Continuous Cover Forestry (CCF) as a potential response to challenges facing Aotearoa New Zealand

Yvette Dickinson, Sebastian Klinger, Tim Payn, Thomas Knoke and Serajis Salekin

Abstract

Production forestry in New Zealand is undergoing a shift in the face of social, economic and environmental pressures. Technological developments such as the use of automation and precision forestry, artificial intelligence (AI) and big data are presenting opportunities for forestry that will allow us to respond to these challenges in ways not tried before. One proposed response to these challenges and opportunities is the development of Continuous Cover Forestry (CCF) systems fit for New Zealand's context. CCF is a suite of forestry systems aimed at providing multiple benefits by maintaining a cloak of forest over the land in the long term, while still allowing for timber harvest. CCF may provide multiple products and services, with a lower environmental impact than conventional forestry systems.

While it has been successfully applied in the northern hemisphere for some time, CCF will require adapting for our local needs, species and environment if it is to be successful. There are also common misconceptions and confusions held by both foresters and the general public, which are hindering our ability to develop and apply CCF at scale in New Zealand. This paper attempts to address some of the most common confusions by describing what CCF is and how it differs from other silvicultural systems.

While CCF is more complex than current forestry systems and implementation is more challenging, there is great potential for economically viable CCF systems in both exotic and native forests in New Zealand. CCF may be particularly attractive in locations where existing clearfell systems are no longer environmentally acceptable and have lost social licence. A number of knowledge gaps have also been identified, including the need to develop site-specific or place-based silvicultural systems, and demonstration sites.

Introduction

Forestry is undergoing a transformational shift with increased expectations of inter-generational economic, environmental and social equity, greater climatic and socio-political uncertainty, and accelerating technological changes. For example, managed forests are now expected to produce the raw feedstock for a greater variety of wood-derived products to support regional and indigenous economies while also:

- Protecting soil, water and air
- Sequestering carbon to mitigate climate change
- Supporting communities and other land uses to adapt to extreme climate events
- Delivering habitat for biodiversity
- Providing a venue for recreation and tourism
- Improving the mental and physical wellbeing of people
- Offering the backdrop to life for peri-urban and rural communities.

The emergence of novel bio-based products to substitute for fossil carbon intensive materials, automation, robotics and artificial intelligence (AI) is also providing new opportunities.

New Zealand forestry is no different, and the silvicultural regimes we use will need to become more diverse in response to public pressure to avoid clearfelling while mitigating climate change impacts, and providing products and services from forests. We expect there will be a shift from relatively simple forest systems that prioritise one management objective (e.g. wood production or conservation) to forests purposefully designed to balance a wider range of management objectives simultaneously. These systems are likely to be more complex, with mixed species and/or multiple cohorts of trees providing a diverse portfolio of ecosystem services, and increased resilience and resistance in the face of climatic and economic uncertainty (Larsen et al., 2022).

In New Zealand, Continuous Cover Forestry (CCF) is one of the potential forest systems that has been proposed as a potential solution to these challenges, both globally and in New Zealand (O'Hara, 2006). There have also been numerous potential advantages of CCF identified, including (but not limited to) the greater structural complexity of forests and the stability of habitat values, more frequent regular cashflow from timber harvest, the ongoing protection of soil and water, and the reduced visual impact of harvests (Barton, 2008, Appendix 1). Three opportunities for CCF have been proposed in New Zealand (Anon, 2023):

1. Transforming existing commercial exotic forestry into CCF with either exotic or indigenous species

With increasing climate change impacts, some areas of commercial exotic forests are becoming too risky to harvest under traditional clearfell regimes, with concerns about erosion and harvest residues causing off-site impacts. The maintenance of living root systems and canopy cover under CCF systems may hold the slopes and a lower residue loading over longer periods of time (Amishev et al., 2014; Anon, 2023). Additional biodiversity, ecosystem and potentially cultural values may also be attained through the transition of existing exotic forests to indigenous species, which could then be managed under a CCF regime (Forbes & Norton, 2021).

