

Review

Economic Comparison of Continuous Cover and Rotation Forest Management in Temperate and Boreal Forest Zones in Northern Hemisphere

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Abstract

Comparing the economic performance of continuous cover forestry (CCF) in the broader context of uneven-aged management (UEA) and rotation forest management (RFM) representing conventional even-aged forest management (EA) has been a long-standing question in forest economics. In this review, we present a literature search of 134 scientific papers published between 1994 and June 2026, combining one keyword set related to economic terms and a second keyword set related to forest management. The search was restricted to temperate and boreal forests in the Northern hemisphere. Within the searched papers, different categories were identified according to their main focus, methodology, and the nature of their results. Of the 134 studies, 64 analyzed economic data covering the entire forest production cycle, but only 31 of them included relevant data to calculate an economic criterion for a correct comparison between CCF and RFM, by using net present value (NPV), or land expectation value (LEV). Regarding timber production, results show that neither CCF nor RFM is economically better overall. Advancements of one alternative over the other depend on site conditions, tree species, initial state of the forest, and interest rate. In contrast, studies have consistently proven that CCF is a better alternative for sustainability in a broader context as it decreases risks, mitigates climate change impacts, and provides non-productive ecosystem services.

Keywords: uneven-aged management; close-to-nature forest management; conventional forest management; economic criterion; net present value; land expectation value; timber production; ecosystem services

1. Introduction

The development of forest management has resulted in the establishment of two basic systems of sustainable forest management. The first is rotation forest management (RFM), based on even-aged forestry (EA), which is applied through cyclic clearcut harvesting with subsequent afforestation of the cleared area. RFM is traditionally implemented through uniform thinning from below over larger areas [1–3]. In the reviewed literature, RFM is often referred to as business as usual (BAU). The second system is continuous cover forestry (CCF), which, in its strict form, is applied through the selection cutting of individual trees or small groups of trees. CCF is associated with natural regeneration, which results in an uneven-aged (UEA) forest structure often comprising several species. In its less strict form, CCF is also applied through small-scale and/or irregular

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shelterwood and continuous cover silvicultural systems known as Dauerwald [4] or close-to-nature forestry [5]. The least strict CCF definition simply excludes clearcutting [6].

The question of whether CCF or RFM is economically optimal in northern temperate [7–9] and boreal forests [10,11] is not new, but remains unresolved. In Europe, adoption of CCF is associated with knowledge gaps and obstacles [12]. Interest in CCF is currently growing due to increasing criticism against conventional RFM, which is often associated with large-scale stand failure due to storms or insect outbreaks [2,13]. Additional concerns include low biodiversity, soil destruction and erosion, low water quality, discontinuous water runoff, and overall, low multifunctional value [1,6,14,15], along with a primary focus on timber production. These shortcomings of RFM compared with CCF are expected to become more severe due to ongoing climate change [16,17]. Therefore, CCF is increasingly discussed as a method that may better support various ecosystem services than RFM [18–24]. CCF also meets the requirements of the new European Nature Restoration Law [25] and the European Forest Strategy [24].

While public discussions often highlight the superiority of CCF regarding improving ecosystem services, there is less focus on the economic consequences of transitioning from RFM to CCF and/or the long-term maintenance of CCF practices in different forest types. Contrary to the high interest in CCF, specific scientific literature about its economics are rare. The last worldwide comprehensive review, which included 22 studies, was provided by [8] and published in the currently most relevant book about CCF. Meanwhile, there is a more current book but it is limited to Scandinavia [26]. A similar study has focused also on the Fennoscandian region [10]. Knoke (2012) [8] suggested an economic criterion based on the simple ratio of an economic indicator of CCF/RFM for their economical confrontation.

In addition to using an appropriate economic indicator for comparison, it is important to correctly classify specific management alternatives into the CCF or RFM groups, taking into account that existing forest cutting regulations and yield systems can be considered as a continuum between these two management systems, i.e., RFM and CCF [27].

The aims of this review paper are as follows:

1. To provide a comprehensive overview of the state of the art in the field of economic analysis and comparison of CCF and RFM forest management systems published during last 30 years;
2. To compare the economic performance of timber production and non-timber productive functions under CCF and RFM systems in temperate and boreal forests in the Northern Hemisphere.

2. Materials and Methods

A literature search was carried out in Web of Science internet platform, covering a time scale of 32 years from 1994 to the middle of June 2026. Two sets of keywords were set as search terms in the filter:

- The first set of six keywords focused on economy: economics, economy, land expectation value, net present value, productivity, and profitability.
- The second set of six keywords focused on forest management: continuous cover forestry, uneven-aged forest management, multi-aged forest management, near-natural forest management, tree selection cutting, and silvicultural systems

At least one keyword from the first set and one keyword from the second set were required simultaneously as a condition for a publication to be selected for analysis. Additionally, the condition of regional affiliation of the study to temperate and boreal forest zones in Europe, North America, and/or Asia was required. The resulting final dataset

included 134 studies, 131 scientific papers, and 3 book chapters for analysis. In the Results Section (Section 3), these 134 articles are further categorized according to various criteria to provide an overview of the relevant topics covered (Figure 1). The classification structure follows increasing relevance for the comparison of the financial values of the two management alternatives, CCF and RFM.

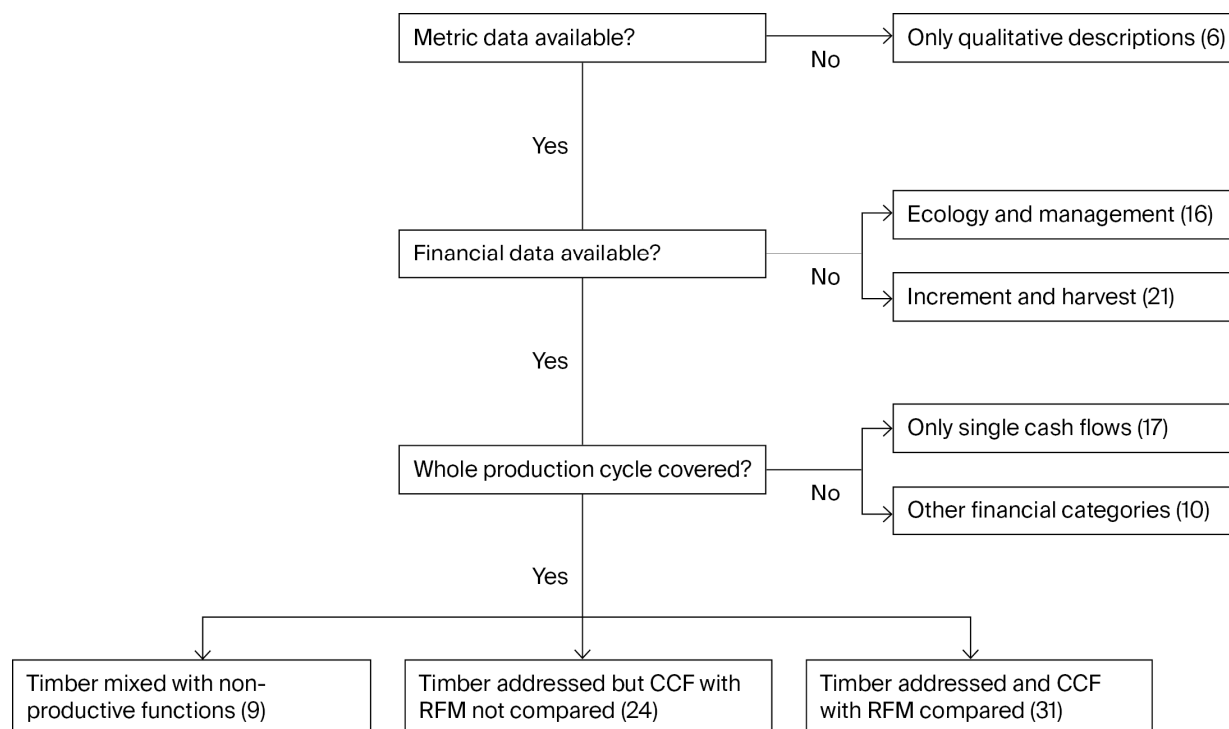


Figure 1. Conceptual scheme for categorizing the papers included in the analysis according to their relevance to the objectives of this review (the number of papers per group is given in brackets).

First, the fundamental messages from all 134 involved papers relevant to the economic comparison of CCF and RFM were identified and interpreted. Found differences were categorized as (1) significantly positive for CCF, (2) significantly positive for RFM, (3) dependent on circumstances or scenarios, or (4) unclear effect. Finally, these results were summarized separately for timber production only, for non-productive functions only, and for timber production plus non-productive functions together. If an article contained a relevant link for more than one of these categories, all of them were evaluated. In this way, 212 relevant comparisons were obtained from 134 analyzed papers.

The most valuable papers, which provided relevant metric economic values for CCF and RFM across the entire production cycle (i.e., 64 papers from three boxes at the bottom of Figure 1), were further evaluated. As the relevant economic criterion for this purpose, the sum of discounted net cash flows over the complete RFM cycle was considered, rather than individual cash flows from partial management operations. This economic criterion is typically expressed as the net present value (NPV), land expectation value (LEV), or equivalent terms such as soil expectation value, bare land value, and/or annuity, which is the transformation of these indicators into an annual basis. Marginality, utility or other comparable indicators clearly linked to economic values and timber production were also accepted for comparison.

