future growth of the stands. Bøhmer (1922) states that some forests at the time were treated with *bledning* (selection system), described as a more systematic selective cutting that takes future stand development into consideration, as opposed to the exploitive *plukkhogst*. The definitions of methods and terms are, however, rather unclear (Bøhmer 1922), and the transition from diameter limit cutting to different kinds of selective cuttings took place at variable rates over the country.

Even though the new methods were considered to be a better form of silviculture than diameter limit cutting, it left a forest with sparse stocking, though long green crowns made it look healthy; called “the green lie” by Barth (1916). Rising concerns about dwindling forest resources led to the Norwegian National Forest Inventory being initiated in 1919 (Aalde 2000), and to intense discussions about the best way to build up the forest resources. Barth advocated multi-storeyed stands and harvesting by selection systems (*bledning*) in his textbooks (e.g., Barth 1905, 1938), though he also pointed to group cuttings and seed tree stands as suitable treatments in spruce forests. Other researchers, such as Eide, argued for even-aged forestry with clearcutting and planting (Nygaard and Øyen 2020). The brief history is that rotation forest management (*bestandsskogbruken*) gradually took over, totally dominating as a harvesting regime from the 1950s. The method must be seen as successful in terms of restoring forest resources in Norway, tripling the standing volume between 1925 and 2018 (Svensson et al. 2021), though other factors like less intensive use of forests for grazing and firewood also contributed.

Today, the interest in alternatives to clearcutting is again on the rise. Concerns about biodiversity and recreation often lie behind this interest, while others claim that CCF creates better timber quality and production equal to clearcut forestry. However, at present, only small areas are treated with harvesting methods other than clearcutting and planting or seed tree stands (see Sect. 2.2.3).

2.2.2.2 Sweden

In Sweden, selective cutting of individual trees was commonly practised during the late 1800s and early 1900s, with inspiration from forest management in Germany. This selective cutting was called *dimensionshuggning*, *blädning*, or *plockhuggning*. During the first half of the twentieth century, both selective cutting and clearcutting were used and seen as viable options (Lundmark et al. 2013). However, the selective cutting was done in a non-sustainable way from a forest production perspective, since there was heavy cutting without sufficient regeneration. Towards the mid-twentieth century, selective cutting had resulted in low productivity and poorly stocked forests (Holmgren 1959; Nilson 2001). To increase productivity and ensure long-term wood supply, the exploitative selective cutting practice was replaced by clearcutting, which became the primary silvicultural system. This transition was a gradual process where both clearcutting and selective cutting were used and refined during the transition period (Lundmark et al. 2013). This transition to a larger-scale and rational forest management fitted well with the times when increased scale and operational efficiency were promoted in many parts of society. Mechanised forestry also began at this time, also contributing to the shift to the clearcutting system.

After this transition in the mid-twentieth century, CCF methods like the selection system or group system have rarely been applied, and cutting large trees in selective cuttings was more or less outlawed, as it was believed to result in poor productivity. However, as shown by later research, this is not always the case, and selective cutting is now allowed. A CCF method that has been more widely practised is the shelterwood system, particularly natural regeneration through shelterwood for Scots pine and beech.

The interest in various CCF methods is reflected in the long-term forest field trials and the research that has been done (Goude et al. 2022). In Sweden, long-term forestry experiments are heavily focused on clearcut forestry. However, there has always been some interest in alternative management, and experiments in what we today consider CCF were set up in the early twentieth century. The oldest experiment still running was started in the 1920s, a study of selective cutting in Norway spruce. However, many of the old experiments have not been managed properly, or have been damaged in some way, making long-term evaluation difficult. Around 1990, the number of new experiments in CCF increased, due to the growing interest in alternative forest management.

With increased expectations for the forest to provide additional ecosystem services apart from wood production, demand for CCF has increased among stakeholders in recent decades. Assigned by the government to develop and increase the

use of clearcut-free forestry (*hyggesfritt skogsbruk*), the Swedish Forest Agency defined the term in 2021 (Appelqvist et al. 2021): “Clearcut-free forestry on forest land intended for wood production implies that the forest is managed in such a way that the land always has a tree cover, without any larger clearcut areas.”

2.2.2.3 Finland

Finnish forestry was revolutionised in 2014 when previous legal restrictions prohibiting the use of selection management were lifted as a result of a broad consensus among industrial, governmental, and environmental stakeholders. This was a major change, as CCF had been virtually banned in Finland since the 1950s in a very drastic move to improve forest productivity and the resource base after a 100-year period of outright abuse.

