# Forest Planning & Architectural Design

*Developing a*
*Common sustainable practices,*
*monitoring and reporting method.*

Author: Lucas Lafont / Chalmers School of Architecture
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CHALMERS
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## Abstract

Forests provide us with oxygen and purify the air we breathe. They filter water and are our greatest ally when it comes to tackle climate change. In recent years, they have become highly important to help our society to leave a Fossil Economy for a fossil-free alternative. This transition comes with a high and increasing demand on wood products. Forests are under heavy pressure. A new fossil-free economy has to be fully aligned with our environment’s natural dynamics.

Interdisciplinary investigations and active engagement of all stakeholders are needed for the definition of shared international sustainable forest policies. This research has explored theoretical and practical knowledge, tools and methods. The outcome of this project has been developed using research for design method as well as research by design. It has resulted from discussions with architects, builders, forest engineers and researchers. This knowledge have been collected during field studies, in parallel with landscape analysis and mapping. In the meantime, concrete experimentations and practical evaluations have been conducted at the author’s farm.

First, the result of this project has been the writing of a proposal for a common sustainable practices, monitoring and reporting system in architectural design and forest planning. This proposal has been designed as a method shared by the forestry and construction industries to better measure, evaluate and adjust their activities for better sustainability, throughout the processes that involves the architectural project. Second, the method has been tested as part of an architectural project, allowing for deeper investigations on new architectural design and forestry practices. Finally, this project sought for first answers and has intended to open discussions on architects’ responsibilities in latest European forest policies.



*Keywords: Closer-to-Nature Forest Management; Natural resources Planning;*


## About me

My name is Lucas Lafont. Prior to doing a Master’s Degree in Architecture at Chalmers University of Technology, I have done a Bachelor’s Degree at the École Nationale Supérieure d'Architecture of Lyon in France, my home country. In 2017, I graduated with a Bachelor’s Degree in Management.

My academic projects have all approached the relations between trees and forests dynamics to a building, park or neighbourhood, as I am passionate about trees and their place on Earth and our society. This passion came from woodworking, where the material of wood raised my curiosity on trees growing behaviours and spatiotemporal organisations within a forest.

I have a modest professional background in different fields of construction, from groundwork to roofwork. These experience were short term but give me a practical approach on the architectural project in its entirety. From 2018 to 2020, I have been renovating a family farm using material from our lands. This has been the opportunity to develop design ideas in a concrete situation and test them by ultimately constructing the building and its elements.

In 2023, I registered myself as a farmer, using the land my family owns in France. This allows me to be the final decision maker in terms of land management and land use practices of our arable lands, pastures and forests.

## Reading instructions

For a better understanding of the field’s background and author’s approach in relation to the thesis project, the reader is advised to read appendix B after having completed chapter *II. Theories*.

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# I. Introduction

To begin with, this first chapter will state the current situation regarding Forest Planning and climate change, while making connections with the field of architecture. Second, the research topic will be introduced with its aim, delimitations, methods and background.

## A. Climate change: A global crisis

Earth's climate has always faced changes. They happened progressively, over periods from tens of thousands to millions of years. However, these changes were the results of natural phenomenon. Today's environmental situation is different. We are witnessing changes in climate happening at unprecedented rates. For the last 150 years, every decades has led to an increase of 0.1°C to 0.2°C of global mean surface temperature (GMST). In 2017, GMST got to 1.0°C above the pre-industrial period. Depending on the changes of the chemical composition of the atmosphere, mainly the increase of greenhouse gases, and climate sensitivity, GMST could reach 1.5°C above the pre-industrial period in 7 to less than 30 years[1]. Climate change impacts are not gradual but exponential, which make them even more unpredictable. Therefore, this next 0.5°C increase of GMST will have greater impacts on the environment than the previous 0.5°C increase had[2], leading to higher uncertainties. What was consider before as extreme climate events are happening more likely today. Increase in average temperatures of cold days and nights, frequency and intensity of floods, duration of heat waves, or intensity of tropical cyclones[3, 4, 5] are some of the most noticeable effects of recent climate change.

The Earth's atmosphere is composed of 5 layers. From the surface to space we find the troposphere, stratosphere, mesosphere, thermosphere and finally the exosphere. The chemical composition of the troposphere is decisive to find life on the planet[6].

| Gas | Percent by volume |
|---|---|
| Nitrogen ($N_2$) | 78.084 |
| Oxygen ($O_2$) | 20.946 |
| Argon (Ar) | 0.946 |
| Carbon Dioxyde ($CO_2$) | 0.0417 |
| Neon (Ne) | 0.00182 |
| Helium (He) | 0.000524 |
| Methane ($CH_4$) | 0.000187 |
| Ktrypton (Kr) | 0.000114 |
| Hydrogen ($H_2$) | 0.000050 |

Table 1: Main gases found in lower atmosphere as of May 2020.

*(1):* M. R. Allen *et al.*, in *Global Warming of 1.5°C: An IPCC Special Report on the Impacts of Global Warming of 1.5°C Above Pre-Industrial Levels and Related Global Greenhouse Gas Emission Pathways, in the Context of Strengthening the Global Response to the Threat of Climate Change, Sustainable Development, and Efforts to Eradicate Poverty*, V. Masson-Delmotte *et al.*, Eds. (World Meteorological Organization, Geneva, 2018), chapter 1.

(2): O. Hoegh-Guldberg et al., The human imperative of stabilizing global climate change at 1.5°C. *Science 365*, eaaw6974 (2019). DOI: 10.1126/science.aaw6974

(3): O. Hoegh-Guldberg et al., in *Global Warming of 1.5°C: An IPCC Special Report on the Impacts of Global Warming of 1.5°C Above Pre-Industrial Levels and Related Global Greenhouse Gas Emission Pathways, in the Context of Strengthening the Global Response to the Threat of Climate Change, Sustainable Development, and Efforts to Eradicate Poverty*, V. Masson-Delmotte et al., Eds. (World Meteorological Organization, Geneva, 2018), chapter 3.



However, over the last 100 years, the balance of these constituents has varied. As a result of human activities, greenhouse gases such as methane and carbon dioxide have increased significantly. In fact, there is today 50% more carbon dioxide in the atmosphere than there was before the industrial revolution[7]. This change in proportions is impacting the Earth's climate, and so the ecosystems that it supports.

## B. Climate change and biosphere

The Earth is a system that can be decomposed in 5 sub-systems. The atmosphere, mentioned above, is one of them. The hydrosphere includes all water bodies, oceans and groundwater, while the cryosphere contains frozen water elements. The geosphere is linked to the soil, it corresponds to the solid earth. Finally, the biosphere that we are part of, represents all matters and organisms that have not decomposed yet.

Life is characterized by the interaction between organisms, oxygen and carbon dioxide. Since the amount of carbon dioxide impacts the Earth's climate and influence global vegetation growth, it has also an impact on the oxygen amount in the atmosphere. Therefore, carbon dioxide becomes an interesting tool to understand what the links between life and climate conditions are. By studying silver firs in the Vosges in France, dendroclimatologist Michel Becker could notice that over the last 150 years, these trees happened to grow and develop on a faster pace than previous times[8]. Yet, he concluded the studies with the hypothesis that if the increase of carbon dioxide in the atmosphere is the initial factor of a faster growth, it has not a direct effect. In fact, it is not directly stimulating photosynthesis but rather impacts the climate conditions that secondarily affect vegetation growth. Nevertheless, an increase in biomass productivity is possible only when access to water and nutritive elements is secured. With climate conditions changing and unpredictable extreme climate events, it is all the biomes that will have to adapt to a new and unstable environment.

## C. Climate change and forests

Trees are one of our best allies when it comes to tackle climate change. First, through the process of photosynthesis mentioned above,

(4): IPCC, *Climate Change 2013: The Physical Science Basis. Working Group I Contribution to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* (Cambridge Univ. Press, 2013); www.ipcc.ch/report/ar5/wg1/.

(5): M. D. Risser, M. F. Wehner, Attributable Human-Induced Changes in the Likelihood and Magnitude of the Observed Extreme Precipitation during Hurricane Harvey. *Geophys. Res. Lett.* 44, 12457–12464 (2017). 10.1002/2017GL075888

(6): Pidwirny, M. (2021, April 15). Laboratory 3: Atmosphere composition, pressure, and circulation. Physical Geography Lab Manual The Atmosphere and Biosphere. https://pressbooks.bccampus.ca/physgeoglabmanual1/chapter/lab3/

(7): Lindsey, R. (2023, May 12). *Climate change: Atmospheric carbon dioxide*. NOAA Climate.gov. https://www.climate.gov/news-features/understanding-climate/climate-change-atmospheric-carbon-dioxide#

(8): Becker, M., Landmann, G. & Lévy, G. Silver fir decline in the vosges mountains (France): Role of climate and silviculture. Water Air Soil Pollut 48, 77–86 (1989). https://doi.org/10.1007/BF00282371

forests are a main actor in the regulation of oxygen and carbon dioxide in the atmosphere. Second, the total surface of forest around the world impacts Earth's planetary albedo. In addition to that, when it comes to rainfalls, forests play an important role with the process of evapotranspiration.

Yet, they are under three main types of threats. First, there are abiotic risks, from non-living parts of an ecosystem. Second, the biotic risks come from living being within an ecosystem. Third, anthropic activities such as land use practices have a direct impact on forests health. Hence, in order to reduce these risks, two factors have to be considered: the forest cover surface, and forest management models.

Forest's development follows four stages: stand initiation, stem exclusion, understory reinitiation and old-growth. Ecologically, a forest reaches maturity right before it enters the final stage of old-growth. A mature forest shows diversity in height and structure, and in its stories composition. Its carbon dioxide balance is close to net zero. Productive forests are following the same stages, with the difference that instead of decomposing slowly on site, mature trees will be extracted to be transformed into products. Regarding of the lifespan of the final product, carbon dioxide originally stored in wood will be released in the atmosphere more or less rapidly.

## D. Forest management and current challenges

Since the Neolithic, forests' structures have evolved alongside our societies and have been shaped by our needs. Pressure on forests fluctuated over time with demographics and manufacturing. With the industrialisation era came artificial, monospecific and even-aged planted forests structures. Coppice-with-standards and short-rotation predominated with species being favoured to the detriment of others. Natural, heterogeneous and dynamic forests have slowly been replaced by such plantations. The natural structure of primary forests progressively gave way to a rationalized structure based on human needs. Forests started to be overexploited and regulations became necessary. In 2020, 75% of European forests have an even-aged structure[9]. Forestry favouring artificial structures have noticeable impacts on forests' health and ecosystems. It affects forest stability, resistance and resilience to climate change led traumatic events such as droughts, wildfires, disease and pest outbreaks. It decreases species diversity, both in terms of flora and fauna that rely on specific species and tree states and forest growth stage. This can be explained by the homogenisation of the forest that lead to a lack of old components

(9): European Commission, Directorate-General for Environment, (2023). *Guidelines on closer-to-nature forest management*, Publications Office of the European Union. https://data.europa.eu/doi/10.2779/731018



such as deadwood, habitat trees and old trees. The simplification of forests structure also alters the spread of underground fungal communities, having ultimately a negative impact on forest's natural regeneration capacities.

In addition to the issues mentioned above, forests are suffering stress resulting of human activities with forestry and agricultural practices. The expansion of agricultural fields and built environment leads to forest fragmentation. The way we harvest forests causes carbon release in the atmosphere, mainly coming from soil erosion and humus disturbance. Forest soil is subject to compaction and rutting, having impacts on water flows and retention. If forest management approaches are changing with the recognition of environmental and socials values of forests, there is a need for a transition for sustainable forestry practices.

## E. Alternative forest management practices

In 1669, Jean-Baptiste Colbert issued a forest ordinance in France. At the start of the 19th century, the first forestry schools were born, and different forest management theories started to emerge. When Germany opted for clear-cutting methods, models based on natural regeneration and selected harvesting were defined in France with Etienne-François Dralet and Adolphe Parade. Research on forestry started in the late 19th century with diverging opinions and debates. Adolphe Gurnaud presented his Control Method at the Universal Exhibition in Paris in 1878. Henri Biolley implemented this method in the forest of Couvet in 1890, which has been managed under this method to this day. In 1875, Karl Gayer defined the principles of "Natural Forestry". In 1900, Arnold Engler first introduce the notions of "Closer-to-Nature Forest Management" and "perennial forests". In 1920, after observing the fragility of even-aged planted forests, Alfred Möller published an article on how to manage perennial forests. However, with growing needs in wood, intensive forestry models such as monospecific planted forests have been privileged. Economic needs prevailed on ecological needs. At the start of the 21st century, new knowledge on ecology and climate change have emerged, as well as new society's conceptions and values of forests. In Europe, new regulations are going towards Closer-to-Nature forest management methods, with the New EU Forest Strategy for 2030 as a common framework.

## F. Need of a new common method

Almost 40 years ago, the United Nations Brundtland Commission defined sustainability as "meeting the needs of the present without compromising the ability of future generations to meet their own needs." This definition has become globally a common target in most of disciplines. However, there are still nuances, levels of depth and different interpretations when it comes to define if a material, product, process, project, practice or policy is truly sustainable. In architecture, a wooden building is not inevitably sustainable. From the delivered building to the seed hidden in a pine cone, there are hundreds of parameters, isolated and put together that have to be taken into consideration in order to conclude that in the end, a wooden building is sustainable or not. The theoretical definition of sustainability has to develop into a practical solution adapted to specific fields and context. There is a need of a new method, a solution that ties architectural design and forest planning to ensure that the whole process of building with wood is sustainable.

On one hand, the project of the Master's Thesis is a good theoretical exercise that promotes regular discussions and evaluations during its process. It is a good opportunity to develop ideas around a project from different perspectives and fields of expertise. On the other hand, owning plots of lands and being registered as a farmer is an ideal situation for practical implementations in the fields of ideas developed as part of the Master's Thesis exercise.

The result of the last two years of studies and work can be found attached to this thesis (see appendix B). It consists of a *Proposal for a Common Sustainable Practices, Monitoring and Reporting Method in Forest Planning and Architectural Design*.



## Research question

***How can architects take part in a transition towards Closer-to-Nature forest management in the context of European forests?***

Developing a method within the European forest regulations framework for a common sustainable practices, monitoring and reporting system in Forest Planning and Architectural Design.

## Key learnings from the project

• There are different levels of understanding the method within the field of architecture, depending on agency's speciality.

• The method has greater impacts when architects have full ownership of the project, thus more authority in decision-making, such as in research projects.

• In practice, architects need to show specific curriculum and knowledge, in order to build trust and be consulted to follow the method and lead a private project.

• In the case of a private project, the potential of the method to provide sustainable solutions lies on the client's will to seek for sustainability.

• The method opens to architects the role of process leader in the design of wooden buildings, thus asks for skills in group work management.

• The method closes the system chain by involving different fields around the architectural project.

• If local processing chains are for the most part adapted to welcome the method, local regulations are sometimes not yet fully aligned with the latest European forest policies that frame the method.

• The choice of developing rather than vulgarising the method has led to difficulties in the understanding of the Master's thesis project as part of its evaluation, within the delimitations of this exercise.

## Aim

This research answers the call for collective experimentations and learning on forestry. We all rely on forests. Therefore, every fields of expertise can contribute to this research. New forests' values are being recognised, calling for new scales to work on in forest and natural resources planning. The aim of this research is to give additional tools to read a forest, to add variables to take into consideration in a new adaptive model of forestry, sustainable for all the functions forests provide: environmental, economic and social. Ultimately, the goal is to make wooden building design and construction more sustainable.

## Delimitations

This project is not about turning old growth or primary forests into productive forests, but rather about exploring the opportunities that opens Closer-to-Nature Forest Management. Therefore, it will not focus on improving productive forests profitability as we hear it today.

This project is not about making forests more efficient to answer our material and immaterial needs, but rather about finding ways to adapt our needs to forest's natural cycles and dynamics.

This project is not about adapting forests' structure to our practices, but rather about adapting our practices to forest's natural structure and composition.



## Methodology

This project looks into both theoretical and practical knowledge, tools and methods. Forests' health is everyone responsibility. Interdisciplinary investigations and active engagement of all stakeholders are needed for coherent, sustainable international practices in Forest Planning.

At its early stages, this project has been articulated around design explorations. The first draft of the proposal sought to answer the question *What if clear felling of forests becomes illegal?* Design by research became a valuable method to find relevant knowledge from literature studies on which the first draft has been elaborated from.

A second draft of the proposal aimed to go beyond the first draft by using the challenges encountered in today's context as opportunities for further development of the method. Rather than designing the method around a prohibition of clear felling, the second draft has been designed within the timeframe of the transition from clear felling practices towards Closer-to-Nature forest management. During this second phase of the project, information driven design has been complemented with case studies, focusing on landscape analysis in relation to land use practices. In addition, owning plots of land has enabled research by design, using the farm as a laboratory for concrete experimentations and practical evaluations.

The first version of the proposal, considered as the final version as part of the Master's thesis project, is an upgrade of the second draft, resulting of interviews and feedback sessions with relevant stakeholders. These sessions have been conducted online and in person during field studies in France, Switzerland, Belgium, Sweden, Norway and Finland. The goal was to seek and open the project to knowledge from different fields of expertise, together with architects, engineers, members of the European Parliament, carpenters, biologists, farmers and forests owners.

The need for a transition towards Closer-to-Nature forest management is the opportunity to develop a common framework where knowledge in Architectural Design and Forest Planning would meet. However, if architects have expertise on the built environment, bringing new knowledge on natural environment dynamics would result in a better cohesion in natural resource planning.



# II. Theories

The second chapter gives analytical keys to architects to facilitate spatial understanding of a forest, based on trees' and forests' dynamics. Different scales and timeframes are approached to give a picture of trees in motion. The aim of the chapter resides in the operational value the reader will find in it. Trees architectural characteristics and models are excellent tools for a better understanding of the relations between forest's dynamics, a standing tree, and the material of wood.

## A. Trees: *Fix* vs. *Immobile*

In order to get a better sense of trees' appropriation of their environment, we will in this part reconsider our time frames and scales. Understand how trees are organised in space first implies to analyse their evolution in time, since in biology form is the result of growth, which is the product of time and space. With this, two time frames should be identified distinctively. In fact, if fauna and flora share the same environment, their time scales can differ notably. In his book relating his tropical canopy exploration[10], biologist Mark Moffett finds a distinctive way to describe these two temporalities. The reader is asked to picture themselves in the heart of a tropical forest. Looking to the right, left, above... what is moving around them? Only animals. The flora seems fixed, both in time and space. Let's now speed up time a thousand times its initial speed. A minute of observation turns into eight days. Fauna becomes hardly perceptible, when all the plants in front of us are reaching towards the sky. Flora's organisation becomes suddenly more intelligible. Let's speed up time once again. One minute of observation turns into two centuries. It is now the whole forest's dynamics that we can see in front of us.

(10): Moffett M. W., (1993). *The High Frontier: Exploring the Tropical Rainforest Canopy*. Harvard University Press, 192 p.

This leads us to distinguish the notions of "fix" and "immobile" when we approach trees. In fact, trees are only immobile in the time frame human beings are living within, but they stay fix in their environment. Fix or mobile beings, that is the main difference between fauna and flora. With this, trees' relationships to time and space becomes very different to what we are familiar to.

If time can be seen as the architect of trees, how do they apprehend space? We will now go through tree's anatomy to get a better understanding of their organisation in terms of volumes and surfaces. This approach will set the stage to then introduce architectural models that we can identify for each tree species. This last point is crucial when analysing a tree, to place it in a time scale and its environment.

## B. Trees: *Volume* vs. *Surface*

Trees' anatomy can be divided in two parts with their aerial and underground organisation. Underground parts insure structural and nourishing functions. Tap and lateral roots anchor the tree in the ground. They are the tree's roots frame. On these main roots can be found



rootlets, covered by root hair. These root hair draw water and minerals that are necessary to elaborate the raw sap.

Let's follow the path sap takes in order to describe the aerial parts of a tree. The raw sap is carried through the roots to the trunk. Trees' trunk are composed of layers, concentric circles in a section, with each layers insuring a specific function. From the inside to the outside are found the heartwood (dead xylem), sapwood (live xylem), cambium, inner bark (phloem) and the outer bark. Raw sap travels through the xylem that have small canals. Then, the raw sap leaves the trunk to go to the branches. Trees' branches are structured in the way that the trunk is layered. They progressively divide themselves like the roots, with main branches, secondary and tertiary branches... to end with the leaves. Leaves are also composed of superimposed layers that have a specific role in the photosynthesis. From the top of a leaf to the bottom, we have the cuticle, upper epidermis, palisade where chlorophyll is found, spongy where water and gas travel, lower epidermis, stoma where carbonic gas and oxygen travel, and finally guard cells that are canals that transport raw sap first, then elaborate sap after the process of photosynthesis.

Trees are the sum of complex mechanisms that aim to capture energy such as light, water and minerals, necessary for their survival. Being fix, trees will maximise not their volume but surfaces in order to capture more energy, available in a limited amount. Thus, the volume of a tree corresponds to the sum of these layers and their articulation and complementary dynamics in space.

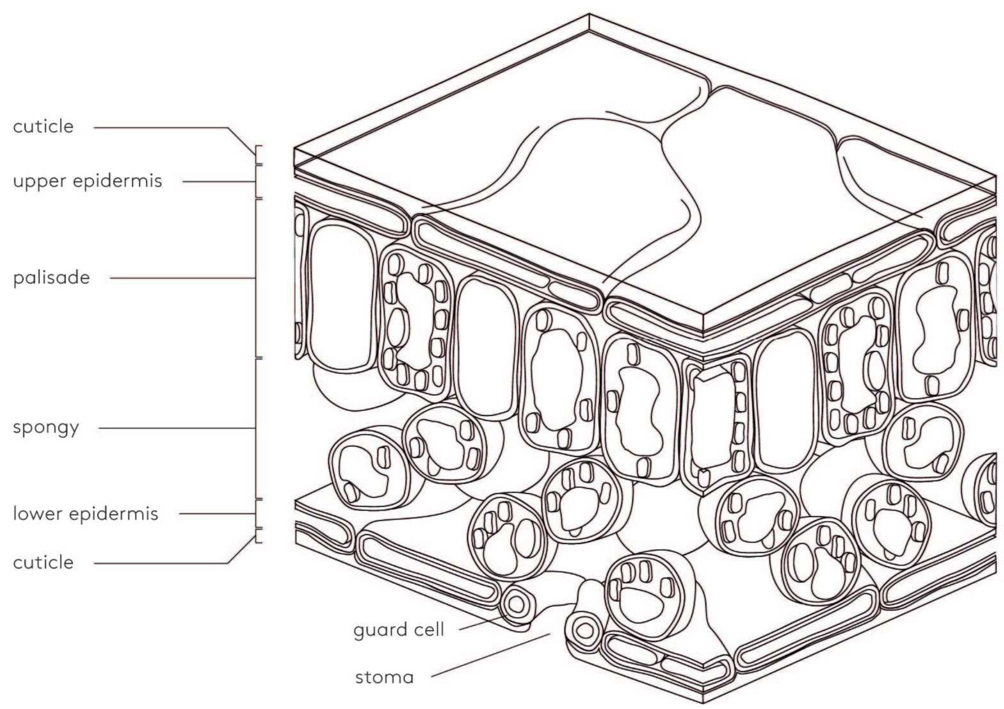



Figure 1: Wheeler R. (2011). Leaf Tissue Structure [Drawing]. https://commons.wikimedia.org

In one of his books[11], botanist Francis Hallé has measured the total surfaces of several trees. These measurements begin with an estimation of the number of leaves and branches of the tree studied. Then, front and back surfaces of a leaf is measured, followed by the measurement of a branch that will be in the end add to the trunk's surface. Roots' and roots hair's surfaces are also taken into consideration. This work being laborious, it has been done on young trees of medium height. Here are some estimations from the book:

- 340 m² for an 8 m tall chestnut tree
- 400 m² for a 3 m tall oil palm
- 530 m² for a 12 m tall spruce

For a 40 m tall tree, an estimation of 10 000 m² for the aerial parts seems reasonable for the botanist, or even underestimated. The underground estimated surface could reach… 130 ha!

This surface representation of a tree differs from the mental picture we make of a tree, where it appears as a volume. Looking at these surfaces above, we can observe that the total surface of a tree increase exponentially depending on the height, so the age of a tree. The notion of growth becomes primordial to take into consideration, in order to make us able to project the picture of a tree we have at a certain point in time. The following part will introduce the notion of architecture of trees, in other terms their form throughout their different stages of development.

## C. Architecture of a tree: architectural characteristics and models

The architecture of a tree consists of its morphology. This notion is not limited to specific parts of a tree observed at a specific time. If fine analyses are necessary and complementary, it is here about observing trees in motion by understanding the forms they adopt in their own time scale.

In the 1960s, botanists Francis Hallé and Roelof A.A. Oldeman have conducted pioneer research on trees' morphologies by studying their forms throughout different cycles of growth[12,13]. This research is known as a global and dynamic approach on trees. If at the beginning studies were conducted on tropical tree species, they inspired other research projects on conifers[14] and temperate climate tree species[15]. The outcome of these research are the elaboration of 24 architectural models. To this day, more than 73 000 different tree species are listed on Earth. All of them follows one specific architectural model. These models correspond of a balance between genetically endogenous rules and exogenous constraints dictated by the tree's environment. It is the result of a process specific to each species that is flexible enough to adapt to the environment in which the tree is growing.

The definition of these architectural models lies on different combinations of architectural characteristics that can be grouped as follows:

- Branching: continuous, rhythmic, irregular or null
- Axes morphology: orthotropic, plagiotropic or oblique
- Axes mode of differentiation: by branching or during the primary or secondary growth
- Flowering location: terminal or lateral

If mathematically thousands of combinations of these characteristics are possible, only 24 have been observed, and to this day, only 7 in temperate climate environments. Figure 2 presents schematic representations of the architectural characteristics mentioned above.

These global and dynamic analyses highlight the different stages of development of a tree throughout its growth, from saplings to senescent trees. They are a key to understand what come from genetics and what is a result of growing in specific environment and conditions. If the final form seems to be the goal of an architectural analysis of a tree, it is as much interesting to analyse the successive forms that a tree will develop throughout its growth. We have discussed previously trees' characterisation in terms of surfaces by exploring their relationships and exchanges with their environment. As a complement, the architectural analysis is an additional key to read a tree and its organisation in time and space.

What are the operational values of these analyses of trees? Knowledge around trees' architecture is still young, especially regarding temperate climate tree species. Still, they become a powerful tool to the ones who can grasp them. They give us keys to read trees at different stages of their growth, to investigate forests' structures at different scales, both in time and space. These keys are fundamental for forestry and forest management, especially when it comes to tackle climate change challenges and become more sustainable. They open new opportunities to (re)think timber quality, forests' biodiversity preservation or forests' social values for instance.

(11): Halle F., (1999). *Eloge de la plante. Pour une nouvelle biologie*. Paris, Seuil, p. 44.

(12): Halle F., Oldeman R., (1970). *Essai sur l'architecture et la dynamique de croissance des arbres tropicaux*. Paris, Masson, 192 p.

(13): Halle F., Oldeman R., Tomlinson P. B., (1978). *Tropical trees and forests: an architectural analysis*. Springer-Verlag, Berlin Heidelberg New York, 441 p.

(14): Edelin C., (1977). *Images de l'architecture des conifères*. Thèse de doctorat en Sciences Biologiques, sous la direction de Halle F. Montpellier : Université des Sciences et Techniques du Languedoc, 255 p.

(15): Millet J., (2012). *L'architecture des arbres des régions tempérées : son histoire, ses concepts, ses usage*. Montréal, 432 p.

