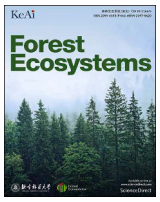
Forest Ecosystems 14 (2025) 100348

Contents lists available at ScienceDirect

Forest Ecosystems

journal homepage: www.keaipublishing.com/cn/journals/forest-ecosystems



The origin and beginnings of modern Continuous Cover Forestry in Europe

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ARTICLE INFO

Keywords:
Sustainability
Forest history
Silviculture
Conservation
Forest structure
Selection system
Individual-based forest management

ABSTRACT

Background: Continuous Cover Forestry (CCF) is a type of forest management that is based on ecological, environmental, and biological principles. Specific definitions of CCF greatly vary and the concept usually includes a number of tenets or criteria. The most important tenet of CCF is the requirement to abandon the practice of large-scale clearfelling in favour of selective thinning/harvesting and natural regeneration methods.
Methods: CCF is commonly believed to have its main origin in an academic debate that was conducted through publications in a number of European and North American countries towards the end of the 19th and the beginning of the 20th century. Our findings are exclusively based on a literature review of the history of CCF and they revealed that the European origins of CCF go much further back to a form of farm forestry that started to be practised in Central Europe in the 17th century. Eventually, this type of farm forestry led to the formation of the single-tree selection system as we know it today. Another influential tradition line contributing to modern CCF is individual-based forest management, which breaks forest stands down into small neighbourhood-based units. The centres of these units are dominant frame trees which form the framework of a forest stand. Consequently, management is only carried out in the local neighbourhood of frame trees. Individual-based forest management also modified inflexible area-control approaches of plantation forest management in favour of the flexible size-control method.
Results and conclusions: We found evidence that the three aforementioned tradition lines are equally important and much interacted in shaping modern CCF. Since CCF is an international accomplishment, it is helpful to thoroughly study the drivers and causes of such concepts. Understanding the gradual evolution can give valuable clues for the introduction and adaptation of CCF in countries where the concept is new.

1. Background

Continuous Cover Forestry (CCF) is a type of forest management that is based on ecological, environmental, and biological principles (Kruse et al., 2023; Pommerening, 2023). Detailed definitions of CCF greatly vary within and between countries and the concept usually includes a number of tenets or principles that are part of the definition (Pommerening and Murphy, 2004). The most important tenet of CCF is the requirement to abandon the practice of large-scale clearfelling in favour of more environmentally friendly, selective harvesting, and natural regeneration methods. This tenet has even given rise to the name "Continuous Cover Forestry" and ensures the continuity of woodland climate and forest soil processes. Typical of CCF is also that there are more than fifty national and regional semi-synonyms denoting variants or redefinitions of CCF such as alternatives to clearfelling, close-to-nature forestry, ecological silviculture, and nature-orientated silviculture. Detailed regional objectives, definitions, and standards can differ but all variants of CCF described by these labels share a common concept and a rather high degree of similarity (D'Amato and Palik, 2021; Palik et al., 2021; Puettmann et al., 2015; Pommerening, 2023).

In recent decades, CCF has been rediscovered in different parts of the world as a toolbox for general sustainability, forest conservation, and mitigating climate change. For example, CCF has been proposed as a key management approach to adapt forests to new and uncertain environmental conditions resulting from the unprecedented pace of ongoing climate change (Brang et al., 2014). At the same time, there has also been growing frustration in Asian, European, and North American societies over highly industrialized practices of traditional plantation or

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Peer review under the responsibility of Editorial Office of Forest Ecosystems.

https://doi.org/10.1016/j.fecs.2025.100348
Received 17 January 2025; Received in revised form 15 May 2025; Accepted 17 May 2025
Available online xxxx

rotation forest management (RFM; Morgenstern, 2007). Recently, the EU forest strategy for 2030 (European Commission, 2021) stated that clearcutting should be "used only in duly justified cases" and that the strategy promotes the "creation or maintenance at stand or landscape level of genetically and functionally diverse, mixed species forests, especially with more broadleaves and deciduous trees". In a similar way, the EU biodiversity strategy for 2030 argues against RFM and clearfelling (European Commission, 2020). These political statements clearly support CCF and a policy paper published by the European Forest Institute provided explicit definitions, justifications, and implementation guidelines for this management type (Larsen et al., 2022).