For all papers and scenarios providing data on the above-mentioned economic criterion, a simple economic comparison between CCF and RFM was calculated according to the method suggested by [8].

$$EE_{CCF_i} = \frac{EC_{CCF_i} - EC_{RFM_i}}{EC_{RFM_i}} \quad (1)$$

where:

EE_{CCF} is the economic efficiency of CCF;

EC_{CCF} is the economic criterion value for CCF;

EC_{RFM} is the economic criterion value for RFM;

i represents specific site, stand, and/or management scenarios.

In addition to the comprehensive overview of the results given in Section 3, a more detailed summary of the main characteristics is provided in Appendix A, while the main findings from all processed papers are presented in Appendix A, Table A1. Finally, a summary of the main findings in the context of their practical use in forest management is presented in Section 4.

3. Results

3.1. Overview of Analyzed Papers

The number of papers combining CCF management and economic topics increased from 2010 to June 2026 (Figure 2). The majority are published in journals focused on forestry, as well as in journals focused on conservation, environment, and ecology. The most relevant journals are Forest Ecology and Management (15), Canadian Journal of Forest Research (14), Forestry, Journal of Forest Research (both 11), and Forest Policy and Economics, and Forestry (9). The main region engaged in CCF economics is Scandinavia, especially Finland, which accounts for one-third of the papers, while studies from Southern and Eastern Europe and Asia are rare (Figure 3).

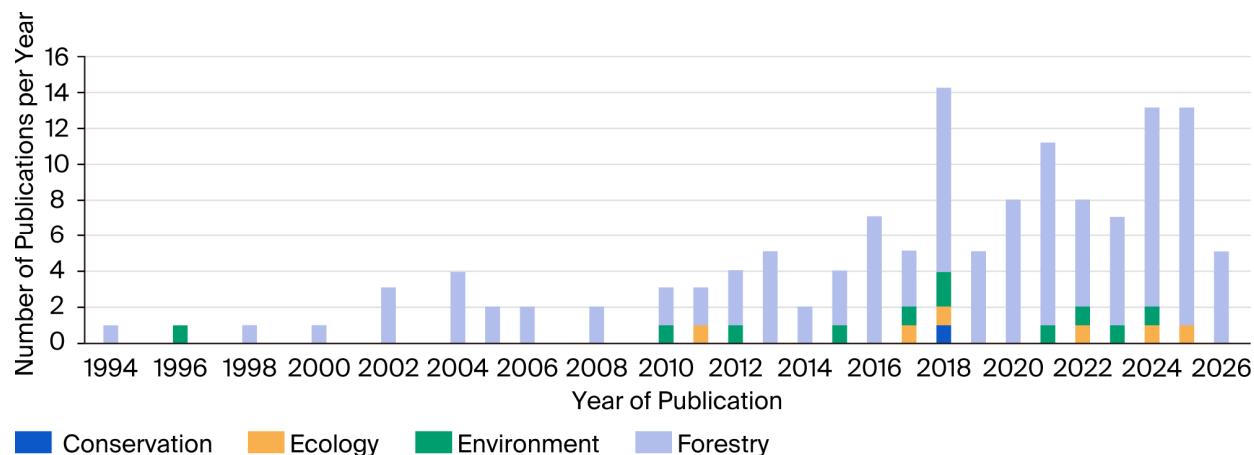


Figure 2. Number of analyzed papers and focus of their source journals (books) during the period of interest (only the first half of 2026 is included).

The investigated spatial units ranged from individual forest stands or experimental forests to the global scale, with the frequency of papers decreasing as the scale increased (Figure 4). One-third of the papers only investigated one species, followed by studies examining combinations of two, three, or four species. Only 10 papers analyzed more than four species simultaneously. Following the prevailing focus on Scandinavian boreal forests, Norway spruce was mentioned in two-thirds, and Scots pine in one-third of the papers. Two-thirds of the papers evaluated species mixtures, with the most frequent combinations involving the above-mentioned two-species mixtures with birch and other broad-leaved species.

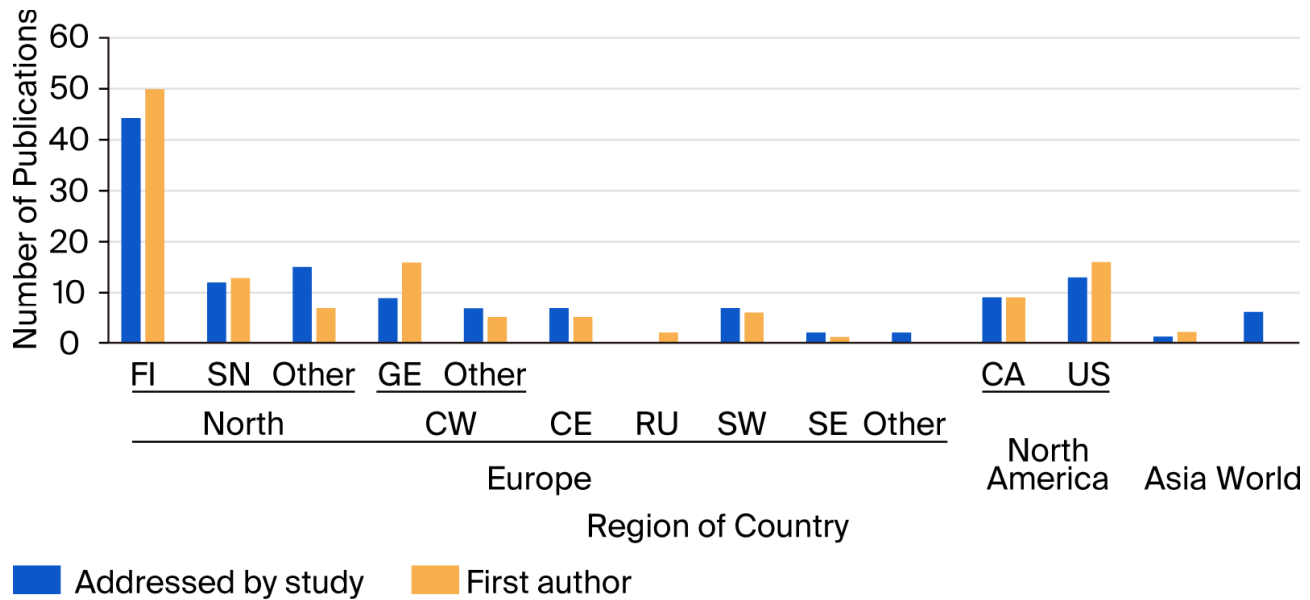


Figure 3. Countries and/or regions of interest. FI—Finland, SN—Sweden, GE—Germany, RU—Russia, CA—Canada, US—United States of America. European regions are defined according to standard Forest Europe reporting. CW—Central West, CE—Central East, SW—South West; SE—South East [28]. Other—multiple countries across regions.

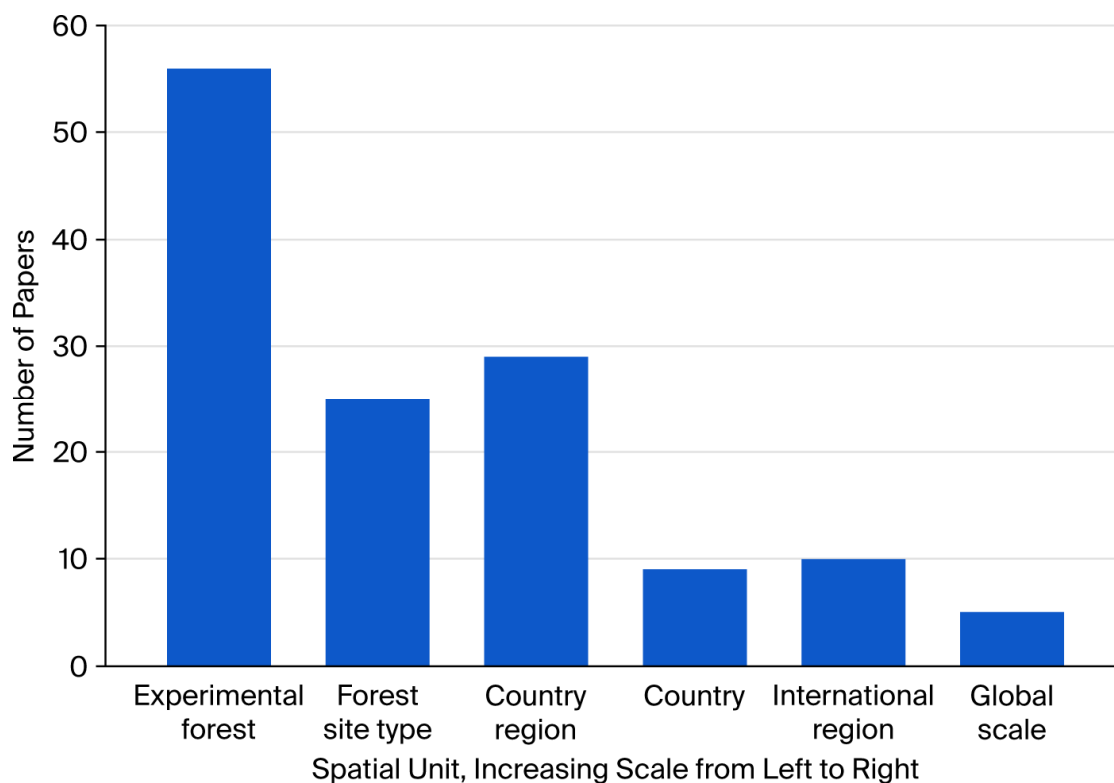


Figure 4. Relevance of spatial units addressed by analyses.

