Continuous Cover Forestry in practice

Guidelines on Continuous Cover Forestry/ Close to Nature Forestry management practices

Christine Sanchez
Forêt.Nature

FORÊT • NATURE

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Composition of the working group
Patrick Auquière, Michel Bailly, Charles Debois, Benjamin de Potter, Pierre Gigounon, Gaëtan Graux, Raphaël Thunus, Philippe Trigalet, Isabelle Van Driessche

Proofreading
Nicolas Luigi (Pro Silva France), Étienne Gérard (DNF), Didier Marchal (DNF)

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ASKAFOR

ADAPTED SKILLS AND KNOWLEDGE FOR ADAPTIVE FORESTS

The Askafor project, which ran from 2021 to 2022, aimed to promote continuous cover forestry (CCF) by reducing the obstacles to its development. Askafor has helped to increase the area of forest managed using this innovative and sustainable form of forestry, which integrates the environmental, economic and social functions of the forest.

The 2-year programme includes :

- Capitalising on experience, practices and knowledge in SMCC in a European reference framework.
- The dissemination of this knowledge through the installation of educational devices (hammeroscopes and workoscopes), the creation of technical training modules and the silvicultural leadership of groups of managers.
- Setting up an international network of reference forests and control plots.
- Scientific research, with the adaptation of a simulator to the evolution of forests managed using SMCC (modelling), technical guides for post-crisis renewal, and a sociological study to identify the obstacles to the development of this innovative forestry.
- Raising awareness of the challenges of this «close-to-nature» forestry through conferences, workshops and a wide range of dissemination tools: videos, brochures, website, social networks.

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1 Introduction

Continuous Cover Forestry forest management is a comprehensive approach to the forest, one that is technical, economic, ecological, and socially integrated. However, it is impossible to set standards that would apply across the board; one must guard against all rigidity in this type of management and instead adopt a free-style approach to sylviculture.

Continuous Cover Forestry forest management is neither normative nor standardisable; it is a sum of technical and economic principles that must be analysed and adopted case by case. Interventions are based on observation and decided upon in situ, tree by tree. Moreover, they require consideration, responsibility, and initiative on the part of everyone involved. The Continuous Cover Forestry vision is best achieved through selective thinning where there is no systematic removal of trees and forestry operations are always selective and never area based.

1.1 Continuous Cover Forestry

Continuous Cover Forestry is a strategy to optimise the management of forest ecosystems so that they, sustainably and profitably, fulfil their multiple socio-economic functions with the function of the production of quality wood first and foremost. To minimise the ecological and economic risks involved, this forest management relies heavily on natural processes. The management procedures applied are therefore based on continuous cover and respect for the natural processes of forest growth and renewal. The procedures can be implemented for a great many species and sites. This forest management is practised on the scale of the individual tree (tree by tree silviculture) rather than on that of the stand. Production focuses on high quality logs, usually very large trees. The under-storey must be managed in such a way that provides space for natural regeneration and then maintains and controls its species composition.

Such forest management gives much more importance to observing, understanding, and supporting natural dynamics, especially in the silvicultural operations phases, limiting the number of operations but focusing on quality.

1.2 Why publish a circular on Continuous Cover Forestry ?

Continuous Cover Forestry and irregular forest management are in vogue. However, behind the possible dictates of fashion we see questions, lack of understanding, dissatisfaction, ignorance, aspirations, and also the will to learn from valid experience and to try to define an alternative, sustainable form of forest management that is both profitable and integrated.

Forest managers across Europe have expressed more and more doubts these past few decades about whether today's forests can meet the current and future needs of our societies. The upshot of this trend has been to challenge the forest management schemes that have predominated until now. The forest management scenarios available for coniferous stands in particular are being re-assessed just about everywhere in Europe25 and the will to move towards more stable and resilient forests is clearly visible. Diversifying the forest's species composition and, following the same logic, diversifying the forest's age structure is often considered one of the solutions.

Observation of the changing economic context and international requirements to maintain diversity have been pushing Wallonia's Wildlife and Forestry Department (DNF) for the past fifteen years or so, in order to support foresters'individual initiatives in the field of Continuous Cover Forestry forest management and to implement this forest management in a more structured manner in its state forests and as much as possible in community owned woodlands.

The position that the DNF took at the annual Continuous Cover Forestry Europe meeting in Wallonia in 2006 was clear: Without making it a compulsory requirement, the DNF wants to spread this form of forest management wherever it is possible. This choice was subsequently enshrined in Article 1 of the Walloon Forest Code in 2008 and then in Circular 2718 in 2013.

This decision is based on many reasons. If the DNF is pushing for change in forest management, this is because the overall context in which forest management takes place has changed, as have the economy and scientific knowledge. The elements of these changes are as follows:

- the costs (of operations, inputs, and labour) have been rising steadily;
- the timber market has become global and a forest owner can only roll with this global market's punches;
- storms and infestations by parasites have revealed the fragility of monospecific even-aged stands;
- today's forests are multifunctional;;
- intensive production has depleted forest soils;
- the loss of biodiversity is becoming alarming; and
- global climate change is producing effects that are still uncertain on the local scale.

The DNF must thus assume its responsibilities as the manager of the region's public forests. Its role is to move forward in order to set an example for all forest owners. It must also ensure a certain revenue stream and strive to produce the best quality timber possible. In addition, it must integrate these aims into the sustainable management of forest assets, that is to say, improve stand stability, conserve the soil, protect ecosystems and biodiversity, etc. These aspects are all the more justified in that they have definite impacts on the profitability of the forest in the short and/or long term.

The measures explained below come under the enforcement of Article 1 of the Forest Code, which provides for the promotion of mixed-species irregular high forests. They also echo the resolutions that have been adopted in various international texts, especially: the recommendations of the Ministerial Conferences on Forest Protection (or the Helsinki Process), the EU.'s 'Birds' and 'Habitats' Directives that govern the implementation of the Natura 2000 network in Wallonia, and forest certification.

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PRO SILVA, AN ASSOCIATION OF PUBLIC AND PRIVATE FORESTERS

Pro Silva Europe is an association that was founded in 1989 by a group of Slovenian, German, French, Swiss, Croatian, Greek, and other foresters who were inspired by their professional and private experiences but also by much older experiences and publications, some of them from the first half of the 19th century.

The Pro Silva movement then gave rise to national or regional associations in the various forest regions of Europe by pulling in foresters who had banded together to promote Continuous Cover Forestry (CCF). More than 6,000 foresters from all parts of Europe, with a good half of them in Germany, currently belong to Pro Silva Europe.

Pro Silva is the brainchild of a foresters' movement that defends the principles of less investment-intensive forest management aimed at the profitable production of high quality wood whilst respecting the natural mechanisms of the forest's evolution and multifunctional integration. These principles are constantly changing and arise out of exchanges of experience in a diverse range of activities.

In France, the Continuous Cover Forestry movement arose in private forests in response to short-falls in labour, equipment, and financial resources and from the need for a more frugal type of forestry.

In Wallonia, the association 'Pro Silva Wallonie' was created in 1992 and now has close to 130 members.

1.3 Aims of the circular and this document

The aim of Circular 2718 is to guide forest management towards Continuous Cover Forestry-type management. It applies to hardwood and softwood forests and stipulates that Continuous Cover Forestry management should be the default option in State forests; failure to apply it must be justified. In the other forests subject to regional forestry regulations, the method will be the preferred option and managers will be required to convince owners of its validity. Priority will be given to applying these principles in implementing a new forest management scheme.

The circular presents the principles to follow in order to perform this type of management most successfully through a series of silvicultural measures to apply. These basic principles are backed up by transitional measures to guide forest management in the transitional forest management phase.

The forestry officer must receive a minimum amount of training in this type of forest management before putting it into practice. That is the purpose of this document; its aim is to explain and describe in greater detail the forest management measures set out in the circular.

Given the large number of situations that one can find in the field, it is obviously impossible to cover all the technical aspects of this type of forest management in one document. That is why the DNF has decided to set up a network of Continuous Cover Forestry pilot compartments to serve as a foundation for creating illustrative forest management scenarios and pathways. Training sessions will be delivered by specialist on these sites.

INSERT 2

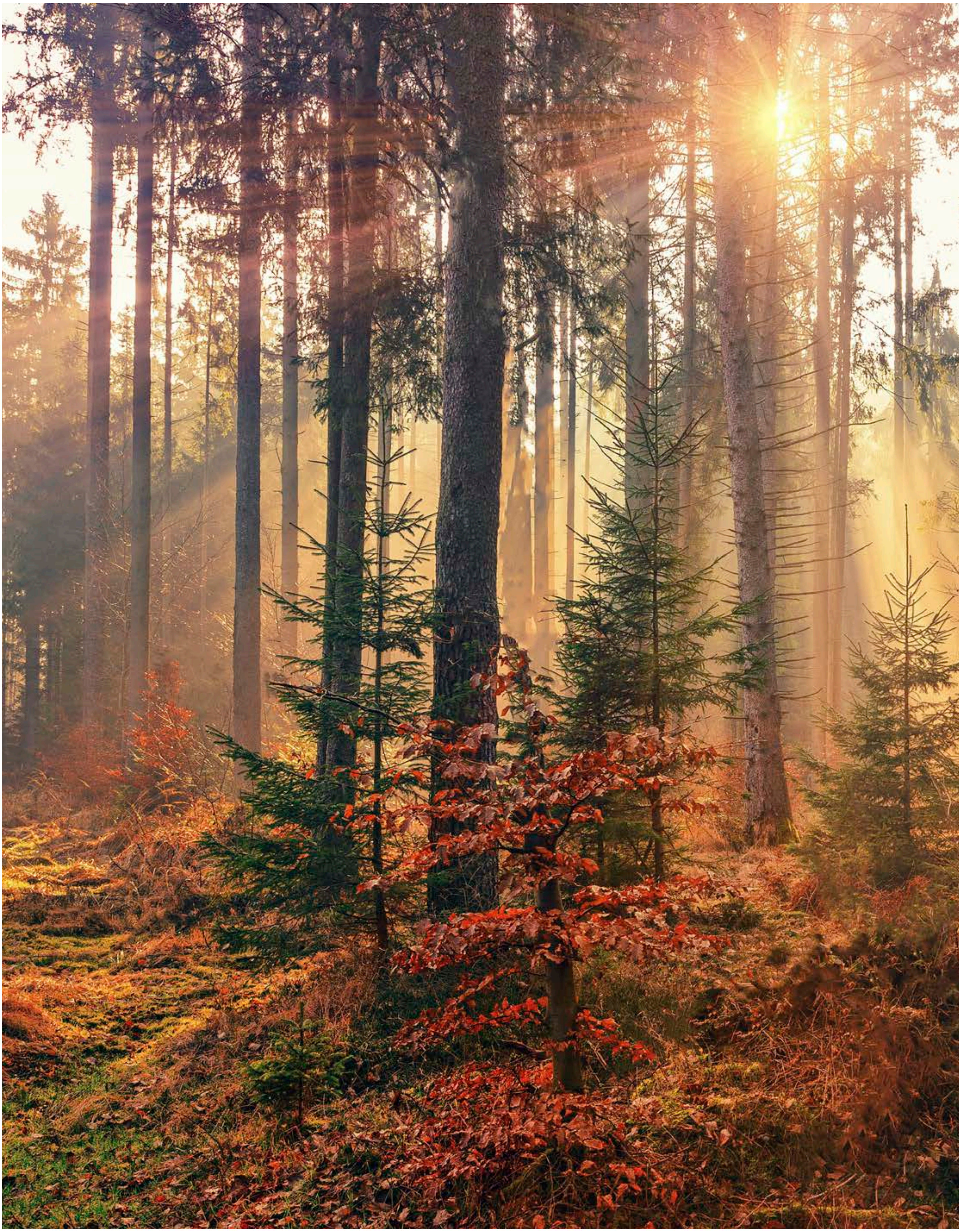
APPLICATION OF THE CIRCULAR: IN PRACTICE

Continuous Cover Forestry forest management will be the preferred path to follow in state (regional) forests. In all other public forests, Continuous Cover Forestry forest management is recommended. This type of forestry entails a change in overall management and thus applies, if possible, to the entire management unit or property, or at least at the scale of a large surface area (several compartments).

A plot may be managed according to Continuous Cover Forestry principles regardless of the type of stand, stand structure, and stage of development, and whatever the quality of the site.

PILOT COMPARTMENTS

A network of pilot compartments will be set up to prime the application of the circular. One compartment will be designated per forest district and undergo accurate monitoring (an inventory) of its stand or stands.



2 The forest management measures advocated by Circular 2718

Irregular high forest management is not in itself a search for a specific structure. The forest's structure is the positive consequence of the management of quality from individual trees, not an end in itself which leads to sacrifices in harvesting potential. Unlike the selection forest, there is thus no reference to what is deemed an 'ideal' stand.

2.1 Measure 1: Applying irregular high forest management and achieving or maintaining a mixture of species

2.1.1 Irregular high forest management

Irregular high forest management embraces all of the interventions (felling and silvicultural operations) that are applied to a stand in order to maintain it or get it to evolve towards a structural, productive, and functional equilibrium. This equilibrium must guarantee the continuous production of quality timber over time and in space and on a fine scale (tree by tree or group by group).

Irregular high forest management advocated by Continuous Cover Forestry is rooted in two fundamental principles, namely, respect for the ecosystem and respect for the individual tree. Quality trees of all sizes are favoured, halo thinned, and harvested according to their individual potential, and all this is done without consideration for age or spatial distribution.

Irregular high forest management is put into practice through what is known as 'selection felling'18 that is, light but frequent cuts that combine the objectives of improving the growing stock, harvesting big trees, and ensuring regeneration without seeking even spacing of regeneration across the compartment.

In the marking of trees for a selection felling, each tree is examined individually to gauge its quality and health status and the situations of its 'rivals' in order to decide between retaining or felling it. Selection felling removes wood of all dimensions and is justified mainly for the following reasons:

1. **harvesting**,
2. **improvement**, and,
3. to a lesser extent, **regeneration**

The reason for **harvesting** applies to trees that have reached maturity and a target size determined by a quality threshold and the site potential.

The reason for **improvement** refers to improving stand quality and corresponds to coupes that benefit the better quality trees; it gives priority to the quality of the stems, regardless of their dimensions. As a rule, such felling takes the form of "crown thinning"*.

The reason for **regeneration** concerns the removal, in all the storeys, of the trees that hamper seedling growth without, for all that, exposing the seedlings to full sunlight. In reality, the diffuse light that is let into the forest by each operation is the main factor that allows natural regeneration to become established and then to achieve quality growth. This principle must be applied without incurring harvesting opportunity costs.

Other reasons for harvesting a tree may be justified in a one-off manner, depending on the case. These include health, structure, logging, safety, diversity, and hosting and aesthetic considerations.

* In « crown thinning », the mean size of the felled trees is greater than the mean tree size before thinning.

The watchwords are: striving for quality and optimising the potential of each tree. The capacity for permanence of the stand must be safeguarded by retaining the young trees and concentrating extraction on the Large Wood material that has reached harvesting size.

2.1.2 Harvesting cycles and extraction rates

The **thinning cycles** set in the DNF's forestry schemes are usually twelve (sometimes sixteen) years for hardwoods and six years for softwoods. It is thus important to envision an inspection at mid-cycle, and even at ¼- and ¾-cycle for hardwoods, if only to see if an intervention is necessary. The exact timing of each cycle is applied with a certain degree of flexibility (to take advantage of an exceptional mast year, for example).

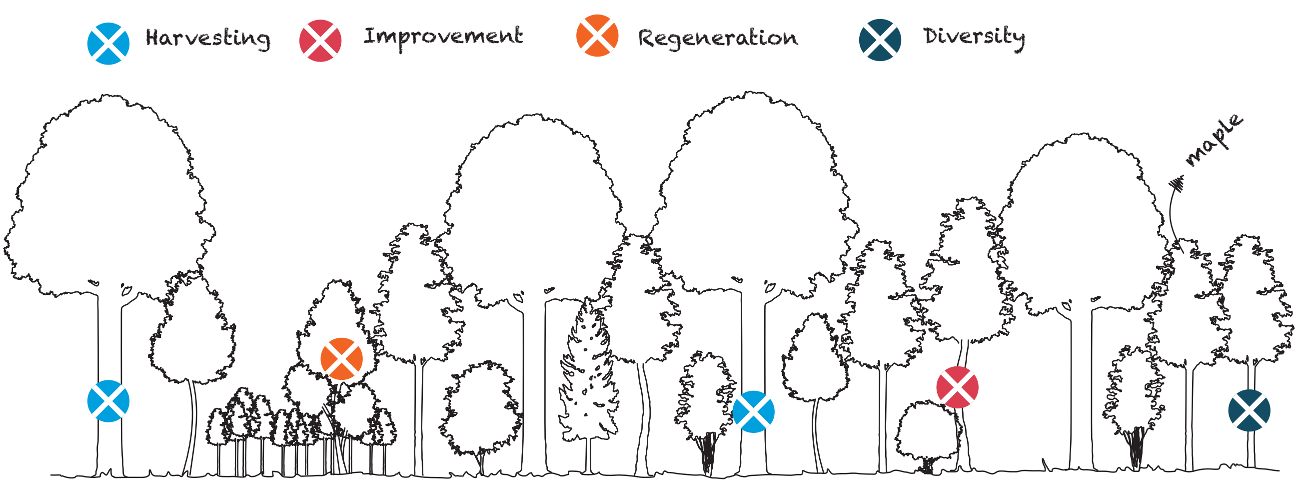
The volume harvest rates for construction timber are of the order of 15-20% of the standing volume for hardwoods and 20-25% of the standing volume for softwoods. In both cases, this corresponds to <20% of the basal area.