2. Management of regenerating native forests

There are at least 1.4 million ha of native woody vegetation on farms across New Zealand (Norton & Pannell, 2018), including regenerating second-growth forests. CCF could potentially maintain consistent carbon stocks and ecological function over time (Assmuth & Tahvonen, 2018).

3. Establishing new CCF forests

Various studies have identified the potential for up to 1.2 to 2.8 million ha of afforestation (e.g. CCC, 2024) to fulfil climate change mitigation commitments. There is a good opportunity and time to design them to be amenable or well suited to CCF, but there may be challenges efficiently establishing a multi-aged forest suitable for CCF on bare land.

While the transformation of existing commercial forestry and the establishment of new forests may take an extended time to develop the multi-aged forest structure required for CCF, the management of existing regenerating native forests may represent our greatest potential for implementing CCF in the near future.

Currently, CCF is rarely implemented in New Zealand and the opportunity is not widely understood. This paper introduces the core principles of CCF and reviews the current state of CCF knowledge to provide a solid foundation for ongoing conversations about it in New Zealand.

What is CCF?

The name 'Continuous Cover Forestry' arose in Europe and is commonly used in New Zealand, but 'close-to-nature forestry' and 'nature-based forestry' may also be used (Pommerening, 2023). In North America, 'Ecological Forestry' and concepts focused on managing forests as 'complex adaptive systems' are widely used instead (Palik & D'Amato, 2023).

CCF is not a single silvicultural system, but rather a collection of systems that share a number of similar characteristics. Silvicultural systems vary in terms of disturbance (management) scale and timing (Figure 1), and CCF includes a range of systems with moderate harvest severities and sizes with varying return intervals. The considerable variation amongst these systems influences the composition, structure and function of the forest and therefore the social, cultural and financial outcomes of forest management. A central tenet of CCF is long-term ecological, social and economic sustainability and, at its core, CCF requires the retention of forest canopy cover across the stand indefinitely while still implementing partial harvesting to sustainably produce a wood flow (Pommerening, 2023).

In New Zealand, there have been a handful of attempts to define CCF in regulation (i.e. Forests (Permanent Forest Sink) Regulations 2007 and the Resource Management (National Environmental Standards for Commercial Forestry) Amendment Regulations 2023). Most recently, the National Environmental Standard for Commercial Forestry (NES-CF) defined exotic CCF as a forest deliberately established for commercial purposes that will not be harvested or is intended for low-intensity harvesting. This definition differs from international usage and adds confusion to the terminology used within New Zealand by allowing for both 'plant and leave' forests and low-intensity harvesting.

The range of CCF forest systems includes uneven-aged selection systems such as single-tree, patch and group selection, irregular shelterwood systems, and their numerous variants (see blue shaded box in Figure 1). These forest systems harvest a relatively small number of scattered individual or small groups of trees, retaining forest canopy cover over the forest stand indefinitely (Pommerening, 2023). In the selection systems, these harvests occur at regular and relatively short intervals, whereas the intervals between harvests can vary greatly within the irregular shelterwood systems (Raymond et al., 2009).

Some definitions of CCF limit the size of canopy openings to less than two tree heights wide, while others limit it to coupe sizes less than 0.25 ha (Hart,