Two-thirds of the studies were based on advanced methods such as simulations, with more than half of these also incorporating optimization. The second group represents

standard empirical studies, i.e., algebraic statistical and regression studies. The third marginal group included descriptive studies and literature reviews (Table 1). Most commonly, the simulation studies investigated a period of 100 years, but periods up to 500 years also appeared. Most papers compared or analyzed multiple conditions or scenarios; half of them examined between 2 and 10 scenarios, while the second half examined more than 10, including some studies that evaluated more than 100 scenarios.

The keyword design was intended to find direct comparisons of financial values between RFM and CCF. Nevertheless, as illustrated in Figure 1, and summarized in Table 1, 43 of the 134 papers did not include financial data, and another 27 papers represented specific single financial aspects. Ultimately, only 31 of the remaining 64 papers covering the entire management cycle met the goal of comparing the economic efficiency of timber production under CCF and RFM using the EE_{CCF} indicator.

Table 1. Overview of all analyzed papers according to methods applied and categories of relevance for the goals of this review.

Relevance	Paper Category		Method Applied			SUM
	Full Cycle Covered	EE Criterion Calculated	Advanced	Standard Empirical	Descriptive	
Highest	Yes	Yes	27	2	2	31
High	Yes	No	31	2	0	33
	SUM all cycles covered		58	4	2	64
Lower	No	No	22	35	13	70
	SUM all papers		80	39	15	134

3.2. General Economic Comparison CCF Against RFM Derived from All Studies

In this section, all 134 papers are assessed. The most relevant studies for addressing the question about the optimality of CCF over RFM are the 31 that included financial values for CCF and RFM (allowing for the calculation of a financial criterion), considered long-term stand development, and focused on timber production only. This selection allowed for excluding cases with “unclear effects” and supported a more accurate comparison of CCF and RFM. In contrast, the less strict selection of studies addressing non-economic and single-period topics (70 papers, Figure 1) resulted in a higher proportion of “unclear results”.

Consideration of only non-productive functions led to a dominance of “unclear effects” and “CCF better” outcomes, with a smaller proportion classified as “dependent on circumstances”, and only one case of “RFM better” (Figure 5). In contrast, in the timber production category, “RFM better” was more common, accounting for 26% of cases where the EE criterion was calculated. One-third of the cases in the timber production category were “dependent on circumstances”.

Advanced simulation and optimization methods were generally the most found category, especially regarding timber production (Figure 6). The most common result was a dependence on circumstances, with only slightly more cases indicating that CCF was better than RFM. Empirical and descriptive methods were less frequent, and only one case was found in which RFM was more beneficial than CCF. The use of descriptive methods focused on non-productive functions led to a high proportion of positive results for CCF and did not reflect dependencies.

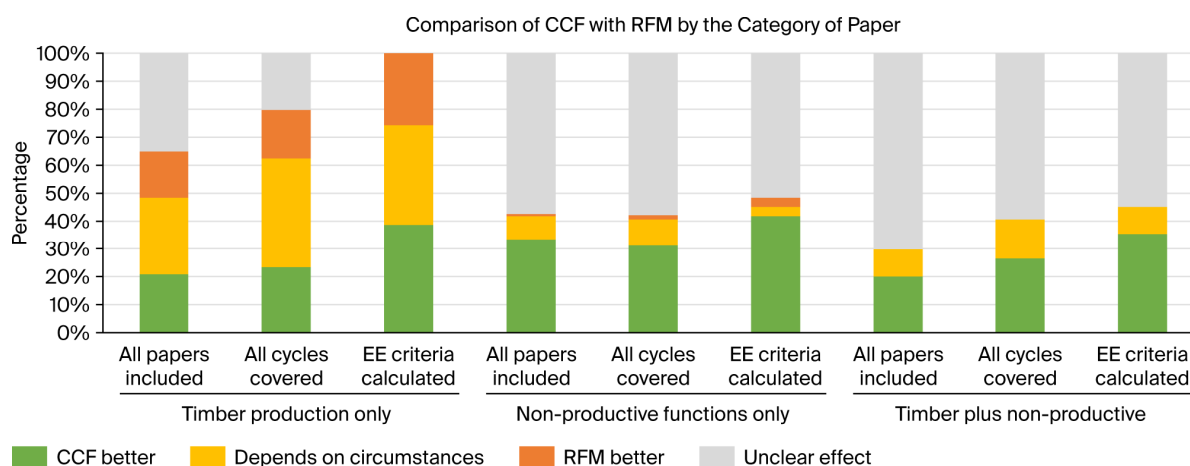


Figure 5. General economic comparison of CCF and RFM based on the study objective and the relevance category of the analyzed papers.

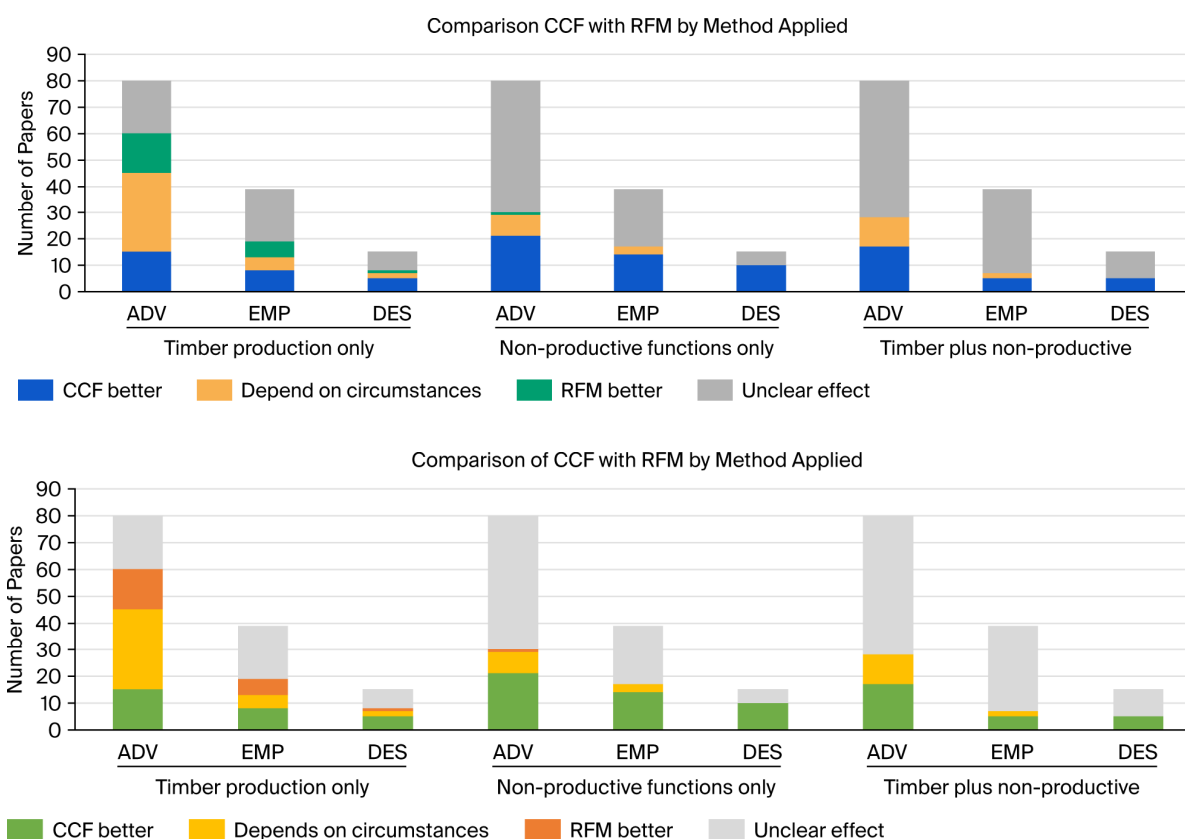


Figure 6. Overall results of comparison (134 papers) categorized using applied methods. ADV—advanced methods (simulation, optimization), EMP—empiric methods (correlation, regression), DES—descriptive methods (single description, review).

3.3. Influence of the Region and Species Composition on the Comparison Results

In this section, which focuses on the main factors influencing the results, only the 64 papers with high and highest relevance to the goals of the study (Table 1) were included.

More than half of the economic studies comparing CCF and RFM cover Northern Europe, followed by other European regions and Northern America, with almost no mention of other areas, especially Asian regions (Figure 7). Optimality in timber production

depended on circumstances in 42% of European studies. Optimality of CCF was similar to that of RFM for timber production in general, particularly for 24% and 21% of cases in Northern Europe, respectively. However, CCF performed twice as well in Northern America, with 25% compared to 13%, and in other European regions, with 23% compared to 8%. Unclear effects on timber production were most frequently reported in Northern America (50%), and other European regions (31%). In the case of non-productive functions, unclear effects predominated, followed by better results with CCF, but almost exclusively in the Northern European region.