The amount to harvest must nevertheless be determined so as not to jeopardise the optimal growing stock or 'capital', that is to say, the equilibrium set for the stand in question. If one knows the state of equilibrium desired and the current increment, it is possible to deduce the harvesting rate and frequency needed to maintain, increase, or gradually decrease the growing stock.

In the case of equilibrium, the amount extracted will be equal to the increment. In stands that are under-stocked ('capitalisation' phase), extraction will be less than the increment. Inversely, it will be slightly

FIGURE 1

SELECTION FELLING



greater than the increment in over-stocked stands ('decapitalisation' phase). In the latter case, the felling passes will be more frequent in order to reduce the risk of destabilising the stand or exposing it to light too suddenly. Inversely, the felling cycle will be extended in compartments where the stock must increase.

2.1.3 Social structuring of trees in irregular high forests[12]

The trees of value in an irregular high forest can be divided into three categories*. The presence of trees in these three categories is vital to ensure the positive social interactions that are necessary for the stability, permanence, and profitability of the ecosystem.

The **first category**, called '**waiting room**' stems, consists of all the established regeneration, including that which has sometimes been established for many years, whose rise towards the upper stratum is temporarily blocked. The various species may remain in this waiting room for shorter or longer times, depending on their specific light and heat requirements. The greater a species is shade tolerant, the longer it may remain in this waiting room. The plasticity of young stems, even of so-called 'light demanders', is very often greater than one thinks. This waiting room is the theatre of natural selection, as a result of which only the most vigorous seedlings emerge. In addition to this natural reduction in the number of stems, we also see an improvement in the stems' form due to apical dominance and lateral competition from neighbours, as well as the need to seek light from above. So, a large part of the stem training and the natural improvement processes that Continuous Cover Forestry forest management makes use of, takes

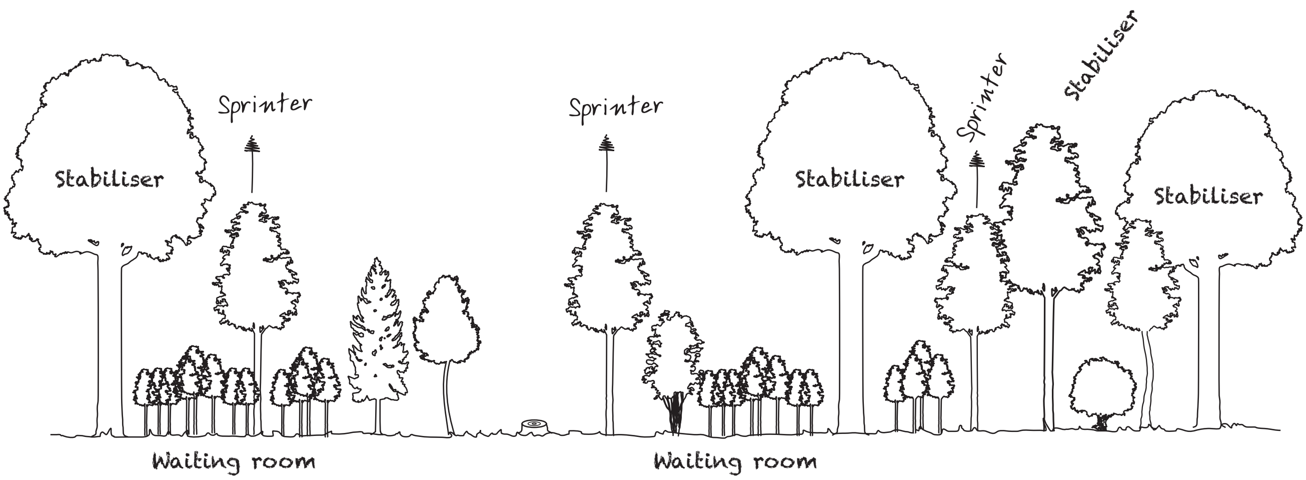
* There are many other types of tree (co-dominated and co-dominant Medium Wood material, big trees with an ecological function, etc.). This three-stage classification is admittedly simplistic but gives a better grasp of the dynamics of quality trees in woodlands.

The harvest and improvements in quality and productive potential always have priority over regeneration.

Selection felling is frequent and light.

FIGURE 2

SOCIAL STRUCTURE IN IRREGULAR HIGH FORESTS



place in this waiting room.
The **second category** consists of the '**sprinters**', i.e., trees that sprint from the waiting room to the canopy thanks to one or more nearby interventions. These trees ensure the permanence of the stand and replacement of the harvested trees. The transition from waiting room seedling to stabiliser is a relatively short period in the life of a tree, since it stretches over a period of two or three decades. This allows very satisfactory renewal with very few stems. There are relatively few sprinters in stands with irregular structures.

The **third category**, that of '**stabilisers**', consists of the large trees that form the backbone of the stand and have the functions of production, stabilising the stand, and bringing up the young trees.

2.1.4 The species mix

Achieving and deliberately maintaining the right species mix for the site, including taking steps to favour rare and threatened species is both one of the ends and one of the means of Continuous Cover Forestry forest management to guarantee the functional, productive, and natural equilibrium of the forest ecosystem.

Despite the frequent monospecific nature of traditional plantations, observation has long shown that natural regeneration is spontaneously mixed. Managers run no more risks, and even run fewer risks, with mixed stands than with pure stands. Today, the management of a species, be it in a regular or irregular high forest stand, can no longer be dissociated from the other species on the site, whether they are

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LES AVANTAGES DES PEUPLEMENTS MÉLANGÉS SOULIGNÉS PAR DE NOMBREUX PROJETS ET ÉTUDES

Coniferous regeneration (Norway spruce and a few Douglas firs) in a mixed stand (Grand Bois, Vielsalm, Belgium).

The FORBIO project that was conducted between 2008 and 2010 brought several universities and research centres together around the topic of mixed stands. The themes of the project included the differences in the ways pure and mixed stands function and analysis of the effects of a species mix on the products and services that the forest provides. The advantages of the mixed stand were identified and described in detail.

Biodiversity is, as a rule, boosted by a mixture of species, which usually allows the development of more diversified insect, plant, and animal communities than pure stands. Mixed stands offer incontestable advantages from this standpoint. However, simple assortment rules do not let one predict accurately the wealth of organisms that will develop in the mixed stands. The effect of the mix is strongly influenced by the type of woody species present. It is preferable to combine a species with just a few other species, even a single other species, rather than with a myriad of other species retained or planted solely to give the illusion of a certain diversity. For example, oaks and whitewood tree species (willow, birch, aspen, etc.) are associated with a variety of insects, fungi, and/or lichens that greatly surpasses those of most other species. As such, they are more interesting than the other species for inclusion in the mixes sought, provided, of course, that they are adapted to the site concerned.

Aside from the advantage linked to biodiversity, there are many reasons why a manager will opt for a mix of species: the desire to diversify the trees and forest products: 'fear of homogeneity' and of pure stands (linked to the fear of decline, windblow, attacks by pathogens, and economic losses); imalready there or envisioned as potential additions. The natural dynamics of regeneration shows that, as a rule, natural mixtures evolve and exhibit a succession of species with different characteristics, each of which facilitates the next one's establishment. The mix must be dynamic, and it is up to the forester to find the right economically viable proportion of species.

2.2 Measure 2: Achieving or maintaining an optimal basal area allowing the forest ecosystem to function well

2.2.1 Optimal standing volume

Managing the standing volume is a vital part of Continuous Cover Forestry management. Monitoring the standing volume is one of the foundations of this type of management, comparable, in terms of importance, to the effort in guaranteeing regeneration in regular high forests.

The appropriate level of growing stock is defined as the level that enables the stand to function well, that is to say [6, 31] :

- optimisation of wood production;
- optimal development of the crowns so as to produce timber of value (vigorous large crown and re-

provements in stand stability, landscaping, and/or production (the productivity of the overall stand is improved by the partial addition of the productivity of each species); and, finally, to reduce damage by game (the mixture can 'drown' an appetising species in a sea of less appetising ones).

The results of the FORBIO project reveal in particular that mixing species can produce positive phenomena that add up, thereby confirming some of the aforementioned advantages, but incompatibilities also exist. The poplar-European larch mix, which is more conducive to rust attacks, is a good example of such a problem, as is the Norway spruce-larch mix, which is likely to increase the two species' sensitivity to woolly aphids (adelgids). On the other hand, many species mixes are beneficial, e.g., pine-Norway spruce (as the pine hosts a parasite of spruce bark beetles), Norway spruce-birch (the birch has a repellent effect on scolytids), pine-broadleaves in general, etc. So, with the exception of a few commonly known negative associations to avoid, mixing species is generally recognised as reducing health risks.

The health advantages of these mixtures can be compounded by other positive effects on the humus, the water cycle, and so on. The buffering effect of mixtures has been seen in certain 'borderline' situations, making it possible to keep species that would compete too much for comfort in pure stands. Similarly, the site is rarely homogeneous on the scale of the plot. A species mix allows better use of the ground, as each species develops according to its needs in line with the micro-variations on the site.

Pine, Norway spruce, and birch regeneration on the edge of a spruce stand (Domaine d'Haugimont, Faulx-Les-Tombes, Belgium).

duced lower branch mortality on adult trees);
- complete and continuous mineralisation of organic matter (substrate conducive to germination);
- the survival and growth of the under-storey (and especially of poles with potential); and
- the recruitment and development of diverse, good quality natural germination accompanied by herbaceous plants that do not block germination.

Too much standing volume reduces growth (less-than-optimal annual increment), reduces the quality of the stems present, limits the establishment of the desired regeneration, and leads to the build-up of organic matter. Inversely, insufficient standing volume does not optimise quality (risk of blemishes on trunks, especially in hardwood stands) and carries the risk of destabilising the stand, causing drought cracks on mature trees and sunburn to seedlings, and favouring the proliferation of herbaceous and semi-ligneous vegetation, which will consequently thwart the establishment of natural regeneration.

This standing volume is usually expressed by the basal area. In irregular high forests, the basal area is preferred to volume because it gives a better indication of the density of the stand and canopy index. This correlation makes it possible to quantify the degree of competition within the stand and, to a certain extent, the light conditions on the ground.

The basal area is assessed by means of direct measurements or inventories that require a minimum amount of work to produce sufficient data (Insert 4).

2.2.2 Remarks about the basal area

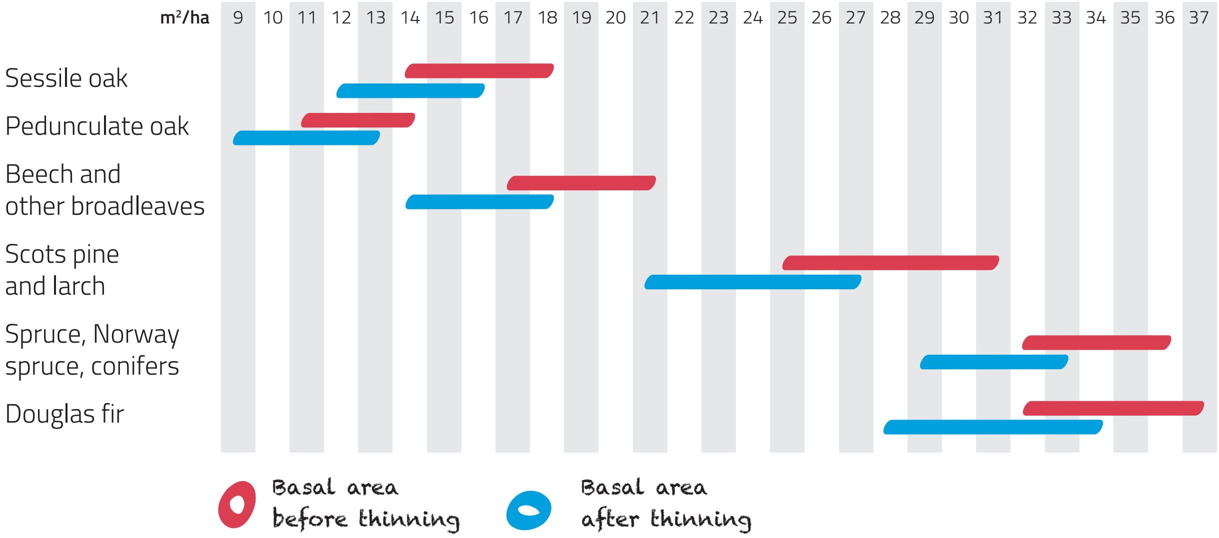
The ideal basal area is not a set value that must be consistent across the stand, but a mean value to achieve and to maintain for the entire management unit. This value may vary to a greater or lesser extent for each group of trees. These basal area ranges are guidelines for the forester to follow in managing each stand.

To know the appropriate basal area, you must refer to the normal ranges (Figure 3 or the literature). However, these figures are indicative only and must be supplemented by other data such as the proportion of trees in the Large Wood class, the species percentages, the fertility of the site, the target species… and observations. Observations by the forester can provide information in this respect, for example, one can appreciate the level of light in the understory from observation of the seedlings' shape and form - and therfore the adequate level of basal area.

FIGURE 3

TARGET BASAL AREAS

Example of target basal areas in uneven-aged stands by species. The ranges given come from field observations made by foresters in Wallonia and France under equivalent site conditions.



Ultimately, the combination of all these facts must make it possible to estimate the equilibrium 'capital', forest block by forest block.

Situations that may appear hopeless can sometimes work themselves out over time due solely to the trees' increments, the vigour of certain individuals, and the build-up of biomass.

Patience is one of the forester's main qualities.[15] A sense of observation and faith in the resilience and adaptability of the ecosystem in question are two other major qualities of the Continuous Cover Forestry forester.

2.3 Measure 3: Harvesting Large Wood at target diameter and thinning Small Wood and pole size material

2.3.1 Harvesting size

Irregular high forest is managed according to the trees' dimensions and opportunities rather than by

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A FEW REMINDERS FOR MEASURING THE BASAL AREA OF A STAND[14]

The most useful time to measure the basal area is when one determines the actual state of the woodland, to estimate the production forecast. One can also calculate the basal area by splitting up the trees into the wood categories SW, MW, LW, and VLW, which will give a better picture of the stand and better idea of the path to take to achieve the desired equilibrium in irregular high forest management. Measuring the basal area just after selective marking and before extraction is also very interesting. It enables one to know, for example, the basal area removed, so that the subsequent marking operations can be refined.

Working by inventories is advisable where the basal area is calculated or measured directly. Optical measuring systems are faster and more widely used.

Optical measurements are made using a Relascope (for example, a chain Relascope) or an angle gauge. Such readings are a quick and inexpensive way to get a good idea of the basal area of a stand, which is vital information for irregular forest management.

Good visibility and sufficient light are necessary. In broadleaf stands it is preferable to take the measurements after leaf fall. Otherwise, there is a great risk of under-estimating the basal area.

Each optical measurement remains relatively rough and one cannot limit oneself to a single reading per stand. A measurement taken at a single point cannot be extrapolated to the entire stand; a series of measurements must be taken at various places in the stand and the measuring spots must be chosen randomly. So, for example, one can walk along a transect taking readings at regular intervals.

Measurement of the basal area with a notched Relascope (Beauraing, Belgium).

The following table gives the recommended number of observation points according to the size of the plot and its uniformity or non-uniformity.

Area	**Number of observation points**	
	Uniform stand	Non-uniform stabd
0,5 to 2 ha	6	8
2 to 10 ha	8	12
> 10 ha	10	16

age. The harvesting periods are thus defined not by age, but by the triad of diameter, quality, and species. So, a tree will have to be harvested when it reaches a market dimension defined by its species and quality and, ideally, when the market is good. It may also be extracted early if it is to release another, more promising, individual. That leaves several years of leeway in setting and adjusting the time for harvesting an individual tree according to its circumstances.[9]

Irregular forest management is thus founded on a technical and economic optimum that is set for each tree according to its species, quality, and immediate environment. The harvesting size is the minimum size that a tree must reach to be harvested. A high quality tree will have to be retained longer than a poor quality tree.

All the trees on a given plot do not reach maturity simultaneously. That is due to factors linked to the tree itself (age and vigour), to the stand (competition, stratification), and to the site (differences in the soil, local micro-climate, etc.).[3]

Just as an example, Table 1 gives the harvesting sizes by butt log quality for the main timber species in Wallonia. These values can vary from one region to the next and according to the market.

