Supplement to slides by Marcus Walsh: CONTINUOUS COVER FORESTRY—WHY TO, HOW TO © Marcus Walsh

To introduce myself: I'm Marcus Walsh, the founder and Board Chairman of Innofor Finland Ltd (INNOvative FORestry, www.innofor.fi), which from 2007 was the first company in Finland to offer forest owners and investors forest management and consultancy options using continuous cover forestry (CCF). Innofor today manages about 30 000 ha of forest for various clients, as well as providing consultancy and training on forest management, forest evaluations and timber sales. We also work with scientists studying both the economic and ecological impact of CCF. Some of these impacts are little studied, but the more we learn the more excited we are becoming about CCF as a potential solution to some of forestry's negative impacts on society—which, unfortunately, are still myriad although things could and should be very different.

I live on Bosgård Farm, one of the largest grazers of High Nature Value Farmland in southern Finland (www.bosgard.com). The farm also has 300 ha of forest, of which 250 ha in commercial use and managed using CCF. When Covid isn't lurking around, we get about 5 000 visitors to the farm annually—mostly to look at our cows on natural pastures on our Natura 2000 site, but with growing interest also in our forestry. Public interest and awareness of CCF is rising rapidly in Finland.

How to define Continuous Cover Forestry? Here are some rules of thumb for successful practicing of CCF:

- CCF is a series of successive high thinning operations carried out at 15-30 -year intervals. It relies on creating sufficient light gaps for shade tolerant tree species to generate and thrive under the canopy layer.
- Thinning is generally carried out to leave tree density 10-14 m2/ha ABH. That means what is left is fairly sparse, but still a forest. Typically, in a mature stand 80-120 m3/ha is removed, = 35-60% of the volume. Less is not economical.
- Deciduous pioneer tree species need to be regenerated by successive small gaps, about 0.25 ha; the forest at the edges of the gaps should be high-thinned to lessen shade and competition to seedlings near the edge.
- Drier pine forests need to be thinned more, to 6-9 m2/ha ABH, as they also need light to regenerate.
- CCF can be applied to both bog and mineral soils; no ditching is normally carried out on mineral soils.
- Optimal CCF high thinning does not imply "creaming" of best timber: apart from retention trees and other measures for biodiversity, poor quality younger trees are removed and closely grouped trees are thinned. The aim is to leave some quality seed trees, but mostly young straight-trunked individuals that will make up future saw wood harvests.

"Easy to write, hard to carry out", cry many forest managers. "We've tried that sort of thing and it doesn't work". "It's not profitable, everyone knows this from forestry school". Etc. I address some of the key practical issues a little later. But first some background on the importance of CCF and the research behind it.

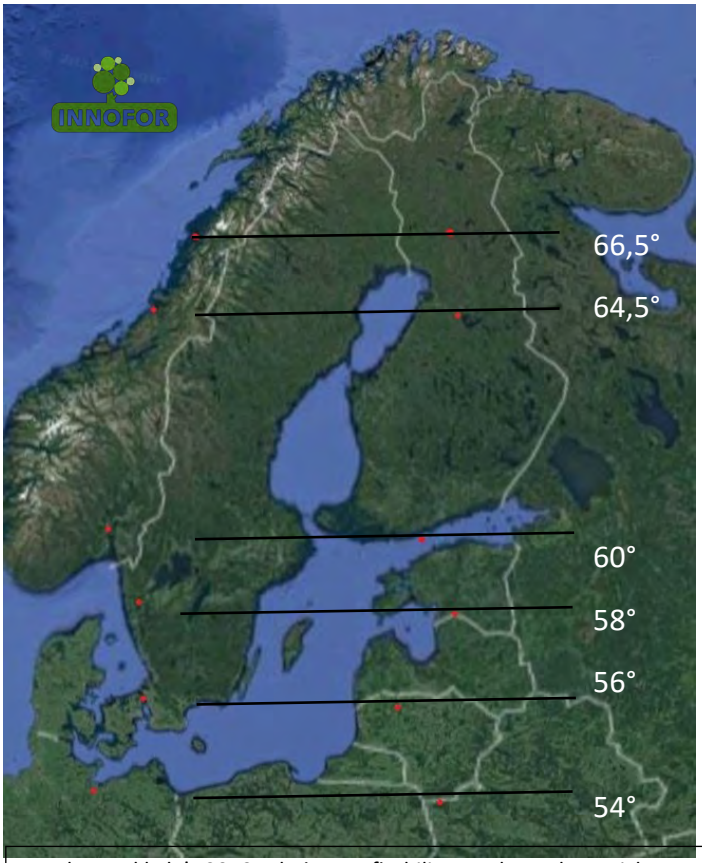
A boreal forest after CCF extraction of 60% timber by volume—vs. the usual result on the right