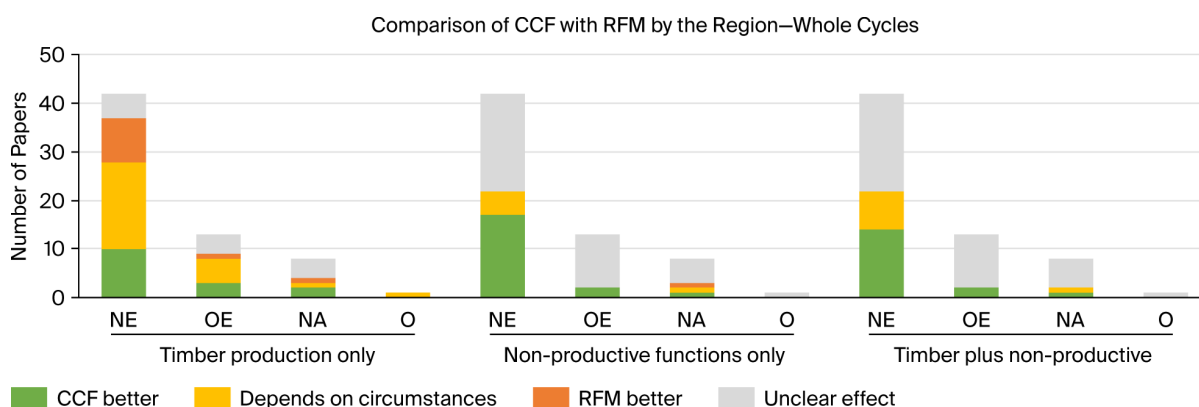


Figure 7. Results of comparison of relevant papers covering full forest production cycle (64 papers) according to region. NE—Northern Europe, OE—other Europe, NA—Northern America, O—other regions of the world.

Regarding species composition, papers about timber production reported a significantly higher proportion of clearly interpretable results, whereas more than half the papers about non-productive functions stated prevalently unclear effects (Figure 8).

Mixed coniferous–broadleaved stands were investigated most often, followed by a similar amount of uniform coniferous cases and fewer cases of other species composition types. Figure 8 shows that species composition did not significantly affect the results. “Dependent on circumstances” was the most frequent result for timber production, with a slightly higher proportion of “CCF better” compared with “RFM better” for conifers and their mixtures. Unclear effects dominated in non-productive functions. Broadleaved forests were examined by only a few studies, which reported “unclear” or “dependent on circumstances” results.

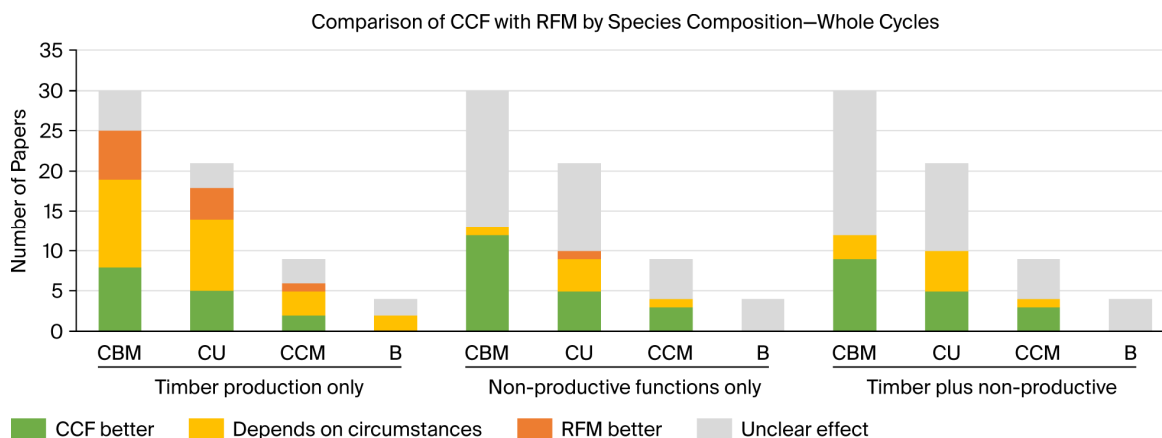


Figure 8. Results of comparison of relevant papers covering full forest production cycle (64 papers) according to species composition. CBM—coniferous–broadleaved mixed, CU—coniferous uniform, CCM—coniferous–coniferous mixed, B—broadleaved.

3.4. Economic Efficiency of CCF Compared to RFM Regarding Timber Production

In this section, only the set of 31 most relevant papers, which included financial values for CCF and RFM, is included, as they allowed for the calculation of the financial criterion EE_{CCF} based on timber production (Figure 9). In general, CCF performed better than RFM in 42% of cases and worse in 48% of cases. CCF was significantly or substantially better for 15% of cases and significantly or substantially worse for 34% of cases compared with RFM.

Economic Efficiency of Timber Production by CCF Evaluated by EE_{CCF}

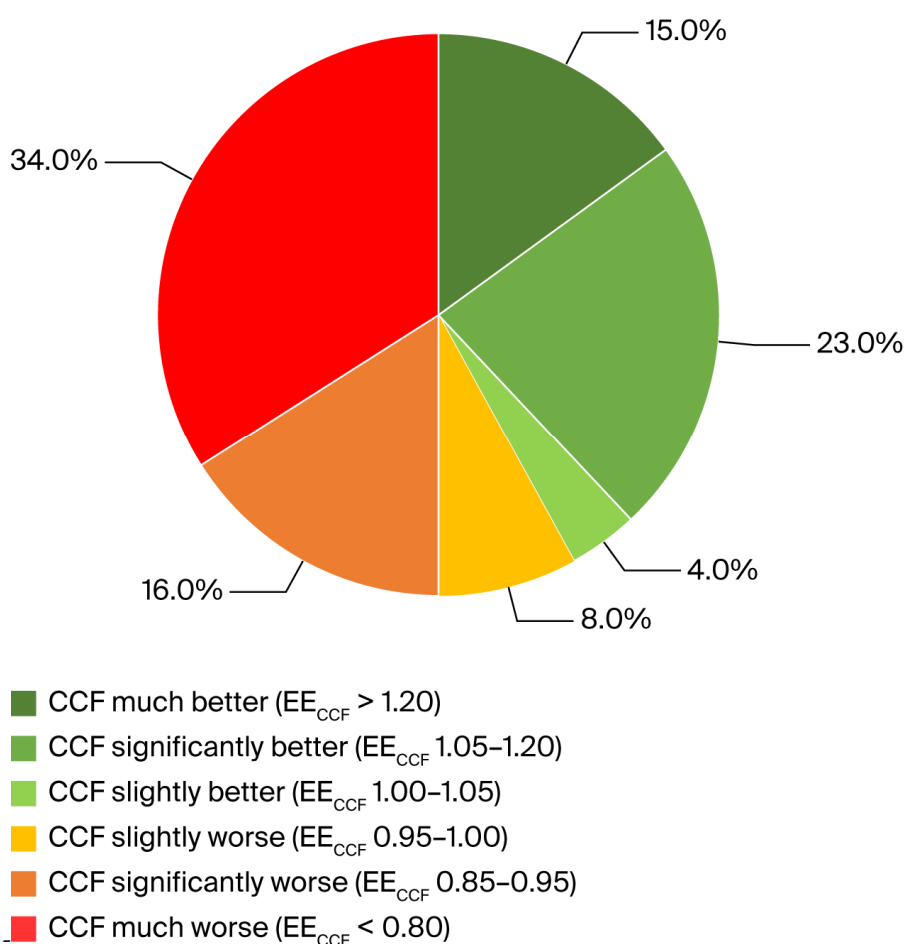


Figure 9. Economic efficiency of timber production under CCF compared to RFM based on the EE_{CCF} criterion, calculated from the 31 most relevant papers, with 135 scenarios focused on only timber production out of a total of 148 scenarios covering timber and non-timber production.

4. Discussion

4.1. Methodological Problems in the Economical Comparison of CCF and RFM

Advanced simulation and optimization methods are used in studies on timber production, as they allow for a more accurate estimation of financial values over longer peri-

ods and are able to better reflect dependencies by scenarios. In contrast, the financial estimation of non-productive functions remains less common and is more multifactorial and qualitative, thus leading to a higher proportion of unclear results.

Very different conditions, as well as the initial and final stages of forest development, influenced forest value, carbon storage, and potential for further growth. These impacts are particularly important in studies evaluating single-time events or different time horizons that do not cover the complete management cycle. Even cases of negative NPVs appeared, disallowing for direct interpretation of EE. Furthermore, missing descriptions, imprecise definitions, and studies examining the transition from RFM to CCF make it difficult to categorize all studies consistently.

Economic consideration of failure risk, or potential failure risks, requires indicators that extend or modify the typically used traditional NPV.

The high relevance of the category of non-productive functions was unexpected and not intended, as the literature search terms focused only on management systems and economy. Nonetheless, many authors related non-productive functions to economic terms, even when not evaluating them. These studies typically provide qualitative literature reviews without any metric data. They address single aspects such as ecology, management, and conservation but rely on qualitative descriptions and subjective weightings rather than exact financial values. This high interest, despite a limited foundation, highlights the need for more research on the financial assessment of non-productive functions in relation to timber production, as previously investigated by [19,22,23,29].

4.2. Economical Comparison of CCF and RFM Related to Timber Production

Better economic efficiency of CCF in terms of timber production, as measured by EE_{CCF} (Figure 9), was observed mainly under the following conditions:

- High interest rates [1,18,23,30–42], with exceptions also reported [43,44], (partly also by [45];
- Successful natural regeneration in CCF in contrast to high artificial regeneration costs in RFM [46]; similar findings were also reported by the non-EE studies [32,36,37,40,41,43,47,48].