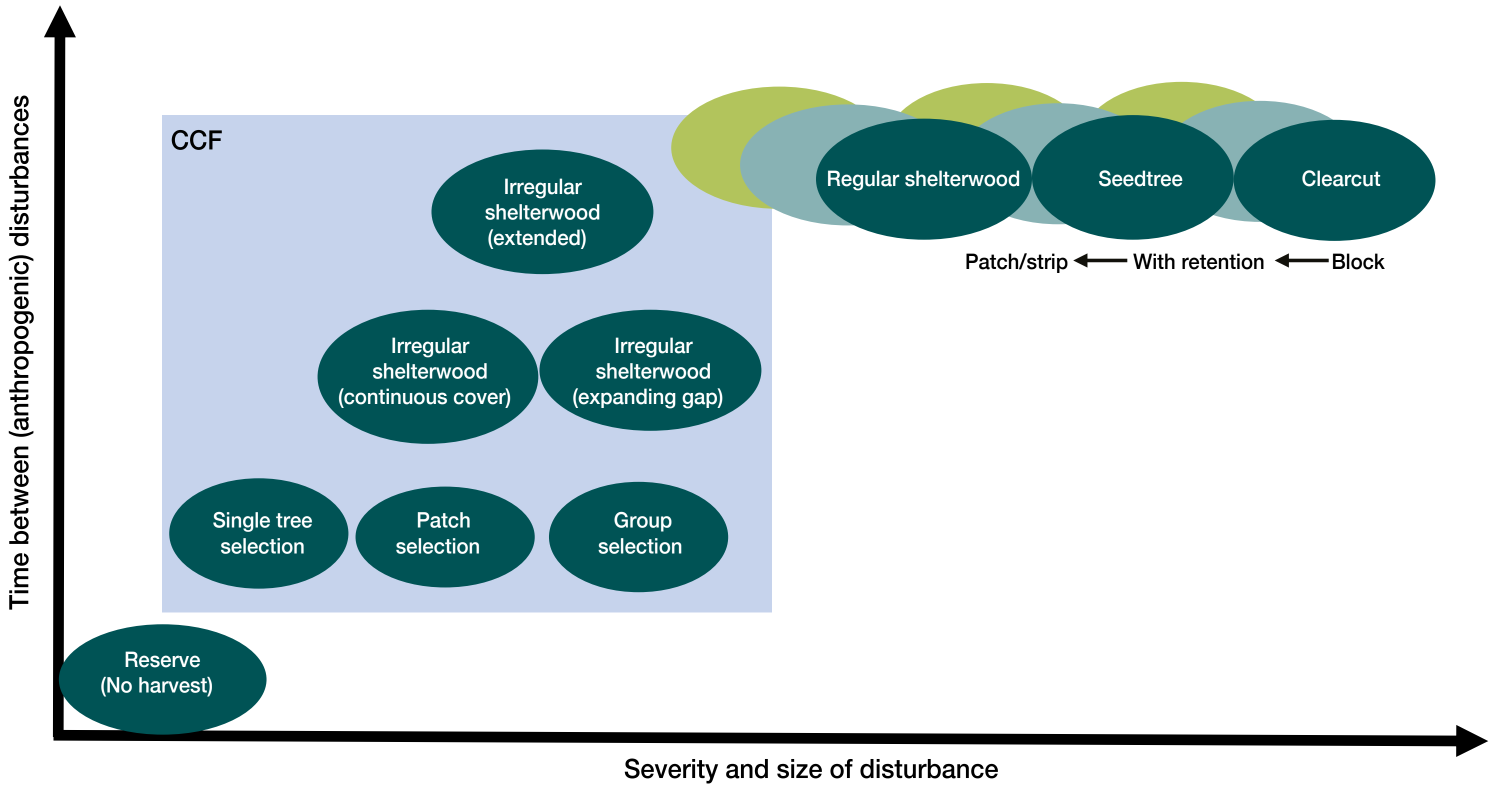

Figure 1: Conceptual framework of silvicultural systems across the gradients of severity and size, and frequency, of anthropogenic disturbances (adapted from Kern et al., 2017), highlighting CCF systems (blue shaded box)

1995). Irrespective of the opening size, the retained forest canopy influences the regenerating cohort. This balance between retaining the canopy while producing wood results in a highly structured forest ecosystem is controlled to maintain a range of tree age-classes (cohorts) within the stand (Knoke & Plusczyk, 2001).