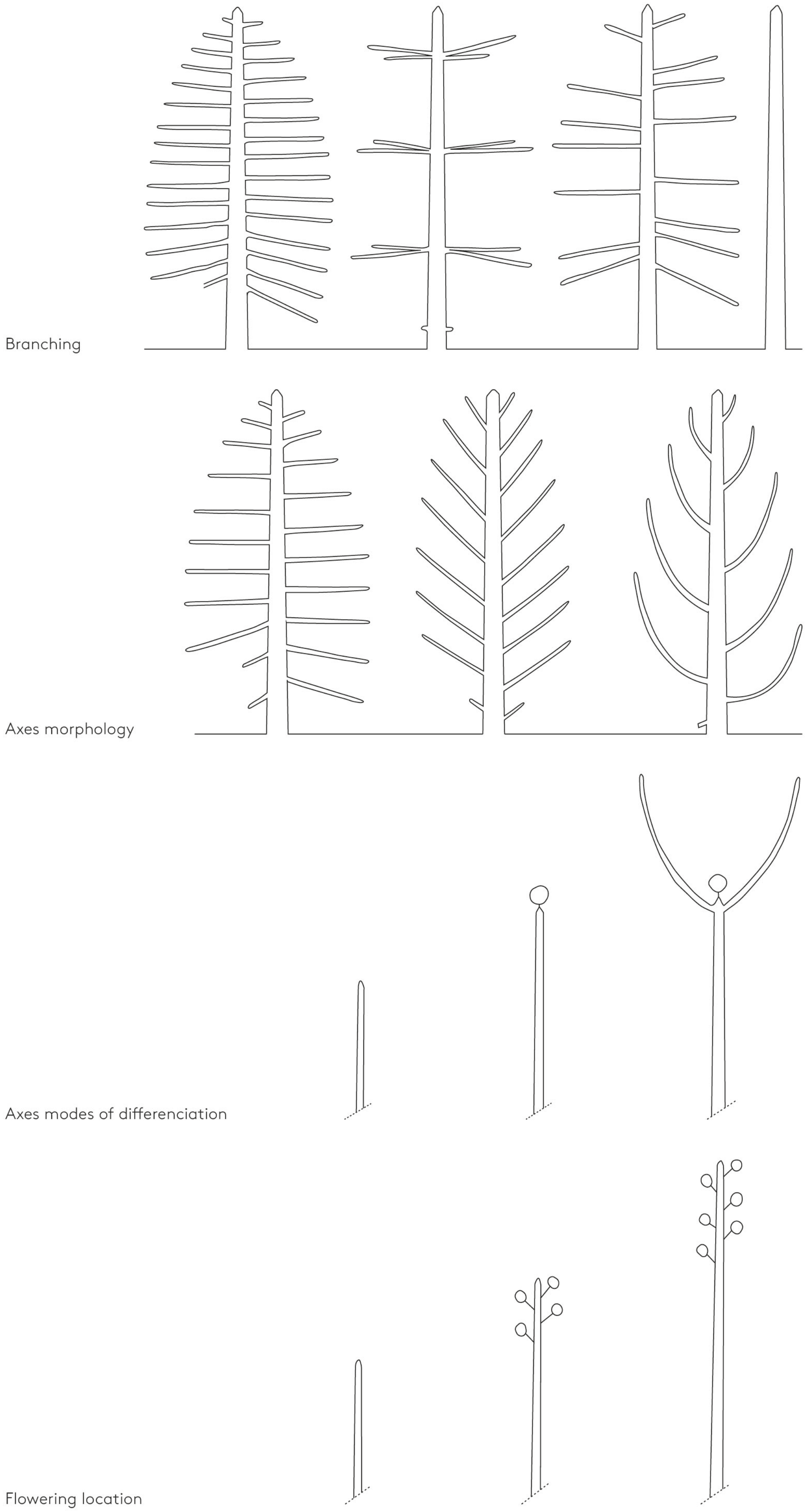



Figure 2: Halle F. (2017 December 19). Des *données récentes sur les arbres par Francis Hallé.* [Video]. YouTube. https://youtu.be/FJgJOkL1AP0?si=PEG2iivRe-_00oMu



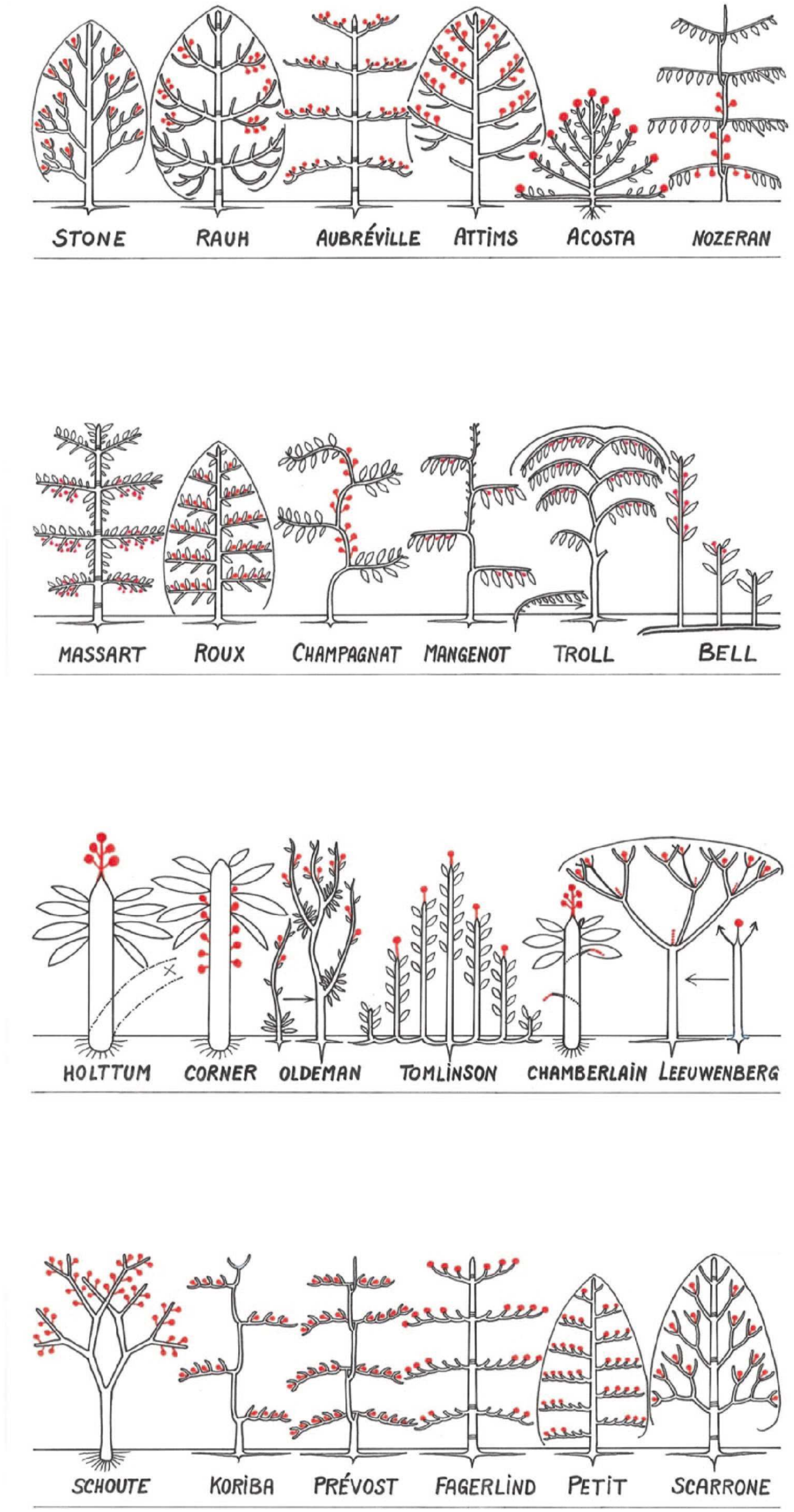



Figure 3: Halle F. (2017 December 19). Des *données récentes sur les arbres par Francis Hallé.* [Video]. YouTube. https://youtu.be/FJgJOkL1AP0?si=PEG2iivRe-_00oMu

## D. Spatial organisation of natural forests

We have seen what are the main structure principles at the scale of a tree. We will now go through the main factors that shape natural forests' structure.

Natural forests' structure is complex, heterogeneous but still harmonious. Their distribution, or distance between each trees, is the enabler of forest's multiple functions and play a big role in forest's ecology. A tree will grow where attraction is greater than repulsion. Attraction consists of regeneration led by forest's dynamics stages of growth, mortality, and recruitment. Repulsion is the result of the competition between neighbouring trees for access to resources such as light, shades or water for instance. At a stand scale, stands' structure is the result of three main factors. First, natural regeneration can take place through different processes such as seed dispersion, development of suckers, sprouts or by layering of branches[16] . Second, microsites will determine conditions for germination and growth. These conditions will be affected by the availability of resources, predation and competition with neighbouring trees. Third, canopy structure regulates the access of light of the forest understory that is crucial for natural regeneration to take place. These are the main factors that shape natural forest's structure. Together with these factors, natural processes and disturbances such as fires, storms, epidemics or senescence for instance, will lead forest's dynamics and play an important role in shaping forests' structure[17].

(16): Koop, H. (1987). Vegetative Reproduction of Trees in Some European Natural Forests. *Vegetatio*, 72(2), 103–110. http://www.jstor.org/stable/20038204

(17): Duchâteau, E., Schneider, R., Tremblay, S., Dupont-Leduc, L., & Pretzsch, H. (2021). Modelling the Spatial Structure of White Spruce Plantations and Their Changes after Various Thinning Treatments. *Forests, 12*(6), 740. https://doi.org/10.3390/f12060740

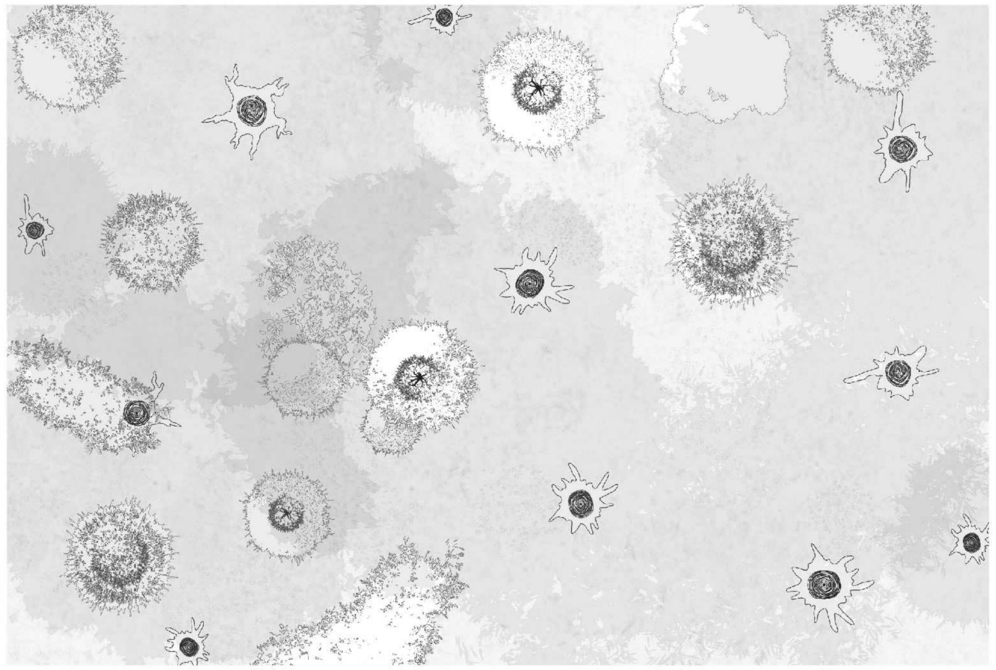


Figure 4: Plan at equilibrium, 5m above ground level (Scale 1:200 - A3)



Figure 5: Section at equilibrium (Scale 1:200 - A3)

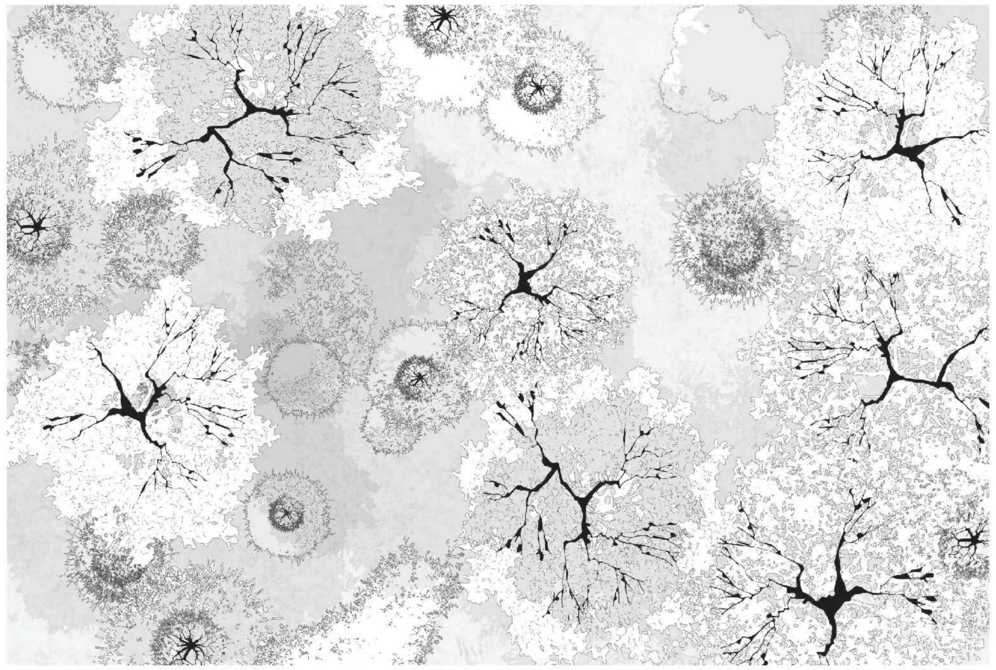


Figure 6: Plan at equilibrium, 25m above ground level (Scale 1:200 - A3)

## E. Spatial organisation of monospecific planted forests

Silviculture in planted forests seeks for maximum productivity in terms of timber production. The goal is to provide to the planted forest the best conditions for it to grow timber, aligned with the desired characteristics of targeted wood products. In the industry, quality timber is characterised by a straight timber with few branches. In a competitive environment, trees individually respond with morphological and physiological adjustments. These can lead to apical dominance, stem and petiole elongation or leaf positioning changes[18] that would alter timber quality. In order to tackle such behaviours, forestry practices seek to manage competition and facilitation forces at a stand level, in other terms, to maximise resource access and use of a stand. Design even-aged and monospecific planted forests allows to distribute homogeneously resources to a stand for steady growth and productivity. In that regard, space is a decisive factor. Follow grid pattern plantation schemes enables to allocate uniformly resources in a defined area. Space is also a factor that has an effect on forest's density and timber production. For example, depending on the station, a monospecific planted forest can be considered as dense when trees are individually regularly spaced by 220 centimetres.

(18): Bongers, F. J., Pierik, R., Anten, N. P. R., & Evers, J. B. (2018). Subtle variation in shade avoidance responses may have profound consequences for plant competitiveness. *Annals of Botany*, *121*(5), 863–873. https://doi.org/10.1093/aob/mcx151

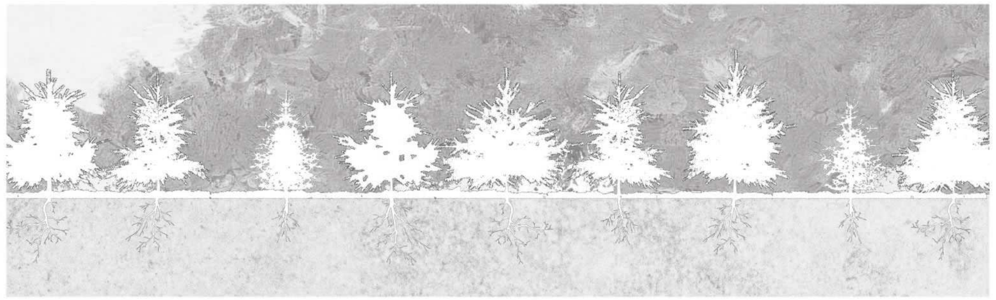


Figure 7: Section, Y5 (Scale 1:200 - A3)

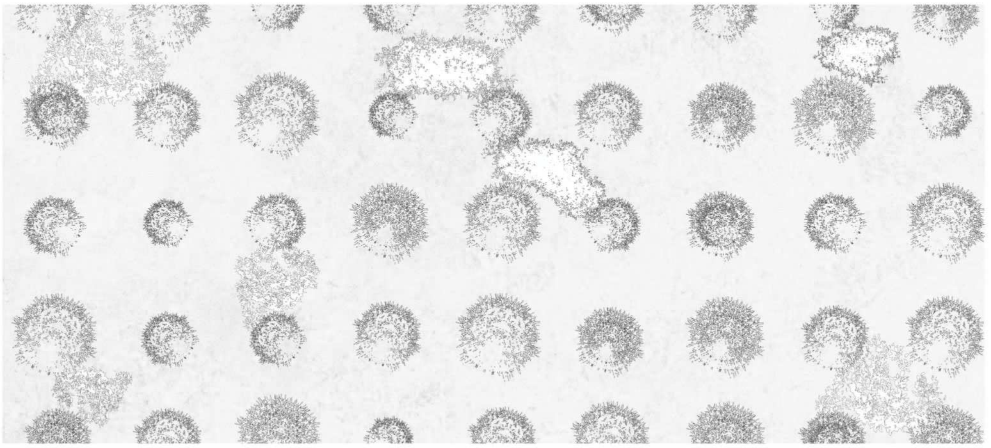


Figure 8: Plan, Y5 (Scale 1:200 - A3)



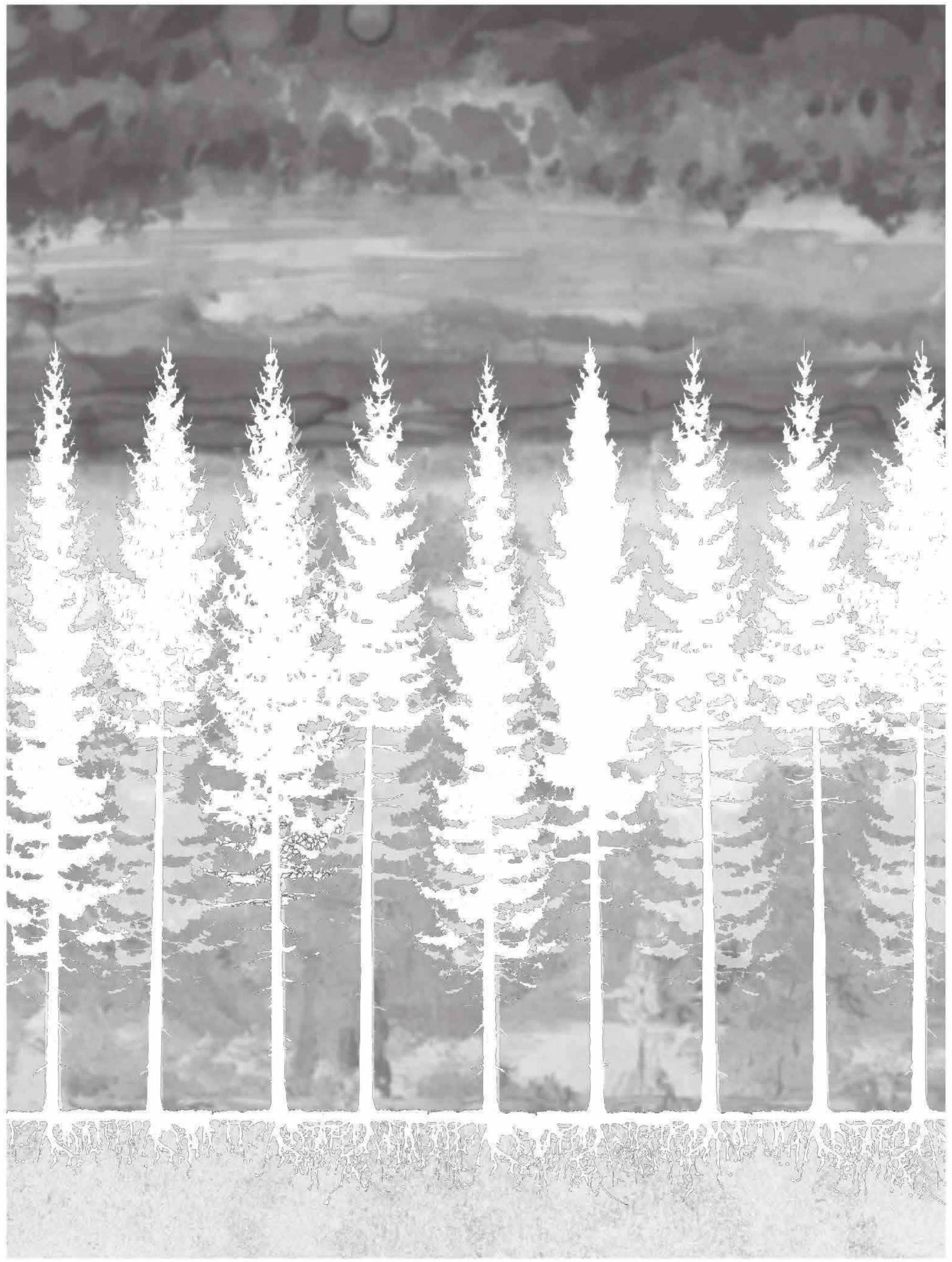


Figure 9: Section, Y60 (Scale 1:200 - A3)

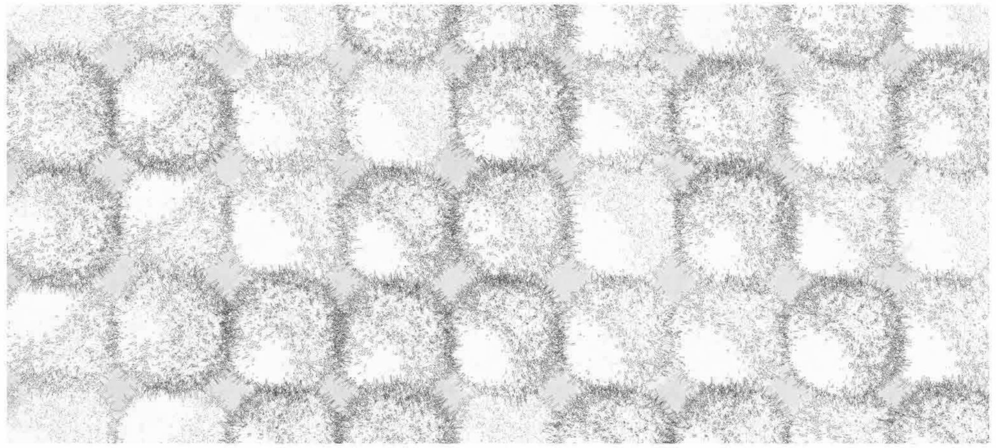


Figure 10: Plan, Y60 (Scale 1:200 - A3)

The variables presented in chapter two tie the fields of Forest Planning and Architectural Design around spatiality and materiality. They helped in the development of the *Proposal for a Common sustainable practices, monitoring and reporting method*, identifying the steps of the process and the roles of the stakeholders involved.



# III. Design

To begin with, the third chapter presents the method overall structure and principles. Then, the chapter highlights the main stages of its development and its respective contributors.

## A. Enabling a transition

In order to support a transition towards a fossil-free economy that operates within environment's sustainable boundaries, a new approach on forestry is needed. If today the industrial sector of forestry dictates forest management practices and provides standardised wood products, new EU regulations are calling for a model where sustainable forestry will determine industrial practices and architectural design.

**Today**

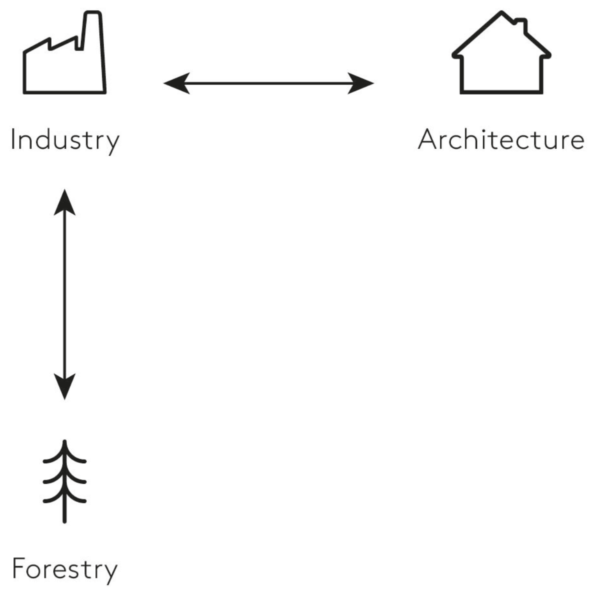



Figure 11: Relations between the Industry, Architecture and Forestry sectors, as it is today.

**Tomorrow**

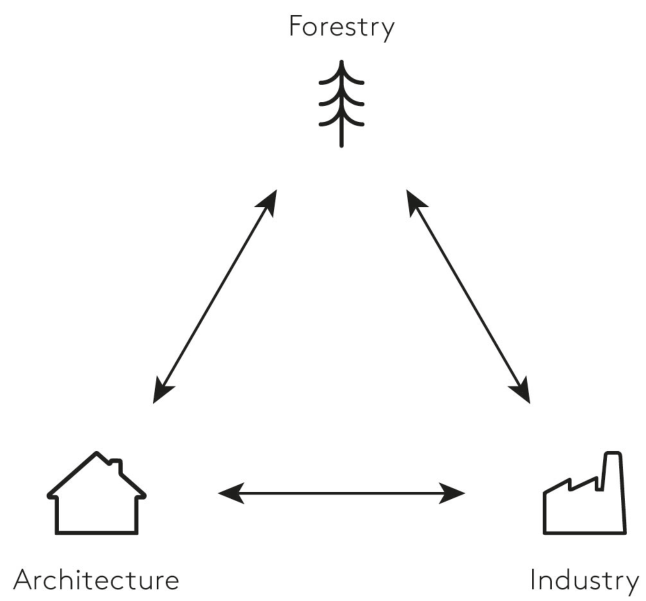



Figure 12: Material and knowledge exchanges within Forestry, Architecture and Industry sectors, based on the latest and upcoming EU regulations.



## B. Proposal's structure

The method developed in the proposal provides a form that will be filled at the start of the architectural project. The form is articulated in four different sections in relation to the main components that are forestry, architecture and industry. Each chapter seeks to detail specific variables involved in the process in order to provide relevant data to ensure clear transparency.

The *Forest* section will be detailed based on the *Tree classification* table's classification keys. The *Architecture*, *Primary processing* and *Secondary processing* sections will be detailed based on the *Wood products classification* table's classification keys.

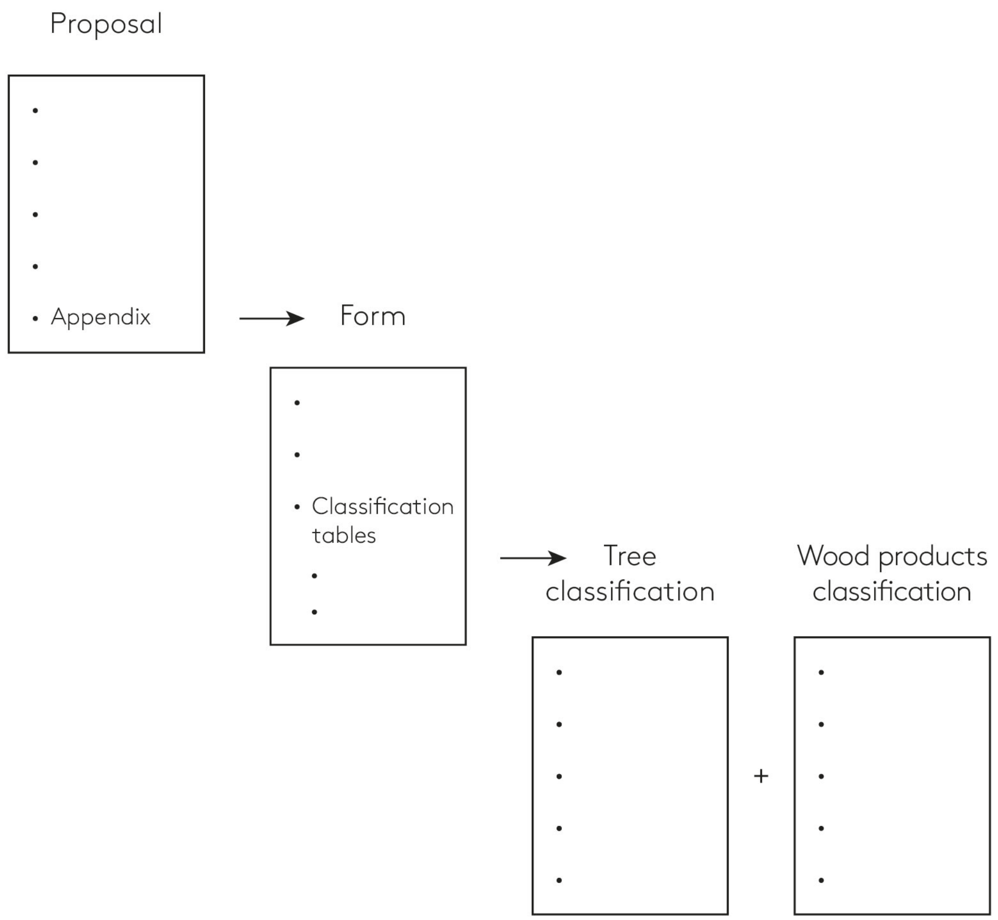



Figure 13: Proposal's branching diagram.