In this context of CCF applications to various forest ecosystems and environmental challenges, it may be appropriate to consider the historical origin and the early beginnings of this management concept in Europe. Understanding the historical context helps us appreciate how CCF practices have evolved in Europe, and how they were influenced by different cultures, regions, and technological advancements. Looking at the literature, there are frequent references to the second half of the 19th century when a public debate centred on academic dissatisfaction with current RFM practices (Mantel, 1990; Hasel and Schwartz, 2006). This debate took place in a number of European countries and in North America and mainly materialised in book publications (O'Hara, 2014; Pommerening, 2023). However, at closer inspection, it appears necessary to revise this view, as historical records suggest that the origin and beginnings of modern CCF reach as far back as the 17th century at least.

The objectives of this paper are (1) to re-examine the historical drivers and origins of CCF, (2) to establish what influence they have on the current CCF debate, and (3) to explore what lessons we can learn from them for questions related to the regional and national introduction and adaptation of CCF.

2. Revisiting the origins of CCF

CCF in a wider sense probably had many beginnings in different parts of the world. Particularly interesting are concepts where indigenous human populations intimately co-evolved with forest ecosystems resulting in a sophisticated sustainable balance between forest use and reverence for trees and wildlife without the influence of academia or state policies (Östlund and Norstedt, 2021; Parkatti and Tahvonen, 2021; Bredero zur Lage et al., 2023; Akalibey et al., 2024). Many such forest management practices may have been lost by now since records were not kept until very recently, and cultural erosion has taken place in many indigenous populations.

Silvicultural systems, particularly those that are used for regenerating forest stands naturally play an essential role in CCF because it is a principle of the concept to regenerate forest stands naturally as much as possible, although partial planting is not excluded. Some of these silvicultural systems or their forerunners such as the seed-tree system even started to take shape in the 15th century if not earlier (Hasel and Schwartz, 2006). Considering this fact would suggest locating the historical origin of CCF much further back in the past. In this study, we do not consider such very early beginnings although the development of regeneration methods clearly indicates an important first step towards the emancipation of forestry from agricultural practices, a process that is still ongoing today and that is also a key element of CCF. We identified three major historical origins of CCF that we refer to as *tradition lines*:

- Central European *farm forestry* (17th–18th century),
- Western and Central European *individual-based silviculture* (17th–20th century),
- European and North American *academic debate* over a growing dissatisfaction with highly artificial, agricultural forms of forestry (19th–20th century).

According to our own definition, a tradition line has formed when a forest management concept emerged and has been maintained until now and when its importance reaches beyond the region(s) where the concept was originally founded. We shall now describe these three major contributions to modern CCF in greater detail.

2.1. Central European farm forestry (17th–18th century)

In Central European uplands (Austria, Southern Germany, Switzerland) but also in the mountain ranges of Eastern France, in Slovenia, and other parts of the Balkan, farmers owned mixed agricultural and forestry properties. The owners' main interest was in the agricultural part of their property, which usually formed the majority of their land whilst the forest area of their property was rather small. As a consequence, the farmers were looking for a method that would minimise the management effort needed in their forests but not compromise the supplement yield required from forestry. This yield was partly for personal use on farmland and for farm buildings and also included high-quality, large construction timber that was increasingly produced for regional and international markets. Although these farm forests were small, the financial contribution to the farm economy was considerable. By trial and error, farmers successively developed a silvicultural system that is now known as the *selection* or *plenter system* (Schütz, 2001). This is not a regeneration method like many other silvicultural systems but a planned treatment programme aimed at the whole lifetime of a forest generation and beyond (Pommerening et al., 2024). The system can be thought of as a kind of process conservation, where an old-growth forest stand is permanently kept in a small-scale disturbance and regeneration phase.