Importantly, CCF systems can be implemented in both mixed and pure stands depending on the species' ecological traits. Generally, mid- to shade-tolerant species are suitable for CCF systems, while many light-demanding species require more canopy removal than is permitted within CCF to achieve adequate regeneration and growth rates. Further, the composition of the forest can be manipulated over time through the pattern of harvests (Pommerening, 2023). As the size and severity of harvest increases from single-tree to group-selection systems, the light availability increases and the favoured species moves from shade-tolerant to mid-tolerant.

Commonly confused silvicultural systems

Other regimes shown in Figure 1, which may sometimes be thought to be CCF, do not meet the criterion of maintaining a continuous canopy while allowing harvesting. Reserves, or permanent forests, are not CCF as they do not result in a sustainable flow of wood products. On the other hand, seed tree and shelterwood systems retain mature trees for only a short period of time to provide seed and promote the regeneration.

The mature trees are removed as soon as the regenerating cohort is sufficient leaving a single age-class for most of the rotation (Ashton & Kelty, 2018). Further, while clearcuts can be modified to smaller patches or strips, or to retain green trees for habitat, the regenerating cohort is generally not influenced by the retained canopy. These modifications to clearcuts can only be considered CCF where there is abundant retained canopy and mature trees still dominate the site.

CCF application internationally

CCF and its allied silvicultural systems developed across the globe. While we focus on its development in Europe and North America, more complete histories can be found (see Pommerening, 2023).

European history and approach

The roots of CCF trace back to the European concepts of Dauerwald and Plenterwald introduced by Alfred Möller in Germany in the 1920s, which refer broadly to sustainable forest management that promotes a stable and ecologically diverse forest ecosystem for the long-term use of forest products, and to a specific individual tree harvesting system aimed at providing a continuous supply of timber, respectively. Möller viewed the forest as a complex system of relationships and interactions (later referred to as an ecosystem), and emphasised the constant interaction and mutual feedback between the tree population, ground vegetation and soil through a continuous nutrient cycle as an essential principle.

Importantly, the focus of both Dauerwald and Plenterwald was on the practical economic