We will now go through the main chapters that structure the proposal, and highlight their features:

1. Why is there a need for sustainable Forest Planning and Architectural Design?

This section first introduces the topic by stating current situation, needs and challenges regarding forest management practices in Europe. Second, it sets the stage for defining the framework of the proposal in the following section.

2. Considerations

This section represents the groundwork of the proposal, based on the European Commission's approach on the topic. First is found a terminology of key terms and notions on which the method lies. Second, the concept of forest management sustainable practices is defined based on the European Commission's Guidelines on Closer-to-Nature Forest Management[19], published on the 27/07/2023. Third is developed a forest management strategy, referring to European Commission's New EU Forest Strategy for 2030[20], published on the 14/07/2021. Fourth, the notion of timber traceability is described providing a jurisdictional framework based on the European Parliament and the Council of the European Union's regulation on the making available on the Union market and the export from the Union of certain commodities and products associated with deforestation and forest degradation and repealing Regulation (EU) No 995/2010[21], published on the 31/05/2023. Fifth are criteria and quality variables established in order to facilitate the report of forests' health in the mapping of the European forests. Finally, this section provides a framework for the mapping and monitoring of European forests and its data management, based on the European Commission's proposal for a regulation on a monitoring framework for resilient European forests[22], published on the 22/11/2023.

3. Objectives

Here are listed the objectives that the method is focusing on. The main objective is to improve sustainability in forestry and design practices. In order to do so, the method bridges the latest EU forest policies to develop a new forest planning practices model, aligned with current environmental, economic and social needs. Based on this model, the whole process of wooden building design and construction is detailed to seek for transparency, especially regarding timber traceability. This would allow ultimately to determine if a wooden building is actually sustainable or not. Wooden building design has to be done within forests' ecological boundaries and capacity of providing raw material, that are defined in the method. Forests' dynamics and natural cycles are taken into consideration in the new forest planning practices model thus allow to maintain healthy forests at an ecological equilibrium. The method also seeks to redefine architects' responsibilities in natural resources planning and uses. This goes along with the implementation of new EU forest policies in the new forest planning practices model, where architects participate in the mapping of the forests that will be harvested as part of the architectural project. This mapping will help to feed a central database that relates past, current and future states of productive forests. The database will give a framework for design thinking, by giving new tools and considerations to enrich the architectural project of a wooden building.

(19): European Commission, Directorate-General for Environment, (2023). *Guidelines on closer-to-nature forest management*, Publications Office of the European Union. https://data.europa.eu/doi/10.2779/731018

(20): European Commission. (2021). *New EU forest strategy for 2030. COM. (2021) 572 final. Communication from the commission to the European parliament, the council, the European Economic and social committee and the committee of the regions.* https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52021DC0572

(21): Regulation (EU) 2023/1115 of the European Parliament and of the Council of 31 May 2023 on the making available on the Union market and the export from the Union of certain commodities and products associated with deforestation and forest degradation and repealing Regulation (EU) No 995/2010 (Text with EEA relevance). (2023). *Official Journal*, L 150, 206-247. ELI:http://data.europa.eu/eli/reg/2023/1115/oj[legislation]



4. General principles

The proposal promotes a method where industrial and design practices are determined from a defined sustainable forest management. Thus, the method is developed around three main components that are forestry, architecture and industry. For each components, a diagram summarising their principles and interdependence is presented figures 14, 15, 16 and 17. This section identifies chronologically the steps that include each components in the process of implementation, defining the general principles of the method.

Forest Planning is seen as a cycle that starts and ends with the mapping of the forest. That is done before harvesting and after harvesting. During this process, a carbon evaluation will calculate the amount of carbon that the forest stores and is sinking in a year of time. A tree classification is made based on the *Tree classification* table's classification keys, reporting criteria and quality variables defined in the sections *2.5.* and *2.6.* of the proposal. From this classification will be done a selection on what should be preserved and what could be harvested, within the ecological boundaries of the forest. Forest mapping involves different fields of expertise, including architects that will report plans, sections and 3D models of the forest. The whole process of forest planning will be monitored at different stages and from different perspectives, in relation to the sectors involved and the environmental, economic and social values of forests.

Architects will support iterations between forests and the architectural project. Their role in natural resources planning will enable direct connections between forest mapping and architectural design. From wood availability, project's needs and wood elements inventory will be determined. Project's carbon emissions will be evaluated and based on the carbon evaluation on harvested forests, will be balanced in 10 years maximum. After the construction of the project, a certification will be granted to the project if it has followed the method in its entirety. The certification scheme still has to be developed.

Industries will support the method by being in capacity to process a wider range of wood types provided by new forestry practices.

(22): European Commission, Directorate-General for Environment. (2023). *COMMISSION STAFF WORKING DOCUMENT IMPACT ASSESSMENT REPORT Accompanying the proposal for a Regulation of the European Parliament and of the Council on a monitoring framework for resilient European forests.* Publications Office of the European Union, 2023. https://data.europa.eu/doi/10.2779/481811

The whole process of wood transformation is divided in primary and secondary processing. Processing ultimately results in the production of structural wood products, paper products or energy. The determination of the different steps throughout the whole process facilitates timber traceability, from the forest to a final product.

5. Targets

This section defines a set of targets as a toolbox to which forest management practices can refer to. These targets seeks to be flexible tools to adapt practices to different contexts, scales and timeline. They are based and put in relation Closer-to-Nature forestry principles with criteria and quality variables defined in sections *2.2.*, *2.5.* and *2.6.* of the proposal.

For each harvested forest, 3 targets will be specifically chosen and guide forestry practices before, during, and after harvesting. These targets will be particularly followed at each forest monitoring stages.

As for evaluation, the evolution of each targets' states will be conducted in relation to guidelines provided section *9.* of the proposal.

6. Benefits

Our view on forests evolves with our societies' needs and demand. Lately, the importance given to the environmental and social values of a forest started to increase, alongside with our awareness on climate change. In addition, with a high and increasing demand on wood products, the economic values of forests are to be considered as one of the main values held by forests. This section goes through the main benefits of the proposal's method on the environmental, economic and social values of forests.

7. Stepwise approach of implementation

This section looks at how the general principles developed section *4.* of the proposal are reported for monitoring in practice through the process of implementation.

8. Ownership

This section discusses the impartiality in the collection and report of data that the method implies. If internal audit is defined as crucial, it will be completed with external audit. Since the method lies on the latest EU forest policies, external audit will be ensured by European government-owned first party audit body. All data collected, audited and shared will be under the ownership of European government.



9. Guidelines

This section defines guidelines for good practices in forestry, architecture and during the industrial processes, aligned with the proposal's method. It specifies quantitative and qualitative delimitations of the criteria (section *2.5.*), quality variables (section *2.6.*) and general principles (section *4.*).

10. Appendix

Finally, in the end of the proposal, the appendix provides the Reporting Form that will be filled at the start of an architectural project of a wooden building. With this form are joined annexes that detail plans and sections of criteria and quality variable mapping, a photographic report of the forest before harvesting, plans of harvested trees, plans and sections after harvesting, and a photographic report after harvesting. Classification tables are provided, with the *Tree classification* table, and the *Wood products classification* table. These will precise identification keys that will be used during the mapping process.

## C. A self-standing proposal

The proposal was initially thought to be integrated in the Master's thesis project's booklet. However, in order to make it self-standing and facilitate its implementation in the fields, the choice has been made to join it separately in the appendix. In the end, the Master's thesis project relates the process of making the proposal. The outcome, appendix B, results of projects and experiences to this day. It represents a first version put into form as part of the Master's thesis project, which will be further developed with author's future professional experiences.

## D. Method's principles diagrams

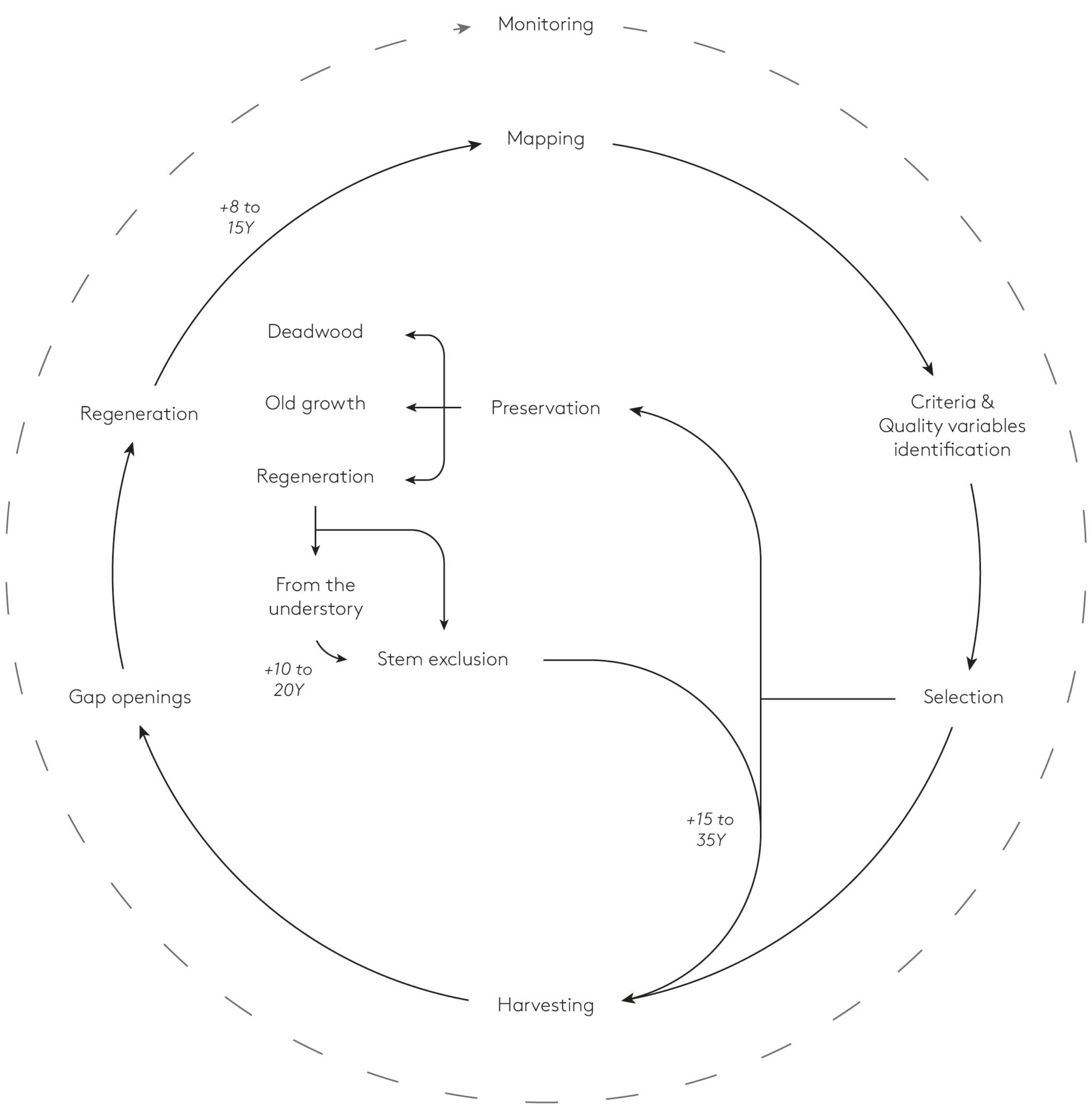



Figure 14: Sustainable Forest Management diagram, following proposal *4.1. Forestry* section's principles.

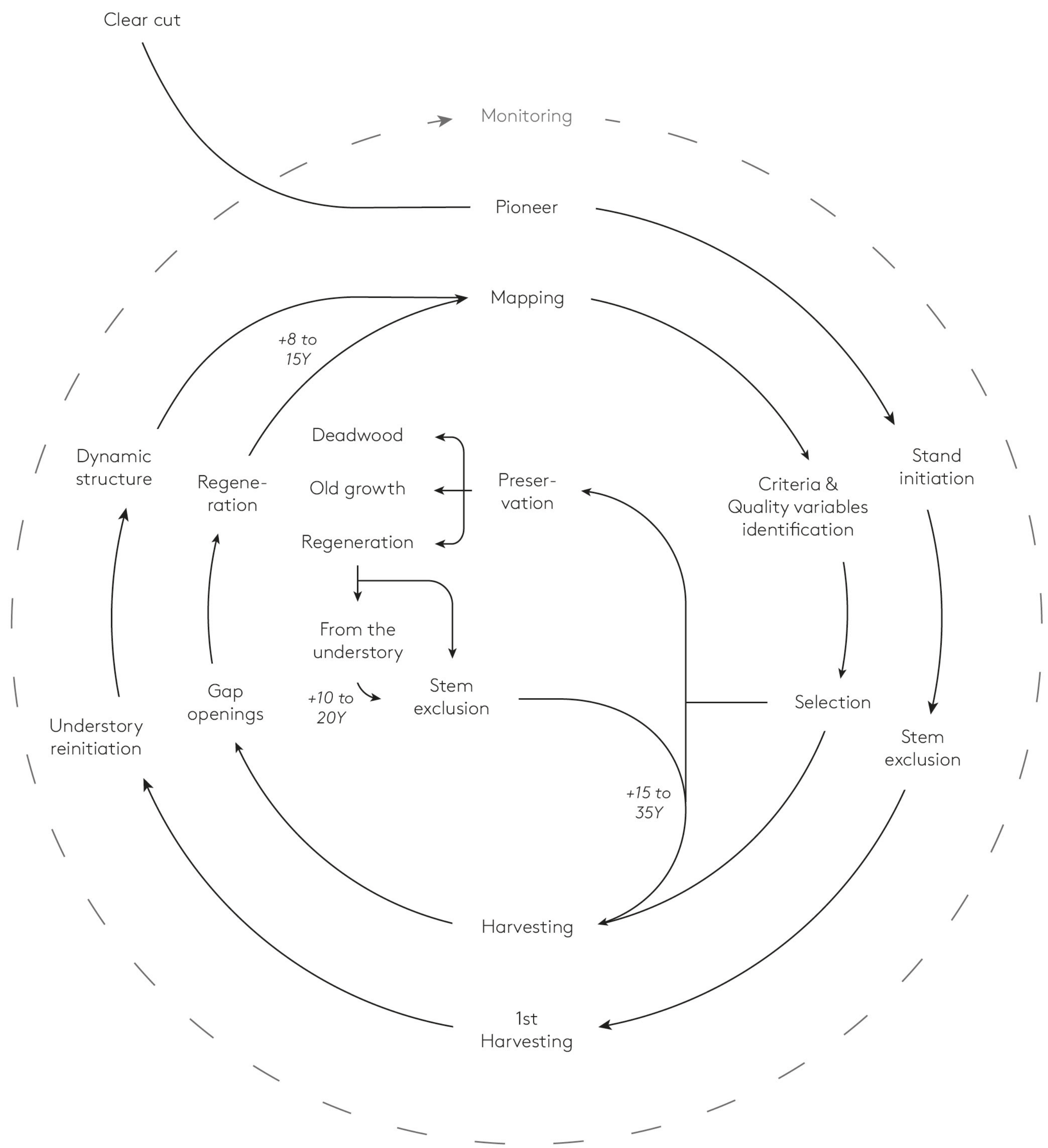



Figure 15: Sustainable Forest Management diagram, following proposal *4.1. Forestry* section's principles after a clear-cut.

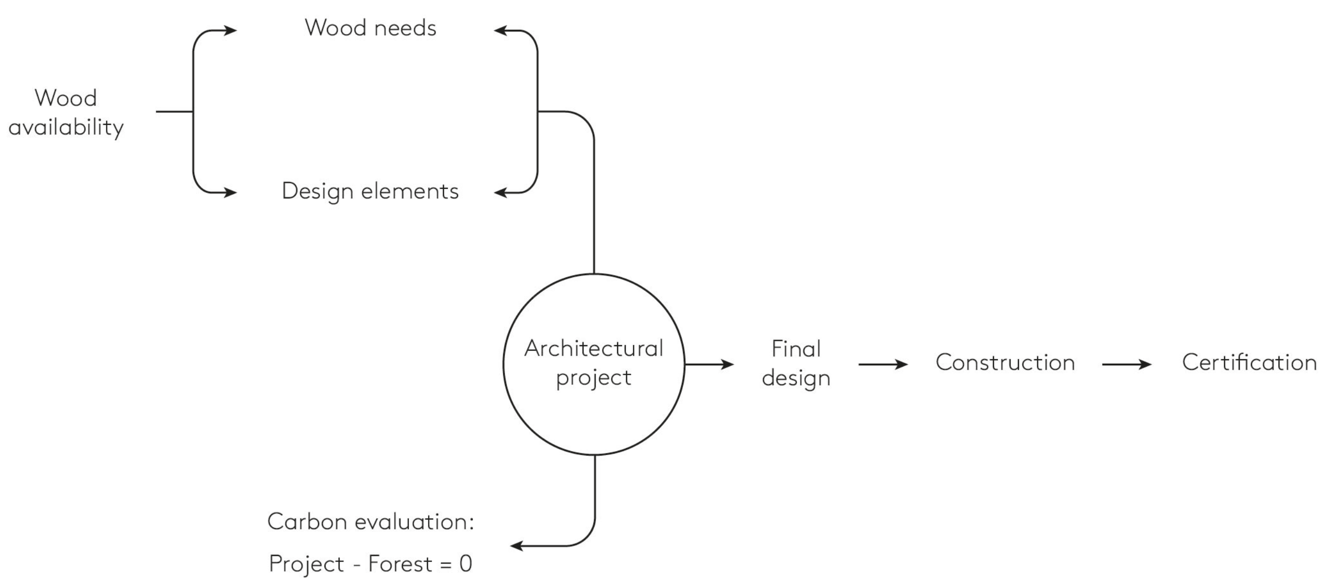



Figure 16: Sustainable design of wooden buildings diagram, following proposal *4.2. Architecture* section's principles.



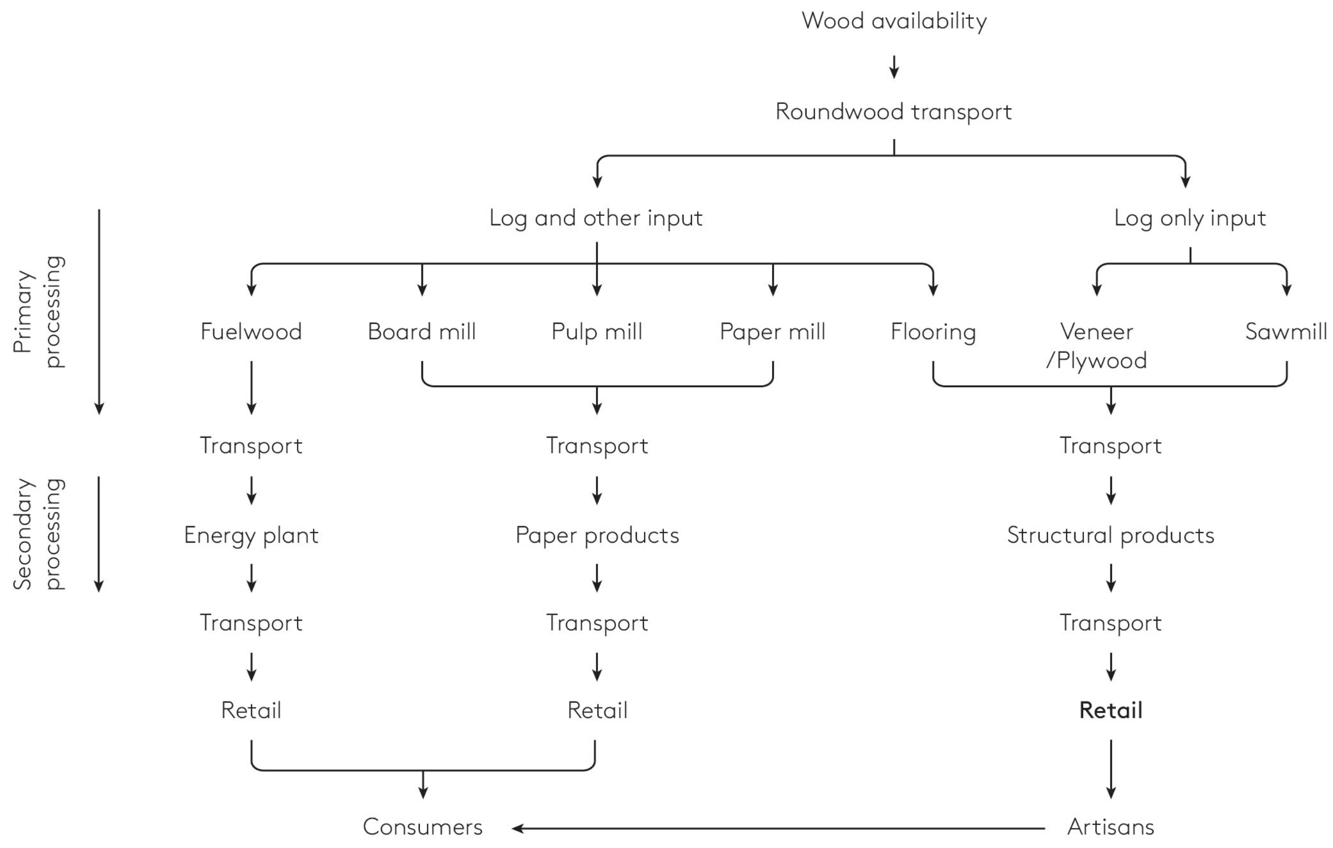



Figure 17: Timber traceability diagram, following proposal *4.3. Industry* section's principles.

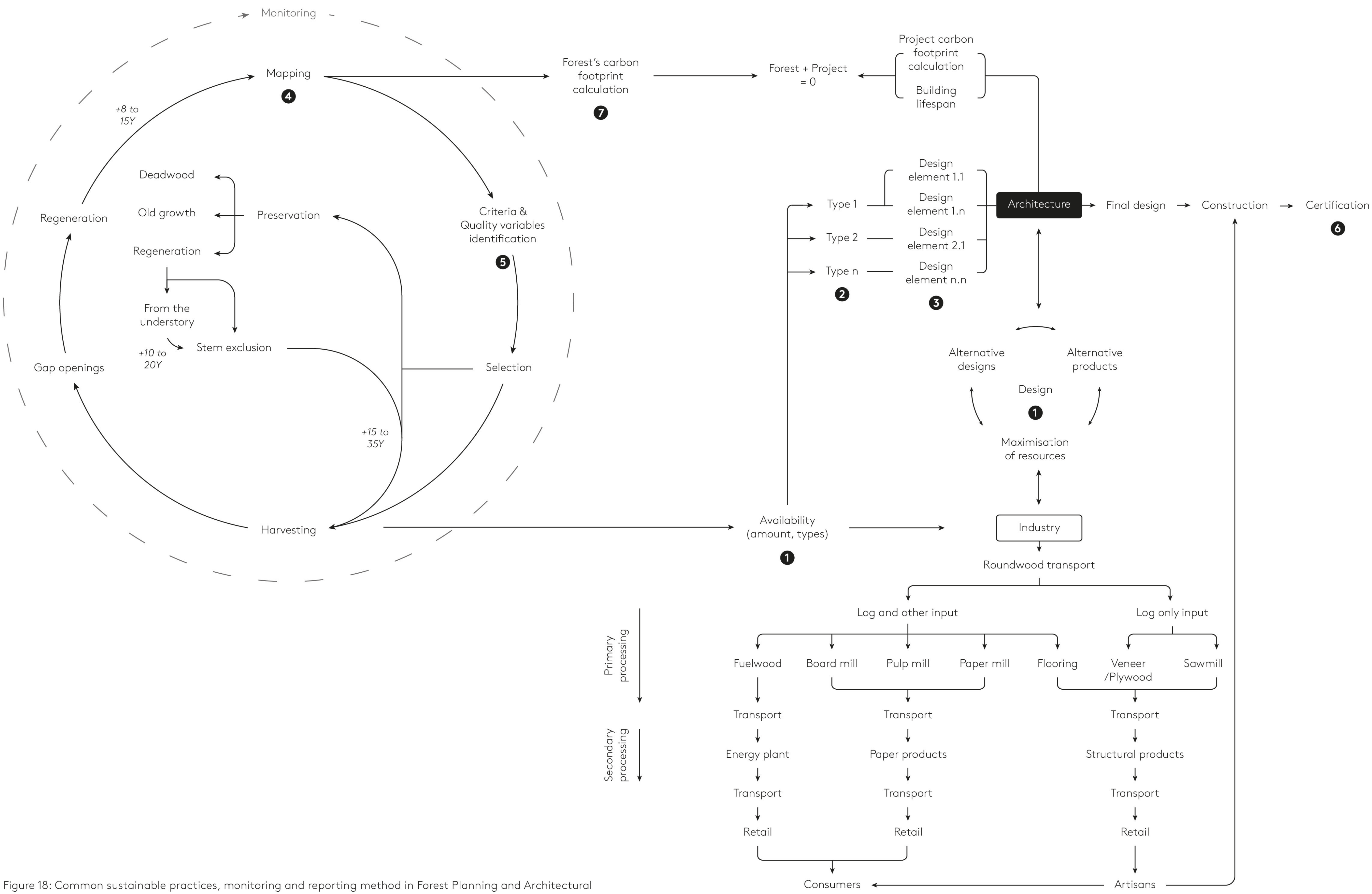



Figure 18: Common sustainable practices, monitoring and reporting method in Forest Planning and Architectural design diagram.

## E. Master's thesis project timeline

**Autumn 2021**

**SEMESTER 5**

Academic urban project. Scale of a tree. Design concepts based on trees' dynamics, for structures and trees to form a single entity.

**Spring 2022**

**SEMESTER 6**

Academic social housing + cultural centre project. Scale of an urban forest. Design concepts based on forests' dynamics, for structures to provide new functions depending on the urban forest current growth stage.

**Autumn 2022**

**SEMESTER 7**

Academic rural project. Scale of a valley. Proposal for sustainable land use practices. Focus on issues tied to how regulations and economic incentives shape forestry and agriculture. Exploration of the Swedish context.

**Spring 2023**

**MASTER THESIS DEFINITION**

Definition of the Master's thesis topic, scope and methodology together with paperwork as part of the farmer registration application.

**06/23**

**FARMER REGISTRATION**

This registration allowed me to become the final decision maker in terms of land use practices and harvested products on my farm's lands.

**Summer 2023**

**1st HARVESTING**

The results from the first harvesting serve as a base of reflection related to a specific context to develop ideas as part of the Master's thesis project.

**Autumn 2023**

**START MASTER THESIS**

1st draft of the proposal. Start of the Master's thesis course. First workshops, seminars and presentations of the project's concepts.

**01/24**

**2nd DRAFT PROPOSAL**

2nd draft of the proposal, ready to be discussed during the study trip.

**02/24**

**STUDY TRIP**

Open the proposal to other fields, add new inputs, values, discuss its structure and relevance. Exploration of the Finnish context.

**03/24**

**PROPOSAL 1st VERSION**

First version of the proposal, following the study trip and mid term critics. This is the final version as part of the Master's thesis, that will be developed alongside future professional experiences.

**04/24**

**THEORETICAL IMPLEMENTATION**

The proposal is tested with a theoretical project linked to the farm, as part of the Master's thesis.

**05/24**

**MASTER THESIS PRESENTATION**

Final presentation of the Master's thesis project together with the method developed in the proposal.

**Autumn 2024**

**PRACTICAL IMPLEMENTATION**

The proposal is tested in the fields following the Master's thesis final presentation critics, and second harvesting of summer 2024 at the farm.

Figure 19: Main steps of the process of defining and developing the proposal.

## F. Method's development

This section of the booklet will detail the main stages in the development of the proposal, from its second draft to its first version, based on interviews and feedback sessions with relevant stakeholders. This work took place from January to March 2024, during which a study trip has been conducted in Finland. Each of the following points are connected to the figure 18.

❶. Wood quality

*Mainly discussed with Marko Huttunen, Juulia Mikkola and Hilda Uusitalo, architects at Livady Arkkitehtitoimisto, and Timo Aro-Heinilä, carpenter at Hirsitikka.*

When opting for Closer-to-Nature Forest Management, wood produced by the forest will present different characteristics than wood coming from a tree of a monospecific planted forest. Spatial and light conditions will have an effect on growth rate, thus on wood density or durability (figure 20). Having architects aware of what the forest can provide, or wood availability, when an architectural project starts can open design opportunities and ignite research on new wood products alongside with engineers. For example, denser wood could provide higher durability for alternative wood products such as wave layered timber (WLT), used in one of Livady's projects (figure 21).