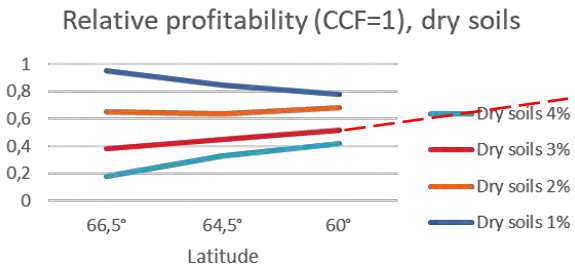
I've often been asked why I started a business researching and advising on Continuous Cover Forestry (CCF). One could turn it around and ask why on earth anyone would want to carry out clearcuts? They decimate the landscape, destroy wildlife and social forest use as well as non-extractive business opportunities They also leave the forest owner with 20-30 years of nothing but costs. More recently it's been discovered clearcuts also hasten climate change in a big way, not just through releasing carbon from wood, but also from the ground through scarification, ploughing and drainage ditches. It's actually quite astonishing that clearcuts are legal at all. In some countries such as Slovenia and Germany they in fact aren't, though the main original reason is avoidance of erosion in what are mostly mountainous areas.

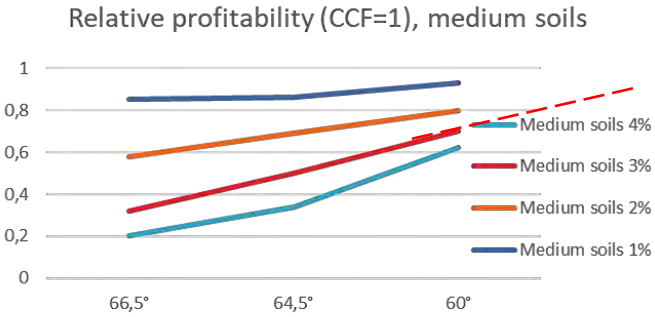
According to Norokorpi (2018), the roots of European plantation-oriented industrial forestry lie in management models elucidated already in 18th century Germany. Despite this, many different types of forest management persisted in the Nordic Countries up to the 1940s. Clearcut models were adopted wholesale e.g in Finland only in 1948 after the publication of an edict about "proper" forest management by a small group of influential professionals ("Harsintajulkilausuma"). That they succeeded so totally is astonishing given the fact that many smallholders knew full well that clearcuts were not to their advantage. An important role was played by the paper and pulp industry, which was vital to the country's economy after WWII and whose actors were convinced that a transition to clearcuts would work in their favour.

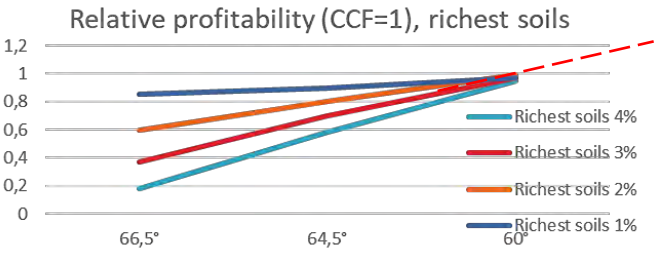
After 1948, clearcut and replant rotational forestry became the norm in Finland and the only model taught in forestry schools at all levels from vocational to university. By the 1980s to question this management premise was regarded in the classroom comparable to asking the professor if they were sure that one plus one equalled two. But as with so many supposedly fundamental truths (whatever the field), the science behind it was outdated and in this case had anyway been steered from the outset not by investigation but political and economic pressures. Yet, despite these shaky foundations, the studying of other forest management premises was in Finland actively discouraged throughout the 2nd half of the 20th century. This is significant, because Finland is a forest "superpower" widely looked to as a model by many in the industry. More's the pity.