A


B

c

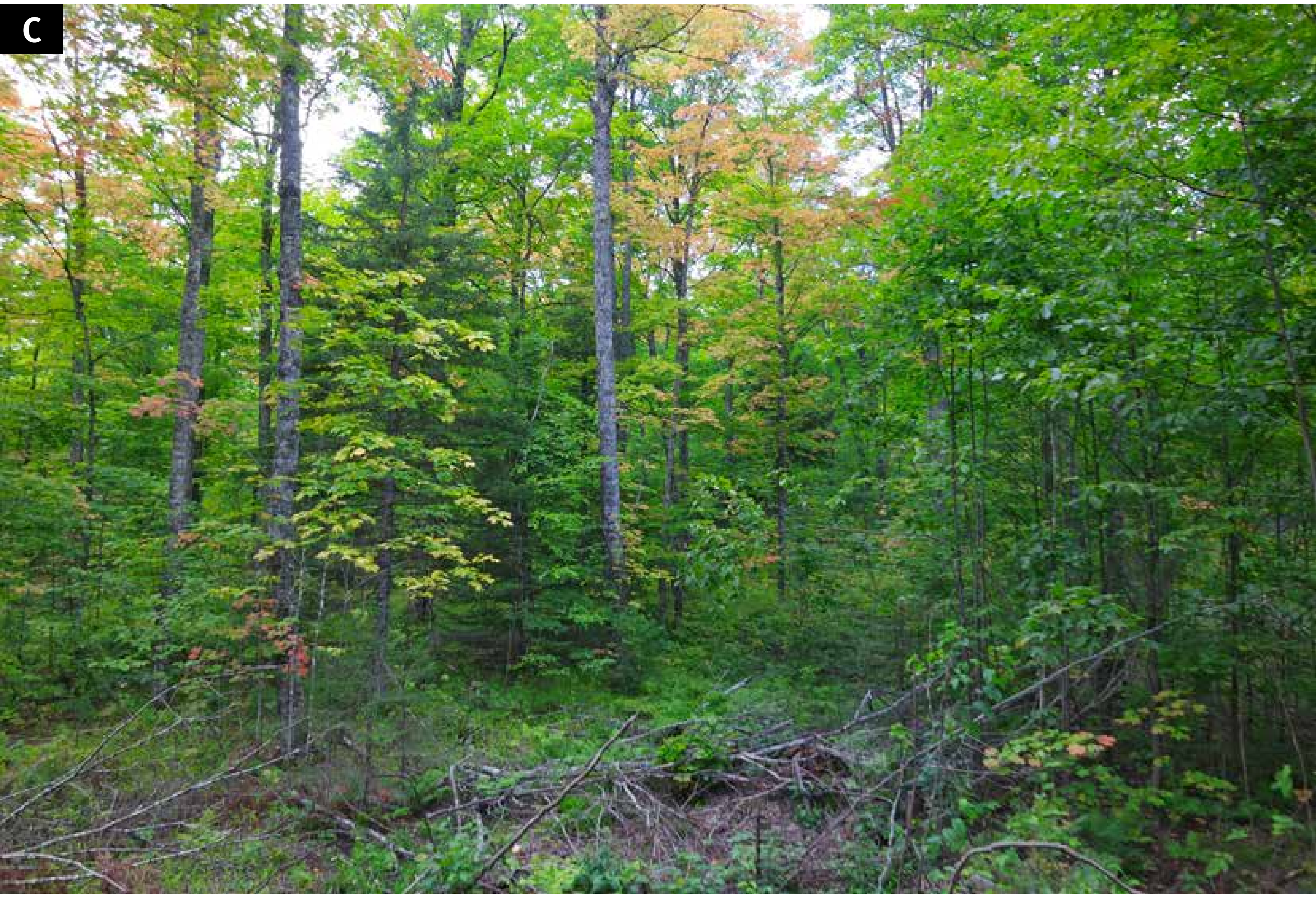

Figure 2: Typical CCF system applied in Northern Hardwoods at the Ford Forest, Michigan on a 15-year cutting cycle: a) The harvest was undertaken using a feller forwarder system during winter; b) the resulting low-grade logs were destined for a local pulp mill (shown), and the higher grade sawlogs were sent to a local hardwood sawmill, while veneer logs and figured wood (e.g. birdseye maple) were individually auctioned; and c) the view inside a group selection coupe the summer following harvest

considerations rather than ecological benefits, which are still recognised today (Knoke, 2009).

The economic performance of CCF is supported in Europe by low establishment costs (once CCF is implemented) (Tahvonen et al., 2010), adapted single-tree harvesting when individual trees achieve economic maturity (Knoke, 2011), and risk diversification through mixing tree species (Roessiger et al., 2011) and age cohorts (Messerer et al., 2017). This results in a good balance between economic return and risk (Knoke et al., 2020), low disturbance vulnerability (Mohr et al., 2024), and a higher stand-level economic resilience than even-aged rotational systems (Knoke et al., 2023). However, increased infrastructure needs and more complicated harvesting operations may cause higher logging costs (Price & Price, 2006). When properly optimised, CCF will be economically at least comparably viable as rotational forestry more often than generally expected (Malo et al., 2021).

North American history and experience

European concepts of forest management were initially brought to North America in the late 1800s, but many of the early attempts to apply these concepts failed and most of the early forest management focused on the exploitation of the seemingly endless existing forests (Zenner, 2014). By the 1920s, it was recognised that the forests were being depleted, and that techniques that ensured a sustainable supply of wood across the regions were needed.