Figure 20: High density material.

Figure 21: Wave Layered Timber (WLT)



❷. Wood types

*Mainly discussed with Juuso Joona, forest owner, agronomist, researcher in Agricultural Sciences and vice chairman of Silva ry, and Timo Aro-Heinilä.*

Forests under Closer-to-Nature Forest Management also provide a wider range of wood types (figure 22). Wood types refers to different sizes and species. Working with uneven aged forests open the capacities for a same forest to provide wood suitable for different structural wood products. Furthermore, selected harvesting in a mixed and dynamic forest enable to work with a larger range in age, with young and old trees. This factor put together with wood quality can give some tools to architects for thinking for alternative options in the design of a wooden building.

Figure 22: Range of wood types resulting of the harvest of an uneven aged forest.

❸. Design elements

*Mainly discussed with Daniel Asp, architect at White Arkitekter, and with architects from Livady Arkkitehtitoimisto.*

When designing a wooden building, draw up an inventory of its wooden design elements would enable iterations between the project and harvested forests. This inventory could include structural elements as well as joineries or furniture. On one hand, forest mapping will give a detailed inventory on the resources a forest can provide. On the other hand, a design elements inventory will enable to establish a first picture of the project's needs on which alternative designs can be elaborated.

❹. Method implementation

*Mainly discussed with Juuso Joona.*

One of the biggest aspect of developing the method has been to define and identify the right action to do at the right time throughout the process. Juuso Joona has currently a project of a barn underway. Timber that is used for the construction comes from Juuso's forests, which were being harvested at the time I have met him (figure 23). Discovering the project at this exact stage could not have been more valuable to develop the method, as iterations between wood availability and design were central at this time of the project.

Figure 23: Harvested log from Juuso's forest.

❺. Method adaptability

*Mainly discussed with Anna Deparnay-Grunenberg, Member of the European Parliament, during the webinar "The future of EU forests – A new EU Framework for Forest Monitoring and Strategic Plans", and Annukka Valkeapää, executive Director at Compensate-säätiö.*

The main objective of the method is to have concrete positive impacts on forests' health while enhancing their values. Thus, the method needed to show practicability and flexibility. Initially, the *Criteria* and *Quality variables* provided by the method were all in the same category which was *Indicators*. An issue highlighted during feedback sessions was that the value of a forest would decrease if these indicators could not be find. In order to tackle that, indicators have been divided in mandatory criteria and quality variables that could be found in different measures in the forest. That point being noticed, numbers had to be given for quality variables to be quantified and measured, while ensuring method's flexibility. This work has been facilitated by the transfer of knowledge from fields outside of architecture, from Nature Conservation, Natural Resource Management and Biodiversity experts.

❻. Certification scheme



*Mainly discussed Annukka Valkeapää and Juuso Joona.*

The first version of the proposal defines the outlines of the method and starts to give factors, variables and numbers that will be reviewed and adapted when the method will be further developed. Make the method part of a certification scheme would give it weight, power and recognition. This could be the next step in the development of the method. Two options could be considered. First, Juuso mentioned that a certification for Continuous Cover Forestry practices was under development. Second, Annukka discussed that the certification could be a next step within existing certification scheme, such as FSC for instance. These are two leads that could be further investigated.

❼. Alternative incomes from forests

*Mainly discussed Annukka Valkeapää.*

Finally, this method integrates in the architectural project other values that holds a forest. By maintaining healthy forests' while supporting our societies' needs, the method favours the development of alternative markets, such as the biodiversity and carbon markets. If financial incentives and payment systems for providing such services are still under development by the European Commission, the method has been developed to welcome in the future the addition of such incentives in the case of productive forests.

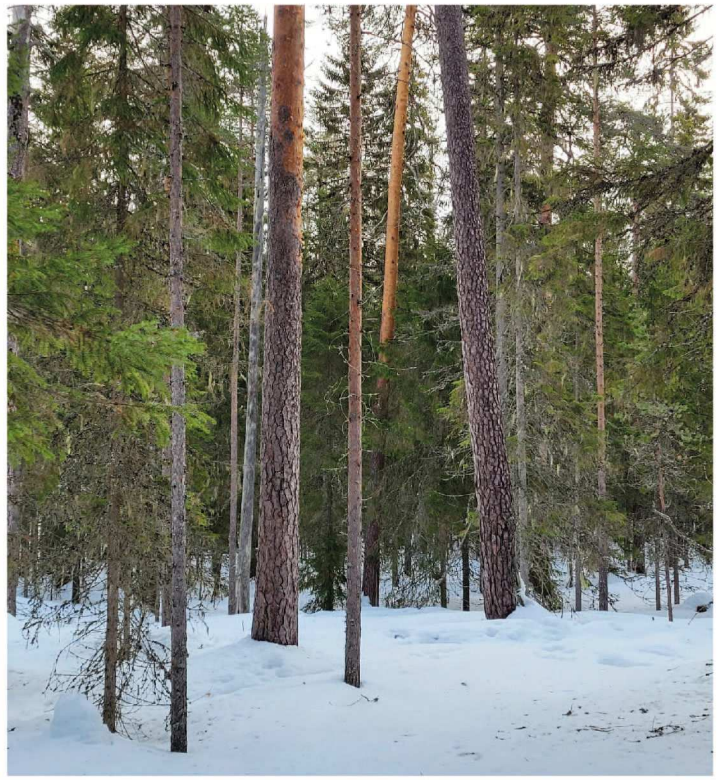


Figure 24: Carbon stored in old scot pines.

The exercise of the Master's thesis gave the opportunity to elaborate and present the first version of the proposal. The student status facilitated the setting up of interviews with practitioners of different fields in relation to Architecture and Forestry, leading to valuable feedback sessions.



# IV. Case study

The fourth chapter introduces the author's farm as the case study. First, the geographical and historical background are presented. Second, the chapter focuses on a landscape analysis, resulting in a land type classification of the farm.

## A. Case study introduction

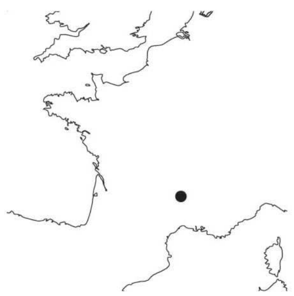


Figure 25: Farm location

The case study is a farm located in Lozère at the heart of the Central Massif, a plateau in France. At an altitude of 1100 to 1200m, the area has a mountain climate with cold winters and very hot summers. Its average precipitation rate is 1000 mm/year. The bedrock is composed of porphyroid granite, gneisses and micaschists.

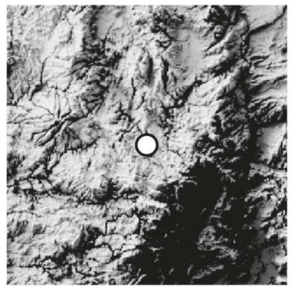


Figure 26: Area's topography

The land and more importantly forests have a big cultural and heritage value in the life of this farm. Regular small interventions are being conducted such as coppice management, crop rotations, silvopatoralism or spontaneous plantation of various tree species. Before 1955, the farm's balance between forests, pasture and arable lands was in favour of pasture and arable lands. However, with natural regeneration of forests, the balance shifted in favour of forests around 1960. In the mid-1970s, parts of the forest have been harvested in order to restore the farm and built a new house for the soon retired farmer, in 1979. The next noticeable change in the landscape occurred after a natural disturbance in 1999 with a storm that took over the Central Massif. Damages were considerable. This event has been the occasion to build a sawmill at the farm, in addition to the existing wood workshop, in order to make the most out of the fallen trees.

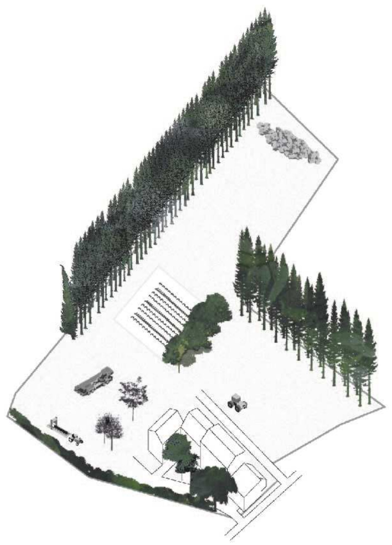


Figure 27: Axonometric view of the farm (No scale)

For the last 15 years, this context has faced tremendous changes. From numerous small farms to a few large ones, small parcels to big fields, it is both the practices and landscapes that have been affected. With these changes in farm typologies, knowledge in agriculture become more exclusive and held by only a small fraction of locals. Also, with industrialisation and agriculture regulations, biodiversity came in second. Old pine forests are erased to create more fields, rocks are being moved and piled up at the corner of every fields. The traditional landscape of the region is going away.



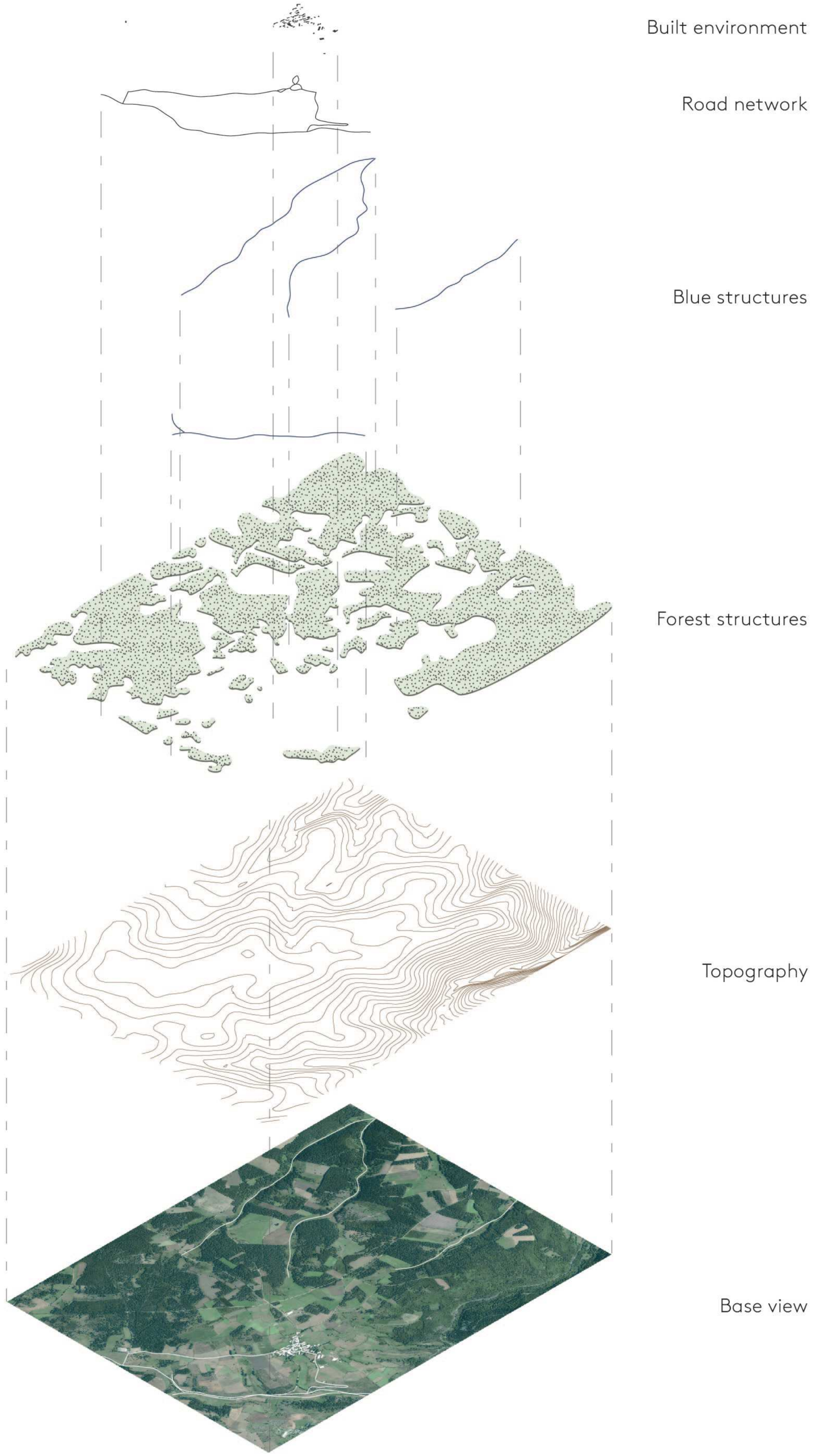



Figure 28: Exploded axonometric view of the farm's surroundings (Scale 1:50000 - A4)

Tables 2 and 3 present the different land types that are part of the farm. They give a picture of the structure and profitability of each types.

Figure 29: Satellite view of the farm (No scale)

## B. Land types (2023)

Figure 30: Parcels 1A
(No scale)

| Type 1A | Silver fir forest | | | Total surface: 3 ha 60 a 00 ca |
|---|---|---|---|---|
| Structure | Main species | Basal area (m²/ha) | Mean dominant height (m) | Log size category |
| | Silver fir | 47 | 22 | Medium |
| | Mature? | Harvestable? | Access conditions | |
| | Yes | Yes | Machineable | |
| Notes | - Silver firs came from natural regeneration after a cut of scot pines around 1977.<br>- Several small plantations spread accross the parcel.<br>- Big age difference between stands.<br>- Trees are suitable for carpentry.<br>- Important stand volume (i.e. woody biomass). | | | |

Table 2: Land type 1A (Silver fir forest).

Figure 31: Silver fir forest (land type 1A)



| Type 1B | Spruce forest | | | Total surface: 0 ha 20 a 00 ca |
|---|---|---|---|---|
| Structure | Main species | Basal area (m²/ha) | Mean dominant height (m) | Log size category |
| | Norway spruce | 32 | 19 | Medium |
| | Mature? | Harvestable? | Access conditions | |
| | Yes | Yes | Machineable | |
| Notes | - Small spruce plantation planted around the 1960s.<br>- No major dieback. | | | |

Figure 32: Parcels 1B
(No scale)

Table 3: Land type 1B (Spruce forest).

Figure 33: Spruce forest (land type 1B)

Figure 34: Parcels 1C

(No scale)

| Type 1C | Heterogeneous scot pine forest | | Total surface: 12 ha 80 a 00 ca | |
|---|---|---|---|---|
| Structure | Main species | Basal area (m²/ha) | Mean dominant height (m) | Log size category |
| | Scot pine<br>Beech<br>Oak | 34 | 19 | Medium |
| | Mature? | Harvestable? | Access conditions | |
| | Yes | Yes | Machineable | |
| Notes | - Fairly old scot pines from natural regeneration.<br>- Big variations in terms of wood quality: trees suitable for carpentry mixed with flexuous trees with large branches.<br>- Some stands show natural regeneration of beeches and oaks in the understory.<br>- Scot pines are valuable for carpentry or pulpwood.<br>- Beeches are valuable for firewood. | | | |

Table 4: Land type 1C (Heterogeneous scot pine forest).

Figure 35: Heterogeneous scot pine forest (land type 1C)



| Type 1D | Heterogeneous forest | | Total surface: 2 ha 20 a 00 ca | |
|---|---|---|---|---|
| Structure | Main species | Basal area (m²/ha) | Mean dominant height (m) | Log size category |
| | Scot pine<br>Beech<br>Birch<br>Hazel | - | - | Small<br>to<br>Medium |
| | Mature? | Harvestable? | Access conditions | |
| | No | No | Challenging | |
| Notes | - Heterogeneous stands from natural regeneration.<br>- Different forest stages of growth: in most of the cases, these stands correspond to a switch in terms of land use, when lands left their initial agricultural function.<br>- Parts of these woods are valuable for firewood. | | | |

Figure 36: Parcels 1D

(No scale)

Table 5: Land type 1D (Heterogeneous forest).

Figure 37: Heterogeneous forest (land type 1D)

38 Figure 38: Parcels 1E

(No scale)

| | | |
|---|---|---|
| Type 1E | Beech and oak stands | Total surface: 0 ha 20 a 00 ca |
| Notes | - Fairly young stand (≈ 30 y/o) from natural regeneration.<br>- Thinning have been done along the years on the oaks.<br>- Oaks have a small trunk diameter and are fairly tall and straight in comparison to other oaks in the area. | |

Table 6: Land type 1E (Beech and oak stands).

Figure 39: Beech and oak stands (land type 1E)



| | | | | |
|---|---|---|---|---|
| Type 2A | Arable land | | | Total surface: 0 ha 91 a 63 ca |
| Structure | Cultivation | Harvested in | Number of parcels | Access conditions |
| | Oat | 08/2023 | 3 | Machineable |
| Harvesting | Straw harvested (in kg of DM) | Profitability (in kg/ha) | Seeds harvested (in kg) | Profitability (in kg/ha) |
| | 1 T 408 kg | 1 T 537 kg /ha | 1 T 650 kg | 1 T 801 kg /ha |
| Notes | - Oats have been planted during winter 2022-23.<br>- The land have not been exploited for 3 years prior to this date. As a consequence, the soil had to be worked specifically in order to start producing cereals again.<br>- Oats are good winter cereals with qualities to improve soil's heath by regeneration and low needs for its growth.<br>- Oats have been a first step before planting rye the following year. | | | |

Table 7: Land type 2A (Arable land).

Figure 40: Parcels 1A

(No scale)

Figure 42: Arable land

(land type 2A)

| | | | | |
|---|---|---|---|---|
| Type 2B | Pasture | | | Total surface: 4 ha 30 a 00 ca |
| Structure | Cultivation | Harvested in | Number of parcels | Access conditions |
| | Hay | 07/2023 | 9 | Machineable |
| Harvesting | Hay harvested (in kg of DM) | Profitability (in kg/ha) | | |
| | 14 T 280 kg | 3 T 321 kg /ha | | |
| Notes | - Rye have been planted during winter 2023-24 on 3/9 of these parcels.<br>- Hay have been cut once. Regrowth have been left for cattle to pasture.<br>- In comparison with previous years, these numbers are a result of a particularly good season. | | | |

Table 8: Land type 2B (Pasture).

Figure 41: Parcels 1B

(No scale)

Figure 42: Arable land

(land type 2A)

The fourth chapter highlighted the heterogeneity of the case study's forests. The land types classification will serve as a base to think about a theoretical implementation of the method on the farm's land.



# V. Implementation

The fifth chapter links the previous chapters together around the architectural project of a wooden barn. Wood availability from a specific land type is put in relation with the project's wood needs, based on the proposal's method. Finally, the *Reporting Form* provided with the method is filled with details related to the project.

## A. Functional needs

The section of the following project has been redrawn from Juuso Joona's current project, designed by the architectural firm ARKPÖ. The plan and elevation are inspired by the same project but adapted to the thesis' site. With the farm operating again, new needs are emerging. This project seeks to answer needs in term of storage. For this, different activities, equipment and products have to be taken into consideration. Also, previous harvests give valuable indications on the needed space.

The barn provides an open space that can be divided in three main areas, as it is visible on the plan below. On the left is space given for the storage of crops. The dimensions of a hay bale are 120x250x70 cm. In 2023, 51 hay bales have been harvested on the farm's lands. The barn gives space to store at least 90 hay bales, leaving room for the activity of farming to grow. On the right is space given for the storage of wood. On the plan are represented sawnwood and roundwood. Roundwood logs are drawn to be 45x45x700 cm, when sawnwood boards are 40x420x3.5 cm. On the centre of the plan is space given for

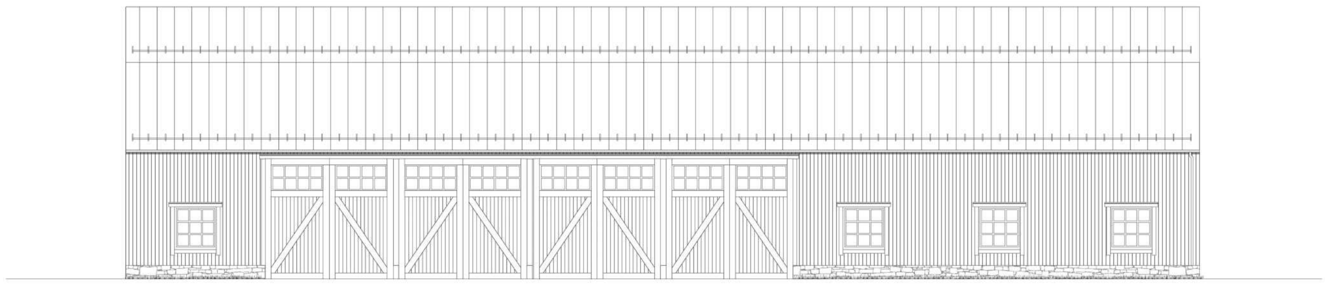


Figure 43: Elevation east (Scale 1:200 - A3)

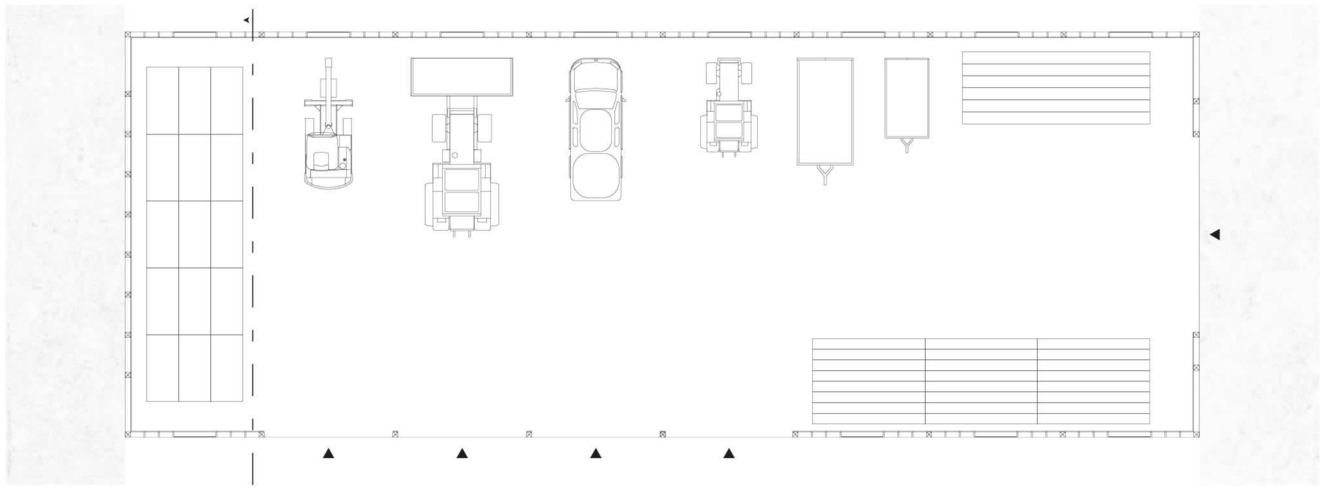


Figure 44: Plan ground level (Scale 1:200 - A3)



machinery and their operation in relation to the products stored mentioned above. On the plans are represented two tractors, two trailers, a truck and an excavator. Here again, a little more space is given than what is needed to answer current needs, this to leave room for future investments in machinery.

Finally, the plan seeks to give flexibility for different uses. Entrances are found in two different facades, with a large entrance of 7 m from the gable end of the building. This gives more ease to manoeuvre the different machinery in the barn. Even though not represented, the construction of an additional floor is possible, leaving the opportunity for more storage space or the inclusion of a new function in this building.

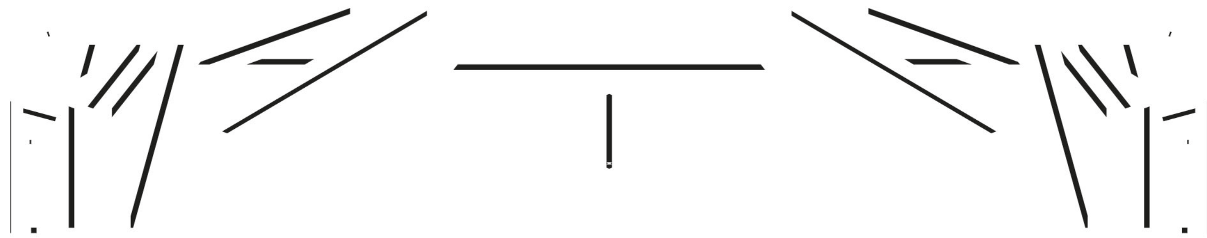


Figure 45: Structural wooden elements (Scale 1:200 - A3)

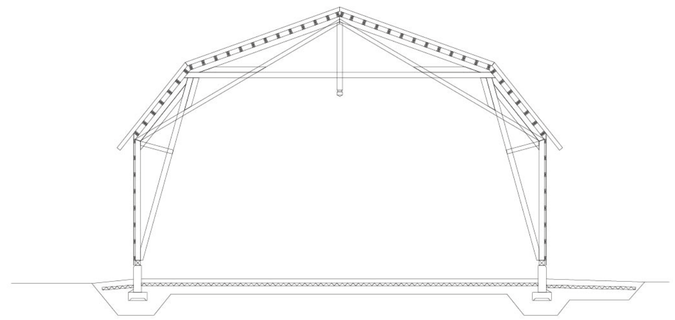


Figure 46: Section (Scale 1:200 - A3)


Figure 47: Structural wooden elements dimensions (mm) (Scale 1:20 - A4)

## B. Wood availability

In the case of the barn project's needs and the implementation of the proposal's method, we will focus on land type *1B Spruce forest* presented table 2. This stand provides mainly spruces which for the oldest have been irregularly planted about 60 years ago. Scot pines can also be found more sparsely, with trees that were on site before the spruces and others that have grown in the spruce stand. Different typologies of mature trees are present on site, showing different characteristics listed table 9. The stands provides harvestable trees, from 50 to 30 cm of diameter at breast height.

In relation to the method's *Reporting Form*, plans and sections before and after harvesting are presented figures 50, 51, 52 and 53.

| | | |
|---|---|---|
| Spruce<br>*Picea abies* |  |  |
| Scot pine<br>*Pinus sylvestris* |  |  |
| Environment | Open | Dense |
| Wood quality | • Higher proportion of heartwood<br>• Fragile where knots | • Higher proportion of sapwood<br>• Fewer knots |
| Bole | Short and large | Long and thin |

Table 9: Harvested trees' caracteristics from land type 1B.



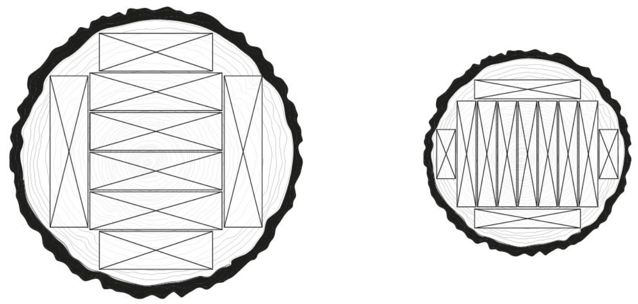
## C. Project and forest

This section connects the project's needs to the wood availability. Table 10 lists for each structural wooden elements the related roundwood type and amount that would fulfil the material needs to build the barn. The soil conditions around the farm affect negatively the wood quality of scot pines, altering the straightness of their trunk. Therefore, spruces are in our case more suitable for the 200x200 mm elements, asking for a bole of 6.9 m and 30 cm of diameter.

Figures 48 and 49 are three preferred options of sawing methods, for roundwoods of 25, 30 and 35 cm of diameter. These options have been selected in order to maximise the harvested resources. They depend also on the final uses of each element and the resistance characteristics that can be obtained following such sawing methods.

| Final element (mm) | 200x200 | 200x200 | 200x50 | 200x50 | 50x175 | 50x150 | 25x140 |
|---|---|---|---|---|---|---|---|
| Lenght (cm) | 690 | 480 | 610 | 470 | 460 | 610 | 200 |
| Diameter (mm) | 300 | 300 | 250 | 250 | 200 | 200 | 250 |
| Amount (pc.) | 15 | 20 | 12 | 40 | 25 | 40 | 60 |

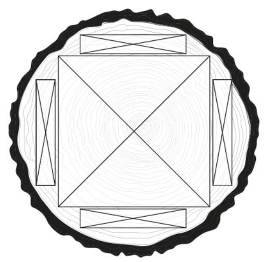
Table 10: Barn project wood needs.



This sawing method fits trunks of 35 and 25 cm of diameter. It provides 50x175, 50x150 and 25x140 mm wooden elements.

The qualities of the inner elements are to be more resistant to warping effects. This is a good property for 25x140 cladding planks.

Figure 48: Parallel boards sawing method (Scale 1:10 - A4)



This sawing method fits trunks of 30 cm of diameter. It provides 200x200 and 25x140 mm wooden elements.