2.3.2 A few general selective marking rules

The so-called 'ideal' distribution curves (Fagneray, Liocourt, etc.) of the number of stems per size class define what is commonly called the selection forest. This type of management is specific to certain contexts and species (spruce, Norway spruce, and beech). For the majority of contexts and stands the equilibrium state must be defined differently, by basal area range in particular. Stem number distributions are special cases, rare in irregular high forests. Referring to an 'ideal' timber distribution curve defined by the number of stems per diameter class takes account of neither the species mix nor the site and allows even less for the initial state of the stand. In contrast, the selective marking rules (Figure 4) lead the stand more certainly and gradually, depending on its initial state, to continuous quality production suited to the species mixes and sites encountered.

Research and the contributions of the Research stand network the AFI (Association Futaie Irrégulière)1, which focuses on observing irregular high forests, have shown that irregular forest management gives a flatter distribution curve than the ideal wood distribution curves for selection forests, with more scope for the production of Large Wood and Very Large Wood. In the lower size classes, the number of stems in the Small Wood class must nevertheless be large enough to allow selection of the best quality individuals[32].

2.4 Measure 4: Regenerating the stands naturally, without sacrificing harvesting potential. Using natural regeneration in all its diversity

2.4.1 Diffuse natural regeneration...

The corollary of the basic principle of continuous cover in irregular high forest is the development of stratified, structured stands presenting a mixture, either tree by tree or in small groups, of individuals with well differentiated functions. These are the stabilisers, i.e., high quality adult producers, but also individual trees of great ecological value; the sprinters, i.e., young trees brought up in the shade of the larger trees and ready to take over when the time is right; and the waiting room, i.e., sporadic natural regeneration that responds the forest environment created by the canopy's cover.

This diffuse natural regeneration, as well as control over its species composition, is induced mainly by the right management of the under-storey, incidental light, and micro-climatic conditions. It must be diffuse in time and space, scattered as a mosaic of cells, cones, or associations, not in 'thick brushes' or distinct areas.

Regeneration is not an end in itself but a positive consequence of the type of management applied.

TABLEAU 1

EXAMPLES OF HARVESTING SIZES FOR SPECIES (IN CENTIMETRES AND IN DIAMETER) ACCORDING TO THE QUALITY OF THE BUTT LOG[6,15].

Billet at least	QUALITY OF THE BUTT LOG Billet at least 3 metres A	3 metres B	C	SPECIES D
Oak and beech	240-300	230-280	180-230	As early as possible if it has no protective, ecological, or landscape role
Beech (if risk of red heartwood)	200-240	200	180	
Ash (Condroz plateau)	180-200	150-180	150	
Sycamore	200	180-200	150	
Alder, birch	170-180	120-140	110-120	
Wild cherry	210-230	180	150	
Douglas fir, larch	240-300	210	150	
Norway spruce	210-240	150	120-140	

FIGURE 4

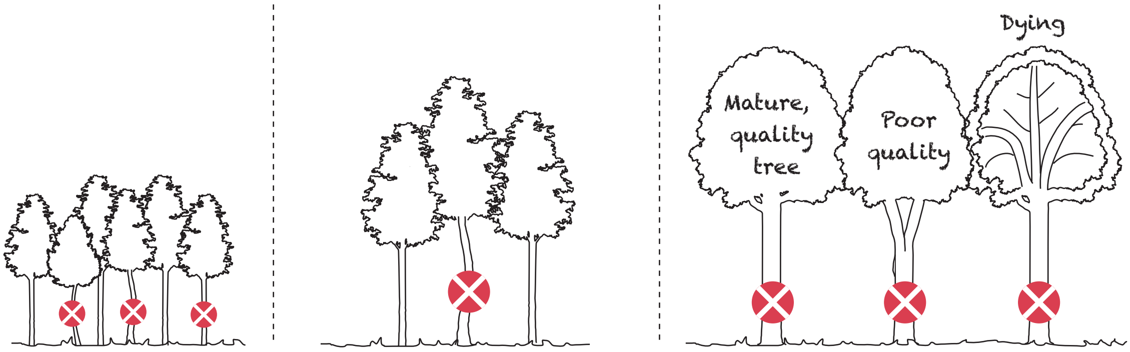
SIMPLIFIED REPRESENTATION OF THE MAIN SELECTIVE MARKING RULES[6, 31]

Bring the standing volume down to within the right range to allow the stand to function properly

Poles and Small Wood material	Medium and Large Wood material	Very Large Wood material
Marking is a priority: dynamic or halo thinning	Marking not priority: moderate thinning	Marking is a priority: health issues, quality trees at risk of depreciation, poor quality trees, and mature quality trees

Total extraction: moderate each intervention
(volume: 15-25%; number: 8-15% basal area: <20% of the growing stock)

Extraction	Extraction	Extraction
Number: high	Number: low	Number: low
Basal area and volume: low	Basal area and volume: low	Basal area and volume: high



Harvesting concentrates on Small Wood and Large Wood categories

Managing the under-storey reduces competition from adventitious vegetation and improves the quality of the saplings due to their being brought up in half-shade and protected against drought, heat, and frost. By maintaining a certain level of cover, one allows the cones of regeneration to spring up sporadically on their own allowing the individuals with the greatest vitality to survive thanks to natural selection. Regardless of the type of stand, when the total basal area of the under-storey increases, the regeneration fraction decreases.26 So, by increasing the amount of diffuse light, thinning the under-storey enables one to manage the emergence and development of natural regeneration in the young stages.

Depending on the case, if regeneration (from young seedlings to poles, from 0 to 17,5 cm diameter) covers 5-15% of the surface area (scattered in small patches), the permanence of the stand is assured. The areas of regeneration are few in number, but must be dynamic over time and space.

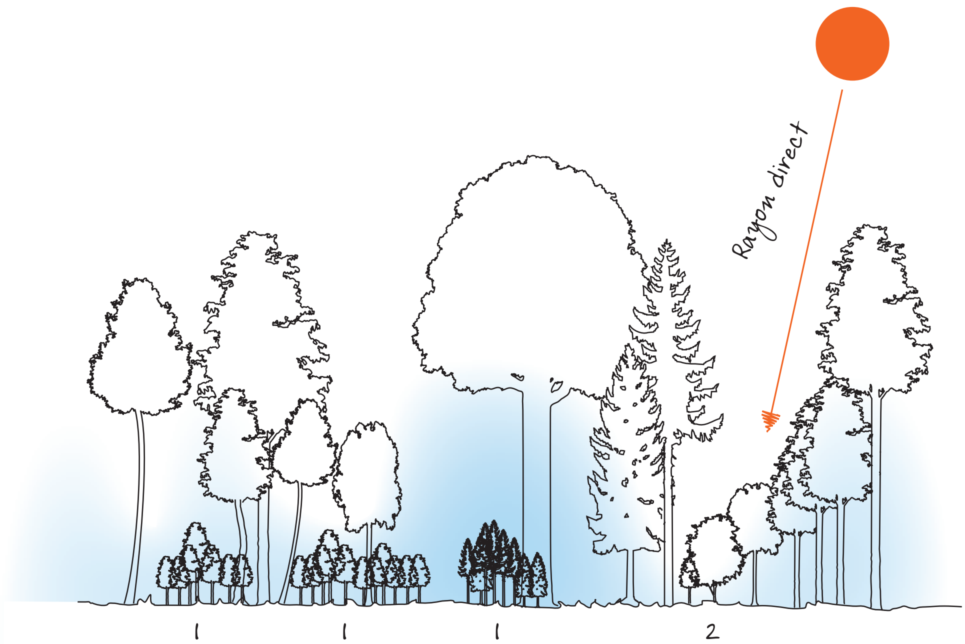
2.4.2 ...and diffuse light

Total incident solar radiation consists of two components,[8] namely:

- **direct light**, which is composed of the rays of sunlight that follow an unaltered path from the light source to the reference area. This type of radiation is high-energy light. It corresponds to the light in the large canopy gaps and clear-cut plots on clear days, as well as as the flecks in dappled light; and

FIGURE 5

DIFFUSE NATURAL REGENERATION...



1. Diffuse regeneration will appear cyclically, even under a relatively closed canopy. This regeneration will cover 5-15% of the surface area and be distributed in islands or cones of regeneration. Under a closed canopy, the seedlings may remain in the 'waiting room' for several years, depending on the species.

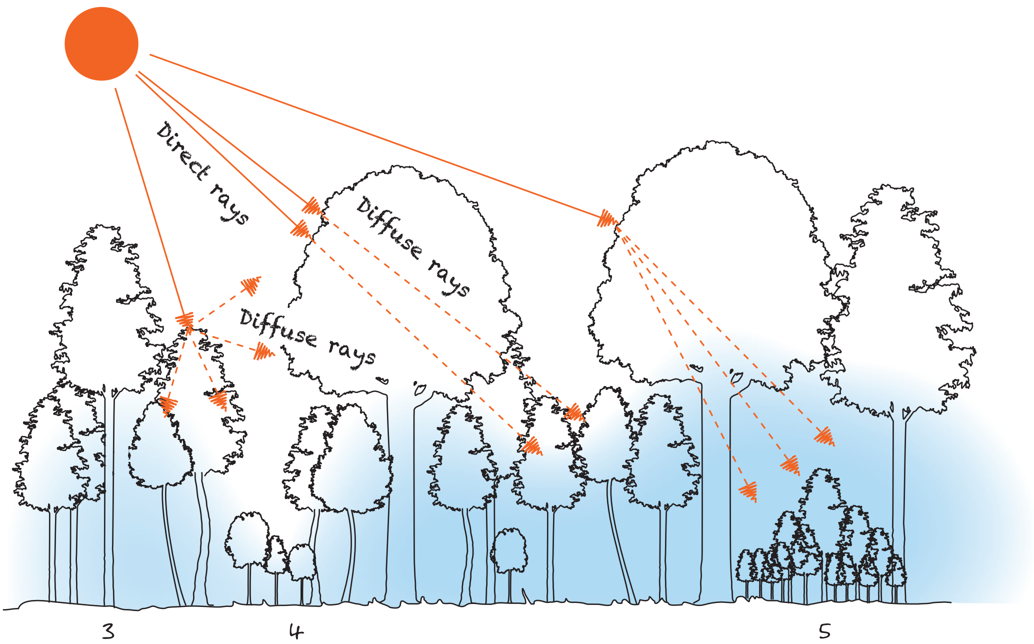
2. A portion of the 'waiting room' stems may grow following changes in the local light conditions (coupes, windblow, etc.). Natural selection of the most vigorous individuals will operate on its own. These few seedlings will grow into saplings.

- **diffuse light**, which is composed of all of the light rays whose paths have been modified since their emission. This radiation has no preferential direction and comes from the entire vault of the sky. The majority of the light in forests consists of diffuse light.

In forests, the sun's rays are more often slanted than vertical, especially at our latitudes. Not only does this diffuse light suffice to guarantee that the regeneration capacity of trees in the under-storey will be maintained (even species such as oaks that are misnamed as 'shade intolerant')[20]. It is also vital for managing the equilibrium between woody and herbaceous plants on the ground by preventing an explosion of the latter. Indeed, direct light leads to the unwanted development of herbaceous and semi-ligneous plants to the detriment of tree seedlings, less differentiation amongst the seedlings, more difficult natural pruning, and a heightened risk of multiple crowns and forks without necessarily increasing the seedlings' vertical growth.[10] Diffuse light is therefore more important for the development of natural regeneration that is scattered and of good quality (germination and seedling stages), whereas direct light is more useful for growth in the first and intermediate stages (thicket, sapling and pole stages).

Balancing the light intensity in an irregular high forest is the result of a balance between diffuse and direct light, which is achieved by fine management of the under-storey and the over-storey through selection felling and forestry operations.

...AND DIFFUSE LIGHT



3. A few of the saplings will gradually have enough space to become poles (sprinters).

4. The light conditions generated by a light canopy and proper structuring make it possible to reduce competition from adventitious vegetation.

5. At our latitudes, the sun's rays are more often slanted than vertical. This diffuse light is the most important factor behind the emergence of good quality diffuse natural regeneration..

2.5 Measure 5: Letting the process of species succession take place

One of the important aims of Continuous Cover Forestry management is to conserve and improve the functional biodiversity of the forest ecosystem. The various forms of life and their life phases are linked to the various phases in the forest's evolution and succession, including those of ageing and decay, but also of open space such as clearings, canopy gaps, running water, ponds and lakes, and many more life forms.

Historically, foresters tended to prevent natural succession running its course by eliminating the secondary pioneer species (birch, rowan, etc.) systematically, by planting the gaps and cleared areas immediately, etc. However, we now know that the resilience of a stand is improved when it contains colonising or pioneer species: following a natural disturbance, the dynamics of reforestation will be faster if these species are present or their seeds are in the soil, and this will also prevent invasion by herbaceous species. Similarly, gaps in the canopy, groups of veteran trees, and dead wood contribute to the overall health and equilibrium of the stand. Also maintaining good overall soil function, especially when it comes to the mineral and organic components of the soil.

This measure relies on the advantage of not systematically blocking the natural development of the various stages of natural succession. The natural processes that occur in woodlands can be modified according to the situation. For example, the proximity of seed producers can accelerate the natural dynamics by short-circuiting a few steps in the forest succession.

The natural succession from pioneers to shade species is respected whilst encouraging the growth of Large Wood of good quality amongst these pioneer species.

INSERT 5

NATURAL REGENERATION: COMPETING VEGETATION AND REQUIRED OPERATIONS

As a rule, natural regeneration always ends up taking hold, even though it may be delayed. Indeed, even in cases known – clumsily – as 'blocked regeneration' (overrun with competing vegetation, for example), observations show that natural regeneration will become established on the majority of sites, as long as you have the patience to wait a few years, except in cases of fauna/flora imbalances.

Intact clump of brambles (Anderlues, Thuin, Belgium).

However, if the manager thinks it necessary, it may be wise in certain situations to back up the natural regeneration with additional planting. In these cases, for example in gaps where regeneration is extremely slow, planting must always be targeted and of limited extent, given the continuous functioning of the system. Preference should be given to high density rather than extensive planting. More and more supplemental (or enrichment) plantings are done in the form of small groups (or 'cells'), in imitation of cones of natural regeneration. This reduces costs of protection.

It may likewise prove useful in certain situations to use more interventionist techniques, such as soil disturbance or releasing or re-spacing the regeneration. Various problematic situations exist (e.g., absence of quality seedlings of the target species, invasion by adventitious vegetation, and quality seedlings threatened by competing woody species). These situations must be handled on a case by case basis, bearing in mind that the releasing must be localised and tending selective. What is more, these operations must help the species that are sensitive to competition first and foremost.

INSERT 6

BEHAVIOUR OF MIXED REGENERATION

When the mixture consists of species that demand light when they are young and others that are more shade tolerant, the matter of renewal is sometimes tricky. Sometimes deliberate action, such as small artificial openings in the canopy, additional plantings, and/or targeted silvicultural operations, will be required in the young stages to keep the light demanding species. Such situations are common in oak-beech mixtures.

The problem of the forest/game balance (over-abundance of deer) can worsen these imbalances and difficulties. In these cases, one cannot leave nature totally alone; intelligent intervention at the right time is needed to help the less competitive target species in the young stages. This can apply to the sessile oak which, even if it survives shade, exhibits reduced growth allowing other species to overtake it.[8]

In this example, the oak, which is a light-demanding species, exhibits phototropism* by deviating from its vertical axis to head for the light. The presence of beech seedlings is thus harmful for the oak's form. The beech, for its part, is a shade-tolerant species that grows straight without problems beside less sciaphilic species. The oak seedlings do not bother it in any event and even have a beneficial training effect on the beech tree's branching angle[23].

In the two following examples, the birch and Scots pine improve the shape of the oak thanks to their thin, light-filtering crowns. Generally speaking, these species are excellent educators for quality oaks, provided that their vigour and positions do not check the oak's growth.

In the presence of oak seedlings, light, relatively frequent forestry operations must be carried out to help the oak by preventing it being smothered by competitors such as beech.

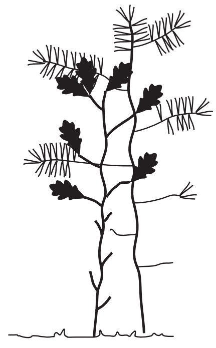
These operations provide an opportunity to remove the immediate competitors from around the crowns of the best stems that are identified ('halo thinning').

The competitors are removed either by breaking stems that are still thin or by girdling thicker stems. Only the true competitors around quality, straight stems are removed. The other stems will continue to play their companion roles, as long as they do not bother the best stems

* Ability of a plant to turn toward the light.


Oak + beech


Oak + birch


Oak + pine

INSERT 7

DIFUSE LIGHT IN THE UNDERSTOREY AND THE TYPE OF THINNING

The relative illumination (given as a percent) in a given spot corresponds to the ratio of the illumination under the canopy over the illumination above the canopy. An illumination map is a map of the relative illumination transmitted in the undergrowth. This tool enables one to visualise the illumination transmitted in the undergrowth of a plot before and after selective felling, for example.

The figure on the facing page shows the illumination map of a 1 hectare plot in an Ardenne beech-and-oak forest (Vecmont Marteloscope, Belgium). The first diagram shows the plot before thinning whereas the next two show the patterns of illumination of the plot after two different types of thinning (Team 1 and Team 2).