This led to the development of sustainable uneven-aged management systems, which are now commonly used to manage the Northern Hardwood forests. Arbogast (1957) developed a system of repeated partial harvests on a regular cutting cycle of 10–20 years to create a specific size class distribution and improve tree quality. This system evolved over time, with a variety of stocking control methods now employed (Pommerening, 2023). Examples exist of forests still producing a sustainable yield after almost 100 years (Figure 2). Uneven-aged management systems have also been applied to other forest types across North America, and an increased focus on ecological benefits have developed into Ecological Forestry (D'Amato et al., 2017).

How is CCF different to conventional rotational forestry?

Rotational forestry is the norm in New Zealand's planted forests: regeneration, tending and harvesting activities occur sequentially over time, and are implemented over the whole stand at once (Figure 3a). CCF (Figure 3b), by contrast, is a fundamentally different approach to forestry because tending and harvesting activities occur simultaneously within the stand, impacting different cohorts within the multi-aged structure of the stand on shorter cutting cycles. Regenerating cohorts must be protected through multiple cutting cycles, adding additional layers of complexity.

Silvicultural management of CCF creates a more complex stand structure through regulating and developing a desirable stem size class distribution (Pretzsch & Knoke, 2017). The desirable distribution depends on the time preferences and objectives of the forest owners. Once a desirable target structure has been achieved, CCF systems aim to balance harvest and growth rates. Too frequent or intense partial harvests or harvests that impact recruiting size classes for future harvests will result in a decline in stand productivity. Alternatively, too infrequent or light