CCF was mainly found to be better than RFM [35,38,41,49,50]. It was better under the conditions of the requirement of large trees and a harvest cycle length of 20 years and longer [51], as well as in studies focusing only timber production [29]. Other studies found the opposite [44], with no requirement for large trees [51] and cycles shorter than 20 years under 4% [51], and in studies considering timber production and red-cockaded woodpecker habitat [29,43]. In some studies, the optimality of CCF depended on the interest rate [42]. It was favored under different conditions at higher interest rates [1,23,33]. In [43], only 1%, there was requirement for reforestation with RFM.

The optimality of CCF over RFM increased with decreasing site productivity [18,30,36,41,49]. In contrast, ref. [52] found no preference, while the opposite relationship was found by [53]. Cases with optimality dependent on sites were 4% with dwarf-shrub zone [18] and 3% on herb-rich sites [30].

Furthermore, shade-tolerant species supported the optimality of CCF [23], with similar findings reported in non-EEF studies [54,55]. Genetic improvements in reproductive material that enhanced RFM reduced the EE [30,45].

4.3. Economical Comparison of CCF and RFM Regarding Non-Productive Functions

Carbon storage is the most extensively evaluated non-productive function, e.g., [18,20,21,23,29,31,56–59], with many of these considering carbon price. This focus may be

supported by the debate about climate change, which partly impacts political and management decisions and supports the development of carbon markets. In contrast, the number of approaches developed for recreation [14,23,60,61] is lower, indicating less interest. Interest in forest biodiversity has developed later than interest in forest production [62]. Many studies identify CCF as supporting ecosystem services, such as setting deadwood limits [3,63–65], but they do not include EC [15] and are vague and without a quantification.

The economics of species conservation are challenging to assess, as they require quantification of ecological forest characteristics created by forest management measures that improve habitat conditions beneficial for a species to be supported, e.g., habitats for the Siberian jay [66], reindeer pasture areas [67], and red-cockaded woodpecker [29]. The latter study represents a unique finding among the reviewed studies about the optimality of RFM over CCF for non-productive functions. The authors state that mature trees provided for cavity formation (which, in this case study, resulted from RFM and not CCF) which was a decisive factor.

Assessments become more complex when considering the different habitat requirements of multiple species, e.g., six umbrella and indicator bird species [19,20,38], habitats of various bat species [68], and the regeneration of shade-tolerant tree species [55]. Identifying management measures that increase the success of a species is ecologically more realistic and economically more relevant than simply assuming the control scenario of management abandonment to be optimal for non-productive functions, as the latter does not automatically support all non-productive functions.

Advanced studies address complexity by simultaneously considering various multi-functional non-productive or ecosystem functions and services, measuring them with specific units and indexes [19,20,22], estimating correlations between them [63], or comparing them through a scoring system [38]. These approaches allow for balancing various public interests in forests, but the number and kind of included estimates may indirectly reflect subjective weighting within multi-objective goals.

4.4. Implications for Forest Management

As CCF typically relies on natural regeneration, it is economically better when RFM requires high investments for artificial regeneration [33,36,37,40,41,43,48,69–71]. Considering variability in individual tree value growth and to harvest trees when they reach financial maturity, favors stand management based on CCF [8,72,73]. Continuing either RFM or CCF in a steady state can be beneficial [11,34]. The best option is to start a planned transition early, whereas continuing with RFM appears to be the better option for older RFM stands [10,38].

The best initial conditions of a forest stand for transitioning to CCF include the following:

- A low number of trees overall [40,41,70].
- A high number of small trees and a low number of large trees [48].
- A mature, uneven-aged, differentiated stand with a varied diameter structure [11].
- Unfavorable initial conditions for transitioning to CCF include the following:
- Bare land without any trees [11,34,45];
- Young, even-aged stands treated with a low number of conversion cuttings [11].

The further relevant site condition of peatland is investigated in the Northern European region, where, e.g., Finnish legislation has been allowing CCF since 2014 [74]. Peatland forests represent a significant proportion of boreal regions, and CCF has been found to prevent climate gas emissions from these areas while also avoiding costs for ditch network maintenance [14,31,35,59]. These studies are based on preliminary work on carbon

[75–77] and specific investigations on peatland [78,79]. Both lines of research highlight the relevance of CCF for climate mitigation, especially in boreal and peatland conditions.

A relevant topic related to CCF is the consideration of risk, e.g., natural disasters [7,17,48,80–82]. The diversification of cutting practices, as applied in CCF, is a solution for forest owners with risk-averse preferences [2,83–85]. Furthermore, CCF supports the resilience and/or resistance of forest stands [50,86–88]. Climate change may increase risks and/or change stand growth [17,77,89,90]. Optimality tends to favor CCF and uneven-aged stands, especially when ecosystem services and multifunctionality are considered. Accordingly, choosing CCF also involves decreasing risks, mitigating climate change effects, and improving the provision of multifunctional benefits.

4.5. Regional Limitations of This Study

A large amount of studies originate from Northern Europe, with fewer from North America and Central Europe, limited representation from Southern and Eastern European regions, and no studies from Asia (except for one study from Northern Iran [91]). Possible reasons for this focus in the literature are as follows:

The control method of [92], based on the ideas of [93] as the first planning tool for uneven-aged forest management, was developed and applied in France and Switzerland. In other regions, planning tools and management experience may have developed later.

Shade-tolerant species are able to naturally regenerate under forest cover, forming the foundation of uneven-aged temperate forests in Central Europe, especially in mountainous regions. Light-demanding species require bigger regeneration patches, contradicting uneven-aged management based on single-tree or group selection forest management and making CCF more challenging and less relevant. Shade-tolerant species have been found to be supportive for CCF [23,54,55].

Management goals in regions under hotter and dryer conditions as in Central Europe may focus more on ecosystem services, such as soil protection against erosion or water retention rather than financial goals. Therefore, economic analyses focusing on timber production or other financial income might be less relevant. Financial quantification of ecosystem services is more difficult.

The high share of peatland forests in Northern European boreal regions mentioned in the last section justifies the higher relevance of CCF for this region [13,31,35,59,75–79].

Boreal forests in Northern Asia and Northern America are managed less extensively and less frequently due to the harsher climate (less precipitation, lower temperature, higher seasonal temperature fluctuations) compared to boreal forests in Northern Europe, which benefit from the Gulf stream [94]. Harsh climate conditions and related slower growth [28] lead to the lower efficiency of CCF, as it requires higher harvest frequency, a higher level of differentiation, and a smaller area scale for planning.

European forests are relatively old and partly overaged, allowing for several stand layers. In contrast, East Asian forests are often younger, newly planted, and are therefore initially even-aged forests. In China, these conditions mainly apply to forests in the North-East (dominated by temperate forests) and Central areas in the recovery phase, while forests in the East and West are in a stable phase [95].

The predefined limitation on boreal and temperate zones in the Northern Hemisphere excluded several interesting studies comparing CCF and RFM in temperate forests in New Zealand, e.g., [96,97]. Thinning experiments have been evaluated for their impacts on vertical stand structure in Chile, e.g., [98,99], and in the subtropical zone directly adjacent to the temperate zone in China, e.g., [100,101], but economics have not been considered. The greater relevance of structurally diversified management practices in Southern China is in line with [95].

4.6. Outlook of Relevance Higher Relevance of CCF for Further Regions

The limited amount of research comparing the economics of CCF and RFM in other regions does not necessarily indicate less optimality or relevance of CCF.

Arguments suggesting that the financial optimality of CCF over RFM may increase globally in the future are as follows:

- Better resistance against climate change and related damages [16,17,77,89,90];
- Increasing demand and political force for ecosystem/non-timber services, which can be better provided by CCF, especially biodiversity [19,20,54], carbon storage (in case of lower carbon prices) [14,20,56], and recreation [14];
- Development of new planning tools and improvements to existent planning tools supporting CCF, e.g., terrestrial LiDAR laser-scanning [54,102], stand simulation, and optimization tools [14,19,20,54,56], as well as for the single-tree level [103,104];
- Technological development supporting CCF, e.g., single-machine systems [105] and smaller equipment [106].

These arguments highlight the need for an increase in research on management and economics of CCF in regions currently not included in investigations. Advanced simulation and optimization models [14,19,20,54,56,105,106] developed mainly in Northern Europe can support such investigations. They are generally applicable in all regions where sufficient data exists.

5. Conclusions

The number of papers focused on economically comparing CCF to RFM has increased during the last several decades, in line with increasing interest in CCF as a safer alternative management approach for timber production and provision of ecosystem services under conditions of climate change. There is no general consensus regarding the optimality of one system over the other for timber production. Studies favoring the economic results of CCF are nearly balanced with those with better results for RFM. In most studies, the results depend on the circumstances. In contrast, when considering non-productive function or environmental risks, CCF is consensually considered as the better option even if rarely clearly expressed in economic terms. An important finding is that an initial stand state with a differentiated diameter distribution in the beginning supports the transition from RFM to CCF and improves the long-term economic results of forest management. In general, no fundamental differences in the results between regions of interest, species composition types, and methods applied were observed. Nevertheless, the literature focuses on Northern Europe which limits the conclusion for further regions. Due to advances in technological and planning, the threat caused by climate change especially to RFM, and increasing demand for biodiversity and climate protection, an increased relevance of CCF can be expected for future, also in further regions.