A look at these diagrams enables us to ascertain that for similar harvesting volumes (64 and 67 m^3), Team 1 did a low thinning (K = 0.8, mean tree volume (MTV) extracted = 0.6 m^3) whereas Team 2 did a crown thinning (K = 1.9, MTV extracted = 1.4 m^3). As the diagrams show, 'low thinning' selection, achieved by selecting a large number of small stems, results in strong diffuse illumination but distributed uniformly across the entire plot. This type of selection will tend to trigger two phenomena, namely, the development of natural regeneration over the entire area (which is not sought in irregular forest management) and a more regular stand structure. It ultimately leads to the differentiation of the stand into two main storeys and the loss of structure, something to avoid in continuous cover forestry. What is more, focusing selection only on the small stems dips into the longevity capital of the stand, that is, its potential for a long and productive future.

The illumination map obtained after crown thinning (Team 2) shows a pattern of alternating areas of shade and light that is suited to differentiating the seedlings in the islands of regeneration and to the development of a mix of shade-tolerant and light-demanding species. What is more, the ratio of the extracted volume over the number of trees is more favourable in this case and can lead to lower operating costs, given the higher average tree size of the extracted tree.

* As a reminder, in the case of low thinning, the mean dimension of the extracted trees is smaller than the mean dimension of the trees before thinning. In contrast, in crown thinning the mean dimension of the extracted trees is greater than the mean dimension of the trees before thinning

« 'To improve the overall light situation, open up the canopy in a "leopard spot" with dense and sparse areas »
(Marc-Etienne Wilhelm, ONF-Alsace)

Before thinning

Baseline state

Basal area of
the stand = 21.7 m^2

Team 1

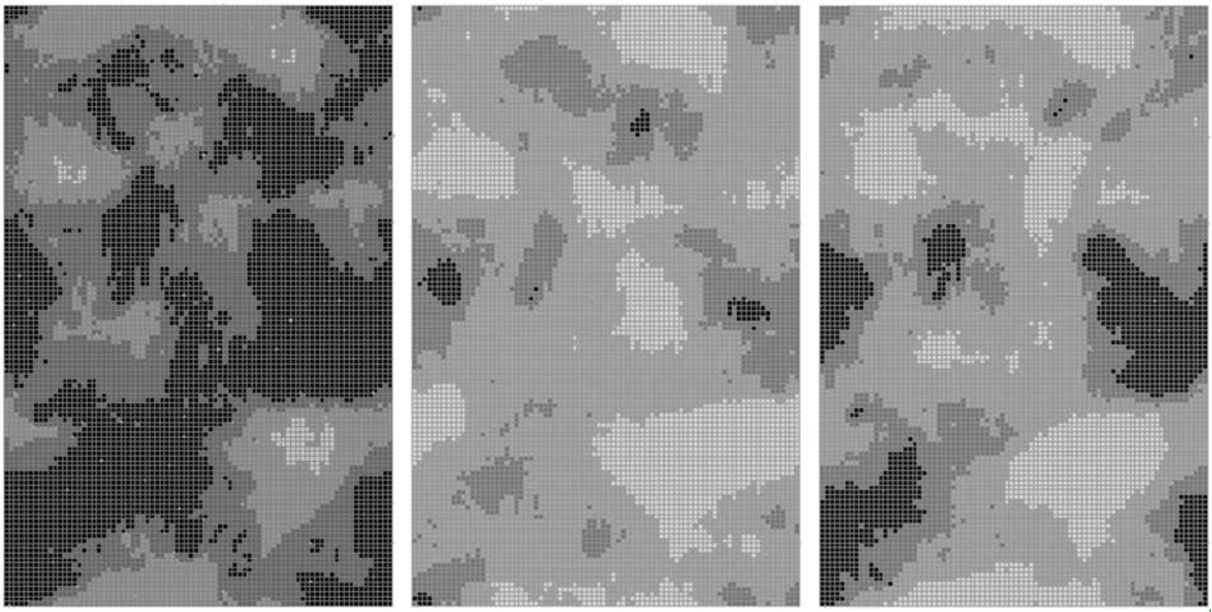
Basal area of the
remaining stand = 13.9 m^2

Selection :
Number of stems = 111
Volume = 64 m^3
Mean tree volume = 0,6 m^3
K = 0,8

Team 2

Basal area of the
remaining stand = 14.7 m^2

Selection :
Number of stems = 48
Volume = 67 m^3
Mean tree volume = 1,4 m^3
K = 1,9



K is a type-of-thinning coefficient:
K > 1: crown thinning;
K < 1: low thinning;
K = 1: mixed thinning.

The calculations are done per 1 m² pixel. The colours correspond to the following relative illumination classes: 0 (black) – 6.5 – 12.5 – 25 – 50 – 100% (white).

Maps by Gauthier Ligot (GxABT, mai 2013). The illumination modelling was done using the Quergus simulator and SamsaraLight library.

INSERT 8

SELECTIVE MARKING IN FAVOUR OF THE ISLANDS OF REGENERATION, BUT WITHOUT MAKING HARVESTING SACRIFICES[7]

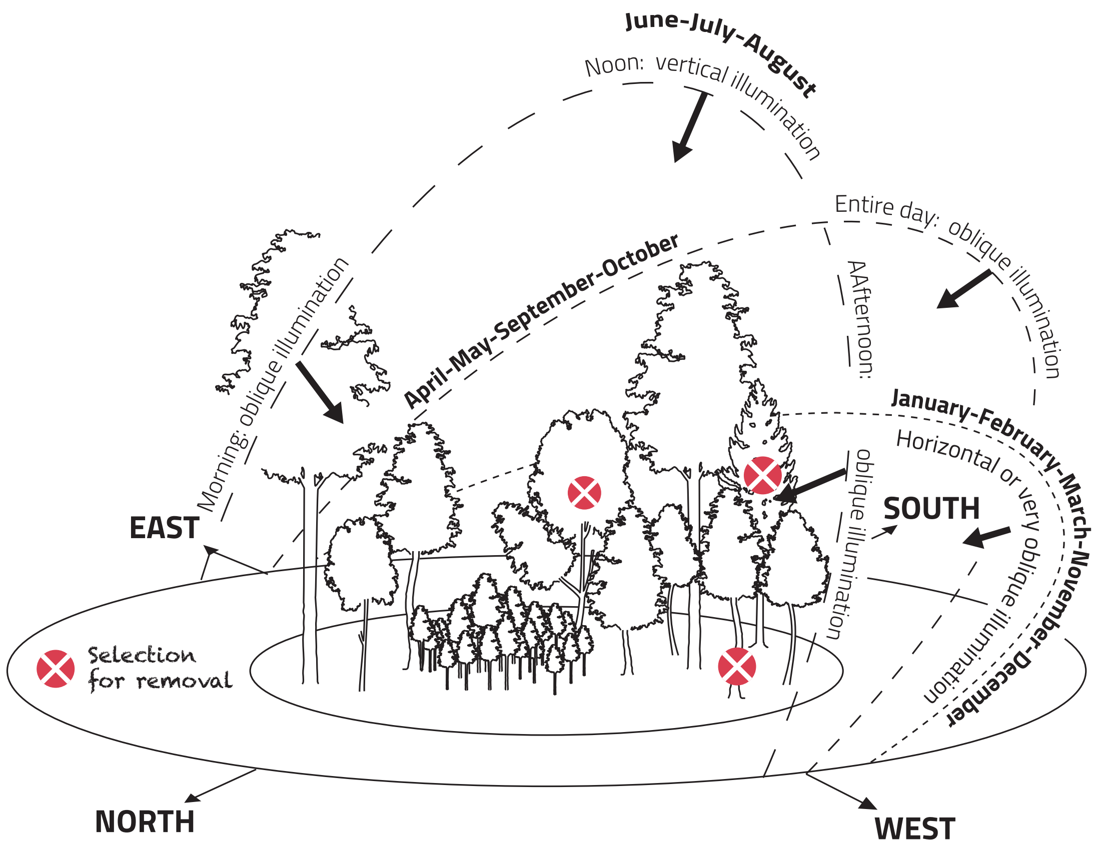
Maintaining an optimal growing stock and managing the under-storey over the entire stand are the two strategies that provide sufficient good quality diffuse light for seedlings to develop. Enlarging gaps systematically must be avoided, for it creates several problems: It can incur harvesting sacrifices by felling quality trees prematurely, lead to the removal of ecologically useful trees, increase the risks of problems for neighbouring trees (epicormics, sunscald and sunburn, and windblow), and increase direct illumination, which will be detrimental to the seedlings and promote the growth of herbaceous species.

Nevertheless, certain measures may be taken near islands of regeneration to promote the seedlings' growth.

Given that the sun's rays are usually oblique, the under-storey and standards can often be felled preferentially on the east, south, and west sides of an island of regeneration in order to increase illumination significantly. This selective marking is done so as to conserve the crowns' stratification in order to conserve good quality filtered and diffuse light that boosts regeneration. In practice:

- fell the poles, whips and coppice stems, and low-branching Small Wood material that hangs over and deforms the seedlings (light gobblers or overprotective nurses). Trees that are not shading and do not get in the way of the seedlings will be retained as long as possible in order to protect the regeneration from direct sunlight.
- fell the big trees of mediocre quality preferentially to the east, south, and west of the island of regeneration in order to provide it with more light. Take care in so doing to conserve the crowns' stratification from the ground up to the dominant stratum.

Remark: Not all islands of regeneration are worthy of selective felling to promote their growth. Those that are close to or located under quality Medium Wood have no future or are in the 'waiting room' and selective felling to give them more light or space is not at all a priority. Indeed, such quality Medium Wood is far from having reached its harvesting size and harvesting it in favour of regeneration material would be a true sacrifice.



2.6 Measure 6: Bringing up seedlings under the canopy and using the natural tree pruning and quality improvement processes

To ensure the good productivity and resilience of a stand, it is necessary to maintain the presence of trees with well determined functions. The reasons for retaining a tree when marking individuals for selective felling are varied, e.g., for production, protection, training, stability, diversity, and so on.

In an irregular structure, the big trees in particular fill many roles: seed production, of course, but also education and training, protection, and maintaining stand structure. The effect of the canopy on the seedlings, poles, and Small Wood guarantees the continuous production of quality timber at reduced costs. The forester must thus take pains to maintain this cover in order to guarantee its role of bringing up the stems-with-a-future, amongst other things.

In irregular high forests, silvicultural operations are only considered when they are demmed necessary. That is, one tries to get the best value from what exists, regardless of the species considered. The manager must thus give himself the means to check periodically whether an intervention is necessary. Rationalising these practices reduces costs, allowing interventions to be more extensive and targeted.2

In areas of natural regeneration one finds pre-existing seedlings that, after germinating, remain, sometimes for many years, under the cover of the adult trees, i.e., in the 'waiting room'. This suppressed regeneration, often known as 'little old men' is useful for regenerating the stands.

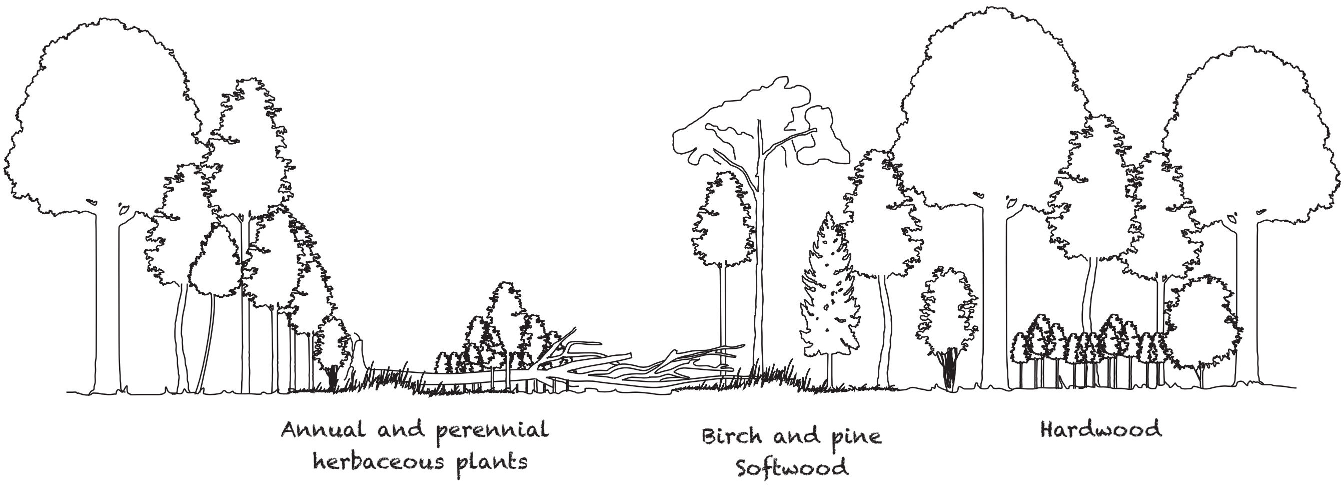
Their poor form due to their long stay in the waiting room often improves over time. For example,11 the beech tree straightens up considerably one year after the canopy is opened, whereas it takes almost three years for sycamore to straighten up significantly once it gets its chance. As a rule, this rapid growth makes it possible to eliminate all except the most obvious flaws (very large fork or bent stems), which disappear only partially.

The use of these 'little old men' procures other advantages, such as not having to wait for good seed years to regenerate the stand, especially when seed production is highly irregular. In addition, the pre-existing seedlings are already big enough to limit the hazards to which subsequent regeneration is exposed to (competition from the herbaceous stratum, browsing, etc.).

FIGURE 6

SPECIES SUCCESSION

The different phases in the forest's evolution and succession, including the phases of ageing and decay, clearings, and gaps in the canopy must be preserved.



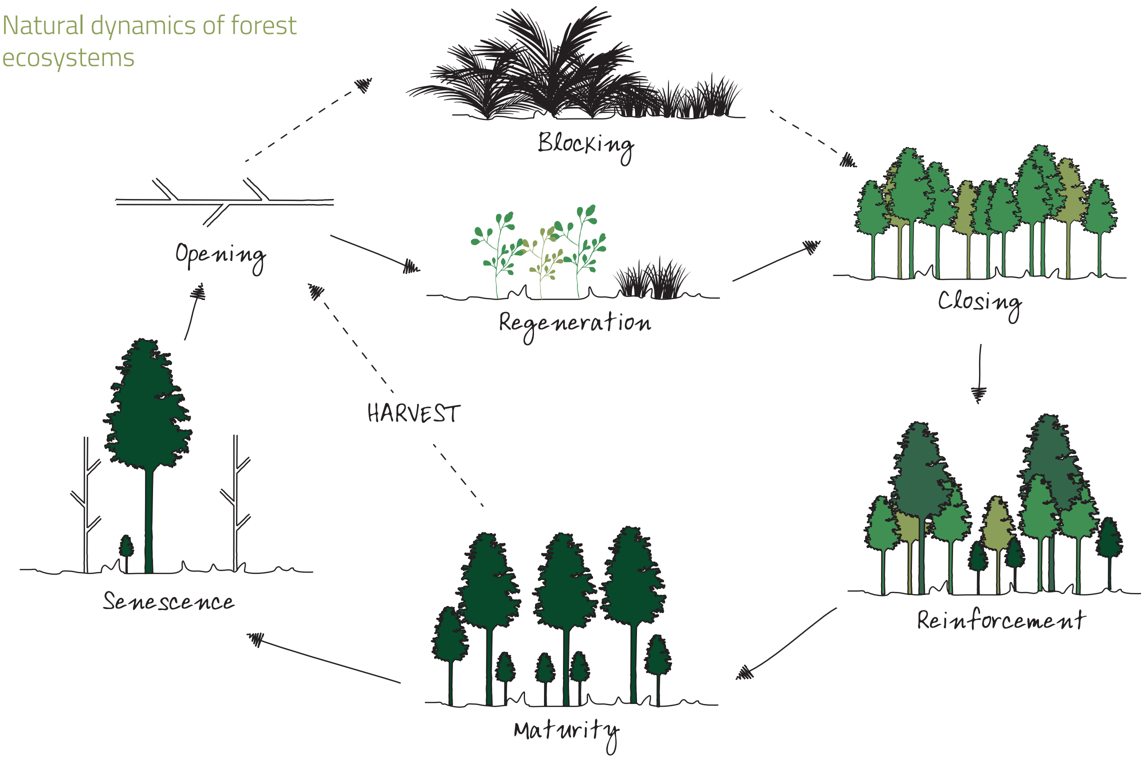
INSERT 9

NATURAL DYNAMICS OF FOREST ECOSYSTEMS [36]

After a disturbance, the natural process of recolonisation quickly sets in to close up the environment. Seeds already present in the soil (soil seed bank) or carried by the wind or animals begin to germinate. Depending on the environmental conditions, the best adapted and most competitive species will remain and form a group of species that will close the cover and gradually evolve, with the addition of new seeds and changes in conditions (light, temperature, humidity). There are several successive phases: the pioneer phase (the stand closes in), the transition phase (new species and reinforcement of the structure) and the maturity phase (final species specific to local soil and climate conditions). Unharvested, the forest then goes through a long senescence phase. New openings are eventually created (dead tree, group of trees, disturbance, etc.). And the cycle begins again. In a natural forest, these cycles occur continuously, on variable spatial and temporal scales. When we harvest, we short-circuit a large part of the maturity and senescence phases, which can normally represent up to 75% of the cycle.