The resource is used at its maximum capacity and it provides a very durable element from the heartwood of the log.

Figure 49: Whole piece sawing method (Scale 1:10 - A4)

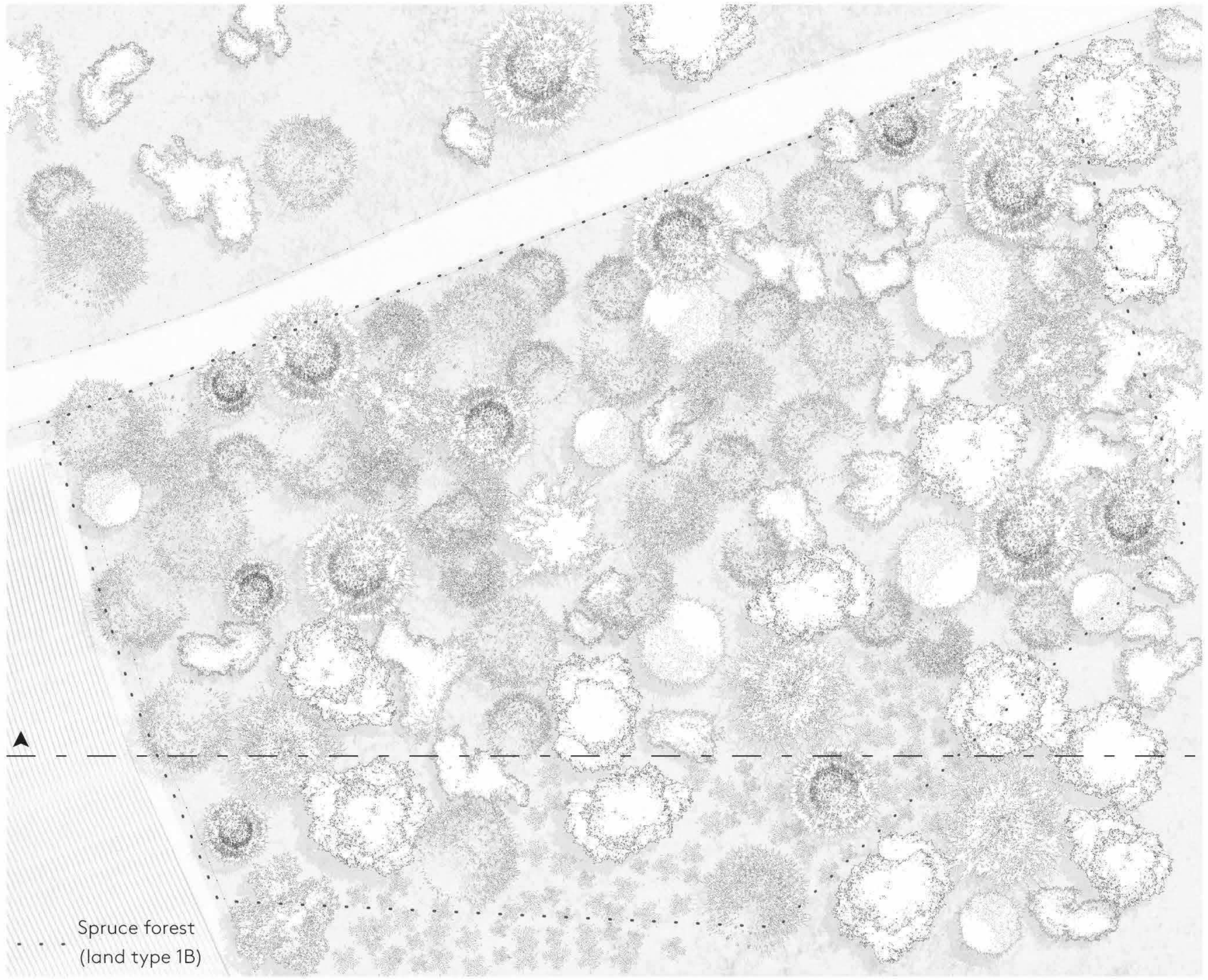



Figure 50: Plan before harvesting (Scale 1:200 - A0)

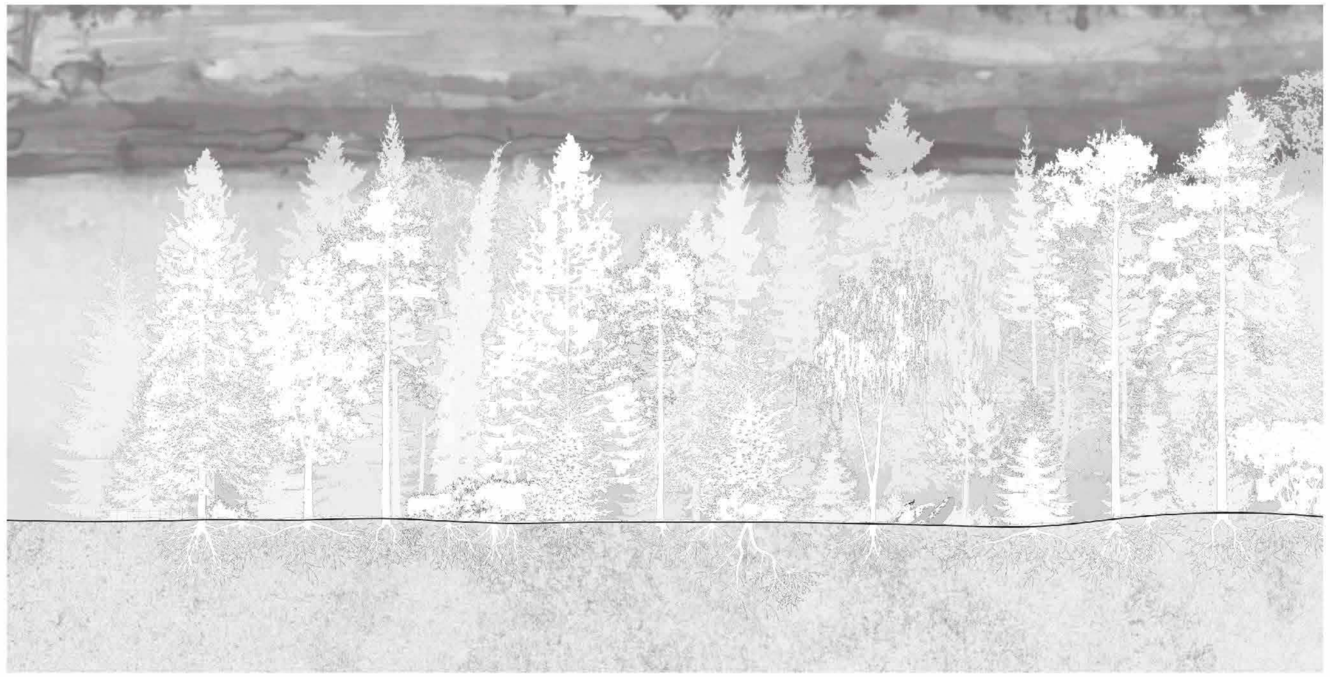


Figure 51: Section before harvesting (Scale 1:200 - A0)



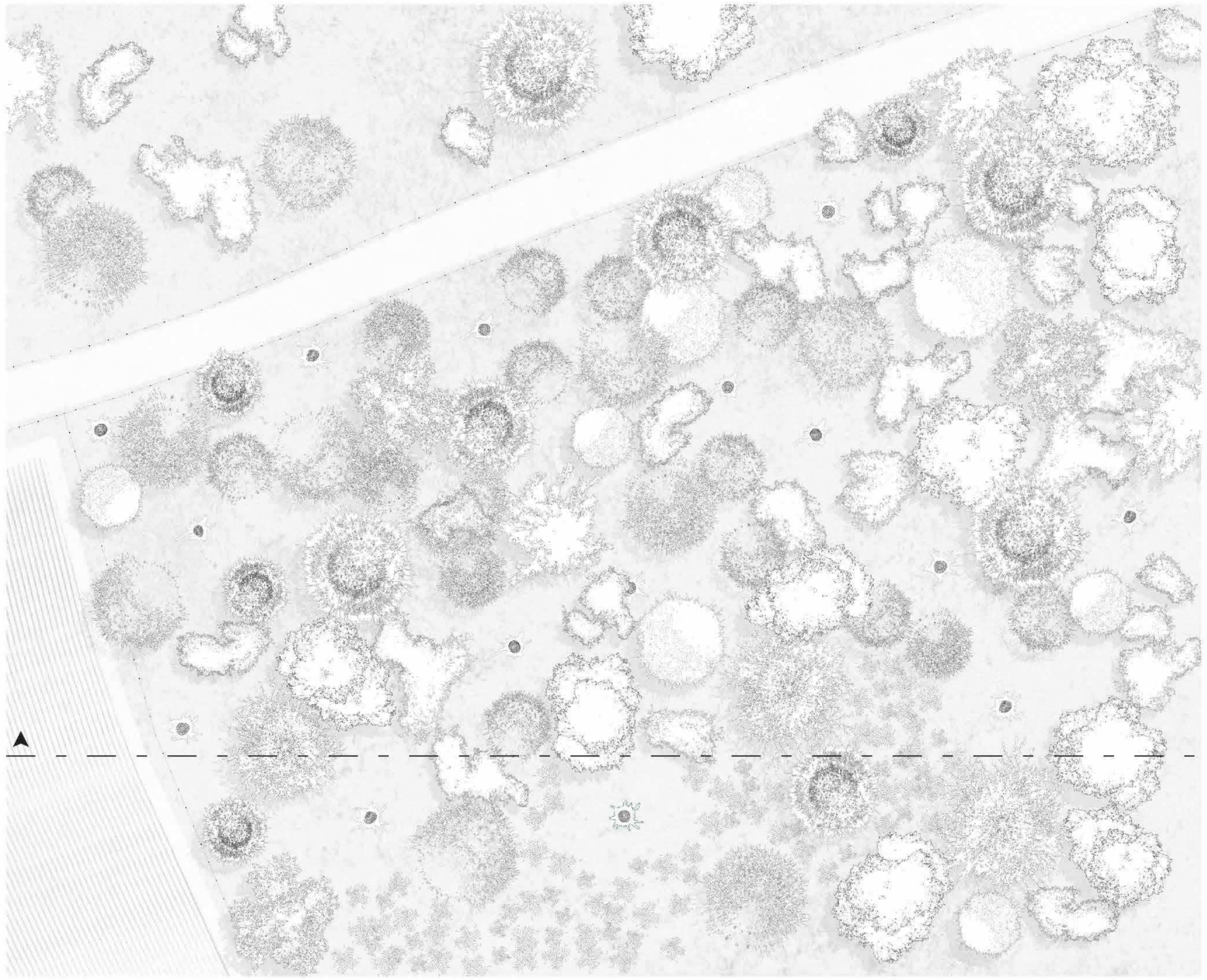


Figure 52: Plan after harvesting (Scale 1:200 - A0)

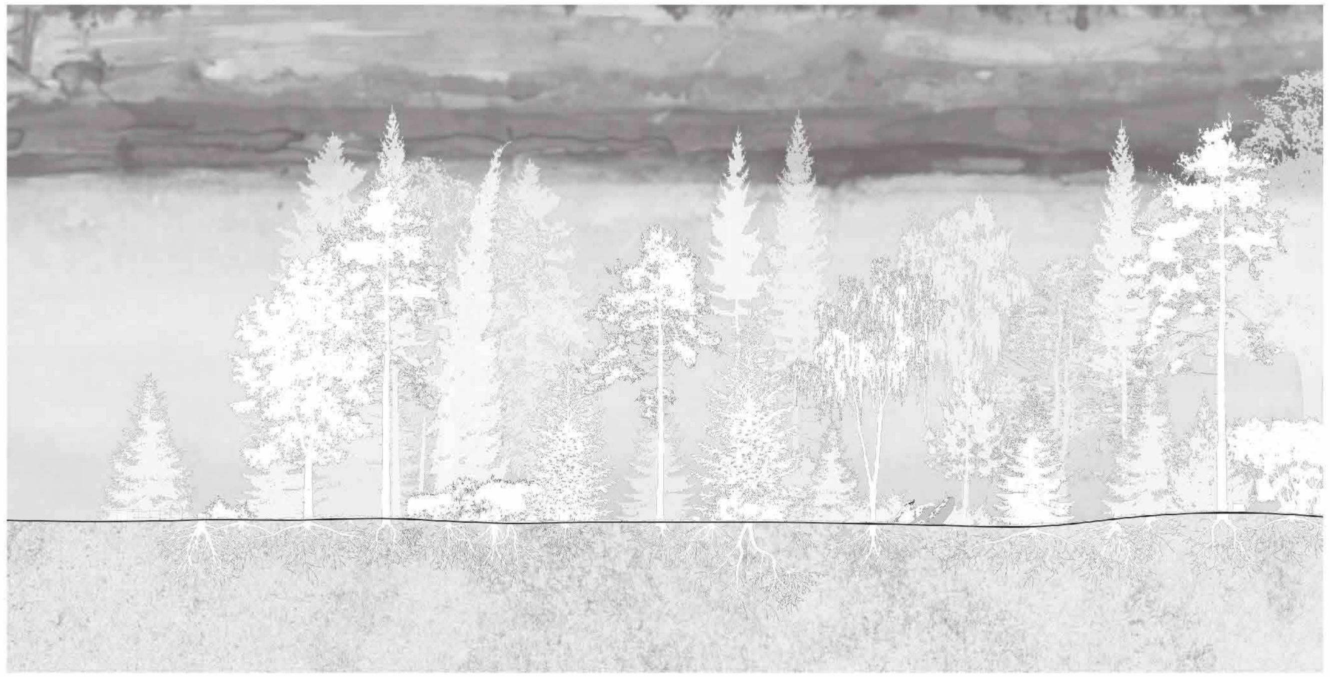


Figure 53: Section after harvesting (Scale 1:200 - A0)

## D. Results from harvesting

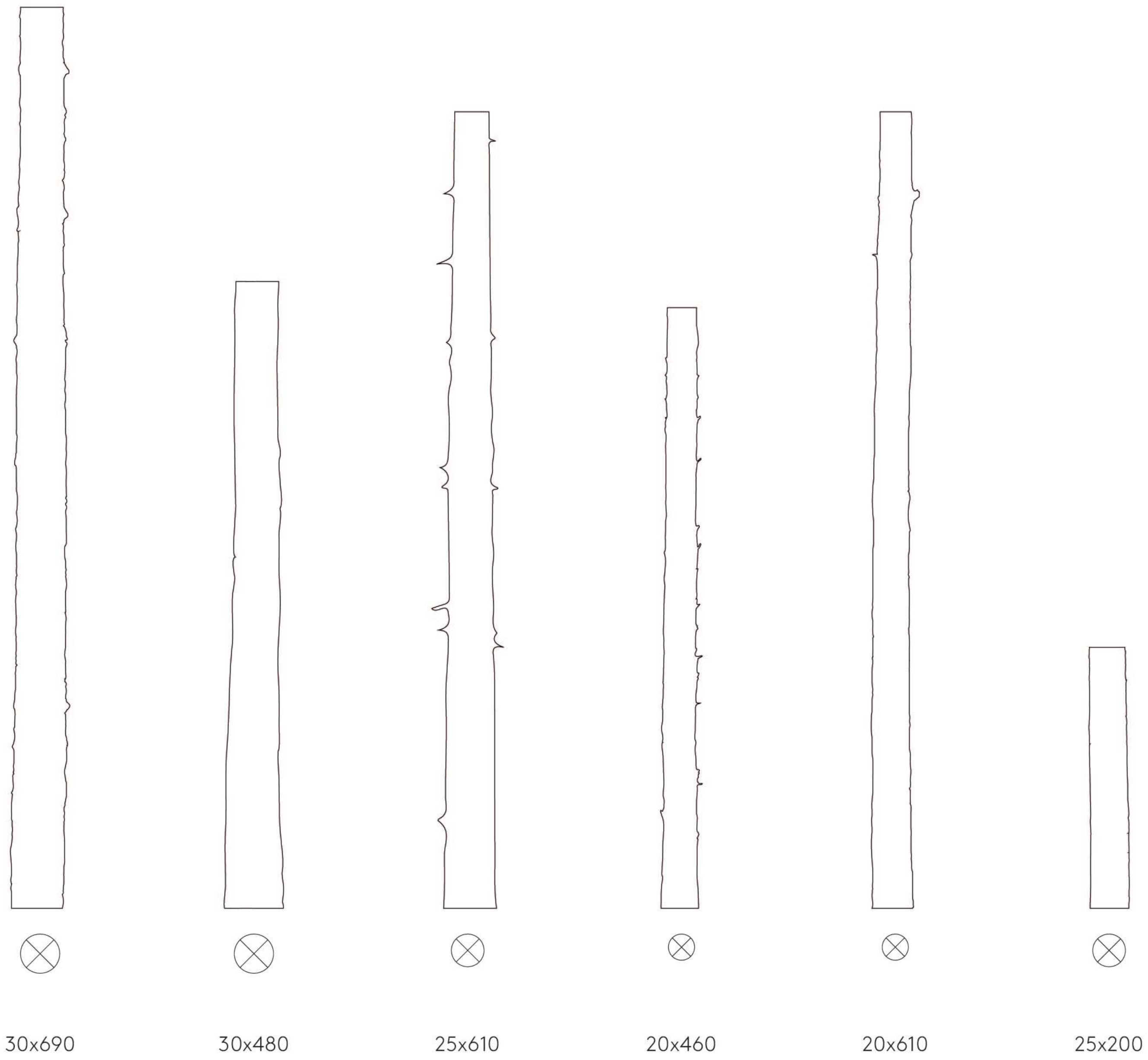



Figure 54: Logs from harvesting (Scale 1:50 - A4)

| Final element (mm) | 200x200 | 200x200 | 200x50 | 200x50 | 50x175 | 50x150 | 25x140 |
|---|---|---|---|---|---|---|---|
| Lenght (cm) | 690 | 480 | 610 | 470 | 460 | 610 | 200 |
| Diameter (mm) | 300 | 300 | 250 | 250 | 200 | 200 | 250 |
| Amount (pc.) | 8 | 1 | 2 | - | 6 | 5 | 12 |
| Amount (%) | 53 | 5 | 16 | - | 24 | 12.5 | 20 |

Table 10: Needs covered by the harvest.



#### Guidelines

The spruce stand has been harvested at its full capacity within its ecological boundaries, defined in the proposal's method. Native tree species have been preserved, when 60% of canopy cover has been maintained over the global surface of the harvested stand.

#### Reporting form

The *Forest* section of method's annexe *1. Reporting Form*, as well as annexes *1.1* to *1.6* can be found appendix C. The *Architecture*, *Primary processing* and *Secondary processing* sections of the method's annexes will be filled in the later stages of the project design.

#### Practicalities

This case of implementation is fairly simple, since only two species have been approached in the harvested stand. This choice was made in regards of the given time available for this chapter, and to make the implementation easier to grasp for the reader. That being said, complexity comes when more diverse stands are being harvested. In that case, more variables are added. On one hand, the level of understanding the method in terms of sustainable forestry becomes higher. Every operation done in the forest have to be measured and its repercussions anticipated. On the other hand, the wood availability from heterogeneous forests create more scenario to work from. This requests the architects to have knowledge on the specific properties that hold each tree species in their materiality. Also, a larger range in wood availability asks for time to develop alternative design solutions, which in the end can lead to a costly project to design. Finally, the forest mapping, project design, harvesting and sawing is done by the same person in this case of implementation. This again simplifies the implementation, but opens questions to discuss in the following chapter.

#### Scenario 2 of implementation

Another case of implementation has been developed, but from a different perspective. That case is oriented towards the expected economic, material and environmental outcomes from the conversion of an arable land to a dynamic forest. The case does not deal directly with a building but covers landscape and wood products questions. Therefore, it is presented appendix D of the booklet.

## E. Conclusions on implementation cases

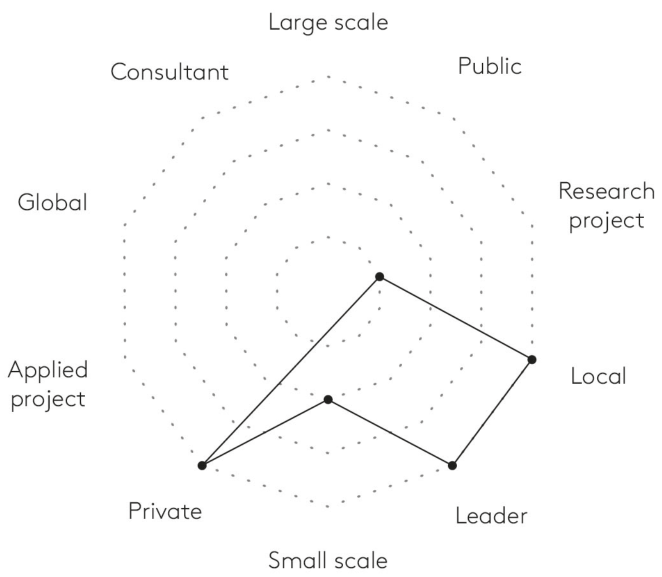



Figure 55: Case 1: implementation of the method as part of the barn project (figures 43 to 47)

### Strengths

- Authority of the architect in decision-making
- Space for design explorations and alternatives
- Mapping and valorisation of local resources: materials, knowledge, site...

### Weaknesses

- Limitations in engineered wooden design element alternatives
- Misleading simplificity of the implementation by the architect's involvement at all stages

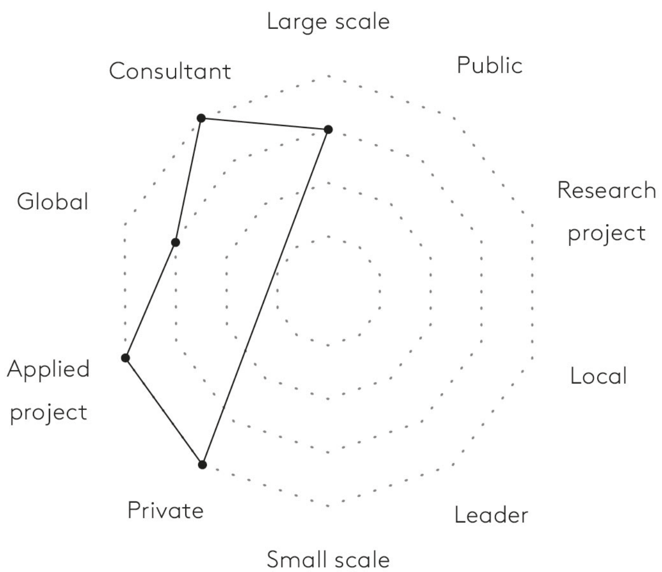





Figure 56: Case 2: implementation of the method as part of a private CLT housing unit project

### Strengths

- Broader approach opens possibilities for the architect to design with engineered wooden design elements or reused materials

### Weaknesses

- Difficulty to influence in decision-making for sustainable alternatives due to consulting position of the architect
- Budget driven decisions: little room left for the architect to seek for alternative design solutions
- Greater impacts on the environment due to the scale of the project
- Client's will has a strong influence in the outcomes of the project

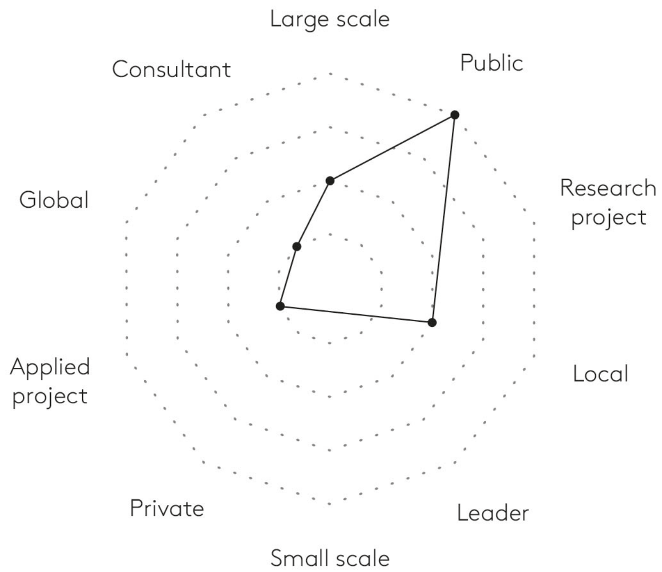



Figure 57: Case 3: implementation of the method as part of a public municipal library

### Strengths

- Process leader position of the architect involved in a trandisciplinarity approach
- Opportunity for the architect to work on different system chain levels
- Opportunity for the architect to develop and implement design explorations in a concrete project
- Broader perspective, knowledge and open-mindedness on sustainable alternatives due to public ownership

### Weaknesses

- Constraints and limitations due to local self-regulations

The fifth chapter has exposed the method to a theoretical case of implementation that connected a building to the land. It raised questions and opened discussions that the method would have to face in the case of its practical implementation.



# VI. Discussion

This final chapter addresses what is in the power of the architects to promote a transition towards Closer-to-Nature forest management. It reflects on what architects could bring and get from the implementation of the proposal's method. Finally, the chapter opens the discussion on the recognition of trees and forests in our society.

## A. Reflections

This project of the Master's thesis ends the studies in Architecture. Thus, the following reflections summarise the academic projects in relation to the thesis' research question. Sustainability has become an inevitable aspect to deal with when designing a building. Renewable resources are considered ecological. It is often that a wooden building project communicates on its sustainability based on its materiality. However, it is rare when information are given beyond the simple materiality. What types of trees have been harvested? How have they been harvested? Where are they coming from? How is their succession ensured? How have they been processed?... This is where sustainability hides. A wooden building is not inevitably sustainable. A wooden building constructed out of local materials is not inevitably sustainable. A wooden building certified by current leading sustainable forestry certification schemes is not inevitably sustainable.

The thesis project has been the opportunity to understand why architects are not going that deep in this question. As mentioned in the first chapter, the choice has been made to intertwine theoretical and practical knowledge, while favouring transdisciplinarity. The different perspectives of the architects, builders, engineers, members of the European Parliament and forest owners met during field studies highlighted different levels of understanding of the process of a wooden building construction. Also, it allowed me to place architects within the field and get a better understanding of their role. The main observations from the field studies are the following.

Working within the context of European forests is facilitated by using a common regulation framework. On one hand, this gives the same foundations to enable a transition towards Closer-to-Nature forest management practices. On the second hand, it helps to define the roles of every actors involved in the field, including the architects. However, there is room for different levels of understanding and interpretations. In that regard, the background and history of the actors and countries concerned become quite relevant. From the field studies, the inputs collected from Swedish, Finnish and Norwegian actors differ significantly from the inputs collected from French, Swiss and Belgian actors. In fact, the perspective from the Nordics has been very practical, with good knowledge on the tree itself and forests, but also the final material that is wood. My personal conclusion is that having a low population rate leaves a lot of space for agricultural lands and forests, with most of the locals owning plots of lands. Also, the total surface of arable land depends on the population rate and its needs in term on food, at least historically. In addition to that, climate



conditions clearly favours forestry rather than agriculture. With great amount of wood available and a challenging climate, the locals had to make the most out of wooden buildings and the properties of the wood material in terms of resistance. Regarding Western and Central Europe, the perspective of the actors interviewed was a lot more theoretical and leaning towards forest management. Going back to the first chapter of the thesis, I believe that this could be explained by their rich history in providing theoreticians in forestry, dating back to the seventeenth century to this day.

Connecting all these contrasting but complementary inputs in the proposal's method has highlighted two main challenges to answer the thesis' research question. First, there is a lack of knowledge within the field of architecture regarding sustainable forestry. Second, the implementation of the method at a large scale would need a specific economic model to be developed. The two following sections will detail these two challenges.

## B. Knowledge in Forest Planning and Architectural Design

Architectural Design and Forest Planning are two fields that for most situations do not share common knowledge. One field is the expert of the built environment when the other focuses on the natural environment. Although, there would not be any built environment without natural resources, as society is organised today. Therefore, there is a need to enable the accessibility and sharing of knowledge between these two fields. Finally, this opens the discussion on the operational value of knowledge in sustainable forestry for the architects.

**How can architects get knowledge in Closer-to-Nature forest management?**

In the case of a wooden building design, the two fields merge around the same project. When this opens the opportunity for cooperation between the fields, it is at this point where the need of understanding the processes that involves the architectural project becomes crucial, in order to navigate up and downstream. From the tree to the building, and from the building to the tree, the dialogue between each stakeholder involved is decisive to make the project sustainable. It is this dialogue that will enable knowledge to be shared between the fields involved.