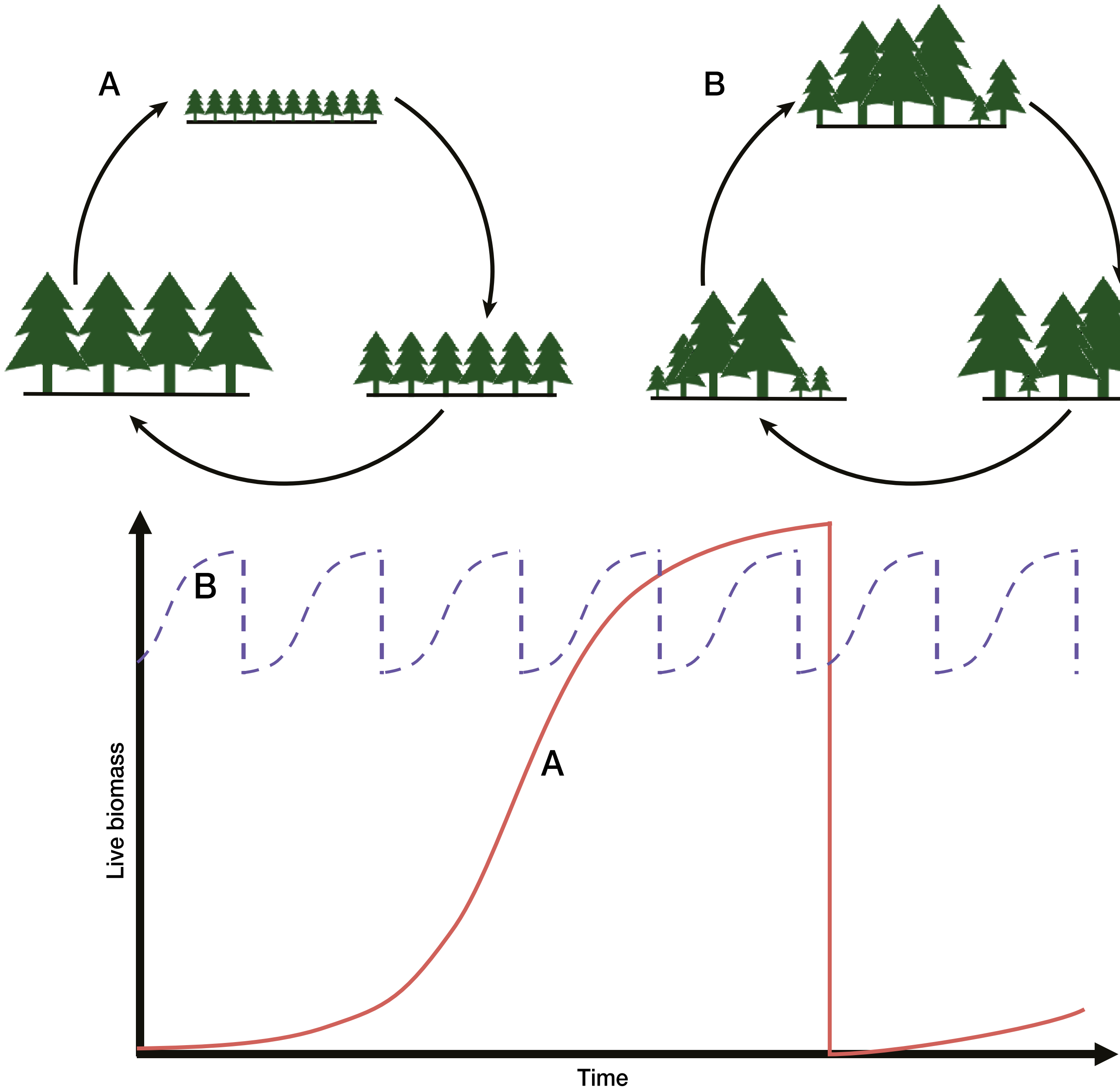

Figure 3: Conceptual diagram showing the differences between: a) conventional rotational forestry (i.e. clearcutting); and b) CCF. Note that both systems could be applied to either mixed species or pure (shown) forest stands, and that the relative severity and time between harvests may vary greatly depending on the specific CCF system applied, site conditions and stand growth (adapted from Barton, 2008; Nyland et al., 2016)

harvests will result in an increase in stand stocking, increased competition among trees and a decline in stand productivity.

Harvests must be well planned based on good inventory data so that they reach optimal stand productivity. There are a number of forest management decisions that can be made that may superficially appear to be CCF, but are unsustainable in the long term. For example, high-grading selectively harvests the most valuable trees, leaving only poorer-quality trees behind (sometimes referred to as diameter-limited or targeted harvesting, or somewhat confusingly, selective harvesting) (IUFRO, nd). This can degrade the forest over time, reducing forest productivity (Lie et al., 2012), and is not sustainable in the long term.

Application of CCF in New Zealand so far

There has been interest in CCF and allied systems in New Zealand for at least 20 years (Barton, 2008), but there are only a few examples of CCF in New Zealand. Three examples highlighted in the 2023 *Continuous Cover Forestry Business Models for Aotearoa New Zealand* report (Anon, 2023) and associated virtual wananga series demonstrate the approach in natives (southern beech and tōtara) (Forever Beech, Tōtara Industry Project, Wardle property) and exotics (*Pinus radiata*) forests (Wardle, 2019).

Further, the harvesting of naturally regenerated native forests on private land under Sustainable Forest Management Permits and Plans regulated by Part IIIA of the Forests Act 1949 is restricted to CCF-like systems, with limits on the size and severity of harvesting depending on the forest type. For example, beech and tawa forests are restricted to coupe sizes of up to 0.5 ha, while podocarps must be harvested individually or in small groups, and adequate regeneration is required before the next harvest. Sustainable Forest Management Plans require harvest rates to provide a sustainable yield in the long term.

Developing new CCF systems for New Zealand

To enable CCF at scale in New Zealand, the *Continuous Cover Forestry Business Models for New Aotearoa Zealand* report considered systemic barriers, required enablers for change and key focus areas (Anon, 2023). These barriers and enablers included market development needs, societal momentum for change, and policy and regulatory enablers. The authors highlighted three potential opportunities for CCF through transforming existing exotic commercial forests, managing regenerating native forests and establishing new CCF forests. For all three opportunities, science and data were identified as a major weakness reflecting the little work done in New Zealand to date and therefore a priority need. In addition to science and data, capability, weed and pest control, silviculture and harvesting systems were common priorities.