During the pioneer phase, depending on the size of the opening, the environmental conditions change to a greater or lesser extent: direct light, drying out (wind), mineralisation of organic matter, possible rise in the water table, etc. The dynamics of re-conquest by the vegetation will depend on a number of factors, such as the pre-existence of seedlings, the seed bank present in the soil, the seed trees present in the landscape, the size of the opening, etc. All these factors will influence the re-conquest dynamics that take place. In some cases, for example in the absence of seedlings or dynamic pioneer seed trees, and often in large clearings, there may be a temporary blockage, which may be difficult for silviculture, but which is never definitive. In general, the environment is first colonised by herbaceous species, then by shrubs and trees. The species will be arranged according to their adaptive strategies.
Pioneers are species that thrive in full light and are able to establish themselves directly in the open (large gaps). They are generally short-lived species, heliophilous for germination and seedling development, with rather soft wood. Their repro-

Natural dynamics of forest ecosystems



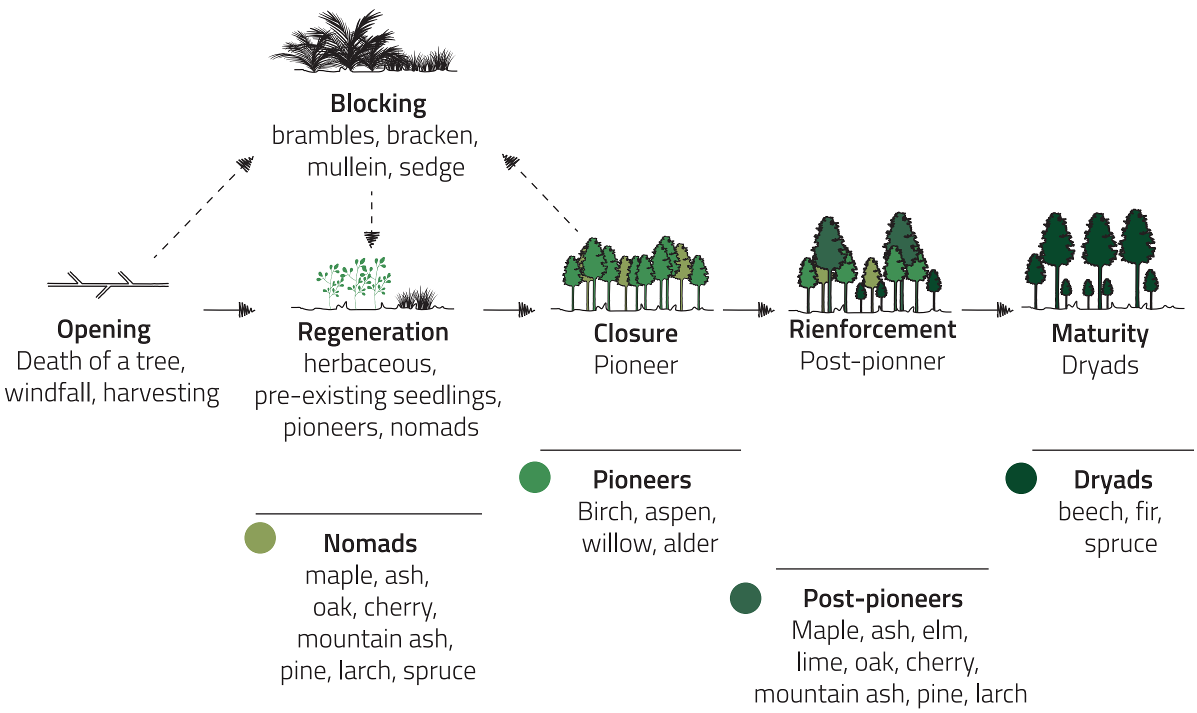
ductive strategy is based on quantity, with many very long-lived seeds (except willow). As they develop, they will close the canopy and create favourable conditions for other species to establish themselves (improved soil, shade, temperature, humidity).

The post-pioneer species arrive next (or directly in the small gaps). They have a harder wood and a more or less heliophilic temperament. They will strengthen the forest structure thanks to their more imposing structure and longer-lasting character.

The mountain avens group comes next (unless conditions are unsuitable). This group includes species capable of germinating with a minimum of light, in the damp conditions of the undergrowth. They correspond to the mature stage of the forest.

Nomads form a special group: they are opportunistic species from the post-pioneer (ash, maple, cherry, mountain ash, oak, pine, larch, etc.) or dryad (spruce) groups, capable of establishing themselves directly with or in place of pioneers, for example in smaller gaps.

In a resilient forest, all the functional groups of species capable of intervening regardless of the effects of a disturbance must coexist (pioneers, post-pioneers, dryads). This is its capacity to heal.



Norway spruce stem disc showing the results of variable growth rate over time.

This tree was in a period of slow growth for about 40 years, with diameter increments of the order of 0.05 cm/year. Thanks to more favourable conditions it then posted girth increments of 0.56 cm/yr on average. This example shows the ability of young trees to remain 'in a latent growth phase' in the waiting room pending the advent of better conditions.

2.7 Measure 7: Favouring scarce indigenous species

Continuous Cover Forestry forestry advocates paying special attention to scarce indigenous species when conducting forestry operations and thinning a stand. This measure makes it possible to have a constantly changing species mix and gradually to increase the proportions of certain species

Secondary indigenous species have effectively shown on many occasions that they greatly increase the attractiveness and habitat value of the stand and deserve as much positive discrimination as possible. Similarly, the resilience of mixtures is increased when they contain colonising or pioneer species. In the event of climatic events or acts of nature, reforestation and healing will be faster if these trees are already present or their seeds are in the soil.

This measure makes sense only if one uses and considers all the indigenous species for production. Considering only the traditional timber species (beech, oak, etc.) when analysing the quality of seedlings in place limits the possibilities of using natural regeneration and creates much more reliance on planting. From an economic standpoint, this measure enables one to diversify production through the addition of rare species such as the wild service tree, lime, alder, hawthorn, rowan, wild apple and wild pear, holly, aspen, and yew, that is, trees that give very high quality logs in small quantities but with enormous added value. The birch, for example, is a fast-growing species with high quality wood that grows easily in great numbers and has great ecological value. What is more, it can be a plus for 'corseting' (protecting) and contributing to the good conformation of other species such as oak.

INSERT 10

REASONS FOR RETAINING A TREE IN SELECTIVE MARKING[28]

Island of natural regeneration of oak under the influence of educators (Gergy Forest, Burgundy, France)

PRODUCER
Tree that will produce a volume of at least C grade wood and thus represents valuable financial capital that can increase even more. In the case of poles, the quality pole belongs with the producers.

PROTECTOR
Tree that does not necessarily produce quality wood but protects, through its presence, one or more neighbours that already exhibit interesting log material that would benefit from more growth. These neighbours run the risk of losing value if the protector is removed (risks of sunscald and sunburn, epicormics, sudden isolation, destabilisation due to wind exposure, and extraction damage to a handsome subject, especially along the extraction racks or in the stacking areas).

EDUCATOR
Tree that does not necessarily produce quality wood but brings up, through its presence, stems that are growing nearby:
- by selecting and differentiating the existing seedlings, thickets, and poles that would otherwise be likely to compete too much with each other or competing vegetation, whether herbaceous or ligneous, as they grew.
- by improving the forms of the seedlings and stems, the branches of which will remain slender and horizontal thanks to shade that is cast.

The educator thus has a positive effect on individuals that have not yet produced an interesting length of log material, unlike protectors, which protect individuals that have already produced an interesting length of log material from spoiling.

SEED PRODUCER
Tree of extraordinary quality that is likely to give offspring of high value and is retained for that reason, even if it could already be harvested. This strategy improves the genetic capital of the regeneration material and could even concern a tree that was damaged accidentally (buckshot, extraction damage), as a result of which its trunk has become less interesting as a source of timber than the seeds that it continues to produce.

DIVERSITY
Tree that participates, through its presence, in the biological diversity of the stand and in the ecological functioning of the woodland in general, especially its soil ecology (addition of minerals, nitrogen fixation, etc.).

ATTRACTIVENESS
Monumental or interestingly shaped tree that has heritage, aesthetic, or emotional value.

Norway spruce and Douglas fir poles protected by a large tree (Grand Bois, Vielsalm, Belgium).

INSERT 11

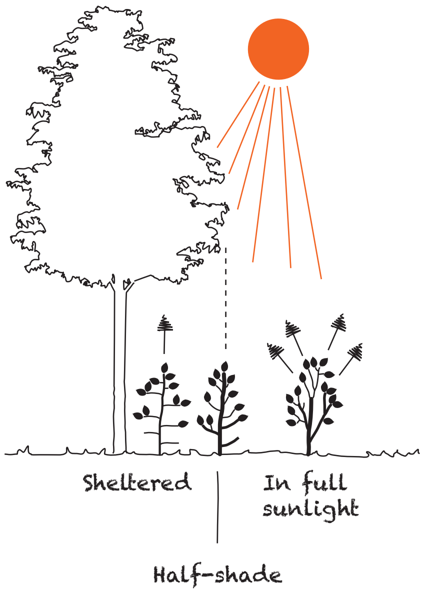
THE EFFECTS OF THE CANOPY ON SEEDLINGS, POLES, AND SMALL WOOD MATERIAL

The regeneration rate is relatively slow because of the sheltering effect of the canopy. This sheltering effect is multifaceted:

- It slows the competing vegetation, i.e., herbaceous plants (brambles, ferns, etc.) but also the young whips and saplings of forest species that compete with each other.
- It maintains conditions of stiff competition, which forces the seedlings to reach for the sky and promotes apical growth, verticality, and differentiation from their neighbours, as well as being conducive to the development of slim side branches that maintain their horizontal growth habit and are gradually pruned naturally.

Observing the regeneration is useful to quantify light and the level of the growing stock. Too little growing stock gives rise to seedlings developing over large expanses. Inversely, too much growing stock may lead to an overly sparse distribution of seedlings. Observing the general shapes of the seedlings also enables one to judge the amount of light (see the figure below).

In the case of mixed regeneration, the degree of competition between seedlings will vary with the quality of the light. The most vigorous species will survive in the long run following exposure to strong

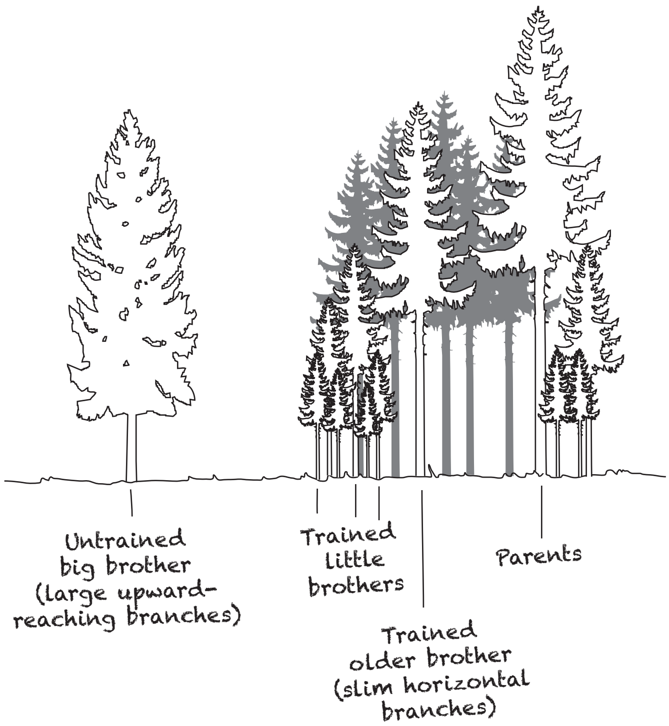


Forms of seedlings under cover and in full sunlight. Under cover: good height growth, upright, slim horizontal branches, and natural pruning.

Observing how the seedlings grow upward and outward can enable one to analyse more finely the local light conditions and state of the standing volume. Example of a Douglas fir seedling: The length of apical growth is greater than that of the shoots at the first whorl, showing that the light is good (Breuil-Chenue State Forest, Burgundy, France).

light, whereas the mix can be maintained and directed more easily in a closed forest environment. The more the seedlings are exposed to strong, direct light, the purer the regeneration will ultimately become.[29]

The trees' educational role can be illustrated by the diagram below.[29] The 'parents' have an education and training role in respect of the younger 'children'. Notice that, in the absence of its 'parents', i.e., the large Douglas firs that towered above it, the 'untrained older brother' is already making large branches (they are less horizontal, reaching upward at an angle) and is likely to become a 'great oaf' or wolf tree. Close observation of this stand shows that the 'big brother' on the right is bringing up its younger siblings in the under-storey without smothering them (they have slim, horizontal branches that will be pruned naturally). By keeping a few trees in the LW class on the plot, one maintains an irregular structure, with the parents 'on the upper storey' and the 'big brothers' that continue to be brought up by their parents whilst bringing up their little brothers in turn.



Slim horizontal branches of a Douglas fir pole brought up under cover (Juillenay Forest, Burgundy, France).

INSERT 12

LIGHT, VARIED, AND REASONED SILVICULTURAL OPERATIONS

In Continuous Cover Forestry forest management, enrichment planting, cleaning and releasing, pruning, and the first thinning operations are kept to a strict minimum. This is made possible by the permanence of a canopy of controlled density and the young stems' being brought up under the canopy's cover. Very often no work has to be done on the seedlings until they reach a diameter of 7,5-17,5 cm (pole stage), and after that the work is done for and around the stems-with-a-future.

However, to take advantage of all existing opportunities, silvicultural operations are sometimes necessary.[2]

The targeted interventions that may be conducted to benefit natural regeneration are:

- defending the species that are sensitive to competition (oak, valuable broadleaves, larch, Douglas fir, etc.) by giving priority to releasing such individuals by breaking or girdling competitors;
- identifying the future stems-with-a-future and focusing the species mix to benefit them. If necessary, one may carry out the first formative shaping and possible additional pruning operations to prepare the future butt logs; and
- protecting the oaks or valuable broadleaves against damage by game, if necessary by fencing them or guarding them individually.

To maintain diversity by introducing rare and/or valuable species or to limit the dominance of a single species, one may:

- enrich the stand by planting sparingly (cell planting) and choosing planting sites carefully; and
- take advantage of the gaps left by the harvesting of Large Wood or the removal of a clump of poor quality wood to introduce oaks or rare/valuable broadleaves, protecting them from game as well, if necessary.

To enhance the value of poles and Small Wood with a future, one may proceed with halo thinning around them and, if need be, the necessary pruning and formative shaping operations. If high pruning is necessary, consult the technical information sheet.[17]

INSERT 13

BREAKING AND RING BARKING

These techniques apply to the sapling (<7,5 cm diameter) and pole (7,5-17,5 cm diameter) stages. Breaking, which is done around better quality stems, consists in bending the upper part of the stem over the lower part until it tears. This is done with two hands to avoid problems of tendinitis. This operation protects the young stems to promote by removing competition but leaves the broken stem in place. Up to a diameter of 5 cm a stem can be broken by hand, without special tools, once it is bent. Above this diameter, a small saw or billhook will prove extremely useful. The stem remains attached to its rootstock and thus continues to live and to protect the stem-with-a-future. The saw is carried in its case at one's waist so that one's hands are free for the other operations. Breaking a circle of stems all around a promising subject is a possibility to create a physical barrier against game. In the case of forked stems, one need merely take one of the branches of the fork in each hand and spread them apart so as to tear the fork's junction.

If breaking a stem becomes too difficult, one then has to girdle it. This consists in causing a tree to die slowly whilst it is still standing by stripping a ring of bark around the entire trunk with a draw knife. This technique takes a little more time.

Both of these techniques also keep a physical barrier against game in order to protect the promising stems, whilst not disturbing nesting birds and forest animal litters by these operations. Breaking is done from mid-June to mid-August, whilst girdling may be done all year long. If the stems are girdled from September to March, they will die more slowly. Depending on the species, the tree may take one, two, or three growing seasons to die, which will enable it to continue to fulfil its protective, corseting, and other roles for a while.

For more information on these techniques, see MESSANT *et al.*[22]

Breaking a birch (La Reid).

Girdling a co-dominant tree with a draw knife (Dierdorf, Germany).