High-grading (*harsintahakkuu, määrämittaharsinta* in Finnish) in its historically notorious extreme form was widely used in Finland until the 1940s. All merchantable sawlog trees were repeatedly removed, leaving behind a heavily degraded forest with no regard for its future productivity. In the historical silvicultural narrative, the well-meaning sustainable selection regime promoted by state agencies, similar to the contemporary form of selection cutting, degenerated into destructive high-grading, with greater use of wood resources for industrial and domestic purposes when sustainability requirements were still far in the future. Repeated high-grading, along with other unsustainable uses (slash-and-burn agriculture, tar production), had resulted in the serious depletion of forests in the southern half of the country, and degradation in many parts of the north.

After 1945, there was a drastic move away from selective harvesting and natural regeneration due to government-promoted adoption of plantation-type silviculture. This was motivated and justified by aspirations to boost timber production, to secure the resource base for a huge buildup of wood-using industries, especially pulp and paper. In this context CCF and uneven-aged silviculture were seen as enemies to progress that had to be rooted out.

2.2.3 Current Legislation, Policy, and Use of CCF

Recently, legislation and policies in Fennoscandia have changed, both by removing earlier restrictions on CCF and by demanding its increased use. We describe current trends in all three countries in this section.

The percentage of forest area managed by CCF has been compiled across Europe in a recent review (Mason et al. 2022), and this shows a range of <1–6% for the three countries in Fennoscandia. Given that definitions of CCF in that study differ from ours, definitions of CCF vary between the national statistics, and different data sources are used in the three countries to compile these statistics, so it is not possible to derive reliable estimates of the current use of CCF across Fennoscandia. However,

in the following sections, we describe and interpret the available national statistics and other sources, to clarify the scale of CCF implementation.

2.2.3.1 Norway

Even though changing forest laws and regulations have focused on protecting forest resources, including regeneration (Girdziusas et al. 2021), and in later years also landscape and biodiversity (Nygaard and Øyen 2020), there have hardly been any regulations regarding which silvicultural system to use in Norway. Today's Forestry Act (<https://lovdata.no/lov/2005-05-27-31>) simply states that "At harvesting, consideration must be given to the forests' future production and regeneration and at the same time to environmental values." However, the Regulations on Sustainable Forestry (<https://lovdata.no/forskrift/2006-06-07-593>) now say that "Where biological, economic and technical conditions are suitable, CCF (*lukkede hogster*) should be used, if good stability of remaining trees and satisfactory regeneration can be achieved at the site."

Most forests in Norway are certified through the Norwegian PEFC Standard (PEFC_Norge 2022). The recent version of the standard (revision 2022) emphasises the use of CCF more strongly than before, stating that "In spruce-dominated forests, CCF (*lukkede hogster*) must be used where the conditions are economically and biologically suitable." The standard also stipulates that the group certificate holder (usually the forest owners' associations) must have the necessary expertise about CCF methods, and describes how the proportion of CCF can be increased in the short and long term.

Approximately 10% of the productive forest area in Norway is certified according to FSC (Forest Stewardship Council). This standard is more or less equal to the Norwegian PEFC standard in terms of harvesting methods. It states that "In spruce-dominated forests, selective cutting or small-scale clearcutting should be used where conditions are economically and biologically suitable." In mountainous forests, the use of selective cutting (mountain forest selection cutting) should be used as widely as possible.

Based on data collected from the annual sample of around 1000 regeneration cuts, the use of harvesting methods included in CCF is modest (Landbruksdirektoratet 2022). In 2021, 4% of the sampled area was felled with small clearcuts or strip cuts (including group cuttings), while another 4.3% was felled using shelterwoods, selective cutting, or *mountain forest selection cutting*. In this last group, cutting of windfall is included. The share of these harvesting methods has been rather stable over the last 30 years, seldom exceeding 10% of the total area (Granhus and Eriksen 2017; Granhus et al. 2018). However, following the definition of CCF in this book, a smaller proportion of the harvesting methods qualify, because small clearcuts might be larger than group cuttings (limit of 0.2 ha in the PEFC certification standard) and mountain forest selection cutting often does not maintain a continuous cover. Following the definition in this book, the annual area treated with regeneration cuts in recent decades defined as CCF might be closer to 5%.