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Abbreviations

The following abbreviations are used in this manuscript:

BAU	Business as usual
CCF	Continuous cover forestry
EA	Even-aged forest structure
EC	Economic criterion
EE	Economic efficiency
LEV	Land expectation value
NPV	Net present value
RFM	Rotation forest management
UEA	Uneven-aged forest structure

Appendix A

1. Papers not using financial data

This section includes papers that do not provide metric financial values comparing CCF and RFM but are relevant for understanding the management and ecological aspects of CCF that impact economics, particularly regarding ecosystem services beyond timber production.

Only qualitative descriptions (6)

This group of papers do not provide any metric data. They analyzed the relevance of different management systems in supporting the multifunctionality of biodiversity, recreation, and/or carbon.

Literature reviews investigated acceptability for recreation [60], ecological and economic output [10], resistance and resilience [88], silvicultural treatment [107,108], and the competitiveness of single-machine harvest systems [105].

Ecology and Management (16)

This group of papers presented criteria comparing ecological and management indicators but no direct economics values.

Other papers presented more specific single aspects, such as stand structure, biodiversity, species regeneration, resistance, and resilience [47,65,68,109,110].

Some papers evaluated soil and carbon in relation to CCF practices [75,76,111]. Ref. [112] investigated these through a meta-analysis. Refs. [59,79] on the same topic formed the basis for further economic evaluations, mainly for boreal peatland (see more in relevant section [35]).

Statistical analyses evaluated the development of an irregular structure following the last stand-replacing fire [109], soil disturbance caused by skidder forwarding [76], and structural complexity tested using terrestrial laser scanning [65,102,110]. Regression studies using data on vegetation sampling investigated how cutting impacts recruitment [47,54], how soil temperature and moisture impact soil CO₂ efflux [75], and how stand structures impact bat activity [68]. Furthermore, studies have quantified the potential area for biodiversity conservation [87] and applied multi-objective optimization to reduce the effects of timber extraction on biodiversity conservation and ecological indices [15]. There was also a literature review on economics [79] and simulations of carbon balance [59], focusing on boreal peatland forests. The same topic is covered by a simulation study of in situ C storage sensitive to climate [77].

Increment and harvest (21)

These papers demonstrated the impact of different management activities related to CCF and RFM on tree or stand growth, often in relation to harvesting activities, particularly harvest intensity.

This section includes simulations of increased silvicultural intensity [89], management objectives of landowners [113], higher increment in dense mixed stands [114], tree productivity under various treatments [115], thinning effects on drained peatlands [78], and the trade-off between structural heterogeneity and stand productivity [3]. Simulations of the transition to CCF caused production losses during the transition due to gap cutting [116] and fluctuations in harvest outcomes with increasing carbon stock when applied rapidly [117]. Simulation optimization tests were carried out on the optimal harvesting interval [118] and additional post-harvest density [119]. Ecological regression studies estimated natural regeneration depending on the speed of removal treatments [120], timber yields and structural diameter diversity [53], ingrowth volume increment [55], and crown efficiency related to disturbance intensity and intra-specific competition [121]. Regression studies investigated harvester productive time consumption [122–124].

Increment was estimated depending on the patch cutting size [125] and found to suffer worse under drought in the long term when comparing clearcut and non-clearcut sites [16]. A stand-type experiment demonstrated higher volume production in structurally rich stands [126]. Increasing tree size was found to be associated with silvicultural intensity when comparing experimental plots [127]. Trends observed in an experimental forest were described [128].

2. Papers using financial data not covering whole production cycle

These papers presented metric financial values comparing CCF and RFM, but not in terms of NPV and LEV related to the whole production cycle, only for single periods and/or specific management operation.

Only single cash flows analyzed (17)

The listed papers typically focused on harvest costs as the most significant negative cash flow in forest management. Some papers also evaluated net cash flows, i.e., the income from timber production minus harvest costs.

Analyses of the literature compared cutting and hauling cost models [129], the equipment used to extract timber [130], and economic outputs using a ratio economic criterion [8]. Regression and statistical models of time consumption investigated costs of operations with harvesters [131], harvesters and forwarders [132–134], draught horses and tractors [106,135], and experimental fellings [136]. Further investigations addressed tree economic value and habitat value [137], as well as transition regimes involving harvested value in various initial harvests [138] and harvesting costs/venues associated with regeneration cuts [139]. Comparative analyses of various unit costs, e.g., harvesting, planting, young growth tending/pruning, forest protection, and roads, compared their dependence on silvicultural systems and other natural and economic factors [140], as well as on management variants considering risks and timber quality [7]. A simulation tested active adaptation strategies to reduce climate change risks [17]. A numerical example demonstrated lost revenue when clear-cutting all trees at once and disregarding the individual financial maturity of trees [8].

Other financial categories (10)

These papers identified factors with an impact on economic optimality but without exact quantification.

Simulation optimization studies estimated the impacts of interest rate and regeneration cost, the number of initial regeneration trees [70], clearcut stumpage prices and bare land value [40], various thinning regimes [141], and the number and size of trees [48]. Simulations were applied to contrasting scenarios: the first aimed to maximize NPV, while

the second aimed to maximize multifunctionality by considering indicators of biodiversity and ecosystem services. Both scenarios were applied to three harvest intensities at the national scale [19]. Studies considered the uncertainty of stochastically implemented natural disasters [48,83]. Analytical (algebraical) extensions of the LEV approach, partly supported by numerical examples, were used to analyze optimal carbon storage [32], the efficiency of stand area utilization [142], and other factors, such as regeneration and management [80,143].

3. Papers using financial data covering the whole production cycle

These papers contain NPV, LEV or similar indicators that characterize the complete forest management cycle and are generally considered the most relevant for comparing different management systems.

Timber production mixed with non-productive functions (9)

These studies aimed to maximize economic value by combining timber production with multifunctional goals, without distinguishing the specific contribution of timber production.

Under this category, all related studies were simulations and/or optimizations. The objectives included evaluating the following: management scenario effects on lichen-rich reindeer pasture area and NPV [67]; maintaining Siberian jay habitats simultaneously with timber production [66]; impacts of deadwood volume requirements on net timber income, harvesting intervals, and biodiversity-related felling by applying size-specific decomposition rates [64]; the effects of applying 30% protection targets of the EU Biodiversity Strategy on growing stock, NPV, and the remaining forest area available for wood supply [144]; the impact of harvest diameter limits on areas with structural characteristics suitable for owl-nesting habitats and NPV using stochastic processes [145]; the impact of carbon offset prices on NPV, size, and species diversity [81]; carbon pricing effects on stands growing on boreal mineral and peat soils, considering low groundwater levels and peat decomposition effects on emissions, NPV, harvest cycles, and post-harvest basal areas [57]; the effects of residual basal areas and cutting cycles on forest growth, carbon, and LEV [146]; and the development of Pareto optimal landscape-level plans for estimating correlations between carbon balance, the amount of deadwood, harvested timber volume, broadleaf volume, and NPV of stands [63].

Timber production addressed, but CCF is not compared with RFM (24)

These papers included values for NPV, LEV, or similar indicators, primarily (or additionally) for a pure timber production goal. However, they do not directly form comparable pairs that allow for comparison between CCF and RFM.

Some of the papers investigated all-aged forestry (AAF), which means there has been no permanent choice between RFM and CCF [52].

An individual-tree simulation and optimization study examined the effects of varying planting density and rotation age within different silvicultural systems on present value [147]. An analytical LEV approach and comparative static analyses evaluated the optimal LEV of UEA stands in relation to the cutting cycle, the residual growing stock level, timber price, and interest rate [148]. A study simulated AAF by optimizing the type, timing, and proportion removed by thinning across diameter classes and species to improve NPV, while further testing site-dependent legal stand basal area limits [74]. A regression analysis and optimization of AAF investigated if full or partial cutting was optimal, depending on forest holdings, interest rates, stand basal area, and mean tree size [149]. A cost-benefit analysis investigated the effects of implementing CCF in boreal peatland forests to increase water quality, mitigate nutrient export, and improve the recreational value of peatlands [14].

An investigation tested the optimization of harvest prescriptions for individual trees in a stand and developed a two-level procedure to reduce the related computational time requirements [104]. Another approach to tree-level decision-making is an evolutionary

search algorithm to specify the financially optimal timing of removals considering individual tree growth, the probability of natural mortality, and price [103].

In a dynamic matrix transition simulation and optimization model for UEA, optimal harvest diameters depended on timber quality, initial number of stems, and basal area [150]; site productivity [151]; and classes representing growth variability and tree species, with the economic maturity of individual trees evaluated according to interest rate [72,73].

An approach to compare the optimality of either CCF or RFM within the same optimization procedure resulted in no optimal solution for RFM when CCF was the better option, allowing for positive EE values only. To reflect the results of these studies, the number of cases that were positive for CCF versus cases positive for RFM were added separately. Using this approach, the impacts of factors such as site productivity, interest rate, artificial regeneration cost, and the number of trees in the initial stand were tested for their impact on the LEV of CCF and RFM, and their rotation period length. The number of scenarios was 55:65 [41], 55:24 with one similar scenario [36], and 18:6 [152], for optimality of CCF:RFM, respectively. In addition to these, studies considering further impacts included species mixtures with 4:4 [71] and 13:12 scenarios [37]. Further studies additionally considered carbon prices, with 14:6 [58], 4:2 [21], 5:13 [153], and 43:38, with four scenarios considering only C storage [56], for optimality of CCF:RFM, respectively.

Simulations considered the risks of wind throw [82] and site index changes due to climate change [90] on financially optimal harvest transformation strategies. Stochastic simulation approaches also considered additional risk aversion by creating an optimized diversified portfolio consisting of single partial final harvests [84,85].