Given the lack of existing data and robust models of CCF in the New Zealand context, it will be necessary to use an adaptive management approach (i.e. 'learn by doing'), to make the most use of what we know while developing new knowledge. Given the interest and urgency, work will need to be iterative and utilise hypothetical approaches or adaptation of systems built for other silvicultural systems as new and specific experimentation is undertaken. Initial CCF systems should be based on our best available ecological knowledge, but will need to be refined over time to develop proven sustainable control systems for CCF.

In the absence of robust control systems, there is the potential for forest degradation through high-grading based on the experience of Europe and North America. Sustainable control systems could be adapted from international systems of area or volume control, such as BDq, Stand Density Index (SDI)-based, Leaf Area Index (LAI)-based or Plenter systems (Pommerening, 2023), which have been honed to local needs, site conditions and forest compositions. The development of these control systems requires fundamental knowledge of:

- Forest light conditions
- Tree physiology and growth under a gradient of shade
- Effects of intra- and inter-specific competition and facilitation on both growth and wood properties
- Understorey regeneration and recruitment rates, particularly of natural regeneration to reduce management inputs
- Mortality rates
- Impacts on carbon sequestration, non-timber forest products and other ecosystem services
- Weed and pest management.

Improvements in modelling systems for mixed species, multiple-cohort forests are also needed.

In addition, the harvesting under CCF systems is more complex. It requires the protection of the future crop trees and soils, while partially cutting the forest on relatively short cutting cycles and potentially on steep erodible slopes. Further, harvesting on short cutting cycles requires planned and maintained skid trails to limit soil compaction. Therefore, novel harvest systems based on an understanding of road design and costing, machinery types and production, and the environmental impacts of harvesting are required.

Finally, an understanding of the potential markets, valuing and incorporating all products and ecosystem services from CCF forests, and the incorporation of cultural values into the economics, are needed to ensure we have a full understanding of the benefits of CCF in the New Zealand context.

A toolkit for CCF regimes will be a useful goal and outcome. The design of the toolkit's framework should be a priority to enable the incorporation of research and other information as it becomes available. For example, the toolkit could include information needed for silvicultural planning such as:

- Growth and yield information
- CCF control system guidelines
- Maximum stand density index, stocking charts or density management diagrams
- Site quality indicators for species likely to be managed under CCF
- Harvesting guidelines
- Cost and revenue information to inform financial analyses.

To date there are no such tools available, although some theoretical studies have been published on Douglas fir (Maclaren et al., 2006) and redwoods (Bown & Watt, 2024) in terms of productivity, carbon and economics. However, both of these studies were based on forest growth models developed using data from even-aged forests, and therefore the authors were required to make coarse assumptions regarding forest productivity under CCF management. Further, Pizzirani et al. (2019) explored the financial returns of a range of potential alternative forestry systems in the Waiapu catchment, including CCF management of rimu. More generally, Bloomberg (2019) undertook a comprehensive analysis of target diameter harvesting in *Pinus radiata* at Woodside in Canterbury.

Given the relative inexperience of New Zealand to CCF, there would be great value in the establishment of long-term experimental and demonstration sites (Anon, 2023; Pommerening, 2023). These sites will allow landowners and practitioners to see CCF in action and, if designed effectively, they will contribute to our fundamental knowledge by allowing for the experimentation and refinement of silvicultural practices. Ideally, these sites should be established across a range of site conditions (with a range of forest compositions and at scales relevant to the forest industry), to provide adequate information to inform future forest management and policies.

Conclusion

CCF has been a proven and economically viable forest management system in various parts of the world for many decades. Landowners in New Zealand have the great opportunity to learn from this experience and develop a version adapted to our local conditions. The challenge lies in filling knowledge gaps to reduce risks and guide decision-making around adopting new forest management practices. However, they can draw on the expertise of experienced forest managers and scientists to support the implementation and ongoing improvement of these new ways of managing forests in the years ahead.

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