As a consequence, regeneration occurs in small groups of different sizes and shapes and at irregular times. Different age/size cohorts in the regeneration and temporary suppression by dominant trees eventually lead to a complex vertical structure with at least three distinctive canopy strata (Fig. 1). The selection system is an individual-tree-oriented concept and a perfectly sustainable silvicultural system at stand level. Selection forests typically have no common stand age and many generations and cohorts of trees are represented (cf. Fig. 1). The system operates without demographic interruption (Schütz et al., 2012).

Abetz (1955) pointed out that the selection system often was the only way to obtain a reasonable income from forestry in the small and fractured forest land of the farmers' ownerships. Historically, there is circumstantial evidence that the selection system may have gradually evolved from *coppice with standards*, a combination of coppice understorey (underwood) and uncoppiced overstorey (overwood) known since the late Middle Ages (Schütz, 2001). The first description of the selection system only appeared in the 18th century, but its application is much older and goes back at least 500 years. The system was empirically refined over many generations of farmers and passed on within farming families like a food recipe or other family traditions long before any attempt of a formal definition was made. Eventually, a kind of demographic equilibrium or steady state formed in each selection forest stand so that all management effort that was required was the occasional removal of a few, very large trees every five to ten years whilst the management of small and medium-sized trees was largely left to natural processes. This steady state assumes demographic continuity and can often be described by a (negative) exponential stem-diameter distribution (Fig. 4), i.e. area-based methods typical of RFM for ensuring sustainability were replaced by size distributions. This principle of minimising management input by exploiting natural processes is referred to as *biological rationalisation* and is another important tenet of CCF (Schütz, 2005; Paluch, 2006).

For a long time until the late 20th century official forestry regarded selection systems as the radical antithesis of RFM to be avoided or converted at all costs. This was partly related to a simple opposition of new ideas, partly to a fear for an increase in illegal logging, and partly because RFM forestry staff were unsure whether timber sustainability could be ensured in selection forests (Schütz, 2001). Laws were even introduced in some parts of Europe to prohibit the selection system, e.g.

Fig. 1. Visual impression of the structure involved in the selection system. Courtesy of Zeliang Han.

in France in 1827 and in the Great Duchy of Baden (Germany) in 1833 (Schütz et al., 2012). The importance of selection systems as a CCF tradition line is motivated by the following reasons:

- Selection systems are held by many European forest practitioners as the ultimate and most desirable form of CCF ("CCF archetype" according to Schütz et al., 2012);
- Selection systems are often used as references for comparing other forms of CCF with, since they represent the greatest structural heterogeneity possible in CCF at a stand level;
- All structural types and management issues of other forms of CCF can also be found and studied in selection forests at a small scale;
- In Europe, the longest CCF experience exists in selection forests;
- Selection systems maximise the use of biological rationalisation, since, when properly designed and managed, only predominant trees need to be removed from time to time whilst all other management can be left to self-regulation processes.

2.2. *Western and Central European individual-based silviculture (17th–20th century)*

As forestry had its origin in agriculture, it seemed "natural" to consider whole forest stands or even larger land units and their global characteristics when assessing timber sustainability rather than individual trees. In a way similar to agriculture, unit yield, and unit growth responses to different management strategies were considered in forest practice and research (Pommerening, 2023) (see Fig. 1).