In the New EU Forest Strategy for 2030, the European Commission encourages architects to develop knowledge and skills on sustainable and climate neutral forestry practices to develop a sustainable forest-based economy. As an answer to this call, the Proposal for a Common Sustainable Practices, Monitoring and Reporting Method in Forest Planning and Architectural Design provides a system that redefines the responsibilities of architects in the design of a wooden building. As it is today, architects mainly play a role downstream in the process. The environmental impacts of the buildings end up to be evaluated in strict and practical ways, detached from forests' ecological realities. In order to tackle this issue, an investigation on latest and upcoming European forest policies has allowed to identify upstream where the expertise of architects could favour a transition towards Closer-to-Nature forest management. In the method, forest mapping is the first step for a sustainable forest management (figure 15). Furthermore, it determines the following actions to take in preservation or harvest within the mapped forest. On one side, forest mapping requires knowledge in biology for an accurate criteria and quality variables identification. On the other hand, forest mapping consists in other terms of the report of trees' spatiotemporal evolutions in a forest, based on plans and sections drawing. Here, architects are in the best position to ensure this mission. By facilitating iterations between the building and the forest, architects and forest engineers, the method promotes transdisciplinarity within the field of Architectural Design and Forest Planning. In the long term, this will help architects to gain knowledge in Closer-to-Nature forest management.

How to use knowledge in Closer-to-Nature forest management within the field of Architecture?

The scale of a project has a great importance on its impacts on the environment, as well as the number of stakeholders involved in its process. In that regard, the implication of architects using the method can differ in the role they will play in the transition towards Closer-to-Nature forest management.

The case of implementation with the barn project detailed chapter 5 relates of a fairly small scale project, limited to one industrial building of a simple design. Within this scale, knowledge in Closer-to-Nature forest management become particularly relevant in the details of design. Being more familiar with trees' spatiotemporal evolutions and forest dynamics helps to get a better understanding of the material of wood and its properties. Ultimately, this will push design thinking to find alternative design solutions for every wooden elements inventoried in a project.

At the other end of the spectrum, large scale projects open



possibilities for architects to use knowledge in Closer-to-Nature forest management in different sectors within their profession. Comprehensive planning is a collaborative process where community development goals are determined. When working on such projects, the architects are exposed to a different complexity and a broader context. Here, architects can play with various levers. Knowledge in forestry will place the architect in a key position of mediator to bridge the gap between the built and natural environments. Relying on latest European forest policies, the implementation of the method in comprehensive planning will confer architects the voice to advocate for responsible forest planning in municipal self-regulation schemes.

## C. A new market

With industrial revolution have increased our needs in raw materials. The model of forestry that has took over since then focuses on producing cubic meters, rather than focusing on producing quality wood.

When it comes to the material of wood, quality lies on strength, durability and density. Wood density is a key factor in wood's resistance properties. Summerwood (900 kg/m3 dry wood) is denser than springwood (300 kg/m3 dry wood). Density consists mainly of the thickness of the summerwood ring in the total width of a growth ring, and of the width of a growth ring itself. Forestry practices can affect the growth rings development of a tree, and so the properties of the material of wood. Closer-to-Nature forest management practices are aligned with natural forest cycles and dynamics. In a dynamic forest, a tree starts to grow in the understory to gradually reach the canopy layer. Its growth rings tend to be stable. Silviculture measures taken in the mid and over stories will determine growing conditions by affecting the light and nutrient access. This will ultimately have an impact on the width of the growth rings. In addition to the growth rate, Closer-to-Nature forest management can opt for longer rotations, by keeping trees longer in the forest. As a tree grows old, its proportion of heartwood increases, improving its resistance properties.

That being said, the material of wood, for a same species, is in most of the cases paid according to the volume and not density. In order to enable a transition towards Closer-to-Nature forest management, wood quality has to get more recognition and become one of the main variables that determine the final price of the material. This is where architects can play a major role in the transition. To this day, architects have built a deep knowledge of our built environment with a focus lately in analysing the environmental impacts of buildings. As mentioned in the previous section of this chapter, the implementation of the method will provide architects new knowledge in Closer-to-Nature forest management. This expertise will place architects in a great position to enable the transition. In fact, as final decision makers in terms of material choices when designing a building, architects can ultimately create a demand for different wood qualities, justified by the material's durability and sustainable qualities. By creating a demand for high quality timber, architects will support the establishment of a new market, where wood produced in Closer-to-Nature managed forests will be trade at its fair value.

With the development of a new market for quality timber come basic economic questions. Since this market will be an addition to the existing global market of wood, competitiveness will become a condition to guarantee its perenniality. The selling price of quality timber will have to be cheaper than regular timber. With that being said, two options can be considered.

The first option would be to enable forest owners to sell quality timber at a higher price. For coherent policies, the European Commission could be the main enabler in the definition of such market prices. The Proposal for a Common Sustainable Practices, Monitoring and Reporting Method in Forest Planning and Architectural Design lies on the latest and upcoming European regulations. Thus, regulation wise, it places the method as one of the good practices that can be implemented in European productive forests. Furthermore, the leading model of even aged forestry and clear-cut practices represents in the eyes of the European Commission a threat for the health of forests. In that regard, a new policy could be envisioned. To regulate prices, the European Commission could apply to its member states a new tax and subsidy system. On one hand, timber provided from clear-cut practices would have to bear taxes for their negative impacts on the environment. On the other hand, timber produced in Closer-to-Nature managed forests would perceived subsidies for setting sustainable practices. This model could initiate the transition towards Closer-to-Nature forest management in the context of European forests.

The second option would induce forest owners to sell quality timber at a lower price, for a cheaper wood end product. In order to balance the economic loss, new incentives would have to be found in the forest. Scenario 2 of implementation presented appendix D seeks to investigate that aspect (table 13). When clear-cut practices provide incomes only from the harvested timber, Closer-to-Nature forest management opens forests to new markets. Payments for Ecosystem Services (PES)[23], carbon market and biodiversity markets can help support and reinforce the new market for high quality timber.

(23): European Commission, Joint Research Centre, San-Miguel-Ayanz, J., Barredo, J., Viszlai, I. (2016). *Payments for forest ecosystem services : SWOT analysis and possibilities for implementation*, Publications Office. https://data.europa.eu/doi/10.2788/957929



## D. Conclusion

To conclude this Master's thesis, we can raise questions about ethicality when it comes to tree harvesting. If latest policies and debates about forestry are tending to focus on forests' health and climate change, arguments are often oriented towards ensuring humans' well-being. In the end, trees are mainly considered for their economic value and their qualities to help our society tackle climate change.

I believe that intrinsically, we humans as individuals show a deeper empathy towards trees. Ask around you the definition of a tree and you will get as many different answers as people approached. The complexity of trees makes it difficult to define. In this exercise, is the scientific discourse more relevant than poetry? Is the real nature of trees hiding in passion, measurements or sensitivity? Certainty rests only in the reality of our imagination. Trees are mysterious, silent beings, passengers of the same planet we are living in.

Throughout history, our societies has shown progress over the years, redefining equity of ethnicities, races and genders. Non-human beings are starting to be reconsidered in the whole ecosystem that we are part of. Yet, the flora is not reaching the same level of protection as the fauna has started to benefit. I hope my proposal will help forests to finally get the recognition they deserve.

Let the tree be sovereign of the forest!

–

# Appendix

## A. Terminology

(24): Food and Agriculture Organization of the United Nations. (2020). *Terms and Definitions FRA 2020*. https://www.fao.org/3/I8661EN/i8661en.pdf

(25): European Commission, Directorate-General for Environment, (2023). *Guidelines on closer-to-nature forest management*, Publications Office of the European Union. https://data.europa.eu/doi/10.2779/731018

**Above-ground biomass**: All biomass of living vegetation, both woody and herbaceous, above the soil including stems, stumps, branches, bark, seeds, and foliage[24].

**Below-ground biomass**: All biomass of live roots. Fine roots of less than 2 mm diameter are excluded because these often cannot be distinguished empirically from soil organic matter or litter[24].

**Canopy cover**: The percentage of the ground covered by a vertical projection of the outermost perimeter of the natural spread of the foliage of plants[24].

**Carbon in above-ground biomass**: Carbon in all living biomass above the soil, including stems, stumps, branches, bark, seeds, and foliage[24].

**Carbon in below-ground biomass**: Carbon in all biomass of live roots. Fine roots of less than 2 mm diameter are excluded, because these often cannot be distinguished empirically from soil organic matter or litter[24].

**Carbon in dead wood**: Carbon in all non-living woody biomass not contained in the litter, either standing, lying on the ground, or in the soil. Dead wood includes wood lying on the surface, dead roots down to 2 mm, and stumps larger than or equal to 10 cm in diameter[24].

**Carbon in litter**: Carbon in all non-living biomass with a diameter less than the minimum diameter for dead wood (e.g. 10 cm), lying dead in various states of decomposition above the mineral or organic soil[24].

**Closer-to-Nature Forest Management**: Set of practices to ensure multifunctional forests by combining biodiversity goals, carbon stock preservation and timber-related revenues[25].

**Deadwood**: All non-living woody biomass not contained in the litter, either standing, lying on the ground, or in the soil. Dead wood includes wood lying on the surface, dead roots, and stumps larger than or equal to 10 cm in diameter or any other diameter used by the country[24].

**Disturbance**: Damage caused by any factor (biotic or abiotic) that adversely affects the vigour and productivity of the forest and which is not a direct result of human activities[24].



**Ecosystem functions**: Ecological processes that control the flows of energy, nutrients and organic matter through an environment[25].

**Ecosystem services**: The suite of benefits that ecosystems provide to humanity, either in regulatory, supporting, cultural or provisioning terms[25].

**Forest**: Land spanning more than 0.5 hectares with trees higher than 5 meters and a canopy cover of more than 10 percent, or trees able to reach these thresholds in situ. It does not include land that is predominantly under agricultural or urban land use[24].

**Forest biodiversity**: Species and populations that are found only in forests or that are particularly sensitive or threatened by forest management practices. The composition of forest species and the genetic diversity of populations of a given species are largely determined by the type of forest management practiced[25].

**Forest ownership**: Generally refers to the legal right to freely and exclusively use, control, transfer, or otherwise benefit from a forest. Ownership can be acquired through transfers such as sales, donations, and inheritance[24].

**Forest policy**: A set of orientations and principles of actions adopted by public authorities in harmony with national socio-economic and environmental policies in a given country to guide future decisions in relation to the management, use and conservation of forest for the benefit of society[24].

**Logging**: This class includes employment in logging and the output of this activity can take the form of logs, chips or fire wood[24].

**Native tree species**: A tree species occurring within its natural range (past or present) and dispersal potential (i.e. within the range it occupies naturally or could occupy without direct or indirect introduction or care by humans)[24].

**Non wood forest product**: Goods derived from forests that are tangible and physical objects of biological origin other than wood[24].

**Plantation forest**: Planted Forest that is intensively managed and meet ALL the following criteria at planting and stand maturity: one or two species, even age class, and regular spacing[24].

**Planted forest**: Forest predominantly composed of trees established through planting and/or deliberate seeding[24].

**Primary forest**: Naturally regenerated forest of native tree species, where there are no clearly visible indications of human activities and the ecological processes are not significantly disturbed[24].

**Protected areas**: Forest area within protected areas that has a long-term (ten years or more) documented management plan, aiming at defined management goals, and which is periodically revised[24].

**Sustainable forest management**: A dynamic and evolving concept, [that] is intended to maintain and enhance the economic, social and environmental value of all types of forests, for the benefit of present and future generations[24].

**Traceability system for wood products**: A system that provides the ability to trace the origin, location and movement of wood products by means of recorded identifications. This involves two main aspects: (1) identification of the product by marking, and (2) the recording of data on movement and location of the product all the way along the production, processing and distribution chain[2].

**Tree**: A woody perennial with a single main stem, or in the case of coppice with several stems, having a more or less definite crown[2].



## B. Proposal for a Common Sustainable Practices, Monitoring and Reporting Method in Forest Planning and Architectural Design

# Forest Planning & Architectural Design

Proposal for a

**COMMON SUSTAINABLE PRACTICES, MONITORING AND REPORTING METHOD**

in Forest Planning and Architectural Design

29/03/2024



**Preface**

*This document is considered as a first version of a work in progress. Its aim is to provide a proposal for a common sustainable practices, monitoring and reporting method in Forest Planning and Architectural Design. This method is shared by the forestry and construction industries to better measure, evaluate and adjust their activities for better sustainability, throughout the processes that involves the architectural project.*

*It is presented in the form of a proposal and seeks to leave the discussion open for its further development. This document has been developed around academic architectural projects over the last three years, and results of active dialogue with Member State experts and key stakeholders. The author sought for a broader perspective, intertwining knowledge from different fields of expertise and geographical horizons. Architects, engineers, biologists, environmentalists, foresters and sawyers to name a few, from France, Sweden, Finland, Switzerland, Germany and Belgium have been approached.*

*A possible next step for further development would be the implementation of the method. This could take place with the design of a wooden building, involving architects, forest owners, engineers and a sawmill around an architectural project.*

*Author: Lucas Lafont*

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## 1. Why is there a need for sustainable Forest Planning and Architectural Design?

Forests provide us with oxygen and purify the air we breathe. They filter water and are our greatest ally when it comes to tackle climate change. They sequester and store carbon, including in long-lived wood products they can offer. If we always have relied on them for the reasons mentioned above, forests become highly important to help our society to leave a Fossil Economy for a fossil-free alternative. This transition comes with a high and increasing demand on wooden products. Forests are under heavy pressure. A new fossil-free economic has to be fully aligned with our environment's natural dynamics.

Since the Neolithic, forests' structures have evolved alongside our societies and have been shaped by our needs. Pressure on forests fluctuated over time with demographics and manufacturing. With the industrialisation era came artificial, monospecific and even-aged planted forests structures. Coppice-with-standards and short-rotation predominated with species being favoured to the detriment of others. Natural, heterogeneous and dynamic forests have slowly been replaced by such plantations. The natural structure of primary forests progressively gave way to a rationalised structure based on human needs. Forests started to be overexploited and regulations became necessary. In 2020, 75% of European forests have an even-aged structure[1]. Forestry favouring artificial structures have noticeable impacts on forests' health and ecosystems. It affects forest stability, resistance and resilience to climate change led traumatic events such as droughts, wildfires, disease and pest outbreaks. It decreases species diversity, both in terms of flora and fauna that rely on specific species and tree states and forest growth stages. This can be explained by the homogenisation of the forest that lead to a lack of old components such as deadwood, habitat trees and old trees. The simplification of forests structure also alters the spread of underground fungal communities, having ultimately a negative impact on forest's natural regeneration capacities.

In addition to the issues mentioned above, forests are suffering stress resulting of human activities with forestry and agricultural practices. The expansion of agricultural fields and built environment leads to forest fragmentation. The way we harvest forests causes carbon release in the atmosphere, mainly coming from soil erosion and humus disturbance. Forest soil is subject to compaction and rutting, having impacts on water flows and retention. If forest management approaches are changing with the recognition of environmental and socials values of forests, there is a need for a transition for sustainable forestry practices.

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[1] Forest Europe. (2020). *State of Europe's Forests 2020.* https://foresteurope.org/wp-content/uploads/2016/08/SoEF_2020.pdf



Almost 40 years ago, the United Nations Brundtland Commission defined sustainability as "meeting the needs of the present without compromising the ability of future generations to meet their own needs." This definition has become globally a common target in most of disciplines. However, there are still nuances, levels of depth and different interpretations when it comes to define if a material, product, process, project, practice or policy is truly sustainable. In architecture, a wooden building is not inevitably sustainable. From the delivered building to the seed hidden in a pine cone, there are hundreds of parameters, isolated and put together that have to be taken into consideration in order to conclude that in the end, a wooden building is sustainable or not. The theoretical definition of sustainability has to develop into a practical solution adapted to specific fields and contexts. In our case, a solution that ties architectural design and forest planning to ensure that the whole process of building with wood is sustainable.

Dealing with the whole process implies to set a common framework that defines variables and key stakeholders. This proposal seeks to bridge the latest EU forest policies together around the method that it develops. It states considerations, defines objectives, principles and targets, identifies benefits and proposes a practical way of implementation of the method.

## 2. Considerations

### 2.1. Key terms and definitions

• Above-ground biomass: All biomass of living vegetation, both woody and herbaceous, above the soil including stems, stumps, branches, bark, seeds, and foliage[2].

• Below-ground biomass: All biomass of live roots. Fine roots of less than 2 mm diameter are excluded because these often cannot be distinguished empirically from soil organic matter or litter[2].

• Canopy cover: The percentage of the ground covered by a vertical projection of the outermost perimeter of the natural spread of the foliage of plants[2].

• Carbon in above-ground biomass: Carbon in all living biomass above the soil, including stems, stumps, branches, bark, seeds, and foliage[2].

• Carbon in below-ground biomass: Carbon in all biomass of live roots. Fine roots of less

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[2] Food and Agriculture Organization of the United Nations. (2020). *Terms and Definitions FRA 2020.* https://www.fao.org/3/I8661EN/i8661en.pdf

than 2 mm diameter are excluded, because these often cannot be distinguished empirically from soil organic matter or litter[2].

• Carbon in dead wood: Carbon in all non-living woody biomass not contained in the litter, either standing, lying on the ground, or in the soil. Dead wood includes wood lying on the surface, dead roots down to 2 mm, and stumps larger than or equal to 10 cm in diameter[2].

• Carbon in litter: Carbon in all non-living biomass with a diameter less than the minimum diameter for dead wood (e.g. 10 cm), lying dead in various states of decomposition above the mineral or organic soil[2].

• Closer-to-Nature Forest Management: Set of practices to ensure multifunctional forests by combining biodiversity goals, carbon stock preservation and timber-related revenues[3].

• Deadwood: All non-living woody biomass not contained in the litter, either standing, lying on the ground, or in the soil. Dead wood includes wood lying on the surface, dead roots, and stumps larger than or equal to 10 cm in diameter or any other diameter used by the country[2].

• Disturbance: Damage caused by any factor (biotic or abiotic) that adversely affects the vigour and productivity of the forest and which is not a direct result of human activities[2].

• Ecosystem functions: Ecological processes that control the flows of energy, nutrients and organic matter through an environment[3].

• Ecosystem services: The suite of benefits that ecosystems provide to humanity, either in regulatory, supporting, cultural or provisioning terms[3].

• Forest: Land spanning more than 0.5 hectares with trees higher than 5 meters and a canopy cover of more than 10 percent, or trees able to reach these thresholds in situ. It does not include land that is predominantly under agricultural or urban land use[2].

• Forest biodiversity: Species and populations that are found only in forests or that are particularly sensitive or threatened by forest management practices. The composition of forest species and the genetic diversity of populations of a given species are largely determined by the type of forest management practiced[3].

[3] European Commission, Directorate-General for Environment, (2023). *Guidelines on closer-to-nature forest management*, Publications Office of the European Union. https://data.europa.eu/doi/10.2779/731018



• Forest ownership: Generally refers to the legal right to freely and exclusively use, control, transfer, or otherwise benefit from a forest. Ownership can be acquired through transfers such as sales, donations, and inheritance[2].

• Forest policy: A set of orientations and principles of actions adopted by public authorities in harmony with national socio-economic and environmental policies in a given country to guide future decisions in relation to the management, use and conservation of forest for the benefit of society[2].

• Logging: This class includes employment in logging and the output of this activity can take the form of logs, chips or fire wood[2].

• Native tree species: A tree species occurring within its natural range (past or present) and dispersal potential (i.e. within the range it occupies naturally or could occupy without direct or indirect introduction or care by humans)[2].

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• Plantation forest: Planted Forest that is intensively managed and meet ALL the following criteria at planting and stand maturity: one or two species, even age class, and regular spacing[2].

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• Primary forest: Naturally regenerated forest of native tree species, where there are no clearly visible indications of human activities and the ecological processes are not significantly disturbed[2].

• Protected areas: Forest area within protected areas that has a long-term (ten years or more) documented management plan, aiming at defined management goals, and which is periodically revised[2].

• Sustainable forest management: A dynamic and evolving concept, [that] is intended to maintain and enhance the economic, social and environmental value of all types of forests, for the benefit of present and future generations[2].

• Traceability system for wood products: A system that provides the ability to trace the origin, location and movement of wood products by means of recorded identifications. This involves two main aspects: (1) identification of the product by marking, and (2) the recording of data on movement and location of the product all the way along the production, processing and distribution chain[2].

• Tree: A woody perennial with a single main stem, or in the case of coppice with several stems, having a more or less definite crown[2].

### 2.2. Forest management sustainable practices

This section refers to the European Commission's Guidelines on Closer-to-Nature Forest Management[4], published on the 27/07/2023.

The aim of these guidelines is to promote biodiversity-friendly and adaptive forest management as part of a common framework for Closer-to-Nature forest management. They have been written to assist competent authorities and key stakeholders in developing and promoting biodiversity-friendly and adaptive practices in forest management across different scales, discussing challenges and opportunities. These guidelines refer to forests that have a commercial use for timber and non-timber forest products, and that are not explicitly designated as protected areas.

The following points have been selected as key sections of European Commission's Guidelines on Closer-to-Nature Forest Management in relation to the method developed in this proposal.

| |
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| Promoting natural tree regeneration |
| • Natural regeneration should be the prevailing approach to regenerate forests.<br>• Natural regeneration promotes genetic diversity in the forest and thus promotes the adaptive resilience of forest stands.<br>• Artificial regeneration may be needed to complement natural regeneration in specific situations[5].<br>• Forest regeneration does not depend on the regeneration of the vegetation exclusively but requires a broader approach covering all forest ecosystems. For example, when soils are severely degraded or are under a very active degradation process, these problems may need to be addressed before artificial or natural regeneration can successfully take place. |
| Ensuring respectful harvest conditions |

4 European Commission, Directorate-General for Environment, (2023). *Guidelines on closer-to-nature forest management*, Publications Office of the European Union. https://data.europa.eu/doi/10.2779/731018

5 Larsen, J. B. et al. (2022). *Closer-to-nature forest management. From science to policy 12*. European Forest Institute. https://doi.org/10.36333/fs12



| |
|---|
| • When planning harvesting operations, it is necessary to take account of the need to preserve all the functions of the forest. This should be achieved by respecting all parts of the forest ecosystem (in particular, the soil, watercourses, and other natural environments within the forest and their buffer zones).<br>• It should also be achieved by respecting all the individual trees and their ecological functioning in the stand, whether they are mature individuals, poles or seedlings.<br>• When harvesting wood, any intensive practice must be avoided as much as possible and subject to thorough qualitative analyses in relation to biodiversity benefits and increasing carbon stock capacity in the forest ecosystem and in the harvested wood products.<br>• The technique proposed by multifunctional approaches to promote diverse stands is partial harvesting (i.e. single-tree selection, group selection, or gap cuts (max. 0.2-0.5 ha)) mimicking natural disturbance patterns, as opposed to 'clear-cutting' larger areas.<br>• Small openings in selection gap cuts (max. 0.2-0.5 ha) can create suitable climatic conditions for species that prefer semi-shaded or semi-open conditions and enrich the forest structure.<br>• Decisions on the timing and location of small openings should reflect a mosaic approach to avoid small openings that are next to each other or within a short distance of each other and that could cumulate to have effects similar to a larger clear-cut scenario.<br>• During harvest, buffer zones along streams should be set to reduce the impacts of harvesting on water courses in the forest[6].<br>• Primary and old-growth forests remaining in the EU should be strictly protected considering their high value for both biodiversity and climate change mitigation[7]. |
| Minimising other management interventions |
| • External inputs should be kept to a minimum and their composition carefully chosen to avoid sudden changes in the pH or nutrient content of the soil. |
| Preserving and restoring soil and water ecosystems in forests |
| • The impacts of heavy machinery and the building of access roads hamper the natural regeneration of forest soil, thus must be avoided as much as possible by promoting minimal intervention techniques.<br>• Protecting natural landforms and geomorphic processes is the basis of healthy soils, but it is also the basis of healthy aquatic ecosystems that make it possible to reduce the impact of droughts on surrounding ecosystems and human activity. |
| Optimising deadwood retention |

6 Kuglerová, L. et al. (2020). Cutting edge: A comparison of contemporary practices of riparian buffer retention around small streams in Canada, Finland, and Sweden. *Water Resources Research, 56*(9), Article e2019WR026381. https://doi.org/10.1029/2019WR026381

7 Barredo, J. I. et al. (2021). *Mapping and assessment of primary and old-growth forests in Europe*. Publications Office of the European Union. https://data.europa.eu/doi/10.2760/797591

• After deadwood volume, the type of deadwood and its stage of decay are the next most important features of deadwood for species promotion.
• Leaving enough deadwood in the forest in all stages of decomposition (including standing dead and dying trees (...)) is therefore an important measure for biodiversity restoration and conservation.
• After deadwood volume, the type of deadwood and its stage of decay are the next most important features of deadwood for species promotion.
• Leaving enough deadwood in the forest in all stages of decomposition (including standing dead and dying trees (...)) is therefore an important measure for biodiversity restoration and conservation.
• Actual volumes, density and locations should be decided with consideration given to fire management, safety aspects (recreation), and the control of pest outbreaks guided by biological knowledge, management objectives, and the situation in a particular stand (forest type, basal area of living trees, stand age, natural disturbances and species composition).

Setting areas aside

• Voluntary set-aside areas can be a measure to support closer-to-nature forest management.

Taking a scale-specific approach

• The management needs to take account of three levels: (i) the level of individual trees and groups of trees; (ii) the level of the stand; and (iii) the level of the landscape.

(i) The level of individual trees and groups of trees

Management measures specified for individual trees or groups of trees should take account of their role in the forest ecosystem throughout their life cycle. During forestry management operations, each tree or group of trees should therefore be evaluated in terms of its usefulness. Criteria for harvesting should consider the trees' role in the ecosystem and should balance climate, environmental, social and economic criteria in line with the overall objectives of: (i) restoring and conserving biodiversity; and (ii) promoting resilience against climate change.

(ii) The level of the stand

The size of a stand can vary from a few to several hectares. Commonalities for delineating a stand should be chosen in line with the stand's closer-to-nature objectives. These objectives could include vertical complexity, soil fertility, tree age or dominant tree species.

(iii) The level of the landscape

Promoting structural complexity and the heterogeneity of a forest ecosystem is also relevant at landscape level.

In addition to environmental benefits, landscape-scale management enables economies of scale on certain services and investments, creating synergies across ownership and balancing the different interests of different players.

For wood harvesting, a mosaic approach to landscape-level management of forests also makes it possible to balance exploitation intensity with biodiversity restoration, conservation and climate change resilience.

Managing ungulate species at natural carrying capacity



• Promoting or maintaining ground vegetation can help to reduce grazing pressure on seedlings and saplings.
• It is necessary to protect existing or expected seedlings so as not to jeopardise the future of the forest in areas where damage by ungulate species is such as to compromise the renewal and natural diversity of the forest.

### 2.3. Forest management strategies

This section refers to European Commission's New EU Forest Strategy for 2030[8], published on the 14/07/2021.

Forests are under increasing pressures resulting from natural processes and human activities. We are witnessing a tree cover loss. With climate change come pests, pollution and diseases, promoting forest fires. This new EU Forest Strategy aims to overcome these challenges and unlock the potential of forests for our future, in full respect for the principle of subsidiarity, best available scientific evidence and Better Regulation requirements. It is anchored in the European Green Deal and the EU 2030 Biodiversity Strategy and it recognises the central and multi-functional role of forests, and the contribution of foresters and the entire forest-based value chain for achieving by 2050 a sustainable and climate-neutral economy while ensuring that all of ecosystems are restored, resilient, and adequately protected.

The following points have been selected as key sections of European Commission's New EU Forest Strategy for 2030 in relation to the method developed in this proposal.

2. Supporting the socio- economic functions of forests for thriving rural areas and boosting forest-based bio-economy within sustainability boundaries

• Sustainably produced and long-lived wood-based products can help to achieve climate neutrality.
• Optimise the use of wood in line with the cascading principle.
• Short-lived wood products and energy also play a role, especially in substituting fossil-based counterparts. Should rely on wood that is unsuitable for long-lived products and on secondary biomass.
• Respect for circular economy principles also crucial: better using, reusing and recycling all wood-based products.

8 European Commission. (2021). *New EU forest strategy for 2030. COM. (2021) 572 final. Communication from the commission to the European parliament, the council, the European Economic and social committee and the committee of the regions.* https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52021DC0572

• Supply of wood products should be in synergy with improving the conservation status of forests, and preserving and restoring biodiversity for forest resilience, climate adaptation and forest multifunctionality.