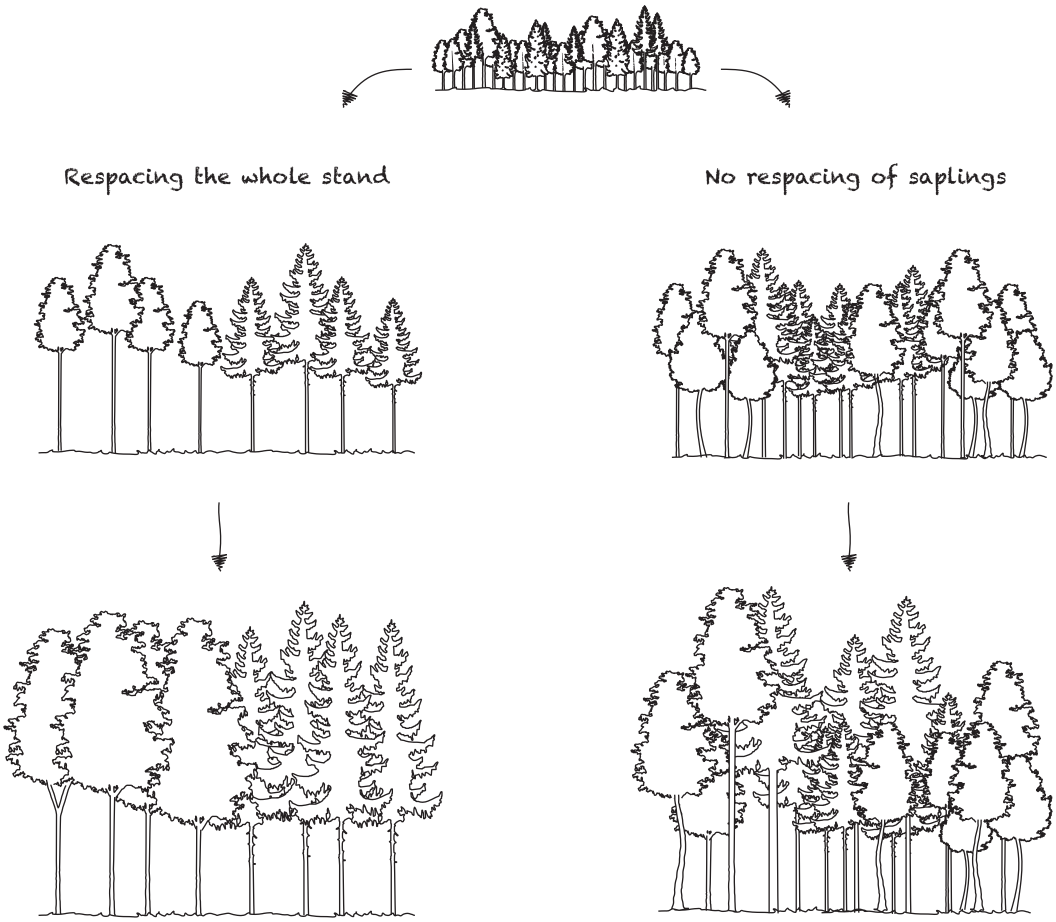
INSERT 14

RESPACING

As for all silvicultural operations, systematic respacing of natural saplings is not part of Continuous Cover Forestry forest management. The aim is to supress the saplings enough to guarantee maximum and optimal natural pruning and ensure that the future stems-with-a-future will grow straight

« Respacing means investing in branch thickness »

Comparison between respacing the whole stand and no respacing. The latter often proves to be more effective, faster, and consequently more economical.



Several years later:
- little differentiation;
- little suppression, less efficient natural pruning.

Several years later:
- marked differentiation of the elite tree, which takes over more and more
- strong compression by the suppressed trees, great natural pruning of the elite trees

2.8 Measure 8: Focusing production on quality Large Wood

Many forest management strategies, known as 'single tree silviculture', make use of the spontaneous forest dynamics on the scale of the individual tree or groups of trees. The goal of 'quality at least expense' or 'getting the most for your money' is clear, without neglecting the demands of integrated forest management aimed at delivering a versatile set of products and services.

Of all the trees in a stand, the quality large trees are the ones that concentrate the largest value increment and are the most useful from both the economic and the ecological standpoint. So, a small number of very high quality trees suffices to procure considerable, lasting, and sustainable income. This vision of things is however difficult to understand in the context of traditional forestry, where trees of extraordinary quality are relatively scattered throughout a forest and are the exception to the rule.[5]

For example, the Douglas fir is a fast-growing species, even at 80 or even 100 years of age. It takes it 35-40 years to reach 1 m³, but each additional cubic metre is achieved in under ten years, and this rate of growth continues until it is 100.

2.8.1 The various 'models' of quality trees

Target diameter birch (La Reid)

One can envisage two tree 'models' in irregular high forest, depending on the situation (species, site conditions, types of product desired, local economic context, etc.). These two models can co-exist in the same stand (Figure 7).

The 'A-D model' strives for very high quality over the first 6, 8, or 10 metres, with the rest being devoted to the out-sized development of the crown as the 'engine of growth' or 'wood factory' to churn out lower quality or Small Round Wood. This model yields Large Wood faster and optimises the production of high quality timber from the individual tree. It is suitable for hardwoods and redwood conifers (pine, Douglas fir, and larch), without for all that being the only option. It is the model of forestry that focuses on target trees accompanied by a matrix of lesser quality.

The 'A-B-C-D model', on the other hand, strives for diversification of the end products, with extraordinary quality over the first few metres (Class A), standard quality (Class B), lesser quality (Class C), and finally SRW (Class D). This model makes it possible to conserve a forest atmosphere and is particularly well suited to whitewood conifers (Norway spruce, spruce).

2.8.2 Selling the Large Wood

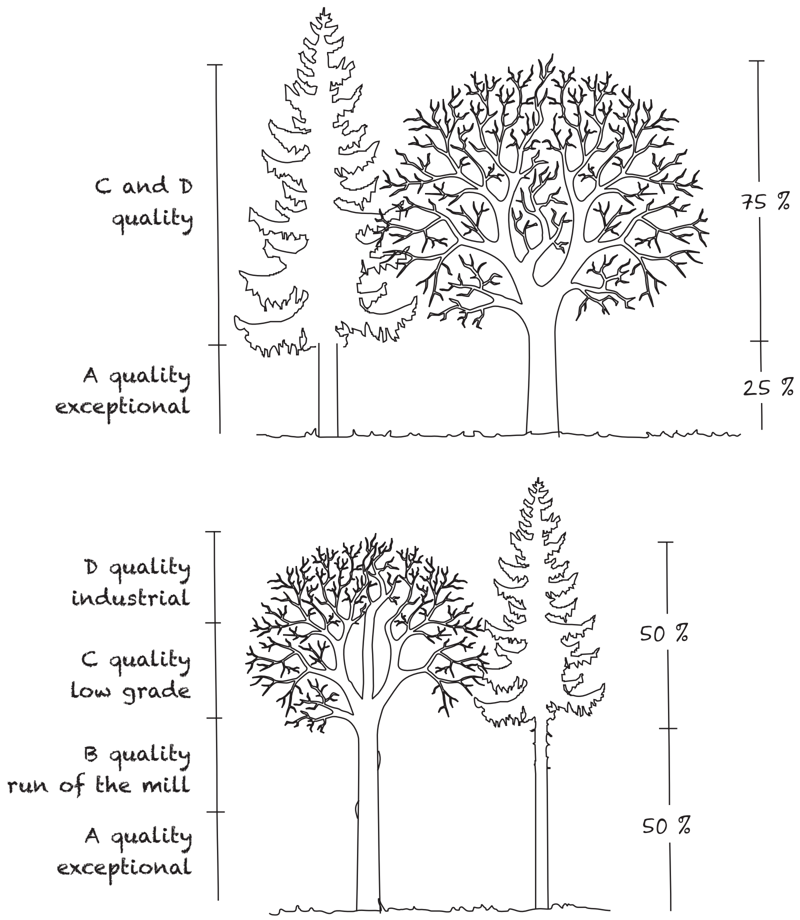
Sawmillers adapt to the resource and have always equipped themselves to deal with what the forest offers. As the sawing yield of healthy, quality Large Wood is always greater than that of Small Wood, it appears to be obvious that when Large Wood is in great supply, the industry will re-equip itself more easily in favour of the LW class than it has done in the opposite direction.

To sum up, the problem of selling Large Wood is above all more one of outlets than of production. Currently, the LW conifers that are produced in Wallonia should attract better prices from potential buyers, even foreign ones.

Let us point out that poor quality Large Wood will obviously have a harder time finding takers on a market that is dominated by standard and medium-sized logs (sawmills with canter lines). In contrast, quality Large Wood combines all advantages: more profitable production (better economic performance of each tree), easier and cheaper harvesting costs expressed per unit cubic metre, increased trade and sales areas for the crude products, increased biomass volume production, and a broader range of milling possibilities.

FIGURE 7

DIFFERENT MODELS OF TREE ARCHITECTURE



A-D model

High quality timber:

- 25% of height
- 50% of volume
- 80% of value

A-B-C-D model

Grade A: slicing, first choice veneer, first choice saw log material (cabinet-making).

Grade B: first and second choice veneer, first choice saw log material (cabinet-making).

Grade C: second choice saw log material (ordinary carpentry).

Grade 3: firewood and woodfuel, OSB material, pulpwood, etc.

2.9 Measure 9: Giving trees of value the necessary space and positioning to ensure their good development

« If you want quality, you have to go for size; and if you want si you have to go for quality »

When it comes to managing quality, the minimum distance between quality trees is very important. It must allow each tree the freedom to develop its crown until the time it is felled. This is even more important when one is confronted with the case of target tree selection in an even-aged stand, where the benefits of multiple stories that are typical of irregular high forests occur less frequently.

Different selection criteria are employed in different stand types: even-aged and monospecific, even-aged and mixed, irregular and mixed, and irregular and monospecific. In these cases, the selection criteria concentrate on the pole and Small Wood class (7,5-27,5 cm diameter). Selection and creating space around the stems-with-a-future is done at the pole-Small Wood stage. Once the bole exceeds 35-40 cm diameter, it is too late. Indeed, selection and a late first thinning may be detrimental to the production of quality timber for the following reasons: higher risk of epicormics (side shoots) during the first thinning operations for certain species; obligation to thin lightly to avoid stability issues (wind and snow); and, if high pruning is required, there is the risk of lopping off branches that are too thick.

The rules to apply in the case of an irregular beech/oak stand are shown in Insert 14. For other cases and for further information, see Baar's technical information sheet.[7]

Finally, the spacing and positioning of trees of value are not absolute rules. In certain situations, two quality trees may grow side by side (Insert 15).

When it comes to the number of quality trees to select in an irregular high forest stand, a simple estimate in a beech forest shows that one big quality tree is harvested per year every two hectares.[7] Consequently, one tree must be selected or elected to the canopy every two hectares each year (or two-three trees selected per hectare every six years) in order to replace the trees that have been harvested. This simple example shows that fewer trees are selected per hectare and per intervention in irregular stands than in even-aged stands.

In practice, however, trees are selected in irregular high forests in line with the opportunities that crop up in the field and according to the degree of regularity or irregularity of the zones that make up the stand. Selection should not lead to harvesting penalties (to maintain a designated tree categorically, for example).

2.10 Measure 10: Maintaining or restoring the forest/game balance to ensure the regeneration and permanence of endemic forest species

The forestry/hunting or forest/game balance is a theoretical notion that confronts the goals assigned to the forest with the pressure exerted by big game (deer first and foremost), given that these animals can prevent some of these objectives' being reached. A common problem is when excessive pressure from big game can jeopardise the achievement of forest management objectives either by preventing the correct rejuvenation of the stands or by reducing site productivity.[21]

The right balance between deer populations and the forest ecosystem is achieved when the forest species (trees, shrubs, and herbaceous plants) on the site can regenerate themselves normally without protection. In some cases, the challenge facing the managers is to determine the state of this flora/large fauna equilibrium. In other cases, the imbalance is clear and the problems lie in the various parties' acceptance and willingness to work out solutions together.

Characterising the equilibrium between the large animals and forest ecosystem is more difficult to tackle in the case of hardwood stands, especially in irregular high forests where the heterogeneous scattering of patches of regeneration makes it much more difficult

INSERT 15

EXAMPLE OF DESIGNATING TREES IN AN IRREGULAR HIGH FOREST

Case of an irregular beech-oak stand

In the case of an irregular stand with a closely intertwined mix of small clumps of trees or individual trees of all sizes, trees must be designated above all at the right time, that is, either when branch die off is complete for the most part over a bole height that corresponds to about 25-30% of the tree's final height. It is useless to designate trees with diameter that exceed 30-40 cm; it is too late.

The target beech or oak trees that are designated must be at least 15 metres apart but also 15 metres from all quality Medium or Large Wood* (for example, quality Medium Wood) that is still far from its expected harvesting time.

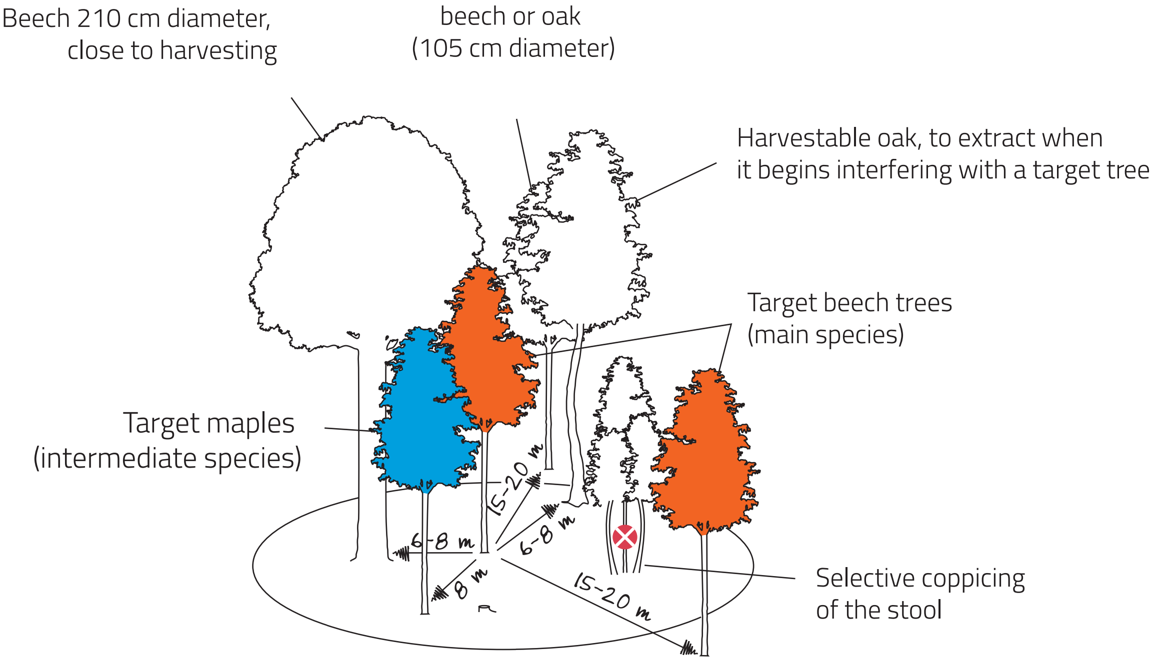
However, thanks to the overlapping strata that are characteristic of irregular high forests, a target tree may be designated less than 15 metres from a Large Wood tree if the latter is going to be extracted in a time period such that it will not hamper the development of the designated tree's crown.

Finally, species that grow faster than the beech or oak may be retained as intermediate trees to within 6 metres from a target beech or oak in the same stage or from a tree close to harvesting, but 15 metres from all quality trees in the standard category (for example, a quality Medium Wood tree) and that are still far from being extracted (more than half of the tree's estimated life cycle remains).

As the oak demands more light, it bears up less well under overlapping strata. Consequently, ensuring that quality oak stems have the right conditions in which to develop is even more important. As a rule, an oak is often designated at a distance of at least 15 metres from all quality wood material.

* Medium Wood: 27,5-47,5 cm diameter. Large Wood: >47,5 cm diameter.

Distances between target trees and the rest of the stand

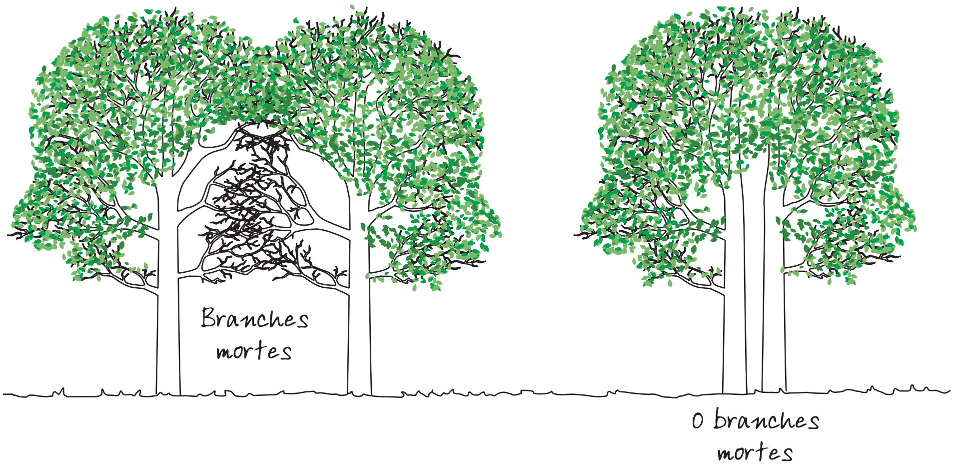


INSERT 16

TREE PROXIMITY

A group of trees (two or more trees) can be very close to each other and grow together without getting in each other's way, harming each other, or even causing flaws in the quality of their wood. This situation occurs when the trees in the group have grown close to each other since their youth and, due to the lack of light inside the group, have only developed branches on the outside of the pair. This group of trees is recognised in the field by its single crown and must be considered a single tree when marking trees for selective felling.