Timber addressed and CCF compared with RFM (31)

The papers in this section directly compared the NPV or LEV of CCF and RFM over the entire production cycle.

A study simulated the transformation from EA to a higher number of stand-layer structures using various types of regeneration and evaluated NPV under declining interest rates [46]. A response to [46] was a repetition based on a conceptual analysis that considered marginality in maximizing the discounted financial utility of consumption [69].

Further simulation studies on transition regimes tested various initial stand states: From a long-term Ecosystem Project [61], studies simultaneously optimized different conversion periods [91], or numbers of conversion cuttings, including CCF as the initial system [11]. Further studies examined optimal harvest intervals combined with post-harvest basal area [34], residual growing stock levels under varying site index levels or intensities [49], two soil types and two CCF density levels [20], and scenarios with and without natural regeneration after a RFM generation [43]. Additional studies considered genetic gains through improved reproductive material in RFM, either combined with three site types [30] or with various site types and peatland locations, and including scenarios initially starting either from bare land or from an ongoing rotation [45]. Some started with an age of 60 years [42], or with a mature stand [33,44]. All tested various interest rates, except [61] and [20].

A forwarder and harvester simulation time study aimed to diversify the EA structure by removing the largest, best-quality trees successively (creaming), clear felling, and group felling, considering the interest rates, timing of revenues, and value growth [39].

Regression analysis and optimization maximized NPV while applying two basal area limits specific to five site types, considering post-thinning basal area and the type and intensity of the thinnings [52].

An optimization study to determine the optimal post-thinning diameter distribution tested uniform thinning and variable density thinning, while also incorporating the requirement for a continuous presence of large trees in the post-harvest forest [51]. The au-

thors of [154] recommended delaying conversion management towards CCF and abandonment in favor of clear-felling until the end of a normal rotation period, as otherwise, high volume losses occur.

CCF outcomes in simulated peatland management scenarios depend on the interplay between tree growth and water table depth and are impacted by ditch network maintenance, basal area after harvest, harvest interval, and interest rate [35]. For the same topic, the effects of applying strip harvesting compared to clearcutting were applied to two water table levels [31]. The study by [18] related lower NPV to tradeoffs associated with reduced greenhouse gas emissions and lower nutrient exports, evaluated over periods of 20 years and 50 years across a series of site types. Another study about peatlands is [45], as mentioned previously.

A higher number of studies compared timber production with further multifunctional or non-productive goals, distinguishing these from timber production alone. These simulation and optimization studies aimed at estimating the effects of various goals, beyond NPV from timber volume production, including cowberry and bilberry yields, carbon tax, and subsidies for young stands. These studies also considered non-financial values, including scenic values, biodiversity, specific structural diversity, and habitat suitability for the Siberian jay or red-cockaded woodpecker, which are typically sensitive to interest rate [1,15,22,23,29,155]. The study by [31], mentioned in the previous paragraph, considered Social Net Benefits as a value comparable with NPV, representing reduced requirements for ditch network maintenance and reduced eutrophication by CCF. The study by [20] did not calculate NPV but applied a cost efficiency index to biodiversity and carbon.

Simulations incorporating risk were used for optimization under various storm scenarios [86] and for evaluating Conditional Value at Risk under storm-related risks and historical cost and price risks [2]. An analytical framework and optimization approach examined economic resilience by focusing on the rate of economic recovery after severe disturbances depending on interest rate and stand age [50].

Table A1. A total of 134 studies found during the literature search and their characteristics. Column RE indicates region. NE—Northern Europe, OE—other Europe, NA—Northern America, OT—other world. Column Spe—species composition: CBM—coniferous–broadleaved mixed, CU—coniferous uniform, CCM—coniferous–coniferous mixed, B—broadleaved. Columns T—timber production only, N—non-timber production only, B—both. Characteristics and colors of T, N, and B: Positive for CCF (green), Depending on circumstances or neutral CCF (yellow), Negative for CCF (red), Out of interest or unclear effect (empty white).

Cite	Re	Spe	T	N	B	Positive for CCF	Neutral Effects/Unclear Situation/Out of Interest	Negative for CCF
Lower relevance: No full cycle covered. Section: Only qualitative descriptions (6)								
Descriptive methods								
[88]	OT	CBM	+	+	+	Increased resistance and resilience to disturbances, thereby limiting major disruptions	Little or insignificant differences in economic return	
[107]	NA	CBM	+			Less cost due to less interventions, Management for ecosystem benefits expensive		
[108]	NA	CBM					CCF not included	
[10]	NE	CBM	+			Ecological performance	Volume output; Economic Output	
[60]	OT	CCM	+			Socially optimal “acceptable” for recreation		

[105]	NA	CBM	+	Competitiveness of single-machine harvest systems for low tract size, harvested volume per hectare, and/or average extraction distance	Less competitive than two-machine harvest systems
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Lower relevance: No full cycle covered. Section: Ecology and Management (16)
Descriptive methods

[87]	NE	CBM	+	Amenity values related to biodiversity and wilderness	
[79]	NE	CBM	± + +	Decreases greenhouse gas emission, improves water quality on drained peatlands, fewer investments to re-generation and ditch network maintaining	

Empirical methods

[75]	NE	CU	±	Soil cover reduced, and controlled soil temperature and carbon soil carbon efflux	
[68]	OE	CBM	+	Highest species richness for most bat species	
[47]	NA	BUM	+	Increases recruitment	
[109]	NA	CU	+	Maintain habitats and functions of preindustrial forests	
[110]	OE	CBM	+	Higher structural complexity	
[65]	OE	BUM	+	Structural complexity	
[102]	NA	CBM	+	Moderate thinning treatments increased canopy structural complexity	
[111]	NE	CBM	+	Stand density and tree size variation increase stand structural complexity	
[112]	NA	CBM	+	Higher live tree carbon pool (earlier than 30–40 years), shorter time for the forest to recover	
[54]	OE	CBM	+	Biodiversity; sapling and seedling densities were highest within the 10 m perimeter of the habitat tree group, shade-tolerant species near center	No impact: tree volume, density, vitality, and composition of habitat tree group effect on re-growth dimensions

Advanced methods

[77]	OE	CU	+	Increased in situ C storage	
[59]	NE	CBM	+	Carbon sinks with low and middle harvest intensity, higher post-harvest basal area, ditch network maintenance less relevant	Harvest cycle
[15]	NE	CBM	+		RFM prevailing only at very high levels of timber harvesting
[76]	NA	CCM			No impact by management, CCF not included

Lower relevance: No full cycle covered. Section: Increment and harvest (21)
Descriptive methods

[128]	OE	CBM	+	Harvesting intensity subsequently increased and improved age structure	
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Empirical methods

[53]	OE	CU	±	+	±	Best-quality sites		
[124]	NE	CCM	+			Harvester productive time consumption related to increased piece stem volume		
[120]	OE	CCM					RFM missing	
[55]	NA	CBM	±			Higher tree-species diversity, regeneration of shade-tolerant species Western Hemlock, Pacific silver fir, Western redcedar, bigleaf maple (species diversity)		Regeneration of more light-demanding species, douglas fir
[121]	OE	BUM					CCF not included	
[125]	NA	CU	-			Increment higher following patch cutting		Increment lower following dispersed single-tree cutting
[122]	NE	CU	-					Harvester productivity lower compared to clear-cut due to lower stem volume and number of harvested stems
[123]	NE	CU	-					The work phases moving the logging device to trunk and felling of tree consumed more time
[126]	OE	CU	+			Higher volume production by structurally rich stand		
[127]	NA	CBM	+			Tree size increasing with intensity, high silvicultural intensity most similar to the natural forest in terms of spatial arrangements		
[16]	NE	CBM	+	+	+	Higher drought resistance of growth		
Advanced methods								
[89]	NA	CBM					Intensities but no type of management	
[113]	NE	CBM	+			Continuous harvested volume		
[119]	NE	CU	±			Longer harvest intervals, lower harvest intensity, left-skewed histogram of age-class distribution		
[118]	NE	CU	±					Fixed harvesting costs, interest rate, old even-aged initial stand
[3]	OE	CBM	+			Production-oriented scenario esp. during years 20 to 60		multifunctional and set - side scenario
[114]	OE	CBM					RFM missing	
[78]	NE	CBM					RFM not included	
[117]	NE	CBM	-			Increasing growing stock		Lower volume of sawlogs, significant variation in annual harvest versus even wood flow in RFM, no slightly increasing harvest levels as in RFM
[115]	NA	B	-			No slow recovery of merchantable growing stock following clearcutting		Low tree productivity

[116]	NE	CCM	-	Early transition options decreased production less than late conversions		Late conversions, starting at the reference final felling age, decreased production
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Lower relevance: No full cycle covered. Section: Only single cash flows analyzed (17)

Descriptive methods

[130]	NA	CBM	-			Twice the time and money into development and training, partial cutting require more intense planning, layout, supervision expect 10–50% higher costs over clearcutting
[129]	NE	CU			Only CCF investigated	
[69]	OT	CCM	+	+	16 papers investigated in a literature review	Further 6 papers
[106]	OE	B	+	+	Farm tractor adequate for low-removal-intensity, high log size	Higher extraction distance