2.1. Promoting sustainable forest bioeconomy for long-lived wood products

• Forest sector holds significant economic potential for improving production of sustainable and legally harvested wood for circular and long lived materials and products.
• Promoting forest management practices, production tools and processes that are better adapted to different future forest resources.
• Wood processing industries should be supported to better adapt to the changing and diversifying resources of forests.
• The most important role of wood products is to help turn the construction sector from a GHG source to a sink.
• The Commission will develop a 2050 roadmap for reducing whole life-cycle carbon emissions in buildings.
• Construction engineers and architects should be incentivised to design buildings with wood. Construction companies, following the principles of life cycle thinking and circularity, should reflect the full benefits of wooden construction in their risk premiums and business models.
• Research and innovation on architecture, green design and construction materials should be amplified.
• Regulatory approaches (e.g., for fire safety) also need attention.
• Incentives for carbon sequestration should include actions and use of long-lived wood products in the full respect of biodiversity objectives.

2.2. Ensuring sustainable use of wood-based resources for bioenergy

• Bioenergy will continue to have a notable role to play in the energy mix, if biomass is produced sustainably and used efficiently, in line with overall availability of wood within sustainability boundaries.
• The overall objective of the Union should be to ensure that the share of forest-based bioenergy remains within the limits of sustainability its possible negative externalities are adequately mitigated.

2.3. Promoting non-wood forest- based bioeconomy, including ecotourism

• The potential of non-wood products and services for generating additional revenues to the owning communities can be further supported.
• Nature tourism and well-being services provide an opportunity to accelerate the green transition of the tourism sector and provide significant income opportunities in rural areas, while further promoting biodiversity conservation and the preservation of carbon stocks.

2.4. Developing skills and empowering people for sustainable forest-based bioeconomy

• The increasing multifunctional role that forests will play in the transition to a sustainable and climate neutral future will require an increased skill-set, among others, experts in enhanced sustainable forest management practices, architects, engineers and designers, food experts, data specialists, chemists, ecotourism facilitators.

3. Protecting, restoring and enlarging EU's forests to combat climate change, reverse biodiversity loss and ensure resilient and multifunctional forest ecosystems



• In light of climate change and biodiversity loss there is an urgent need for adaptive forest restoration and ecosystem-based management approaches that strengthen the resilience of EU forests.
• This is also a great economic opportunity as forest owners and managers are properly supported in the transition.
• We need robust approaches to risk reduction in the context of significant uncertainty. The awareness of climate change by forest owners and managers needs to be increasingly translated into actions and management practices.

3.1. Protecting EU's last remaining primary and old-growth forests

• All primary and old-growth forests in particular will have to be strictly protected.
• There is still an immediate need to map the primary and old-growth forests and establish their protection regime.

3.2. Ensuring forest restoration and reinforced sustainable forest management for climate adaptation and forest resilience

• Forest management practices that preserve and restore biodiversity lead to more resilient forests that can deliver on their socio-economic and environmental functions. Therefore, all forests should be increasingly managed so that they are sufficiently biodiverse.
• There are significant opportunities for win-win measures, which simultaneously improve forest productivity, timber production, biodiversity, carbon sink function, healthy soil properties and climate resilience.
• Management practices that support biodiversity and resilience are essential, such as the creation or maintenance at stand and landscape level of genetically and functionally diverse, mixed-species forests, especially with more broadleaves and deciduous trees and with species with different biotic and abiotic sensitivities and recovery mechanisms following disturbances, instead of monocultural plantations.
• Management practices like uneven-aged and continuous-cover forestry, sufficient quantities of deadwood, regulation of wildlife densities and the establishment of protected habitat patches or set aside areas in production forests help ensure long-term environmental and socio-economic viability of forests.
• In addition, forest related risk management practices, such as integrated landscape fire management systems will increase forest resilience against wildfires, pests, diseases and create other positive spill over effects.
• Conversely, some other practices, such as clear-cutting, should be approached with caution, notably these which affect above ground biodiversity, and cause the loss of carbon in the roots and part of the carbon in the soil.
• Undue use of unsuitable machinery that cause negative environmental impacts such as soil compaction should be avoided.
• The Commission will develop a "closer-to-nature" voluntary certification scheme, so that the most biodiversity friendly management practices could benefit from an EU quality label.

3.3. Re- and afforestation of biodiverse forests

• There is potential for extending forest and tree coverage in the EU through active and sustainable re- and afforestation and tree planting.
• It is important to capitalise on this potential as enhanced afforestation is also among the most effective

climate change and disaster risk mitigation strategies and can create substantial job opportunities. Also, exposure to green and forested areas can greatly benefit people's physical and mental health.

3.4. Financial incentives for forest owners and managers for improving the quantity and quality of EU forests

• Strengthened forest protection and restoration and more biodiversity friendly management are the right thing to do, but will not happen without the engagement of forest owners and managers. The right thing to do must also be economically viable.
• Forest owners and managers need drivers and financial incentives to provide also ecosystem services and to increase the resilience of their forests.
• Member States are specifically encouraged to set up a payment scheme for ecosystem services for forest owners and managers.

4. Strategic forest monitoring, reporting and data collection

• The information concerning the status of forests in the EU, is patchy and there is insufficient planning for the forests. This leads to a situation where, on the one hand, Member States have agreed at EU level to rely to a great extent on forests and forest-based bioeconomy and on the other hand, there is no strategic framework, which would make it possible to demonstrate that the EU is on the right track and that the forests can actually deliver on their multiple demands and functions.
• The Commission will put forward a legislative proposal for a Forest Observation, Reporting and Data Collection framework as an EU-wide integrated forest monitoring framework.
• Monitoring should be regular and on more frequent cost-efficient reporting and update of data on priority EU policy-relevant topics, such as effects of climate change, biodiversity, health, damages, invasive alien species, forest management, and the biomass use for different socio-economic purposes.
• The share of forest areas covered by forest management plans (FMPs) should cover all managed public forests and an increased number of private forests.

5. A strong research and innovation agenda to improve our knowledge on forests

• Research and innovation will increase the effectiveness of enhanced sustainable forest management under changing climate conditions, among others, by reinforcing the knowledge on climate change impacts, contributing to a greater diversity of forests and genetic resources, and providing evidence-based and practically feasible guidance for climate change mitigation and adaptation in line with biodiversity objectives.
• The Commission will work with Member States to strengthen the role of forestry in the European Innovation Partnership-AGRI. The aim will be to accelerate the uptake of forest related innovations, to promote knowledge exchange, cooperation, education, training and advice in support of enhanced sustainable forest management practices and unlock the socio-economic and environmental potential of forests in rural areas.

6. Inclusive and coherent EU forest governance framework

• The wider contribution of forests to the European Green Deal objectives necessitates a more inclusive and better coordinated EU forest governance structure, reflecting all the objectives of the new EU Forest Strategy and their interlinkages. Given the increasing interest of the European public in the future of EU's forests, transparency of the governance should also be guaranteed.

7. Stepping up implementation and enforcement of existing EU acquis

• The implementation and enforcement of the EU acquis of relevance for forests and forest management issues needs to be stepped up, for instance, the Habitats and Birds Directives, the EU Timber Regulation and many more.
• Illegal logging is particularly worrying when it concerns primary and old growth forests or forest habitats with very small areas left due to the irreversibility of the damage.



## 2.4. Timber traceability

This section refers to the European Parliament and the Council of the European Union's regulation on the making available on the Union market and the export from the Union of certain commodities and products associated with deforestation and forest degradation and repealing Regulation (EU) No 995/2010[9], published on the 31/05/2023.

Deforestation and forest degradation are the result of the expansion of agricultural land, which is linked to the production of the commodities covered by this regulation. As a major consumer of these commodities, the EU can reduce its contribution to global deforestation and forest degradation by making sure these products and their supply chains are deforestation free. The regulation sets out binding rules for European Union (EU) operators and traders that place on the EU market or export from the EU wood, rubber, cattle, coffee, cocoa, palm oil and soy, with the aim being to minimise the EU contribution to global deforestation and forest degradation, and reduce the EU contribution to greenhouse gas emissions and global biodiversity loss. The regulation is part of the EU's biodiversity strategy for 2030, the EU's new EU forest strategy for 2030 and the European Green Deal.

The following points have been selected as key sections of European Parliament and the Council of the European Union's regulation on the making available on the Union market and the export from the Union of certain commodities and products associated with deforestation and forest degradation and repealing Regulation (EU) No 995/2010 in relation to the method developed in this proposal.

[9] Regulation (EU) 2023/1115 of the European Parliament and of the Council of 31 May 2023 on the making available on the Union market and the export from the Union of certain commodities and products associated with deforestation and forest degradation and repealing Regulation (EU) No 995/2010 (Text with EEA relevance). (2023). *Official Journal*, L 150, 206-247. ELI:http://data.europa.eu/eli/reg/2023/1115/oj[legislation]

Article 3 – Prohibition

Relevant commodities and relevant products shall not be placed or made available on the market or exported, unless all the following conditions are fulfilled:

(a) they are deforestation-free;

(b) they have been produced in accordance with the relevant legislation of the country of production; and

(c) they are covered by a due diligence statement.

Article 4 – Obligation of operators

1. Operators shall exercise due diligence in accordance with Article 8 prior to placing relevant products on the market or exporting them in order to prove that the relevant products comply with Article 3.

Article 5 – Obligations of traders

3. SME traders shall collect and keep the following information relating to the relevant products they intend to make available on the market:

(a) the name, registered trade name or registered trade mark, the postal address, the email address and, if available, a web address of the operators or the traders who have supplied the relevant products to them, as well as the reference numbers of the due diligence statements associated to those products;

(b) the name, registered trade name or registered trade mark, the postal address, the email address and, if available, a web address of the operators or the traders to whom they have supplied the relevant products.

Article 8 – Due diligence

2. The due diligence shall include:

(a) the collection of information, data and documents needed to fulfil the requirements set out in Article 9;

(b) risk assessment measures as referred to in Article 10;

(c) risk mitigation measures as referred to in Article 11.

Article 9 – Information requirements

1. Operators shall collect information, documents and data which demonstrate that the relevant products comply with Article 3 (...):

(a) a description, including the trade name and type of the relevant products as well as, in the case of relevant products that contain or have been made using wood, the common name of the species and their full scientific name; the product description shall include the list of relevant commodities or relevant products contained therein or used to make those products;

(b) the quantity of the relevant products; for relevant products entering or leaving the market;

(c) the country of production and, where relevant, parts thereof;

(d) the geolocation of all plots of land where the relevant commodities that the relevant product contains, or has been made using, were produced, as well as the date or time range of production;

(e) the name, postal address and email address of any business or person from whom they have been supplied with the relevant products;

(f) the name, postal address and email address of any business, operator or trader to whom the relevant products have been supplied;

(g) adequately conclusive and verifiable information that the relevant products are deforestation-free;

(h) adequately conclusive and verifiable information that the relevant commodities have been produced in accordance with the relevant legislation of the country of production, including any arrangement conferring the right to use the respective area for the purposes of the production of the relevant commodity.

2. The operator shall make available to the competent authorities upon request the information, documents and data collected under this Article.

Article 10 – Risk assessment

1. Operators shall verify and analyse the information collected in accordance with Article 9 and any other relevant documentation. On the basis of that information and documentation, the operators shall carry out a risk assessment to establish whether there is a risk that the relevant products intended to be placed on the market or exported are non- compliant.

2. The risk assessment shall take into account, in particular, the following criteria:

(a) the assignment of risk to the relevant country of production or parts thereof in accordance with Article 29;

(b) the presence of forests in the country of production or parts thereof;

(c) the presence of indigenous peoples in the country of production or parts thereof;

(d) the consultation and cooperation in good faith with indigenous peoples in the country of production or parts thereof;

(e) the existence of duly reasoned claims by indigenous peoples based on objective and verifiable information regarding the use or ownership of the area used for the purpose of producing the relevant commodity;

(f) prevalence of deforestation or forest degradation in the country of production or parts thereof;

(g) the source, reliability, validity, and links to other available documentation of the information referred to in Article 9(1);

(h) concerns in relation to the country of production and origin or parts thereof (...);

(i) the complexity of the relevant supply chain and the stage of processing of the relevant products, in particular difficulties in connecting relevant products to the plot of land where the relevant commodities were produced;

(j) the risk of circumvention of this Regulation or of mixing with relevant products of unknown origin or produced in areas where deforestation or forest degradation has occurred or is occurring;

(k) conclusions of the meetings of the Commission expert groups supporting the implementation of this Regulation, as published in the Commission's expert group register;

(l) substantiated concerns submitted under Article 31, and information on the history of non-compliance of operators or traders along the relevant supply chain with this Regulation;

(m) any information that would point to a risk that the relevant products are non-compliant;
(n) complementary information on compliance with this Regulation (...).

Article 11 – Risk mitigation

1. Except where a risk assessment carried out in accordance with Article 10 reveals that there is no or only a negligible risk that the relevant products are non-compliant, the operator shall, prior to placing the relevant products on the market or exporting them, adopt risk mitigation procedures and measures that are adequate to achieve no or only a negligible risk. Such procedures and measures may include any of the following:
(a) requiring additional information, data or documents;
(b) carrying out independent surveys or audits;
(c) taking other measures pertaining to information requirements set out in Article 9.
2. Operators shall have in place adequate and proportionate policies, controls and procedures to mitigate and manage effectively the risks of non-compliance of relevant products identified. Those policies, controls and procedures shall include:
(a) model risk management practices, reporting, record-keeping, internal control and compliance management, including the appointment of a compliance officer at management level for non-SME operators;
(b) an independent audit function to check the internal policies, controls and procedures referred to in point (a) for all non-SME operators.

Article 22 – Reporting

1. By 30 April of each year, Member States shall make available to the public and to the Commission information on the application of this Regulation during the previous calendar year.

Article 29 – Assessment of countries

1. This Regulation establishes a three-tier system for the assessment of countries or parts thereof. For that purpose, Member States and third countries, or parts thereof, shall be classified into one of the following risk categories:
(a) "high risk", (b) "low risk" and (c) "standard risk".

Article 31 – Natural or legal persons' substantiated concerns

1. Natural or legal persons may submit substantiated concerns to competent authorities when they consider that one or more operators or traders are not complying with this Regulation.

### 2.5. Criteria

In order to ensure consistency, and allow for evaluations and comparisons, this section defines a list of criteria to be used for forest mapping and monitoring. Aligned with the guidelines defined section 9. *Guidelines* of the proposal, these criteria have to be strictly represented in a forest for it to be considered healthy enough to maintain conditions for



biodiversity to thrive and consider the method of this proposal respected.

• Native species: Native tree species show great capacities to support forest resilience. They have adapted overtime and many generations to local conditions of the environment. They support and have evolved alongside local biodiversity. Therefore, they are key to maintain forest biodiversity and structural complexity.

• Canopy cover: The canopy cover surface represents the area of a land that is under the vertically projected tree crowns. The tree crowns closure represents the density of the canopy, which can varies from sparse to dense. The forest canopy plays an important role in defining conditions for microhabitats, one being filtering light that reaches the ground. Light access is a crucial variable to enable natural regeneration of trees in the understorey. Light access is a crucial variable to enable natural regeneration of trees in the understorey.

### 2.6. Quality variables

In addition to the criteria previously mentioned are here defined a list of quality variables. If they do not have to be strictly respected, these variables will provide deeper data on forest's natural qualities and composition. Aligned with the guidelines defined section 9. *Guidelines* of the proposal, they will help during monitoring to analyse forest's structural dynamics and guide practices to maintain or improve forest's health and natural qualities.

• Deadwood: Deadwood plays an important role in the forest ecosystem by serving as a natural habitat, a nutrient pool, water storage and a precursor of soil organic matter for several thousand species. In addition, deadwood accumulation is positively correlated with higher stand age and greater growing-stock volume, and it has also been found to be linked to higher quality in forest soils[10,11].

• Old or large trees: A tree is qualified as "old" when it reaches 3/4 of the maximum age known for the species based on local site conditions. A tree is qualified as "large" when it reaches 3/4 of the maximum diameter as breast height dimension known for the species based on local site conditions. Old trees host specific ecosystems, provide profitable

10 European Commission, Directorate-General for Environment, (2023). *Guidelines on closer-to-nature forest management*, Publications Office of the European Union. https://data.europa.eu/doi/10.2779/731018

11 Bujoczek, L. et al. (2021). *How much, why and where? Deadwood in forest ecosystems: The case of Poland.* Ecological Indicators, 121, Article 107027. https://doi.org/10.1016/j. ecolind.2020.107027

below-ground conditions for tree natural regeneration and bear seeds in their canopy. They have high social values, carrying historical and cultural heritage.

• Stand origin: Forest stands can originate from natural regeneration or planted forests. Stands that originate from natural regeneration show great natural qualities that support local ecosystem services. Stands that originate from planted forests can acquire such qualities overtime when they reach natural structural heterogeneity.

• Structural complexity: This is linked to the forest age or management regime. Old growth forests are generally characterised by structural complexity. This can include a multilayer canopy structure, horizontal structural diversity and soil microrelief structures such as mounds caused by uprooting[12].

• Habitat trees: Habitat trees are defined as a "distinct, well delineated structure occurring on living or standing dead trees, that constitutes a particular and essential substrate or life site for species or species communities during at least a part of their life cycle to develop, feed, shelter or breed"[13].

• Indicator species: A forest can host rare species found in a certain forest type, as well as endangered species including species on the red list of the International Union for Conservation of Nature (IUCN). Such species has to be identified in the mapping process.

• Resilient trees: Highlight tree's resilience to climate change analysing tree decaying. This observation requires an understanding of trees' architectural characteristics and architecture models and relies on the ARCHI diagnostic[14]. A tree is considered resilient when overcoming a stress to go back to a normal growth, or presents a crown dieback with a regenerative dynamic.

• Biomass volume: A tree is composed of below-ground and above-ground biomass. Below-ground biomass corresponds to its roots system. Above-ground biomass includes tree's trunk, branches, stem and foliage. All these are components that need to be taken into consideration in forest management practices.

• Regeneration patches: Resulting of natural regeneration, the patches can vary in sizes and ages. They are very valuable and ensure forest's succession. At early stages, they will be approached at a stand level. The stem exclusion stage that will occur later on will enable a more specific approach at a tree level.

• Seed bearing trees: A tree starts producing fruits and flowers when it reaches maturity. The age when reaching maturity depends on the tree species and local conditions. It reaches a peak in productivity then declines when trees move on in their life cycle. Seed bearing trees are essential to ensure natural regeneration.

### 2.7. Forest inventoring

This section refers to the European Commission's proposal for a regulation on a monitoring framework for resilient European forests[15], published on the 22/11/2023.

The general objective of this initiative is to develop an EU-wide monitoring framework for resilient European forests, which will seek to, as a general objective related to the implementation of Article 191 TFEU, contribute to the EU commitment to combat climate change and achieve sustainability goals, and improving the level of preservation, protection and quality of the environment. This will be achieved by ensuring more data-driven decision and policy-making on forests, which is expected to increase public trust in forest management, reduce illegal logging, incentivise and reward more sustainable forest management, and support the adaptation of forests to climate change, therefore contributing to the Commission policy priorities outlined in strategic policy documents such as the EU Biodiversity Strategy, the Adaptation Strategy and the New Forest Strategy for 2030. This initiative is about better data, knowledge and planning but does not impose on forest management policy choices and objectives of the Member States.

The following points have been selected as key sections of the European Commission's proposal for a regulation on a monitoring framework for resilient European forests in relation to the method developed in this proposal.

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12 European Commission, Directorate-General for Environment. (2023). *Commission guidelines for defining, mapping, monitoring and strictly protecting EU primary and old-growth forests*. Publications Office of the European Union, 2023, https://data.europa.eu/doi/10.2779/481811

13 Larrieu L. et al. (2022). *Key factors determining the presence of Tree-related Microhabitats: A synthesis of potential factors at site, stand and tree scales, with perspectives for further research.* Forest Ecology and Management, 515 (2022) 120235. doi.org/10.1016/j.foreco.2022.120235.

14 CNPF. (2010). *La Méthode ARCHI*. https://www.cnpf.fr/nos-actions-nos-outils/outils-et-techniques/archi#

15 European Commission, Directorate-General for Environment. (2023). *COMMISSION STAFF WORKING DOCUMENT IMPACT ASSESSMENT REPORT Accompanying the proposal for a Regulation of the European Parliament and of the Council on a monitoring framework for resilient European forests.* Publications Office of the European Union, 2023. https://data.europa.eu/doi/10.2779/481811

### 2.7.1. Mapping and monitoring

Article 1 – Subject matter

1. This Regulation lays down a forest monitoring framework for the Union by providing for rules:

(a) Ensuring timeliness, accuracy, consistency, transparency, comparability and completeness of forest data within the Union and their public accessibility;

(b) Supporting the voluntary development of integrated long-term plans at the level of the Member States through an evidence-based, inclusive, cross-sectoral and adaptive approach;

(c) Setting up a strengthened governance between the Commission and the Member States.

2. This Regulation lays down rules for collecting and making accessible information to support:

(d) The implementation of Union legislation and policies pertaining to the conservation, restoration and sustainable use of forest ecosystems and their services, with particular attention to the objective of increasing forest resilience and enabling to safeguard the multifunctionality of forests, including in relation to: climate change adaptation and mitigation, biodiversity, disaster risk prevention and management, forest health, forest biomass use for different socio-economic purposes, invasive alien species;

(e) National forest management and integrated long-term planning by the Member States, *inter alia*, to increase forest resilience against wildfires, pests, droughts and other disturbances.

Article 3 – Forest monitoring system

1. The Commission shall set up, in cooperation with the Member States in accordance with Article 11, and operate a forest monitoring system comprising the following elements:

(a) a geographically explicit identification system for the mapping and localisation of forest units, as set out in Article 4;

(b) a forest data collection framework, as set out in Articles 5 and 8;

(c) a forest data sharing framework, as set out in Article 7;

2. The forest monitoring system shall consist of electronic databases and geographic information systems and shall enable the exchange and integration of forest data with other electronic databases and geographic information systems (...).The forest monitoring system shall ensure the regular and systematic collection of:

(a) forest data on the basis of aerial or space-borne ortho-imagery, by Copernicus Sentinel satellites or other equivalent systems;

(b) in situ data through a network of monitoring sites.

Article 4 – Geographically explicit identification system for forest units

1. The Commission shall set up the geographically explicit identification system for the mapping and localisation of forest units (the 'identification system').

2. The identification system shall be a geographic information system. The Commission shall establish and regularly update the identification system on the basis of aerial or space-borne ortho-imagery data, with a uniform standard that guarantees a level of accuracy that is at least equivalent to that of cartography at a scale of 1:100 000.

3. The identification system shall:

(a) enable the precise mapping and localisation of forest areas and, subject to the establishment of methodologies pursuant to Article 8(3), of other wooded land across the Union;

(b) uniquely identify forest units on the basis of a combination of forest data referred to in Article 5(2) and Article 8(1);

(c) facilitate the detection and location of change between land containing and not containing forest.

Article 5 – Forest data collection framework

2. The Commission shall collect the following forest data in accordance with the technical specifications set out in Annex I, thereby ensuring the standardisation of the data:

(a) forest area;

(a) tree cover density;

(b) forest type;

(c) forest connectivity;

(d) defoliation;

(e) forest fires;

(f) wildfire risk assessment;

(g) tree cover disturbances.

3. Member States shall collect the following forest data, in accordance with the frequency specified in Annex II :

(a) forest available for wood supply and forest not available for wood supply;

(b) growing stock volume;

(c) net annual increment;

(d) stand structure;

(e) tree species composition and richness;

(f) European forest type;

(g) removals;

(h) deadwood;

(i) location of forest habitats in Natura 2000 sites;

(j) abundance of common forest birds;

(k) location of primary and old-growth forests;

(l) protected forest areas;

(m) production and trade of wood products;

(n) forest biomass for bioenergy.

4. For the purposes of paragraph 3, points (a) to (h), Member States shall collect in situ data on the basis of ground surveys in combination with, where available, data from Earth Observation, and data from other relevant information sources. The ground surveys shall be based on a network of monitoring sites that are representative of, and consistent with, the Member State's forest area referred to in paragraph 2, point (a).

Article 7 – Forest data sharing framework

1. (...), the Member States shall share the latest available forest data referred to in Article 5(3) in accordance with the technical specifications set out in Annex II, by making them publicly accessible. The Member States shall ensure data harmonisation by sharing aggregated forest data in accordance with the descriptions set out in Annex II. Sharing of the geographically explicit location of monitoring sites shall be subject to the establishment of the safeguards referred to in Article 9(2).
2. The Member States and the Commission shall make publicly accessible the data referred to in Article 5(2) and (3) and in Article 8(1) in an open format that is machine-readable and that ensures interoperability and re-usability in accordance with Article 5 of Directive (EU) 2019/1024.

Current forest states will be dressed within this framework. The database that will result from this inventory will include digital models and technical drawings of forests, such as sections and plans. The scale of drawings will vary from 1:1000 for the mapping of forest units to 1:100 for the report of diversity, natural qualities and specificities found in the forest. This inventory will allow to detail forest's layers based on its structure (see *E. Criteria* and *F. Quality variables*) and dynamics according to space and time. These representations will be elaborated as a cooperation between the fields of biology, construction and architecture. This will ultimately contribute to the expansion and share of common knowledge around forestry and architectural practices.

### 2.7.2. Data management

Previous sections define the geographical, jurisdictional and technical scopes of the method. A clear transparency is fundamental to enable monitoring and traceability from forests to final products. Thus, centralisation and digitalisation of collected data become essential. All stakeholders taking part in the processes that involves the architectural project will report their practices in a central database accessible at a European level.

At each steps, verification of accuracy, reliability and quality of collected data will be ensured by a European government-owned first party audit body. Confidentiality have to be preserved at all costs without affecting the transparency of the method. Data ownership will be developed in section *8. Ownerships*.

Article 10 – Data quality control

1. The Commission and the Member States shall be responsible for the quality and completeness of the forest data that they collect and share under the forest monitoring system.
2. Member States shall annually assess the quality of the data shared in accordance with this Regulation. Where the assessment reveals deficiencies in the data, Member States shall adopt appropriate remedial actions. Member States shall submit to the Commission the assessment reports on the quality of data and, where appropriate, the description of the remedial actions and the timetable for their implementation by 1 July following the calendar year in which the deficiency was identified.
3. The Commission is empowered to adopt delegated acts in accordance with Article 14, to supplement this Regulation by establishing accuracy standards for data shared under this Regulation and rules on the quality assessment referred to in paragraph 2 of this Article and Article 6(2), point (c).
4. The Commission is empowered to adopt implementing acts to specify the contents of the assessment reports on the quality of data and arrangements for their submission to the Commission as well as the description of remedial actions referred to in paragraph 2, second subparagraph. Those implementing acts

Article 11 – Coordination and cooperation

1. The Member States and the Commission shall coordinate their efforts and cooperate to improve the quality, timeliness and coverage of forest data.
2. The Commission shall support the Member States, upon request, in the development or adaptation of their voluntary integrated long-term forest plans referred to in Article 13, by providing information on the state of the underlying scientific knowledge and by facilitating knowledge and good practice exchange.
3. Member States shall cooperate among each other and coordinate their actions to improve the quality, timeliness and coverage of forest data. Such cooperation and coordination shall be based on open scientific debate and shall aim to promote impartial scientific advice.
4. Member States and the Commission may use existing regional institutional cooperation structures, including those under regional Conventions and other forest relevant fora and processes.

Article 12 – National correspondents

1. Each Member State shall designate a national correspondent and shall inform the Commission thereof.
2. The national correspondent shall, in particular, carry out the following tasks:
   (a) coordinate the preparation of the forest data to be shared under this Regulation, taking into consideration all competent authorities, including those responsible for disaster risk prevention and management;
   (b) coordinate attendance of relevant experts in expert group meetings organised by the Commission and other relevant bodies.
3. The national correspondent shall serve as focal point for the exchange of information between the Commission and the Member State for the development or adaptation of the voluntary integrated long-term plans referred to in Article 13. Where several authorities in a Member State are participating in the development or adaptation of the voluntary integrated long-term forest plan, the national correspondent shall be responsible for the coordination of that work.

Article 13 – Voluntary integrated long-term plans

3. Member States shall encourage the active involvement of all interested parties in the development of their integrated long-term forest plans. Member States shall make the plans publicly available.

## 3. Objectives

### 3.1. Bridge EU latest forestry policies together to improve sustainability in forestry and design practices

Bridging latest European forest strategies, management guidelines, deforestation regulation and forest mapping and monitoring together defines common framework, scope and practices. This is a fundamental starting point to build a central database that will facilitate the analysis and evaluation of our current practices. Ultimately, the database will give inputs and variables to work from to improve sustainability in forestry and design practices.

### 3.2. Improve transparency throughout the whole process that imply wooden buildings design and construction

Transparency is key to approach a process as a whole and to decompose it in steps of actions. Independently and together, the identification and analysis of these different steps will give a better leverage to adapt our practices in the aim of reaching sustainability at different scales and levels.