The fundamental European idea of individual-based forest management has roots that apparently go as far back as 1763 when Duhamel du Monceau mentioned the use of frame trees for the management of *Quercus* spp. in France (Klädtke, 1993; Schütz, 2003). Increasing knowledge of the successful management of single-tree selection forests with their individual-tree tending approach started to question the traditional stand or unit approach in forestry. In the 19th century and at the beginning of the 20th century, individual-based forest management was gradually introduced to commercial forestry applications in Austria, Germany, and Switzerland. Schädelin (1926, 1934) and his successor Leibundgut (1966) systematically developed and promoted the concept in Switzerland where the historic cradle of this concept lies. The rationale of this method was to concentrate commercially valuable timber on just a few trees, e.g. 100 trees per hectare, which are referred to by different names, e.g. frame, target, or future-crop trees, as opposed to maximising overall volume production of a forest stand. The latter is the traditional management objective of RFM. Concentrating all silvicultural input only on a subset of trees (Fig. 2) is an important principle of biological rationalisation (Schütz, 2006) and implies that a low overall yield is acceptable as long as the frame trees in the long run produce an economic surplus (Knoke, 1998). Schädelin's original idea was to work with non-permanent frame trees, i.e. in each intervention, new frame trees would be selected, which could, of course, largely overlap with the frame trees selected in the previous intervention, but did not have to. Schädelin also proposed to initially appoint a large number of frame tree candidates (also referred to as potential crop trees) in early stand-development phases, which were later reduced to a smaller, definite number. The definite frame trees would then be promoted in later stand development through heavy release thinnings, i.e. by providing ample space around the crowns of each frame tree. Along with a number of precursors and colleagues, Abetz (1975, 1976) in Germany and Pollanschütz (1971, 1981, and 1983) in Austria modified this concept by advocating a permanent selection of frame trees. In Poland, Schädelin's ideas were introduced to forestry practice by Professor Ilmurzyński in 1961 (Ilmurzyński, 1951). After a heated scientific debate and after examining the results of many experiments, it was acknowledged that permanently selecting frame trees is usually superior to a temporary selection. It also turned out that initially selecting a large number of candidates is inferior to selecting a low number of final frame trees right from the start (Pommerening et al., 2021; Pommerening, 2023).

Any management intervention in individual-based forest management aims at relieving frame trees of local competition as much as necessary given a thinning cycle of 5–10 years after which another intervention would follow. To ensure sustainability, a method of *size control* was introduced to replace *area control* of RFM: Individual trees are no longer harvested because they grow in a certain area of land earmarked for harvesting but only when they have reached a certain

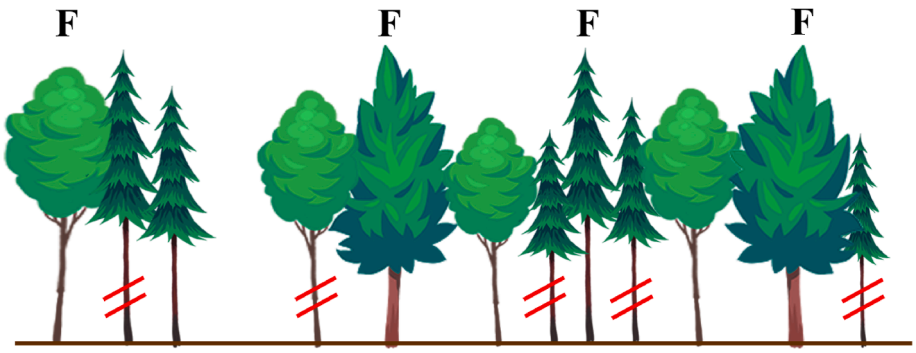

Fig. 2. Sketch of an imaginary mixed-species forest where frame trees were recruited from different species populations to support tree species diversity. The frame trees are indicated by the letter "F", and the stems of neighbours selected as perceived frame-tree competitors are crossed by double red lines. Modified from Pommerening (2023).

maturity which is defined by their individual size, typically by stem diameter at breast height. Such trees reaching maturity can occur anywhere in a given forest stand, hence the selective harvesting approach.

The international trend towards individual-based forest management was supported by advances in computer technology. Towards the late 1970s, the increasing availability of individual-tree data and computing resources gave rise to new analysis and modeling methods that made individual-tree approaches even more feasible and particularly helped with checking up on timber and other forms of sustainability (Pommerening et al., 2021; Pommerening, 2023).