The only professor who in the 1980s dared start up field studies comparing different methods—rather than merely different follow-ups to clearcuts— was professor (now emeritus) Erkki Lähde and his colleagues Dr Olavi Laiho and Dr Yrjö Norokorpi. Their work has been built on by professors Timo Pukkala of the Univ. of East Finland and prof. Olli Tahvonen of Helsinki University. With data from Lähde's field trials Pukkala and Tahvonen have published this century tens of peer-reviewed studies on the profitability of Continuous Cover Forestry, conclusively proving the method's viability in terms of net profits from stumpage prices alone without the need to factor in any other benefits. However, the more one takes into account other economic and social factors—for example, carbon sequestration improvements, improved timber quality, game bird preservation (such as Capercaillie), the value of the forest for fungi, berries or nature tourism, ecosystem services such as watershed management, or local recreation—the more profitable CCF becomes over clearcuts.







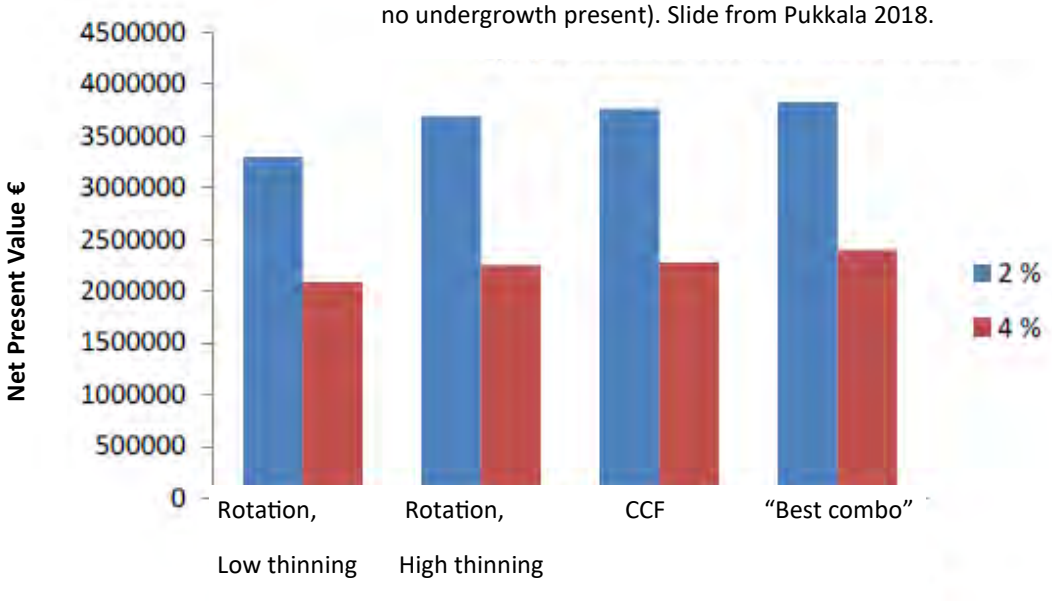


Based on Pukkala's 2010 relative profitability results, only on richest soils (characterised by plants such as *Corylus, Maianthemum)* will rotation forestry be more competitive in the Baltic States, with CCF predicted better on all drier types (*V. myrtillis, V: vitis-idea* and drier types).