Empirical methods

[131]	NE	CBM	±		High average tree volume		Lower stand size
[140]	OE	CBM	±		Lower costs for agrotechnical drainage, forest protection	Fire protection	Higher costs for principal activity, regeneration, infrastructure, tending, harvesting and skidding, Longer forwarding distances, loading time in patch cutting
[133]	NE	CBM	-				
[135]	OE	BUM				Only selection cut	
[134]	OE	CU				Both cases are transition from RFM to CCF	
[136]	OE	CU				RFM missing	
[138]	NA	B	-		No increase in the high vigor tree proportion, allowing for more similar future harvests		Low harvest value
[132]	NE	CBM	-				Stem A41 damage to understory, costs preserving understorey
[137]	OE	B	+	+	Optimal 10 habitat trees		
[139]	OE	B	+	+	regeneration cuts support structural heterogeneity		

Advanced methods

[17]	NE	CBM	±	±	South region since 2020–2080, North only until 2080,		Middle region
[7]	OE	CU	±		Consideration of risks of RFM		Case of lower timber quality of CCF

Lower relevance: No full cycle covered. Section: Other financial categories (10)

Empirical methods

[32]	NE	CU	±	±	Interest rates, Carbon price, Regeneration costs for RFM		
[142]	NE	BUM	+		Larger trees utilizing the area more efficiently		
[143]	OT	CBM				Analytical, no strict limits	

[80]	OT	CBM				Model did not consider specific values		
Advanced methods								
[48]	NE	CBM	±	±	High interest rate, high number of small trees, low number of large trees, high regeneration costs of RFM, no natural disasters			
[141]	NE	CU	±				Repeated high thinnings in stands not previously thinned	
[70]	NE	CU	±		Interest rate relative value of large trees		Number of trees in initial state	
[40]	NE	CU	±		Interest rate regeneration cost initially forested and negative bare land value			
[83]	OE	CU				RFM and CCF not clearly distinguished		
[19]	NE	CBM	+	+	Multifunctionality, Biodiversity			
Lower relevance: No full cycle covered.								
Section: Timber production mixed with non-productive functions (9)								
Advanced methods								
[81]	NA	CCM	±	±	±	Moderate carbon offset prices		
[57]	NE	CCM	±	+	+	CO ₂ price on mineral soils but not on peat soils		
[66]	NE	CU		+	+	Nesting habitat of Siberian jay	Feeding habitats of Siberian jay	
[63]	NE	CBM					RFM and CCF not distinguished	
[64]	NE	CBM					Only CCF included	Dead wood requirements
[146]	NA	CCM				High carbon price; Loblolly pine is better than longleaf pine and slash pine	Only CCF included, residual basal area	Cutting cycle
[145]	NA	CCM					Stand states changing and not differentiated into CCF or RFM	
[144]	NE	CBM	-	+	±			Additional protection resulted in intensified harvesting in the remaining forest area available for wood supply with the current harvest level.
[67]	NE	CCM	-	+	+	Halts the decrease in lichen-rich reindeer pasture area		NPV 5% lower
High relevance: Full cycle covered.								
Section: Timber production addressed but CCF with RFM not compared (24)								
Empirical methods								
[149]	NE	CBM	±			Basal area of pulpwood-sized trees		Stand basal area, mean tree size
[148]	NA	CCM				Timber price	RFM not considered, cutting cycle, residual growing stock	Interest rate
Advanced methods								

[84]	OE	CBM	±	Risk reduced by 50%	Annual payment reduced by 25%
[74]	NE	CBM	±	Case of allowed switching or alternating between CCF and RFM.	
[147]	NA	CCM	+	Rotation age (<120 years), thinning	Planting density of 150–300 trees/ca, rotation age (>120 years)
[82]	NE	CBM	- + +	Cutting cycle, faster transformation; European Beech, Douglas Fir	Harvesting premature; Norway spruce, Sitka spruce
[150]	OE	CU			RFM not included
[72]	OE	CBM		Accounting for growth variability within tree harvesting.	RFM not considered
[37]	NE	CBM	+	Interest rate regeneration cost	Presence of Scots Pine
[58]	NE	CU	± ± ±	Carbon pricing, interest rate	
[21]	NE	CU	± ± ±	Interest rate preserving pastures as reindeer grazing grounds	Carbon price
[41]	NE	CU	±	Low or moderate site productivity, interest rate above > 2%, artificial regeneration cost,	Number of trees in initial stand state
[71]	NE	CBM	+ + +	Regeneration cost of RFM thinning	
[153]	NE	CU	± ± ±	Interest rate thinning	Carbon price including carbon in soil
[36]	NE	CCM	±	Interest rate regeneration cost site productivity Norway spruce	Scots pine
[14]	NE	CBM	± + +	Beginning with age of 60 years; water quality, mitigate phosphorus export on peatlands, recreational value, mesic site for i 3% and 5%	Until age of 60 years, afterwards immediately switching, interest

Advanced methods

[73]	OE	CBM			RFM not considered
[151]	OE	CU			Steady states not considered, RFM Cyclical management on high productivity stands
[90]	NE	BUM			RFM not included
[85]	OE	CU	±	Inclusion of risk aversion	
[152]	NE	CBM	±	Interest rate 3%, Admixture of Scots Pine	Interest rate 1%
[56]	NE	CU	± ± ±	High interest rate, low carbon price	
[104]	NE	CBM		Shortening of computing times tree-level harvest optimization	
[103]	NA	B		Diverse, structurally, and demographically complex stands	

Highest relevance: EE criterium calculated.**Section: Timber addressed and CCF compared with RFM (31)****Descriptive methods**

[50]	OE	CU	±	business-as-usual consumption, Ct = C0 constant, without consumption growth rate	Marginality of discounted utility
[22]	NE	CBM	+ + +	Middle and South	North

Empirical methods

[52]	NE	CBM	+	Decision for thinning rather than clearcut: South, basal area, temperature sum, basal area of pulpwood-sized trees + Herb-rich, mesic, and sub-xeric site	Decision for thinning rather than clearcut: North, allowed post-thinning basal area, interest rate × mean diameter
[15]	NE	CBM	+	South	North, green-tree retention
Advanced methods					
[1]	NE	CBM	+	Interest rate	
[38]	NE	CBM	±	Interest rate	Stands ready for final harvesting
[33]	OE	CBM	±	Interest rate	
[34]	NE	CU	±	Interest rate, UEA mature initial	Bare land or young initial, harvest interval, post-harvest basal area
[49]	OE	CBM	±		Site index
[42]	NE	BUM	±	Interest rate	
[44]	NE	CU	-		Interest rate
[46]	OE	CU	-	Successful natural regeneration, one or two layers	Three or four layers
[35]	NE	CBM	+	Peatlands: interest rate, ditch network maintaining when needed	Harvest interval of 15 years, post-harvest basal area (4 10 16 m ² /ha for interest rate 5% 3% 1%, respectively)
[39]	OE	CU	+	“Creaming the best” (removal of the largest best quality trees), establishment costs, interest rate	
[11]	NE	CU	+	Young, medium-aged, and mature EA and UEA initial stands	Mature EA initial stand under a 20% faster dbh and height growth
[29]	NA	CU	+	Only timber production	Management conversion costs not considered
[86]	NE	CBM	+	Historic and increased storm scenario, most vulnerable plots, specified resilience value concerning storm risks	No consideration of storms
[51]	NE	CU	+	Forced continuous presence of large trees in the post-cutting forest	
[155]	NE	CBM	+	Higher standing volume and structural diversity	Lower mean annual harvest and growth
[8]	OE	CU	+	Total forest value, economically recovered from disturbance faster, interest rate, stand age	
[2]	OE	CU	+	Consideration of storm risk, price-cost level 1980–2015, consideration of carbon price esp. in the first rotation	Price-cost level 1850–1900
[23]	NE	CCM	+	Only timber: Norway spruce better than Scots Pine, Carbon price, mid-	1%; Total: Norway spruce interest rate, Scots pine interest rate 1%, Scots pine Carbon price

					ble interest rate 3%, 5%; total: bil-	
					berry price, Norway spruce carbon	
					price 15 €	
[61]	NA	CBM	-	+	Recreation, non-traditional forest products	No significant difference
[91]	OT	BUM	±		Initial mature EA, followed by UEA, two-storied stand, and young EA	Interest rate
					Interest rate, NPV only 4% dwarf-shrub site, less greenhouse gas emissions over 50 years (considering living biomass and soil), sink on dwarf-shrub average (also single case of RFM), Vaccinium vitis-idaea site (only CCF), lower nutrient exports	NPV all sites in order herb-rich site (richest), Vaccinium vitis-idaea site, Vaccinium myrtillus site, dwarf-shrub (poorest), more greenhouse gas emissions over 20 years
[18]	NE	CBM	±	+	±	
					No ditch network maintenance required, reducing eutrophication, high interest rate, higher water table level 35 cm, lower water table level 37 cm	
[31]	NE	CU	-	+	±	
						Conversion before reaching normal rotation, aiming at an inverse J-shaped size distribution at time of thinnings
[154]	NE	CU	±			Genetic gains improving reproductive material in RFM, herb rich site type, low interest rate 1%
					Early conversion management	Natural regeneration after clearcut scenario
[30]	NE	CBM	±			Genetic gains improving reproductive material in RFM, starting transition from bare land
					Mesic heat site type, high interest rate 5%	
[43]	NE	CBM	±			
					Low interest rate	
[45]	NE	CBM	-			
					Starting transition from ongoing rotation, one case North Finland bare land 5%	
[20]	NE	CBM	+	+	+	Carbon, biodiversity, peat soils

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