In the case shown here, the beech grew next to an oak that began growing before the beech (Westerwald, Germany).



Example of a group in which proximity is detrimental. In this case, there may be flaws in the wood (off-centre pith, reaction wood).

No branches, whether living or dead, inside the group. Note that in this case the different sides of the tree may be of different quality. Wood buyers must take account of this by considering one side to be of good quality and the other to be of lesser quality.

to observe the forest's regeneration and measure the pressure exerted on it. What is more, the degree of pressure to which the regrowth is subjected can reach such levels that the regrowth disappears altogether, preventing all measurement of this pressure. Finally, this absence of regeneration can be explained by other factors that are harder to identify than the 'tooth marks' of game. These include immature stands, soil compaction, invasive vegetation, etc.[21]

When it comes to the type of regeneration, the impact of roe deer, for example, is completely different depending on whether natural regeneration or plantations are involved. The destruction of 1,000 seedlings/hectare is not very visible in natural regeneration of 100,000 seedlings/hectare, but is catastrophic in a plantation of 2,000 seedlings. What remains, both in absolute numbers and in spatial distribution and quality, is what is important.[15]

Thanks to the diversity of niches that it offers, the irregular forest is, on the whole, an extremely favourable biotope for game. However, the sensitivity of the irregular high forest to exaggerated herbivore over-density is just as great as that of a regular high forest. Saplings grow more slowly in the waiting room than in full sunlight; they are consequently exposed to the herbivores' teeth for many more years than saplings growing out in the open.[15]

As explained before, renewal can also be achieved by a relatively small number of saplings in an irregular high forest. However, if these few saplings are destroyed, continuity is no longer guaranteed. AFI's results show that overpopulation by deer jeopardises in a great many cases the achievement of sufficient, diversified regeneration. This is also true in regular high forests when regeneration is concentrated in a specific area or over a given period.

Finally, let us also say that the normal deer densities are also the most favourable for the health, condition, and reproductive rates of the animals themselves.

INSERT 17

ENCLOSURE/EXCLOSURE EXPERIMENTS

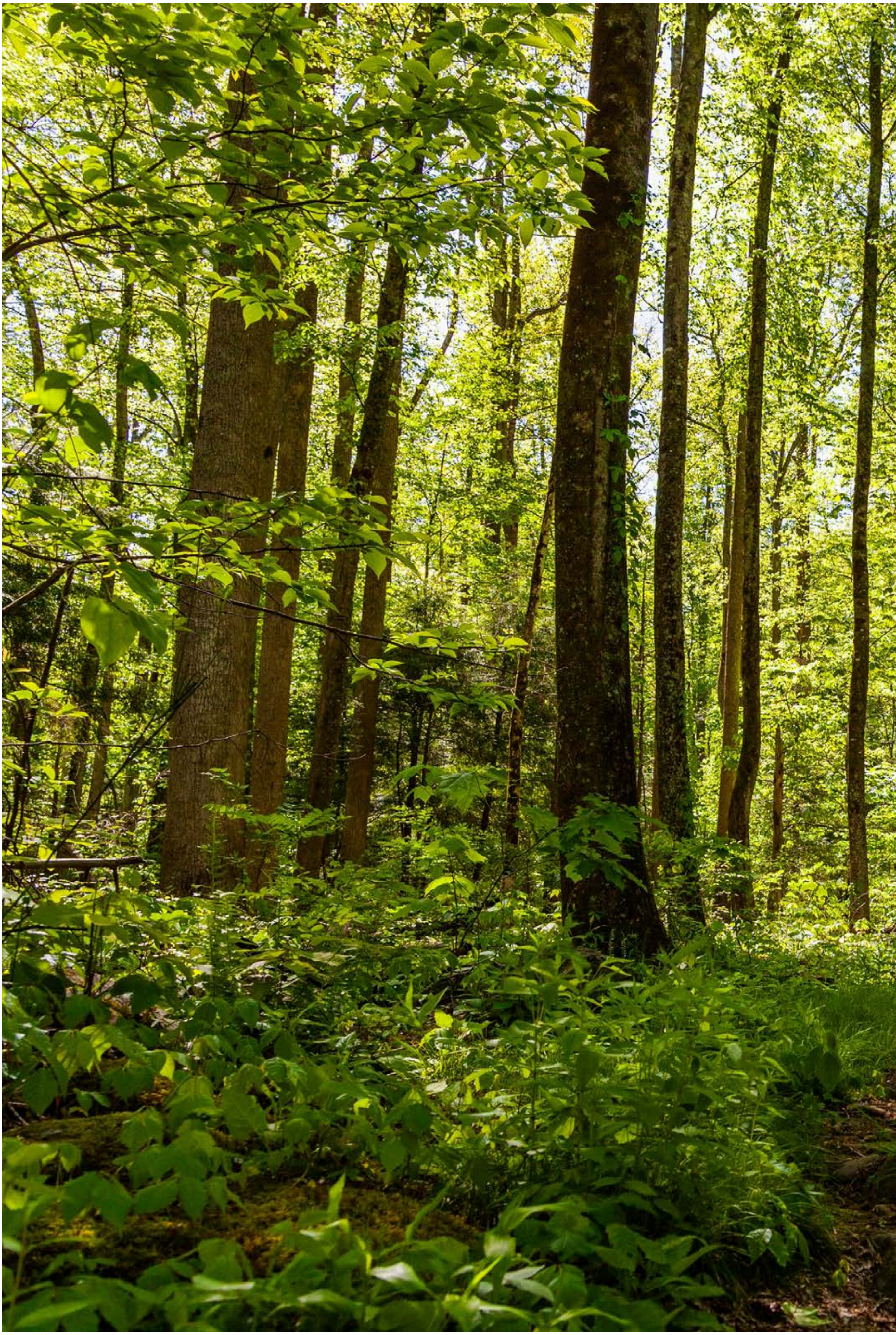
Enclosure/exclosure experiments enable one to observe the dynamics of stand regeneration in the absence of herbivores. They can thus reveal situations of imbalance or provide early detection of any deterioration in a situation that was initially deemed acceptable. Such fencing lets one visualise the effects of game, assess this balance, and see which species are potentially suited to the site.

Enclosure/exclosure arrangements are a useful way to argue the case with the woodland's owner and to get an objective picture of the flora/large fauna balance on a territory.

The principle of the enclosure/exclosure experiment is to compare the real environment (outside the enclosure) that is completely accessible to the large animals present in the study area and a 'control area' (enclosure) that is inaccessible to all or some of the ungulate populations. A good balance is considered to be achieved when the state of the flora is similar inside and outside the enclosure.

Enclosure/exclosure experiments are undeniably useful for teaching purposes, as they reveal, side by side, two situations that may contrast greatly. A protocol[21] for setting up and monitoring enclosure/exclosure experiments has been drawn up for the specific case of broadleaf forests

Enclosure/exclosure experiment at Odeigne, Belgium.



3 Best practices

The following measures are not specific to Continuous Cover Forestry but are integral parts of this forest management method. They are already integral and are part of current forestry management, whether applied through the Forest Code or internal circulars.

Protecting the soil, water courses, stream banks, springs, spawning grounds, and trees during harvesting operations are already amongst the concerns of Continuous Cover Forestry forest management. With the abandonment of clear cutting, variations in standing volume over time and space are greatly reduced. Best practice in harvesting operations is extremely important, especially the intelligent use on modern harvesting machinery. Concerns linked to soil compaction are topical issues in all forest management methods. To control forest soil degradation, setting up permanent extraction racks is recommended. The SPW published a brochure13 in 2009 precisely to help managers to take the right decisions and to know how to set up a network of racks and tracks.

Retaining veteran trees or trees of high ecological value, and dead trees in situ is in line with the principle of allying economic profitability and respect for ecology and social concerns that is specific to Continuous Cover Forestry forest management. The instructions to follow in this circular are listed below (Insert 17).

When it comes to chemical inputs, Article 42 of the Walloon Forest Code stipulates that the use of all herbicides, fungicides, and insecticides other than the exceptions set by the Government is banned. The exceptions are described in Article 23 of the order implementing the Forest Code.[19]

Generally speaking, Continuous Cover Forestry sees the overall management of woodlands as ecosystem management and in no event are the use of pesticides or fertilisers and reduction of the trees' genetic foundations envisioned.

The long term nature of its production forces the forest to find its own self-defence mechanisms in adaptability, which requires the conservation of its entire diversity. The soil humus compounds that result from the decomposition of underground biomass and the forest litter (leaves, twigs, and small branches) contribute to the forest ecosystem's natural fertility and thus help to replace highly energy-wasteful fertiliser applications. What is more, the continuous cover avoids the nutrient losses from leaching that are typical of clear cuts.[27]

When it comes to the application of game repellents to the heads of young saplings, all chemicals are prohibited in Belgium. Proven alternatives, such as sheep's wool, exist. The DNF's note on repellents recalls that, given the prohibitive costs of protecting regeneration from browsing animals, it would be wiser to adapt the culling targets in order to bring the game population densities down to values that are compatible with the environment's carrying capacity.

INSERT 18

INSTRUCTIONS RELATING TO ARTICLE 71 OF THE FOREST CODE[16]

Dead tres

In broadleaf stands, retain dead trees or wind-blow greater than 40 cm diameter at the rate of two trees per hectare, with the exception of trees of great economic value* and those that are safety threats.

* A tree of great economic value is a tree with at least 3 metres of grade B or higher log material.

Trees of biological interest

Retain one tree of biological interest per 2 hectares. A tree of biological interest is, in order of importance:

- an oak that is more than 65 cm diameter or a tree with a cavity;
- an indigenous broadleaf that is more than 50 cm diameter;
- any other broadleaf deemed biologically interesting.

Trees of great economic value may be excluded*.

Sheep's wool protecting beech and Douglas firs from browsing (Bullange).

4 Transitional or exceptional measures

Certain situations in the field can force the forester to adopt measures that are not compatible with the Continuous Cover Forestry forest management framework. These measures are sometimes necessary, e.g., in the case of a simple transformation (change of species).

4.1 Food patches and feeding

In ensuring the forest/game equilibrium, the creation and maintenance of food patches are not ruled out as temporary measures, but maximum advantage should be taken of fire-breaks, open areas, and existing meadows, which should be developed as naturally as possible. Supplementing the diet by feeding should be ruled out to the extent that this is possible.

The forest management measures that are advocated effectively allow the maximal development of the forest vegetation specific to the site. Improving the territory's ability to support game can have a negative effect if no actions are taken at the same time to keep the game population at an appropriate level, i.e., within the area's carrying capacity. The effects of feeding or providing food patches for game are detrimental to the vegetation in a several hundred metre radius around the area.

4.2 Enrichment planting by groups or clumps under shelter

As indicated in Measure 4, it may be necessary to resort to planting if natural regeneration is not sufficient, proves to be of mediocre quality, or is composed of species not suited to the site. In all events, making an accurate diagnosis will hinge not on foreseeing or acting upon preconceptions regarding such or such a situation, but on observing what is actually going on in the field. This type of special case may be encountered, for example, in the transformation of a spruce stand for which the necessary diversification species are not naturally present.

Where ever possible, planting should be done under the canopy, in groups or cells (seed spots). In this case, natural regeneration will often improve the quality of the planted individuals. Insert 18 gives the example of an experiment conducted in the district of Bullange.

Shelterwood plantations under the canopy are possible, but the trials carried out are not conclusive (high cost, extraction of the adult trees not as easy, etc.). These methods are detailed in the summary of methods for turning spruce stands into irregular forests.[24]

Other methods exist. They include enrichment planting in natural regeneration already in place 5-15 years after the adult trees have been harvested.4 Planting in groups or clumps with lateral shelter (after extraction in strips or by small clear cuts) may also be envisioned as a transitional measure in certain cases.[4]

4.3 Transformation and conversion to mixed irregular stands

The transformation of softwood stands to irregular stands concerns a large proportion of the Walloon Region's public forests and will be carried out relatively frequently in the Continuous Cover Forestry pilot compartments. In this context, transitional measures will have to be applied and a set of general principles, translated into forest management pathways and selective marking instructions, should be followed.

In applying these measures and principles, one must make adjustments for each field situation. There effectively is not one way of doing things. To start with, the manager must set the transformation target and estimate the time that transformation will take. The latter can be highly variable and the estimate may be more or less precise, depending on the objective: 30, 40, 50 years, etc., an indeterminate period, or even a plan in which the Large Wood material will be kept standing as long as possible.

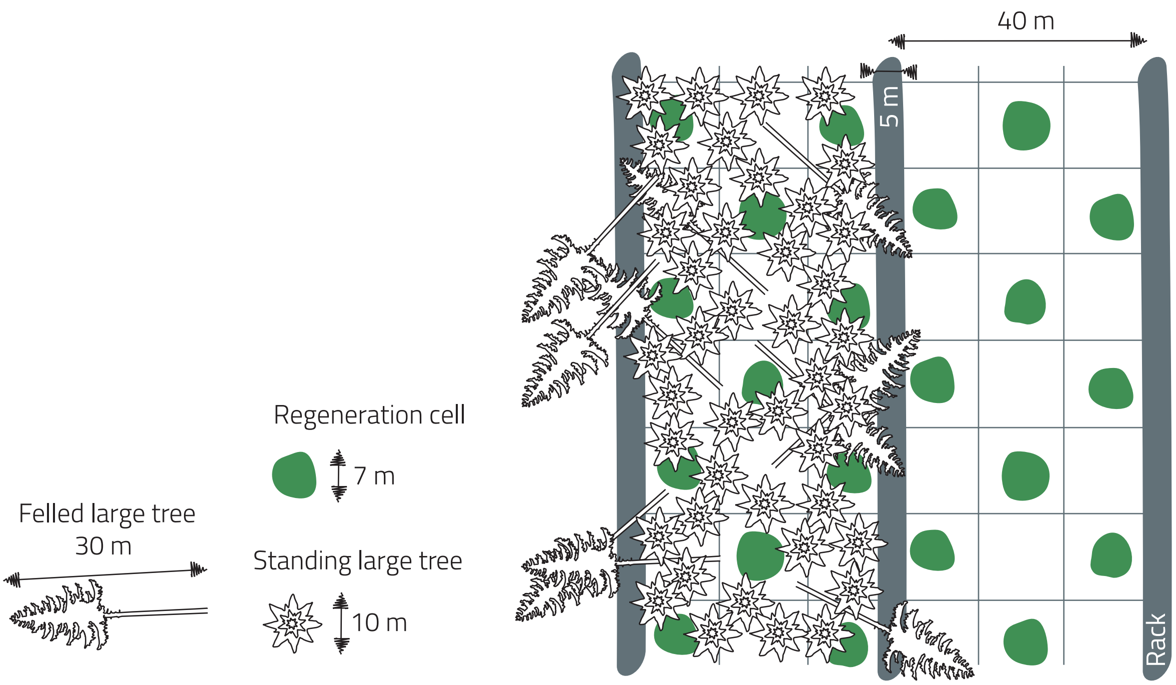
Just as examples, two cases are described in Inserts 19 and 20. The first one concerns a mature spruce stand transformed following selection instructions inspired by several training courses given by the Alsace division of France's National Forestry Office (ONF Alsace).[30, 31] The second one is the case of a young spruce stand transformed according to a target-tree designation pathway.

INSERT 19

EXAMPLE OF SPRUCE STAND DIVERSIFICATION BY SPOT PLANTING IN BULLANGE, BELGIUM

Experience has shown that it is possible to diversify or transform stands by establishing other species in existing stands by enrichment planting. It is preferable to avoid establishing clumps that are too large, on pain of losing the advantages of the proximity of the pre-existing regeneration and the species mixture effect.

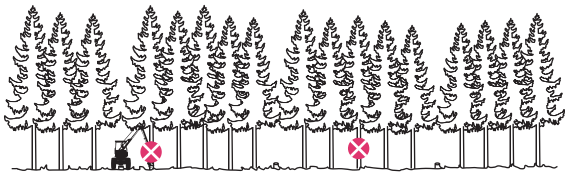
This technique avoids re-stocking by area and provides the advantage of enjoying a forest environment that is favourable for the seedlings' growth and development. The initial investment is recovered very quickly from selective felling within the matrix, and saves money subsequently, both directly and indirectly, since the stems are brought up naturally. Natural regeneration, which is generally facilitated, can even lead to abandoning the system of planting and clear cutting. Harvesting the Large Wood material between the planted cells is likewise easier.