2.2.3.2 Sweden

In the current Swedish Forestry Act from 1993, production goals and environmental goals are weighted the same. This marks a major change from previous forestry acts, in which forest productivity was the main focus. One of the intentions of the new forest policy was to favour biodiversity and diversity in management methods. However, diversification in silvicultural systems has been slow. An assessment by the Swedish Forest Agency in 2002 reported that previous management with clearcutting needed to be adjusted, and that other silvicultural systems needed to increase, to attain this goal of giving the same weight to production and the environment (Appelqvist et al. 2021). In the following decades, the Swedish Forest Agency was given many tasks defining alternative forest management, such as CCF, in Swedish conditions and how it could be implemented to complement traditional forest management. The new definition of *hyggesfritt skogsbruk* (clearcut-free forestry), together with the debate in Sweden on how forests can be managed to provide more ecosystem services than just wood production, has increased interest in CCF. This interest is voluntary and not directly pushed by any legislation.

In Sweden, in 2022, a majority (67%) of productive forest land was certified. Of the certified forest area, 75% is certified according to both FSC and PEFC, 19% to only PEFC and 6% to only FSC. In its standard for Swedish forestry, FSC states that 5% of the productive forest should be managed to promote long-term development of natural and/or social values as the primary management goal (FSC_Sweden 2019). CCF methods like selective cutting and gap cutting are given as examples of alternative management to clearcutting, which does not promote natural and social values according to FSC. This request for CCF methods is on top of the 5% that should be set aside to promote natural and biodiversity values. In the PEFC standard, alternative management, like CCF, is recommended when other goals than timber production are promoted, like natural and social values (PEFC_Sverige 2017). However, it is also stated that other management alternatives than clearcut forestry have little research results and experience in Sweden and should be applied in suitable stands only, to avoid jeopardising long-term productivity.

No statistics are available on how much of the forest is being managed through CCF, since selective cuttings are not registered by the Swedish Forest Agency, unlike other harvesting methods. Use of CCF is also difficult to capture in the Swedish National Forest Inventory (NFI), since the inventory does not consider the intention of the forest owner. Estimates from the Swedish NFI have indicated that 2–4% of the forest area is fully layered and with a high enough standing volume for selective cutting to be used appropriately (Hannerz et al. 2017). However, this does not include forests where shelterwoods or gap cutting could be implemented, which would include a much larger proportion of the current forest area.

In 2021, the Swedish Forest Agency conducted a survey, asking forest owners if they applied *hyggesfritt skogsbruk* (clearcut-free forestry) on any part of their forest. Both large industry forest enterprises and smaller family enterprises were included in the survey. The estimated productive forest land managed with *hyggesfritt skogsbruk* (clearcut-free forestry) with a long-term plan to continue was 728,500 ha, i.e.,

3% of the total productive forest land area. Most of this, 487,500 ha, was on land owned by smaller family enterprises (Skogsstyrelsen 2022).

2.2.3.3 Finland

The Finnish Forest Act is rather liberal in allowing the landowner a free selection of silvicultural methods, including those of CCF. The basic operational logic in the application of the Forest Act is that a minimum basal area of viable trees is to be retained in intermediate cuttings, including thinnings, single-tree, and group selection cuttings. The limits are lower for selection cutting. The maximum gap size in CCF is 0.3 ha. Failure to adhere to these limits triggers the obligation to regenerate (which applies to all types of regeneration cuttings). This means that a seedling stand with a sufficient number of stems with an even spatial distribution and a mean height of 0.5 m has to be established within 10–25 years, depending on latitude (faster in the south).

Conversely, there are no legal restrictions on clearcutting or requirements to use CCF instead. Indirectly, clearcutting is virtually banned on a set of ecologically valuable habitats explicitly defined in the Forest Act. Their essential ecological features may not be significantly altered by cuttings, but careful selective cuttings are feasible in some cases. However, the habitats and the requirements are designed to make them economically unimportant, with a very small area limit (legal maximum 2 ha, actual average 0.6 ha), and they constitute less than 1% of the forest area (Siitonen et al. 2021).

In the widely applied Recommendations for Best Practices in Finnish Forestry (Äijälä et al. 2019), CCF methods and instructions are presented alongside the predominant traditional management. Adversities and potential practical problems are invariably listed and emphasised for CCF, but much more seldom for traditional management in the same manner.