What have Lähde's, Pukkala's and Tahvonen's results established? They underline that forest owners have for decades confused speed of timber production with net profitability. It is undoubtedly true that planting seedlings, the equivalent of ten years' growth from seed, leads to a faster harvest compared to natural regeneration. But this is not the same as better profitability considering the costs and the long period of no income following a clearcut. Specifically, here is what has been proven:

- For the normal 3-4% expected profit rate, CCF is more profitable in all forest and mineral soil types at Finnish latitudes—and by implication also in most of Sweden and Norway. Based on Pukkala's (2010) results, this is probably true as far S as Lithuania for mixed pine-spruce stands and dry pine ones, with only richest soils making rotation forestry worthwhile, if measured by current stumpage prices alone. However, simulation with local Baltic growth models would be needed to confirm this and to see more precisely where the profitability limits actually lies for different forest types.
- CCF increases the percentage of harvested saw timber, and over time also its quality. Since the average price of saw timber is over three times that of pulpwood, this is a major factor in CCF profitability as well as the savings on management costs because of natural regeneration.
- The further North you go and the poorer the soil, the more profitable CCF gets. The main reason is the extremely slow forest growth, post-clearcut.
- In computer simulations where management could vary freely for maximum profitability, Pukkala (2018) found that for a wide variety of initial conditions in Finland carrying out a clearcut was the optimal economic solution in only 3% of cases comprising all forest types.
- The more factors you take into account in addition to stumpage prices, the greater the profitability of CCF over rotation forestry. As an interesting example, Pukkala (2021) recently calculated that in N Finland no logging of any sort was any longer profitable —compared to letting the forest grow and sequestrate carbon—once the carbon price reaches 30€/ton CO_2-equiv. As it happens, that *is* close to the current price on the carbon stock exchange. The price is expected to reach 50€/ton or more in the next ten years, by which time in principle—at current timber prices—Finnish and Nordic forests will be more profitable left standing than logged!

Typical Finnish medium rich forest (pine-spruce-birch mix, *V myrtillus* understorey), C Finland. Data from 350 ha. Low thinning + clearcut = Finnish norm = weakest result! High-thinning + clearcut already much better, brings result closer to CCF is terms of stumpage price. "Best combo" = Allowing algorithm to freely choose management for each stand at each intervention moment. Chooses 97% CCF, clearcut 3% of cases (mostly even-aged old spruce with no undergrowth present). Slide from Pukkala 2018.



In comparative studies of CCF vs rotation forestry, mistakes—some perhaps intentional, others due to poor thinking—are common. It is easy to establish profitability one way or the other by choosing suitable limitations on variables, or unfavourable initial conditions. CCF can be defined in many different ways and this of course can have a profound effect on the predicted outcome. For this reason, the assumptions behind published studies should be studied carefully. For example, the study by Andreassen and Øyen (2002) and studies by Wikström in Sweden are frequently quoted as proof of the poor profitability of CCF. But it turns out that the study compares economically optimal forms of rotation forestry with many different kinds of CCF praxis, taking the average yields of all the latter. Not surprisingly, rotation forestry comes out on top. But when the optimal versions of CCF are compared separately with optimal rotation, the former is more profitable.

For successful modelling, equally important to using optimal procedures for all management types is the availability of growth and ingrowth models reliably established over long term field measurements. According to scientists, this is currently the largest obstacle to establishing precise management recommendations outside of the Nordic and N Baltic region. With added harvesting costs and timber prices, the resulting matrix models are discrete-time nonlinear optimization problems. Since the functions are continuously differentiable, optimization can now be carried out computationally to a degree unimaginable 50 years ago, and for many scenarios, thus laying to rest some of the eternal debates about profitability vs. management choices.

Awareness of the need to compare optimised rotational and CCF management is of course not enough—it requires a lot of knowledge to set these parameters correctly within the models. Theory may conflict with what in reality is practical, or in some cases may even be against prevailing forestry law. Such factors need to be taken into account as additional boundary conditions.

On a general level, the higher the return requirement and the poorer the soil, the more profitable CCF becomes over rotation. CCF adds 0-10% to the timber yield compared to low thinning-based rotation. Adding high-thinning to rotation is already much better for profitability, see graph above. That CCF produces also more timber in some cases may sound odd, since CCF management grows less dense stands, but is explained by the faster growth of the remaining trees (due to less competition) and rotation forestry's long unproductive period post clearcut. There are now so many studies confirming CCF profitability at Nordic latitudes (and zero studies proving the opposite!) that any study claiming to show the opposite should be viewed with suspicion until its initial conditions, growth models and parameter values have been carefully checked. Especially typical is the mistake of comparing sub-optimal CCF praxis with optimal rotation forestry. But CCF optimisation is *not* that hard!