Individual-based forest management has now become an important element of modern CCF in many countries and is even considered a tenet in its own right in many CCF definitions. Among other advantages, the concept helps break down large forest stands into smaller neighbourhood-based units that can be conveniently worked through one by one. As such individual-based forest management carries an important didactic advantage making CCF management easier for novices.

2.3. European and North American academic CCF debate (19th–20th century)

As mentioned in Section 1, this historical process is often described as the only or actual beginning of modern CCF. Towards the 19th and 20th centuries, large even-aged coniferous plantations were established to meet the increasing timber demand of growing human populations. Such mono-species forest stands enabled forest services to provide more timber in less time and also helped to put an end to illegal logging and timber thefts due to the uniformity of plantations which makes it easier to spot missing trees (Pommerening, 2023). Towards the end of the 19th century, the disadvantages and risks of creating large conifer plantations became more and more evident on the European continent and the advance of soil and site sciences helped develop a deeper understanding of the potentially adverse effects and risks associated with RFM. Concerned about the resilience of such commercial forests German Professor Karl Gayer (1886) emphasised the advantages of uneven-aged, mixed-species forests in his seminal book "*Der Gemischte Wald*" (The Mixed Forest) and encouraged species mixtures in groups by applying group shelterwood systems (Bauer, 1968). In the north of the country, his colleague Alfred Möller coined the famous term "Dauerwald" (continuous or perpetual forest) in 1913 (Möller, 1922). At the beginning of the 20th century in many parts of Europe and North America, the time had ultimately come for a change in forestry methods. For many years, leading continental silviculturists had vehemently expressed their disapproval of any kind of forest management not following the rigid idea of the so-called normal forest, a simple area-based timber sustainability concept, with clearfelling as the only harvesting method. According to Schütz (2001), one of the main reasons for this was that forest management following the normal forest idea could be controlled more efficiently. This was in fact an important point at a time when illegal logging was still very common in many parts of Europe.

In Poland, Professor Sokolowski presented a novel approach to silviculture based on the principles of forest ecology in his silviculture textbook of 1921 (Bernadzki, 1997). In 1922, Möller published his famous book "*Der Dauerwaldgedanke: Sein Sinn und seine Bedeutung*" (The Dauerwald Idea: Its Meaning and Significance) which initiated a long-running debate. He was among the first forest scientists to understand managed forests as forest ecosystems in a holistic way (Thomasius, 1996) and also among the first in Germany to consider an individual-tree approach along with the size-control principle. Uno Wallmo, a Swedish forester, promoted "blädningsskog" at the end of the 19th century, often translated as selection forest (or "Plenterwald" in German). However, what he advocated was selective tree removal as opposed to clearfelling (Krutzsch, 1952; Lundmark et al., 2013). In Switzerland, preceded by forester Henry Biolley in canton Neuchâtel, silviculture professors Arnold Engler and Walter Schädelin acted as pioneers of selective tree management and CCF. In France, Adolphe Gurnaud was an influential CCF pioneer working in the Vosges Forest (Alsace). This was also the time of Carl Schenk's "Biltmore Lectures on Silviculture" in North America where he described forms of selective forest management. He was joined by other North American authors such as Graves and Hawley (O'Hara, 2002). In Canada, Bernhard Eduard Fernow began to introduce CCF principles around this time. In Russia, Georgy F. Morozov finished the first draft of his silviculture textbook in 1912. In his text, he came to the conclusion that working against the nature of a woodland community on a given site is not what silviculture should attempt to do (Morozov, 1959). A similar statement at the time was made by Stanislaw Sokołowski in Poland. He wrote: "The primeval forest is the model on which the science of forestry and forest management must rely in order to fulfill their most important tasks, which are to increase timber production, uninterrupted continuity of use, and the permanent existence of the forest complex (Sokołowski, 1930)." At the same time, management demonstration sites were set up in various countries to explain and illustrate the new forestry concept along with data collection and gave rise to considerable "pilgrimages" by forest managers as well as members of the academia. In Britain, the origins of CCF are located more towards the 1950s and 1960s and were preceded by a major national afforestation phase following a dramatic timber shortage during World War I and the foundation of the Forestry Commission in 1919 (James, 1990).