Most forests in Finland are certified through the Finnish PEFC Standard (PEFC_Finland_-_Finnish_Forest_Certification_Council 2022). The system generally neither encourages nor discourages the use of CCF, and it seems that the general aspiration among its stakeholders is to uphold the status quo. In some special cases the possibilities of CCF are recognised, for instance in peatland stands with existing structural complexity.

The alternative Forest Stewardship Council (FSC) certification system covers some 10% of the productive forest area in Finland. The use of CCF is directly encouraged, with a requirement that some 5% of productive forest area is to be set aside as special sites and managed without stand-replacing regeneration cuttings. Some other provisions also favour CCF with less specificity.

The proportion of forests managed with CCF is still relatively low compared to the predominant traditional management, which is not surprising as the legal ban on CCF in commercial forests was not lifted until 2014. The proportion of CCF is not well defined or recorded in NFI and statistics. The entry in Mason et al. (2022) for Finland (representing 2019) was based mainly on statistics produced by Suomen

metsäkeskus, the state authority responsible for law enforcement, governance, and guidance in forestry. The proportion of CCF is given as the proportion of selection and gap cuttings of all harvesting within each year. As there is no explicit indicator of whether the cutting belongs to CCF or traditional management, let alone which systems are applied as a whole, the entries are very unreliable.

When asked directly in a comprehensive standard survey, 57% of private non-corporate forest owners responded that they apply CCF on all (14%) or part (43%) of their forests (Horne et al. 2020). Metsähallitus (the agency managing state forests in Finland) has long been the frontrunner in applying CCF in its vast multiple-use forests and fragile areas in the north. It has recently (2020) decided to increase the use of CCF from 15% to 25% of its annual area of final harvests, which represents an addition of some 6000 ha annually. Similarly, several major cities have harnessed CCF as the guiding principle in their urban and peri-urban forests, and later extended it to cover all of their forests, with a categorical exclusion of clearcutting. Given the lack of proper statistics, we use the listed indications to estimate the order of magnitude of CCF use according to the definitions in this book as slightly above 5%.

The increased use of CCF on drained peatlands instead of traditional management would very likely bring about major ecological, economic, and social benefits. There are some four million ha of productive forests on peatlands that were drained mainly between 1960 and 1980, and the bulk of them are beginning to approach economic maturity and regeneration cuttings. Recent studies have revealed that the predominant method of clearcutting followed by ditch network maintenance, site preparation, and often planting is associated with much greater detrimental environmental consequences than previously assumed. They arise mainly from runoffs of suspended solids, dissolved organic carbon, and nutrients, resulting in watercourse pollution across the country (Nieminen et al. 2018a, b). In CCF, such drastic measures are mostly absent, mainly because transpiration by the continuous forest cover helps keep the groundwater table level in check without ditch maintenance (Leppä et al. 2020) and because natural regeneration is fully used. In addition to water quality, CCF can reduce the emission of greenhouse gases by stabilising the groundwater table at consistently favourable levels (Korkiakoski et al. 2023; Rissanen et al. 2023). This approach has gained ground among major forestry and environmental stakeholders, and the first steps are being taken. A major advance is under consideration in legislation, i.e. withdrawing government subsidies for ditch network maintenance.

2.3 Conclusions

We define *continuous cover forestry* (CCF) as the group of silvicultural systems that maintain a continuous forest cover. We refrain from giving a detailed definition of a *minimum forest cover* in terms of density, height, homogeneity, and continuity of the cover in our definition of CCF. An overview of definitions for a minimum forest cover in the three countries is given. Silvicultural systems that are, or can be, used

in Fennoscandia to maintain a continuous cover are the *selection system*, the *shelterwood system*, and the *group system*. Only the long-term application of one of the silvicultural systems qualifies for CCF, not an individual cut. Conversion to CCF is not included as CCF in our definition. However, conversion will be an important activity in the near future for forest owners that wish to apply CCF.

Bad practices and experiences with selective cutting before 1950 led to CCF being banned, the introduction of rotation forest management, and a loss of experience and willingness to practice CCF in a more controlled way until recently. Approaches and experiences for conversion to CCF are largely lacking in Fennoscandia. Suitability for CCF or conversion to CCF is a complex assessment process with many and varying criteria, for example depending on the silvicultural system to be converted to. Assessment criteria have not yet been developed. Climate adaptation will make it necessary to modify CCF approaches in the region. Recent changes in legislation and policy indicate an increased demand for CCF in Fennoscandia. Despite this rising interest, the current practice is only roughly 5% of the annual area treated with regeneration cuts.

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