What does optimal CCF look like in practice? It is important to emphasise that we are here talking “basics” = commercially optimised management based on maximising profit from timber sales only. As discussed earlier, bringing in other factors to the optimisation such as carbon pricing, forest game bird management, tourism income or local recreational concerns can result in very different logging emphasis. Clients’ targets may vary, and it is important to map these carefully, as well as advising owners of the opportunities CCF brings for improving biodiversity, carbon sequestration and gamebirds amongst others. In future these are likely to play an increasing role in determining the overall commercial value of forests.

I refer to the general definitions of CCF on page 1 of this presentation. Here are some pictures of what richer spruce and then drier pine forests look like after a typical round of high thinning. Here we need to emphasise the vital role of the harvester driver in CCF: his skills in deciding what to cut and what to leave will be decisive. Fortunately it has proven fairly easy for harvester drivers to learn high thinning principles, although in many cases it is the exact opposite of what they learned in forestry school! One of the main motivators is their own economy: harvesting is paid by the m3, not by the hour, so concentrating on trees of larger diameter suits the drivers just fine. It turns out that compared to a rotation cycle, where in the first thinning harvesting costs are very high compared to m3s achieved, CCF harvesting costs over one whole economic tree cycle of 60-80 years, involving 3-4 interventions, are about the same for rotation and CCF.

When planning a CCF management procedure, you will seldom start with an optimum structure—that is to say, one where there is a multi-layered canopy with a plentiful healthy understorey to leave behind—see pic. So what do you do if (1) From the effects of previous management you’re starting CCF with an even-aged tree cohort with little undergrowth? Or (2) What to do with young stands where following a clearcut there is mostly not yet much more than a young planted spruce monoculture?

Where there are even aged older spruce stands with little undergrowth, and clearcuts are not desirable, initial thinning needs to be cautious: too much will tend to see a lot of grasses seeding, which slows natural regeneration. A second reason is the higher risk of windfalls, as trunks in a thinned stand face greater forces than a dense one. By contrast, multiple-layer forests are better protected from wind, which is inhibited from gathering maximum force if there are different sized trees to break its path.

Pure pine stands require more extensive thinning in order to regenerate naturally; another approach is to make small gaps, but near the edges natural regeneration will be poor, so another set of gaps is needed later on. On the other hand, pines regenerate naturally very well from seed trees and are less susceptible to wind.

Where there are limited numbers of deciduous trees these should always be left to enrich the soil and neutralise the acidity of coniferous needles. It is currently not clear how many cycles of natural spruce regeneration CCF can use before it is advisable to make small gaps in order to regenerate deciduous trees such as birch, ash and aspen, which cannot regenerate in shade and will therefore eventually all die out. In nature they regenerate in gaps following storms, fires and pest outbreaks.

Regeneration in gaps can be significantly slowed by grasses as well as grazing deer and moose. The latter problem is at its greatest near forest edges and lowest in the middle of larger forest tracts. Grasses are most problematic on the richest soil types.

On bog soils the general consensus is that in future only CCF types of forestry can be profitable at any latitude. This is because clearcutting alters the water table so drastically that very expensive ditching operations are needed to prepare the site for replanting. In most bog types subsequent tree growth cannot justify this expense. However, even where it in theory makes economic sense timber-wise, it has been shown that the CO_2 and methane releases associated with bog ditching are so massive that on a larger scale they will affect the country's GHG reduction targets. This means that e.g Finland's leading forest researchers now advocate stopping all drainage ditching on bogs. And that means stopping clearcuts on bog soils altogether.

Finally, I turn to those cries one always hears from foresters about CCF not being possible in practice, leading to forest destruction and being very uneconomical. What are the typical negative claims made about CCF and are they really a problem?

"Repeated CCF high thinnings spreads root rot". Root rot affects conifers, spruce generally rather more than pine. Rot has become more widespread mostly due to summer logging practices (there are no spores in the air in mid winter) and more recently climate change warming up N Europe. If you have significant spruce root rot, you will not eradicate it except by removing all conifers, even the stumps, and growing a generation of deciduous trees. This is a fact regardless of what management type you favour. More generally, growing CCF-style mixed stands in fact inhibits the growth of root rot, as monocultures are of course the most susceptible. In addition, clearcutting and then *replanting new spruce* is of course not a solution either, since the fungus spreads from the ground. So rotation forestry as such is not an answer to root rot.