3. Influence of the three historical processes on current CCF

When providing CCF training courses or teaching CCF at university in Europe, one cannot help but see how much influence the three historical processes have had on modern Continuous Cover Forestry.

Comparisons of the consequences of different forms of CCF or comparisons of CCF with RFM are typically not straightforward, since CCF can take any form as long as clearfelling is avoided (Fig. 3). This stresses the need for clear definitions of CCF management scenarios. When comparing CCF applications, forest structure, particularly in terms of the vertical growing space, is an important criterion for distinguishing different forms of CCF (Pommerening and Murphy, 2004; Pommerening, 2023). The application range of possible forms of CCF stretches from even-aged coniferous woodlands managed on a non-clearfelling basis (thus representing maximum uniformity) to the aforementioned selection forest (representing maximum heterogeneity).

Fig. 3 clearly shows that both RFM (far left) and selection forest (far right) mark the boundaries of CCF through their respective size structures and therefore often act as references in comparative CCF studies. For practical use, this structural range of CCF applications has often been simplified by distinguishing between *simple* and *complex forest structures* (Mason and Kerr, 2004). Simple CCF structure would involve one or two canopy layers, whilst complex CCF structure would have three or more layers on a permanent basis. Also in this simplification, the selection forest acts as a prominent reference, since it is represented by the term complex structure.

The horizontal and vertical structures of selection forests are so heterogeneous that elements of regeneration methods (shelterwood systems) can be recognised at a microscale. Therefore the study of selection forests is instructive for drawing conclusions with regard to other structural forms of CCF.

The most important part of the selection forest's long-lasting legacy, however, is that its concept maximises the principle of biological rationalisation (Schütz, 2001; Paluch, 2006), which is an important tenet of CCF, i.e. self-management of woodlands through an encouragement of structural heterogeneity. As a consequence, in favourable situations only a few large trees need to be removed in each intervention (Fig. 4). This removal of large dominant trees then sets processes in motion that encourage regeneration, the development of mid-storey trees, and self-thinning in clusters of high tree density. At the same time, these processes ensure that regeneration is not too prolific so that

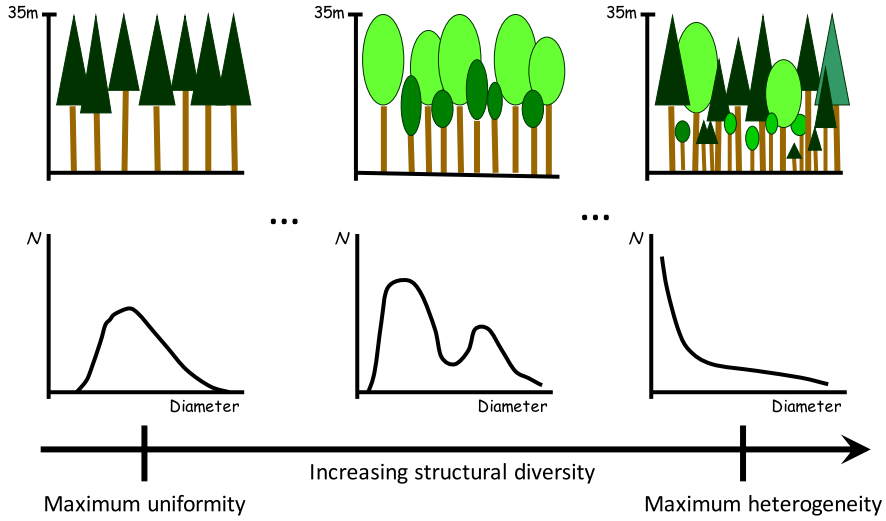

Fig. 3. The continuum of CCF stretching from maximum uniformity (e.g. in an even-aged coniferous woodland managed on a non-clearfelling basis) to maximum heterogeneity (e.g. in a single-tree selection forest). Modified from Pommerening (2023).

costly respacing operations are not necessary. Biological rationalisation thus saves interventions and their respective costs, and at the same time reduces the human impact on forest ecosystems.