INSERT 20

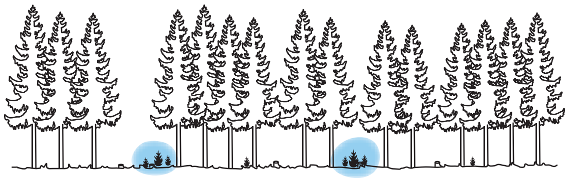
EXAMPLE OF MARKING INSTRUCTIONS IN A MATURE SPRUCE STAND (60 YEARS AND OLDER)

Year 0

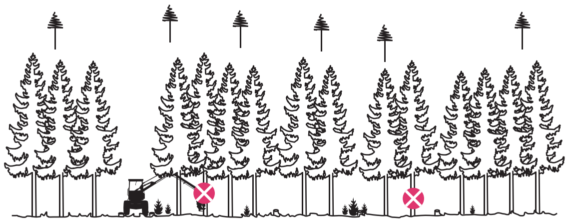


Harvesting: between 4 and 7 m²/ha,
preferentially large trees

Year 5

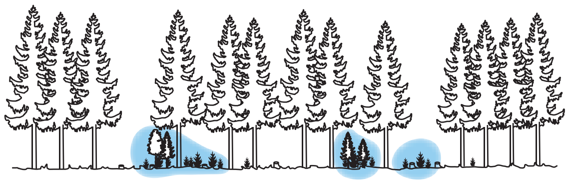


Year 6

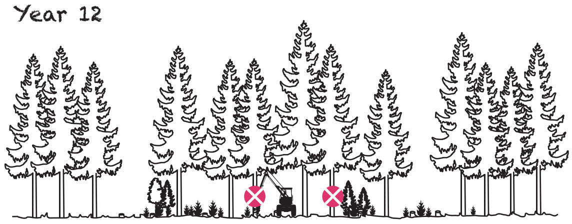


Harvesting: between 4 and 7 m²/ha,
preferentially large trees

Year 11

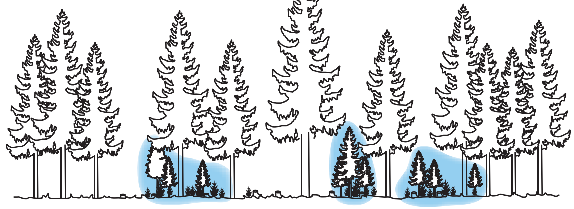


Year 12



Harvesting: between 4 and 7 m²/ha,
preferentially large trees

Year 17



Year 18

Harvesting: between 4 and 7 m²/ha,
preferentially large trees

Year 23

Year 24

Year 29

INSTRUCTIONS BEFORE SELECTIVE FELLING

Principles

Reduce the basal area to within a range that allows good functioning of the stand and regeneration by concentrating selection on a small number of stems

Instructions

- Measure the basal area.
- Refer to the target basal areas per species (see Figure 3, page 14).
- Estimate the quantity to harvest (harvesting yield = annual increment G x Harvesting cycle).

CONSIGNES PENDANT MARTELAGE

Principles

Careful! Moderate each intervention: do not exceed 100m3/ha, 15-20% of the volume, 8-15% of the number of stems.

Do not drop below the lower limit of the basal area range.

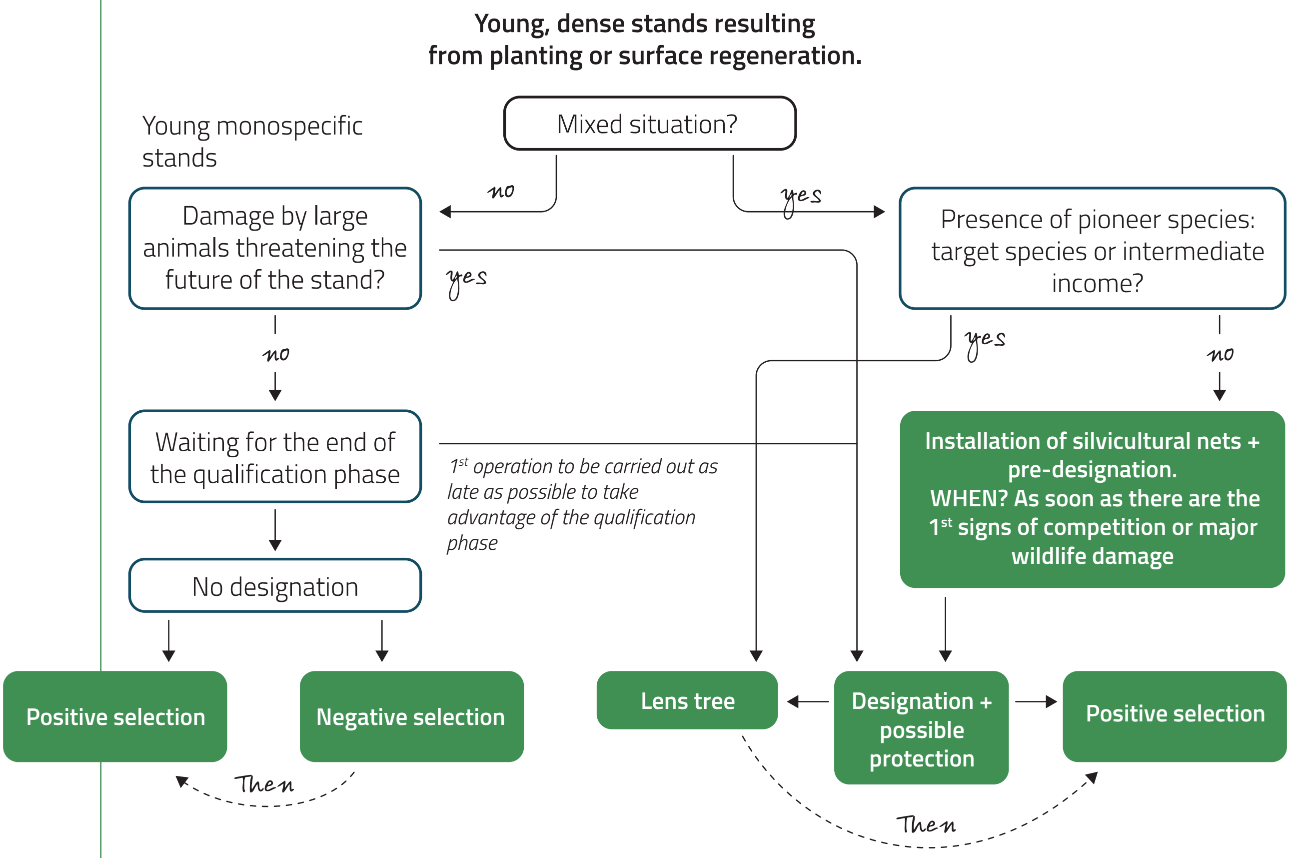
Optimal harvesting intensity: between 4 and 7 m^2.

Instructions

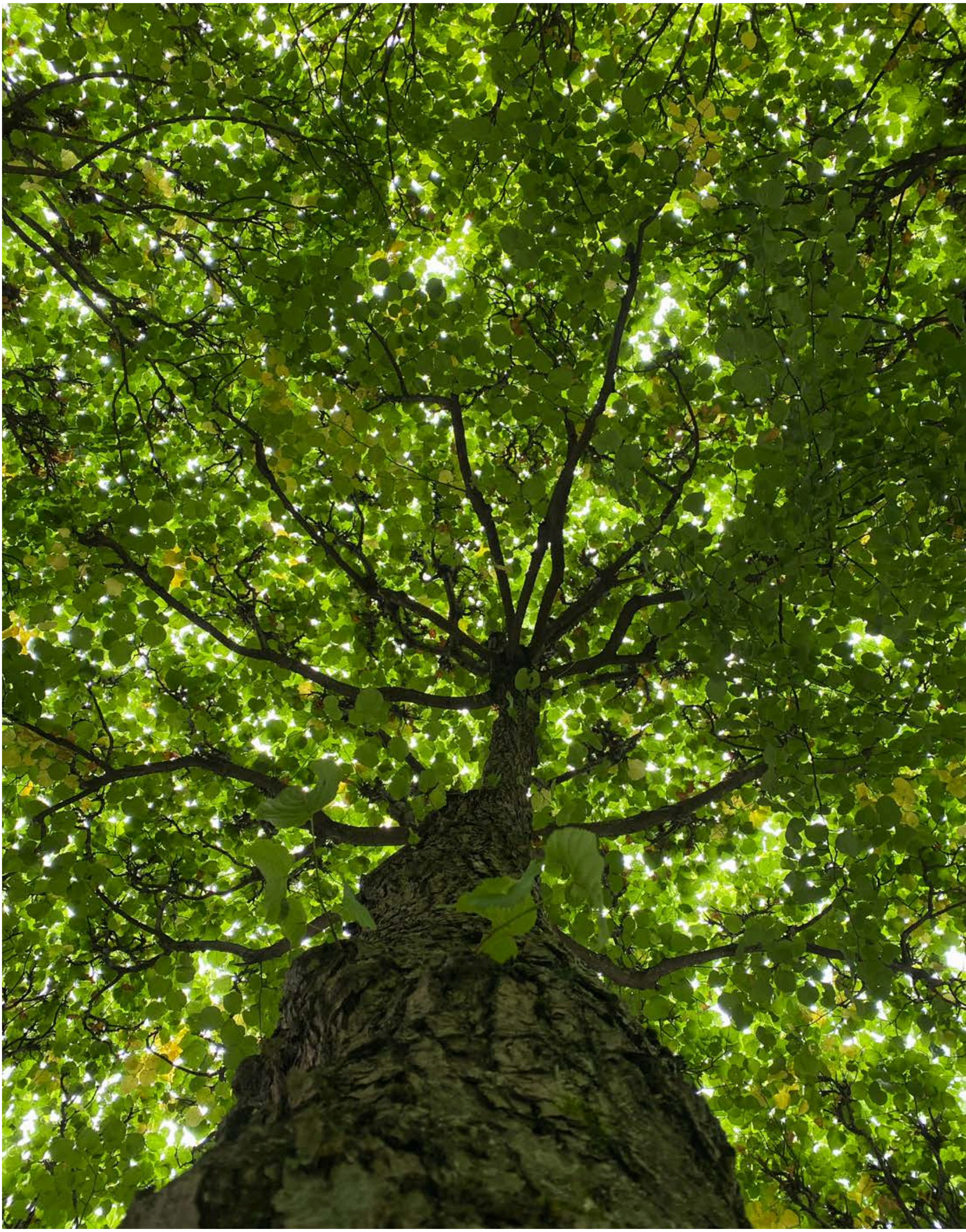
- Extract Large Wood material preferentially (those with risk of disease, quality trees that risk losing value, poor quality trees, and mature quality trees ready for harvest).
- Retain small and thin trees.
- Do not select to favour the spatial distribution of the trees.
- Do not extract locally to favour regeneration.

INSERT 21

EXAMPLE OF A DECISION KEY FOR ADAPTING THE ACTIONS TO BE CARRIED OUT IN YOUNG DENSE STANDS ACCORDING TO THE INITIAL STATE[32]



For more information on the itineraries associated with green boxes, consult the Forêt.Nature training booklet «Martelage en traitement irrégulier». [32].



5 Conclusions

« *The difficulty lies not so much in developing new ideas as in escaping from old ones* »

This statement by the British economist John Maynard Keynes could not be more true in the forest world. Humankind have always used the resources that the forest offered, be it to eat, to keep warm, to clothe themselves, to house himself, etc., and this utilisation has never ceased to evolve with changes in human society and people's needs.

Changes in our needs were the source of modern forest management methods. Europe's populations devastated their forests in the 18th and 19th centuries. With the advent of large-scale coal mining in the 19th century wood charcoal, which until then had been the main forest product, lost its importance in favour of more noble products. So it is that regular high forest methods, which were easy to apply to large, homogeneous areas, spread. Our 19th and 20th century ancestors were thus necessarily 'builder' foresters and used 'mechanical' engineering to rebuild our forests.

Whereas at the time the forest was considered above all to be a method of production, we are forced to acknowledge that this is no longer the case. The forest is no longer a simple reservoir of timber; it has become a natural environment to be protected, a recreational area, a biodiversity conservation area, a landscape element, and so on.

We are lucky, given the current context, even to have the forests inherited from our builder forebears. However, we still have the collective memory of those builder foresters of old, a memory that tells us to 'build forests'. Now, we should use the term 'biological' engineering rather than 'mechanical' engineering to promote our forests' development. This approach begins above all by stepping back, by observing the natural mechanisms at work, and by working frequently and lightly, just enough to direct nature towards a final harvest. We must focus on the harvest and care to take when harvesting.

The drawbacks most often associated with Continuous Cover Forestry forest management are the difficulties of management (lack of clear instructions, difficulty achieving equilibrium, and need for constant observation by the forester), of harvesting the crop (dispersed harvests, relatively low volume per hectare at each thinning, and insufficiently trained forest operators), and of marketing (heterogeneous products and the variety of ages at maturity).

Yet Wallonia's experience has shown that forest managers cope quite well with this situation and can even propose solutions. These solutions include raising the prestige and wages of the forester's job (and job protection); ensuring better forest infrastructure; sourcing the products locally and providing access to market (especially for valuable species), including special clauses in timber sales contracts; and giving more importance to the presence of the district officer or ranger during timber extraction.

When it comes to marketing forest products, the products that come from an irregular stand are obviously heterogeneous in terms of both species and size. An appropriate way of selling them is thus required, at least one that involves the formation of homogeneous lots. The decision to carry out Continuous Cover Forestry forest management clearly entails giving yourself the means to do so.

In conclusion, we have seen that Continuous Cover Forestry forest management cannot be governed by strict rules or rigid standards. The interventions are decided upon in situ and call for observation, understanding, appraisals, and diagnoses on the part of the forestry officers. The latter must have got a minimum of theoretical training but above all they must have acquired maximal field experience, through a further training process, so as to be able to make enlightened choices in all circumstances whilst limiting their intervention to what is strictly necessary.

More broadly, all the professionals who work in the forest, including woodcutters and forwarders, will have to acquire forest management knowledge and skills so as to be able to decide on site, case by case, the direction of felling and hauling paths that will cause as little damage as possible in stands that are designed to persist.

6 How can I get trained in CCF ?

To understand how the ecosystem works, to dose your actions and to acquire the right gestures, you need to acquire complementary skills, whatever your own knowledge and at whatever stage of your career. Forest managers, landowners, naturalists, elected representatives, teachers and anyone with an interest in the forest can learn about CCF by combining various forms of learning (bibliography, practical training in the field, online, etc.).

Askafor

Adapted Skills and Knowledge
for Adaptative Forests

Brochures and leaflets

- Today's forest landscape, with its strengths and weaknesses
- Why go for continuous cover mixed forestry?
- Framework of management principles for continuous-canopy mixed forestry (CCF)

Videos

- Let's discover together a forest landscape of today, with its strengths and weaknesses.
- How can CCF meet the challenges of tomorrow's forests

Technical documents

- Mixed forestry with continuous cover: instructions for use
- Practical guide to encourage mixed renewal in forest stands managed according to the principles of the CCF - Post-crisis restoration

askafor.eu

Mooc CCF

Objectives : to improve the level of information, knowledge and skills of forest managers and owners with regard to CCF in order to have an impact on their practices for the benefit of management adapted to the challenges of climate change.

Key points

This introductory MOOC to SMCC will be accessible to all:

- remotely
- from the field to the learner
- by recognised specialists in the field
- trilingual in English, German and French
- for all private or public managers or owners with a basic understanding of the forest ecosystem and its management
- with a focus on continental, Mediterranean and young forests

This MOOC will be divided into 8 chapters over 8 weeks, each chapter including :

- 1 theoretical video of 20 to 30 minutes
- 3 in-the-field application videos, 5 to 7 minutes long
- 1 field guide for each partner country
- 1 quiz of 30 questions
- 1 60-minute interactive question and answer session

forestmoocforchange.eu

Forêt.Nature

Training
- Theoretical basis of CCF
- Support in setting up the CCF in your fields
- Hammering in irregular hardwood and softwood treatments
- Hammer scopes: assess your hammer blow
- Travailloscopes: targeted forestry work
- Natural regeneration of oak
- Natural regeneration of conifers
- Softwood irregularisation
- Post-crisis management
- Development of forest edges

Online technical bookshop
Forêt.Mail: free monthly press review on forests and nature
Technical **visits and conferences**
Resources and international **bibliography**

foretnature.be

Pro Silva France

Training
- Introduction to mixed forestry with continuous cover
- Description of stands and planning of continuous cover silviculture operations
- Tree marking, timber quality and harvesting. Applications in hardwood and softwood forests
- Plan and implement silvicultural work in mixed continuous-canopy forestry. Theory and practice
- Monitoring and controlling irregular forest management. Inventory systems and permanent plots.

French-language resources and **bibliography**
Newsletters and news
CCF **technical visits**

prosilva.fr

Arbeitsgemeinschaft Naturgemäße Waldwirtschaft

CCF **technical visits** in each Land :
- ANW Sarre
- ANW Rhénanie-du-Nord-Westphalie
- ANW Rhénanie-Palatinat

Newsletters and news

anw-deutschland.de

Pro Silva Wallonie

CCF **technical visits**
Newsletters and news

prosilvawallonie.be

Pro Silva Luxembourg

CCF **technical visits**
Marteloscopes
Newsletters and news

prosilva.lu

Pro Silva Europe

Newsletters and news

prosilva.org

7 To go further

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This instruction manual for the CCF, initially produced and illustrated for the publication of circular no. 2718 by the Department of Nature and Forests (Wallonia) in 2013, has now been updated and republished thanks to the Interreg Askafor project. It is intended for forest practitioners and managers, both public and private, and is a tool based on the silvicultural measures set out in the circular. The booklet has been translated and published in four other languages: English, German, Dutch and Basque within the Pro Silva Europe network.

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