"High thinning in CCF removes the best trees; leaving the slower growing individuals weakens the forest genetically". Well no, it doesn't. CCF removes also poor quality smaller trees and retains the best ones. Many of the smaller trees will be offspring of the taller ones, but having seeded later remain smaller until given more light. They are not genetically weaker. Additionally, it is generally a mistake to make a crop genetically less diverse through planting of clones, no matter how well they may initially grow in laboratories. Loss of diversity can lead to big problems with disease and lack of adaptability to changing conditions, as experiences with many food plants testify. Climate change will require maximum genetic diversity for forest survival.

"CCF is no guarantee of biodiversity. Without big retention trees or Woodland Key Habitats it is no better for nature than rotation forestry". True, but why on earth would CCF *not* leave retention trees and retain Woodland Key Habitats? Of course it does, and by retaining the forest around them partially intact, maintains their significance to a far greater degree than if it were clearcut.

<u>A final word regarding nature conservation vs CCF:</u>

Commercially optimised CCF leaves forests sufficiently intact to be useful for many species, but CCF most emphatically is not a substitute for properly protected biodiversity conservation areas. The overall area and average size of sufficiently strictly protected forests in Europe is currently woefully inadequate. CCF is not a substitute for proper protection and should not be billed as such. However, CCF forests are good buffers around protected sites compared to clearcuts, better preserving e.g. groundwater tables and microclimates within the former. For similar reasons, CCF also enhances the biodiversity value of large retention trees and Woodland Key Habitats. Clearcutting the surroundings of WKHs usually alters their microclimate and water table sufficiently to quickly extinguish any specialised species or biological features for which they are retained—thus rendering the whole programme useless.

A few final thoughts to take home:

The debate on rotation forestry vs. CCF usually revolves exclusively around stumpage profitability, i.e. which method will ultimately yield the greatest return in timber sales over some 60-100 years. Can I honestly guarantee to the owner that moving over to CCF will give him, say, 10% more money? Of course not, because the time horizon is too long and so many things can change over such a period—not least the targets of both the owner and of society and how it e.g. taxes forest use. All that can be said as to stumpage profitability is that current research results mostly favour CCF.

However, the wise forest owner can still do some bet-hedging, and indeed should do so, given that failures in forestry can be very costly and take decades to redress—meaning that errors can lead to a whole generation getting no income from the the family forest at all. When considering forest management, it is perhaps better to not get caught up all the time in small cost factors and instead look at the bigger picture. The following factors are true regardless of whether the stumpage price forecast for your forest using CCF is plus 10% or minus 10%:

1. *Consider the effects of climate change*: The climate in N Europe is set to change more rapidly than elsewhere. Already we are seeing large tracts of more sensitive conifer species drying out, also in C Europe. Diseases and pests are spreading too, and storms are more violent. No-one knows for sure how forests will adapt. Planting monocultures is not a good strategy, as you stand to lose more than growing mixed stands, where there will be survivors as well as losses. A mixed stand is more resilient to droughts and disease — and even to storms, if it is sufficiently multi-layered.
2. *How forests are taxed and legally used may change dramatically:* Forests retain carbon— but not if they are turned into toilet paper and cardboard with a life of a few weeks. Only long term wood products retain carbon. Similarly, CCF retains forest soil carbon much better than rotation forestry, and completely unmanaged forest continues to sequester more carbon than any other option for at least 300 years before reaching equilibrium. In future, you may make the biggest profits by not logging at all, or by using occasional CCF only.
3. *Continuous Cover Forestry retains your forest use options:* once clearcut, you will not use the stand for any form of recreation, game bird hunting, foraging or tourism for at least 30-50 years. Whereas, using CCF will not in most cases jeopardize your timber profits, but retain all other options. With an eye on future possibilities and challenges, it is rotation forestry and its clearcuts that pose risks, not CCF.