In Switzerland, these advantages of biological rationalisation have motivated private and state forest owners to transform the principles of the selection system for use in larger areas, which is now technically known as the *Swiss irregular shelterwood system*. This system involves larger gaps than the single-tree selection system and has become the country's foremost method of managing CCF woodlands. A similar method applies to many parts of the Black Forest area in south-western Germany (Rittershofer, 1999; Schütz, 2003; Mayer, 1984). The irregular shelterwood system has also been successfully introduced in Poland, e.g. in the mountain regions of the Carpathians and in some lowland areas of the western and northern parts of the country (Jaworski, 2003).

The single-tree selection system most likely also inspired the development of individual-based forest management, since this system clearly emphasises individual trees and their requirements. This is also supported by the fact that individual-based forest management was first published in Switzerland along with a theory and the percentage of single-tree selection forests is very high in this country. From a theoretical point of view, however, individual-based forest management is largely independent of management type and can also be successfully applied to RFM. In the context of CCF, individual-based forest management facilitates the transformation process from RFM to CCF and can help introduce heterogeneity to a forest stand provided the number of frame trees is comparatively low. Particularly the process of transformation from RFM to CCF requires an appreciation of individual trees and their potential contribution to more complex forest structures (Schütz, 2001). This appreciation and understanding of the role of individual trees often does not exist among forestry staff who were trained in RFM. The lack of experience in individual-based silviculture becomes particularly evident in silvicultural training and takes some time to develop in the human mind.

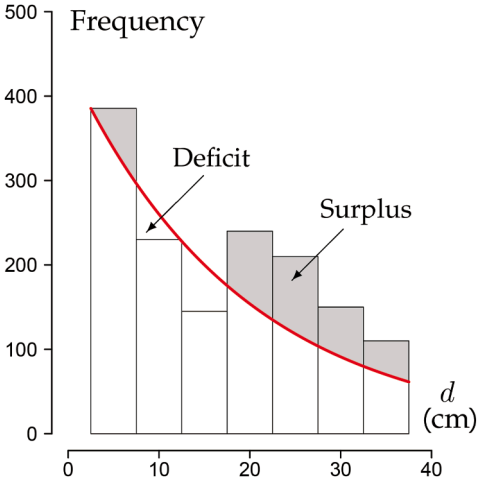

Fig. 4. An equilibrium curve overlaid on an empirical stem-diameter distribution of a selection forest. The parts of the empirical distribution that are meant to disappear—in the large classes through selective harvesting, and in the lower classes through biological rationalisation—are highlighted in grey. *d*: stem diameter at 1.3 m above ground level. Modified from Pommerening (2023).

When the CCF debate really started to manifest itself publicly towards the end of the 19th and the beginning of the 20th century in publications, the protagonists were able to draw at least partly on methods and experiences that already existed. Gayer (1886), for example, formalised the group (shelterwood) system for mixed-species forests by using experience that was made in single-tree selection systems. Other protagonists soon realised that individual-tree forest management and the individual-tree view, in general, proved to be an asset for transformation from RFM to CCF (Schütz, 2001). This still to this day is particularly evident in countries where individual-tree forest management has not historically evolved in the forestry profession as it did in Central Europe. In such countries (e.g. in Britain, Ireland, North America, and Scandinavia), it is often very difficult to overcome inflexible area-based sustainability approaches which are typical of RFM.

4. Discussion and conclusions

CCF in Europe is often assumed to have had its origin in an academic debate that started at the end of the 19th and the beginning of the 20th century in some European countries and in North America. This view is probably owed much to the fact that this academic discussion was partly carried out by means of publications which are still readily accessible historical documents; in addition, the debate was very visible and public in the forestry profession. However, long before this CCF debate even started a form of small-scale farm forestry, the selection system (Fig. 1), paved the way for a later, successful uptake of CCF by providing the

necessary methods and experience. This view is supported by the fact that in countries where a tradition of selection forests existed, CCF started earlier and was more strongly developed in those areas of the respective countries where selection forests occurred. In Germany, for example, there is a clear south-north trend in terms of CCF history and experience which is owed to this circumstance. In Poland, for the same reason, the trend of CCF use decreases from the mountain regions in the south towards the northern lowlands. Still to this day, CCF is strongest and most prominent in those countries where selection forests had formed a long tradition, even if their woodland cover percentage has been comparatively small (Schütz, 2001).

In Europe, the tradition of individual-based forest management was first at least subconsciously influenced by the selection system experience and by the ongoing CCF debate. Later, individual-based forest management contributed a range of valuable methods to CCF without which modern CCF would hardly exist. Methods of individual-based forest management clearly facilitate the uptake and practical implementation of CCF. These methods now form the basis of what sometimes is referred to as "free-style" silviculture (Bončina, 2011) and deliver the size-control method of sustainability. Individual-based forest management also contributed much to the principle of biological rationalisation (Schütz, 2005), which is an important tenet of CCF.

Without these two additional historical pathways, modern CCF would have taken a very different course in Europe. Alternative pathways of CCF can be gauged from applications in North America, Britain and Sweden (Pommerening, 2023) where historically area-control methods borrowed from RFM were used instead of individual-based methods. In North America, for example, variable-density thinning (VDT) has been designed as a method of converting even-aged stands to stands with diverse sizes and spatial structures (Willis et al., 2018; Palik et al., 2021; Brunner, 2024). This method is based on area control, where certain, predefined areas in a forest stand are earmarked and fixed for specific treatments. Similar area-based methods such as graduated-density thinning (Vítková and Ní Dhubháin, 2013), the Bradford-Hutt plan (Kerr et al., 2017), and the Anderson group selection system (Wilson et al., 1999; Kerr et al., 2010) were developed in Britain largely due to a lack of experience with individual-based forest management. Area-based approaches are usually easy to explain and can thus even be delegated to laypersons, however, this comes at the expense of flexibility due to the rigidity of the area-control method. Flexibility as offered by size-control and individual-based methods is in fact a necessary precondition for responding efficiently to rapidly changing, unforeseen stand conditions, as, for example, can be caused by ongoing climate change (Pommerening, 2023). Unlike in previous centuries, humankind is now in a better position to handle the resulting complexity due to modern information and harvesting technologies.

Our historical review highlighted that it is worth looking closely into the international emergence of concepts in order to better understand their causes and drivers: Such analyses are helpful in situations where concepts are introduced in a new country in order to better anticipate difficulties or obstacles that may exist in the specific circumstances given in the respective country but perhaps not in another one. This can then lead to a smoother adaptation of existing concepts to different conditions. For example, in countries where individual-tree forest management did not historically evolve in the forestry community, special attention has to be paid to this important tenet of CCF through dedicated education and training courses (Kruse et al., 2023).

CRediT authorship contribution statement

Arne Pommerening: Writing – original draft, Visualization, Methodology, Investigation, Conceptualization. **Ulrika Widman:** Writing – review & editing, Writing – original draft. **Janusz Szmyt:** Writing – review & editing, Writing – original draft, Visualization, Conceptualization.

Data availability

Not applicable.

Declaration of generative AI and AI-assisted technologies in the writing process

During the preparation of this work, the authors did not use any AI or AI-assisted technologies.

Funding

This research was supported by the Swedish Government Research Council for Sustainable Development (Formas) grant #2023-00994.

Declaration of interest

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

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