### 3.3. Elaborate a method to evaluate forest's operational capacity of providing raw material

The method developed in this proposal seeks to determine the actual amount of wood that can be harvested from a forest for it to stay healthy, meaning being able to provide its ecosystem services and keeping its natural qualities and diversity. Ultimately, the method sets boundaries within which an architectural project can be designed.

### 3.4. Redefine architects' responsibilities in natural resources planning and uses

The way we manage and use natural resources today shape our landscapes and have big environmental and social impacts. As experts in built environment design, architects sit right at the frontier of the built and nature. They are in a key position in discussions between forestry and industries, and have an influence in the choices we make in terms of materials uses for our built environment. Now, in order to cross that border between the built and natural, architects will take part in the mapping of forests, using their spatial expertise and tools such as technical drawings. This will open the discussion and promote transdisciplinarity, to ultimately support the transparency of the whole method.

### 3.5. Provide a central database based on past, current and future states of forests

Each harvested forests will have to go through a mapping process. This process includes an historical analysis of the forest, a report on its current composition and dynamics, and



a report on its state after harvesting. This database will be used for evaluations and decision making in regard of forest monitoring.

### 3.6. Database as the design thinking framework

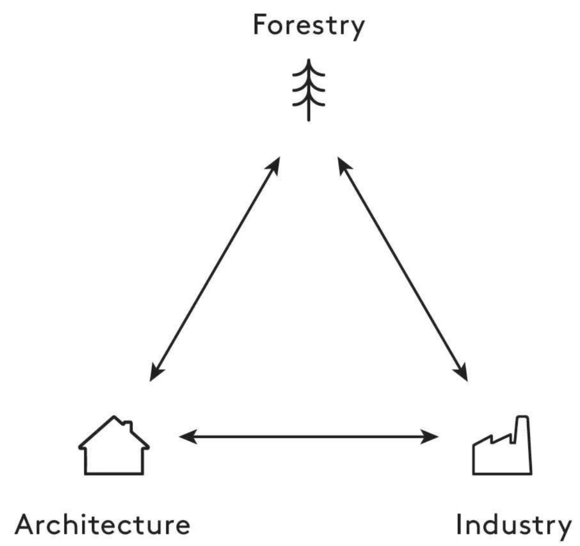
Forest management practices promoted by the method will determine industrial and design practices. They will provide a larger range in available wood products and new alternatives in wooden building design. Iterations between forestry and design will be key to reach the full potential of the method. This last point will be facilitated with new architects' role and responsibilities in natural resources planning and uses mentioned above, section *3.4.*.

### 3.7. Define forestry practices priorities of a local context

The method seeks to be flexible by taking into account the complexity of a natural forest structure. It is based on strict criteria and quality variables. If criteria apply and should be verified in all types of forests, the quality variables allow to work with specific contexts.

## 4. General principles

This proposal promotes a method where industrial and design practices are determined from a defined sustainable forest management. Thus, the method is developed around three main components that are forestry, architecture and industry. This section will identify chronologically the steps that include each components in the process of implementation. These steps will be further developed section *7. Stepwise approach of implementation*.




Material and knowledge exchanges within Forestry, Architecture and Industry sectors. Source: Author.

4.1. Forestry

4.1.1. Mapping

The first mapping is done before harvesting. It will serve as foundations for monitoring and give data about a forest at its current state. This mapping consists of a report based on the proposal's criteria and quality variables identification in the mapped forest.

4.1.2. Forest carbon evaluation

A carbon evaluation of the mapped forest will complement data collected from mapping. This evaluation will determine how much carbon is currently stored in the forest, and estimate the amount of carbon that the forest sinks for a year.

4.1.3. Tree classification

Mapping will specify forests' composition and structure. This analysis will result in a classification of trees found in the mapped forest, based on the *Tree classification table* provided annexe 2 in the proposal's appendix.

4.1.4. Selection: Preservation/Harvesting

Once mapping and classification stages completed, conditions for sustainable harvesting are set and thus enable a selection at a tree level. Respecting the guidelines defined section 9. *Guidelines* of the proposal, the selection will be conducted following the principle *Should it be preserved/Could it be harvested*. Trees that have been preserved during first harvesting could potentially be harvested on a harvesting conducted later on.

4.1.5. Natural regeneration

Selected harvesting will keep the ability of the forest to ensure natural regeneration of various local established species. The environmental qualities of the forest will be kept and will provide suitable conditions for the forest to complete its natural cycles.

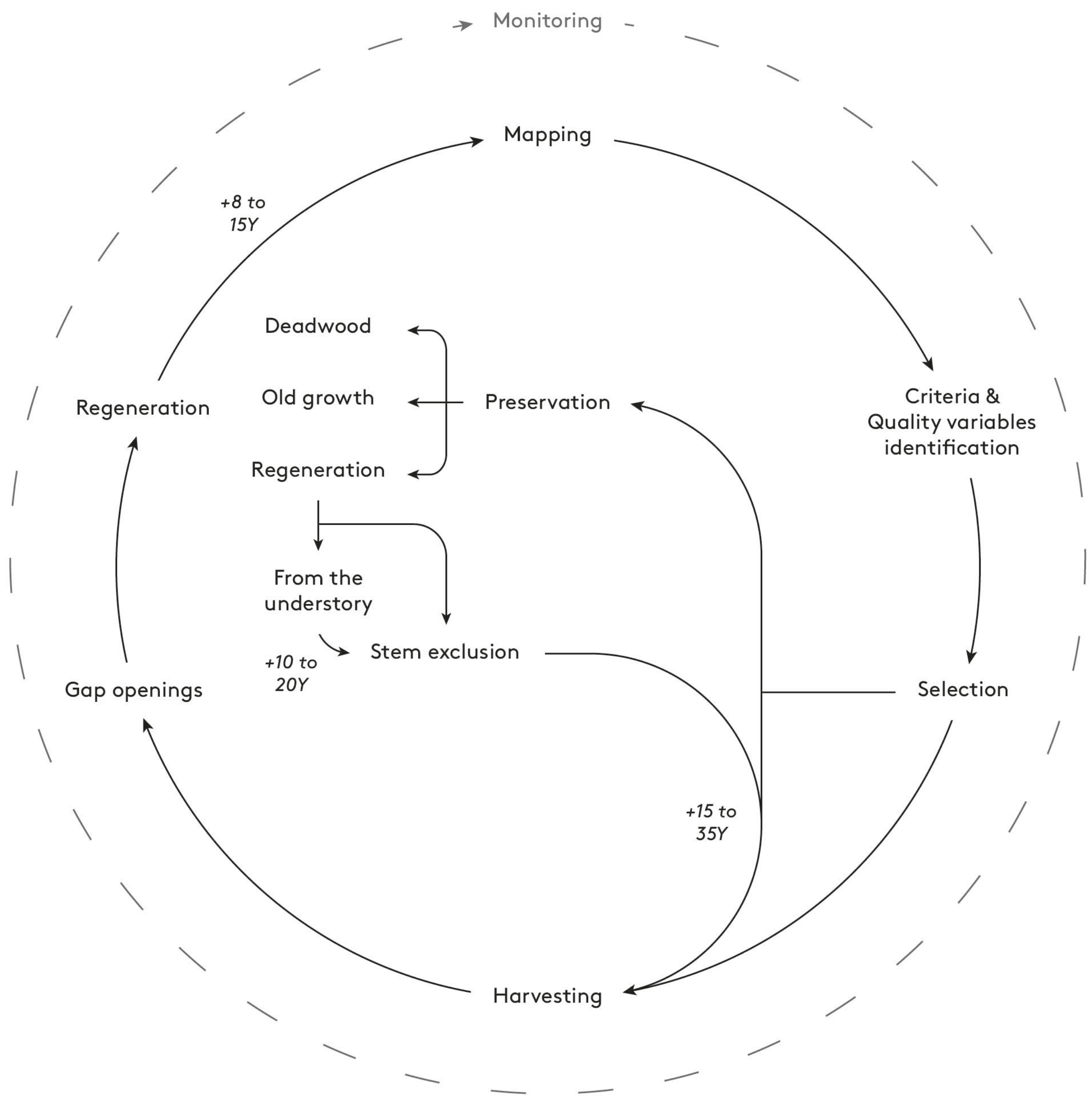
4.1.6. Monitoring

All previous steps mentioned above will be monitored to ensure that the forest stays healthy while undergoing the forest management model promoted by the proposal's method.

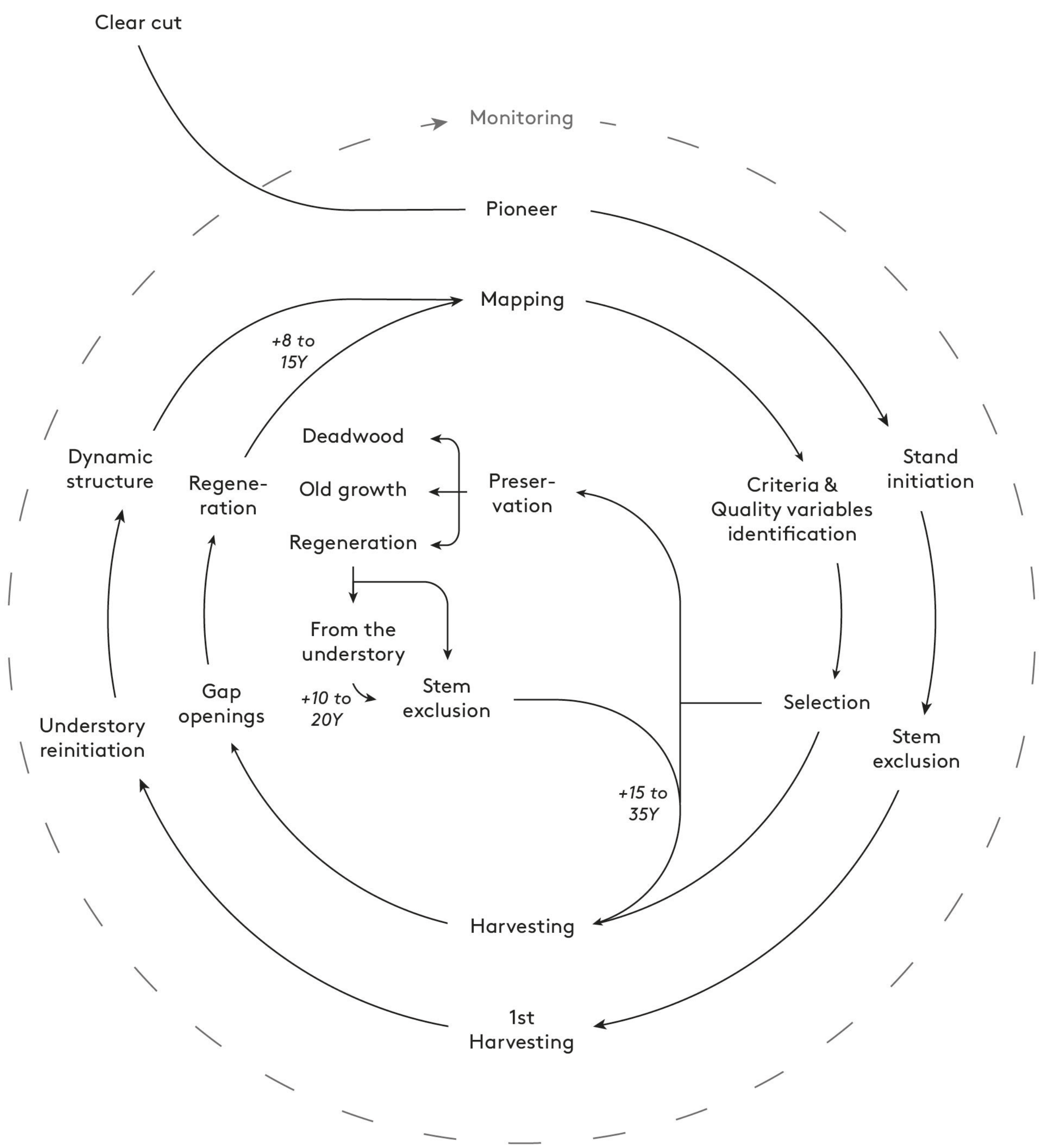
4.1.7. Mapping



Finally, as a cycle, mapping will be conducted again before next harvesting, and will lead to the following steps mentioned above.




Sustainable Forest Management diagram, following *4.1. Forestry* section's principles.
Source: Author.




Sustainable Forest Management diagram, following *4.1. Forestry* section's principles after a clear-cut.
Source: Author.



## 4.2. Architecture

### 4.2.1. Wood availability

Iterations between forests and the architectural project will be facilitated. The proposal's method will provide a larger range in types of wood harvested. This will serve as a material bank in which the architectural project will seek for alternative and sustainable design proposals.

### 4.2.2. Project's wood needs evaluation

This stage will evaluate the project's needs in terms of wood types and amounts for the building to be fully constructed.

### 4.2.3. Project's design elements inventory

The architectural project will be detailed by identifying the wooden design elements that will be part of the building.

### 4.2.4. Project carbon emissions evaluation

This stage will be done in relation to stage *4.1.2. Forest carbon evaluation*. The aim is to balance the carbon emissions resulting of the project with the carbon sinked by the harvested forests that provided materials for the project.

### 4.2.5. Project's final design

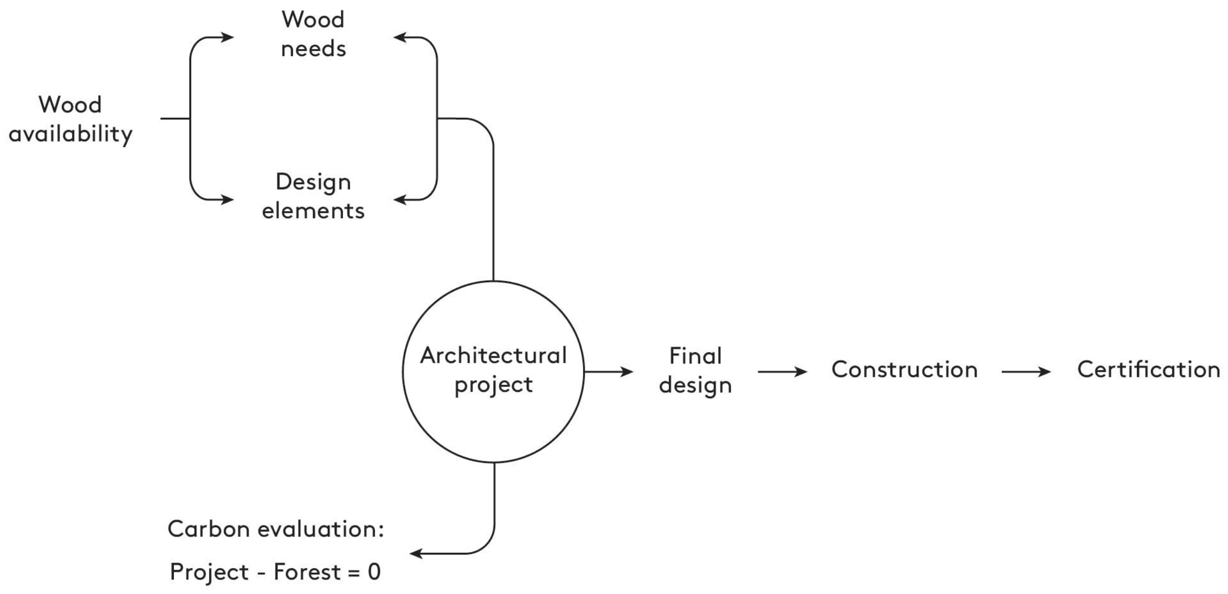
Based on stages mentioned above, a final design proposal will be presented. This design proposal will result of design explorations determined by the material and immaterial outcomes provided by the harvested forests.

### 4.2.6. Construction

The building is finally being built.

### 4.2.7. Certification

The harvested forests and final building are linked together by a certification that guarantees that the proposal's method has been followed in its entirety.




Sustainable design of wooden buildings diagram, following *4.2. Architecture* section's principles.
Source: Author.

## 4.3. Industry

### 4.2.1. Project's design elements inventory

The architectural project will be detailed by identifying the wooden design elements that will be part of the building.

### 4.3.2. Wood availability

Roundwood is being classified, marked and collected from harvesting site. Classification is made from the size and quality (straightness, abundance of branches, wounds...) of each round logs.

### 4.3.3. Transport to primary processing site

Roundwood is being transported from harvesting site to the primary processing site.

### 4.3.4. Primary processing

This stage distinguishes log only inputs (plywood, veneer and sawmill) from log and other inputs (flooring, board, pulp, paper, fuelwood).

### 4.3.5. Transport to secondary processing site

Primary products are being transported from the primary processing site to the secondary



processing site.

### 4.3.6. Secondary processing

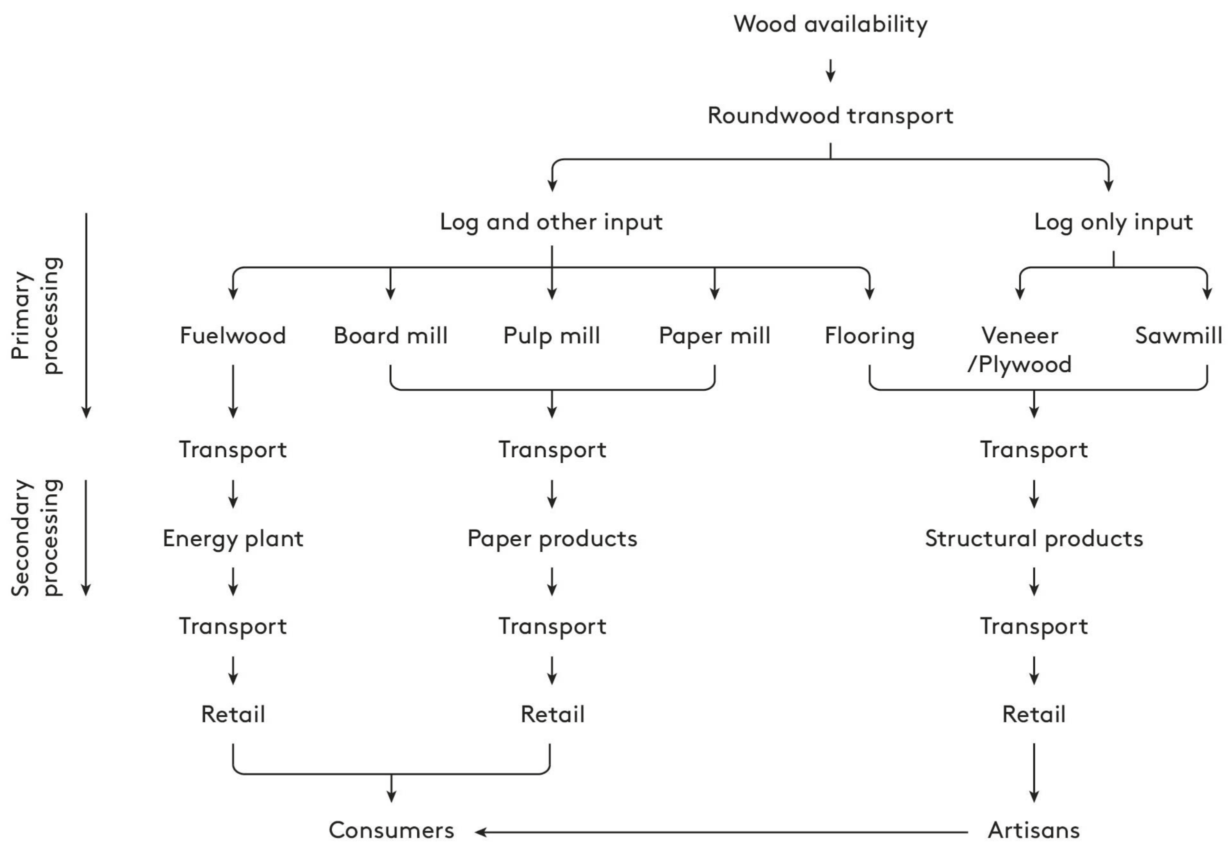
This stage distinguishes structural, paper and energy products.

### 4.3.7. Transport to retail centre

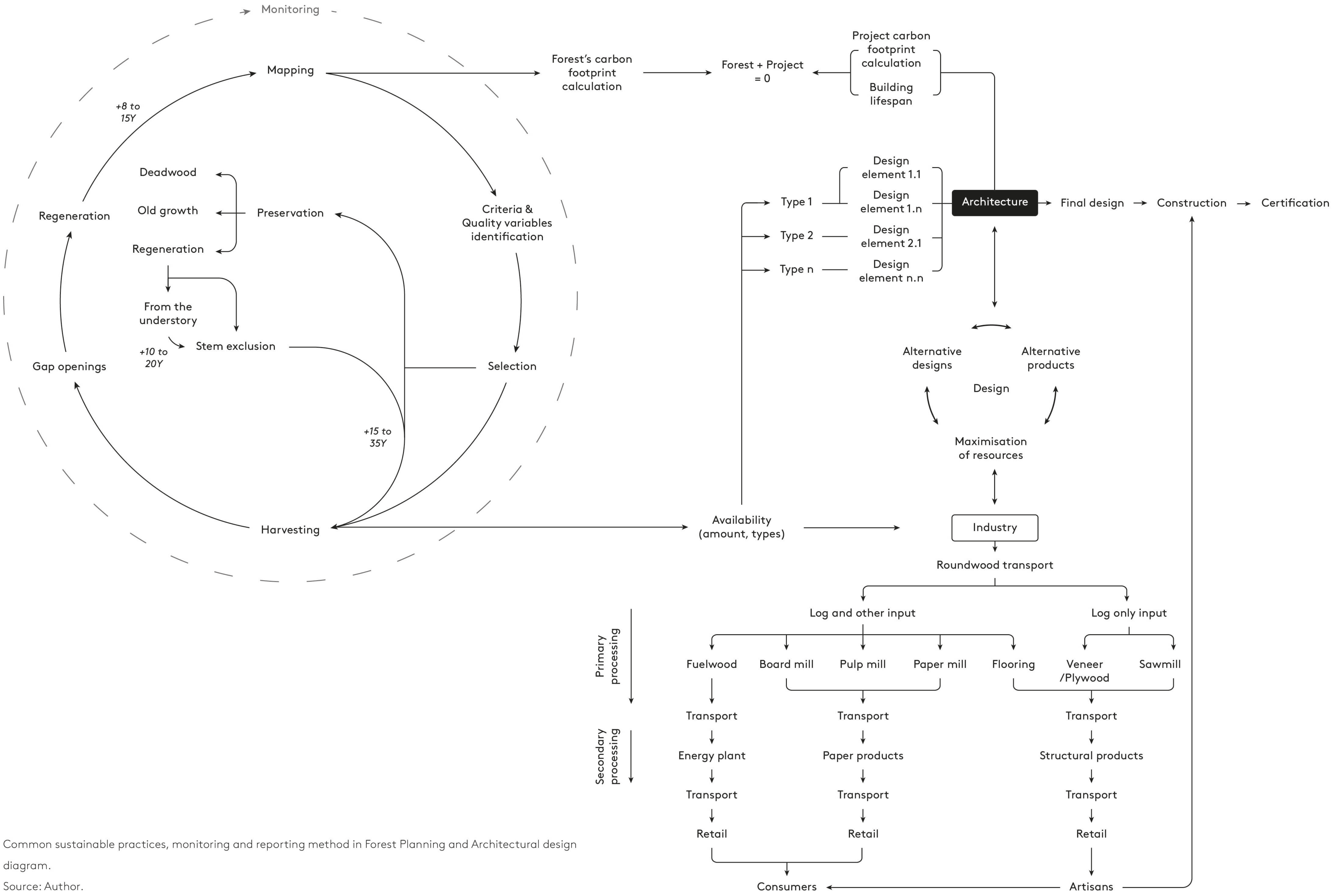
Final products are being transported from the secondary processing site to retail centres.

### 4.3.8. Final use

Wood products find their final use. This includes packaging, energy, and construction (see section *4.2.6. Construction*).




Timber traceability diagram, following *4.3. Industry* section's principles.
Source: Author.




Common sustainable practices, monitoring and reporting method in Forest Planning and Architectural design diagram.
Source: Author.

## 5. Targets

This section defines a set of targets as a toolbox to which forest management practices can refer to. These targets seeks to be flexible tools to adapt practices to different contexts, scales and timeline. They are based and put in relation Closer-to-Nature forestry principles with criteria and quality variables defined in sections *2.2.*, *2.5.* and *2.6.*.

For each harvested forest, 3 targets will be specifically chosen and guide forestry practices before, during, and after harvesting. These targets will be particularly followed at each forest monitoring stages.

As for evaluation, the evolution of each targets' states will be conducted in relation to measures provided section *9. Guidelines*.

### 5.1. Develop forest composition diversity

Composition refers here to the range of tree species that can be found in the forest. Depending on the natural context where the forest is established, a mixed composition with evergreens and deciduous trees will be promoted.

### 5.2. Develop forest structure diversity

Structure refers here to trees' age and origins. With natural regeneration as a main principle, forest's structure becomes more uneven and gain in complexity following forests' natural cycles.

### 5.3. Tree cover extension

This targets evaluates on a plan the total surface covered by trees. This includes the evolution of canopy cover as well as forests' stems density.

### 5.4. Increase old or large trees ratio

This target calculates the percentage in terms of biomass of old or large trees found in a forest.

### 5.5. Preservation of regeneration patches already established on site

This target aims to ensure forest's succession by preserving patches of saplings and young trees resulting from natural regeneration already established on site.

### 5.6. Protection of endangered species



When a forest is established in an area where endangered fauna and flora species can be found, forest management practices should not disturb the ecosystems that depend on those species. Precautions should be taken, and monitoring should have included an adapted timeframe and specific criteria to measure.

### 5.7. Restore soil

Soil should preserves its filtering and retention qualities of water, nutrients and carbon. If those conditions have been altered from previous climate events or human activities, forest management practices should permit their restoration.

### 5.8. Restore water bodies and streams

Natural water flows should be ensured and no prone to pollution. When ditches have been dug, restoration projects can be conducted together with Closer-to-Nature forest management practices to restore the natural qualities and dynamics of the site.

## 6. Benefits

Our view on forests evolves with our societies' needs and demand. Lately, the importance given to the environmental and social values of a forest started to increase, alongside with our awareness on climate change. In addition, with a high and increasing demand on wood products, the economic values of forests are to be considered as one of the main values held by forests.

This section goes through the main benefits of the proposal's method on the environmental, economic and social values of forests.

### 6.1. Environmental benefits

#### 6.1.1. Heterogeneous structure

Forests adopt a dynamic structure and become multigenerational, uneven aged, as opposed to planted monospecies forests. Such structure supports biodiversity and forests ecosystem services.

#### 6.1.2. Heterogeneous composition

Forests are composed of mixed species, with endemic species, evergreens and deciduous trees. The flora is adapted to the local environment conditions and ecosystems.

#### 6.1.3. Natural regeneration

Heterogeneous structure and composition provide ideal germinating and growing conditions for natural regeneration, thus support forest's natural cycles establishment.

#### 6.1.4. Resilience

Forests build a better tolerance and adaption to climate change conditions, extreme weather events, pests and diseases.

#### 6.1.5. Soil conditions

Closer-to-Nature forest management practices rely on methods that avoid soil compaction and erosion. This prevent carbon release in the atmosphere and water flows alterations, improving water quality.

#### 6.1.6. Canopy cover preservation

Preserving a certain percentage of canopy cover after harvesting provide good light conditions for natural regeneration while intercepting airborne pollutants.

#### 6.1.7. Harvesting scales

Selected harvesting support wildlife by maintaining habitats interconnections on a larger scale than the harvested forest.

### 6.2. Economic benefits

#### 6.2.1. Supply and demand evaluation coordination

Forest monitoring and mapping gives a clear picture of wood supply. When put in relation with demand, it helps to maximise the resource value by determining the actual value of a specific type of wood material.

#### 6.2.2. Harvesting outcomes diversity

Growing and harvesting various tree species give a leverage at medium term and ways to adapt to timber prices fluctuations. It opens the possibilities to harvest different wood types and qualities.

#### 6.2.3. New business opportunities



Taking into consideration new forests' values such as carbon removals and ecosystem services, the method supports the development of new markets, opening new job opportunities.

#### 6.2.4. Increase efficiency of supply network

The transparency of the whole process that the method enables facilitates monitoring and decision making in response measures to identified issues at specific stages of the process.

#### 6.2.5. Transdisciplinarity and cooperation

Developed around a common database, the method breaks the boundaries between fields and facilitates communication and knowledge exchange.

#### 6.2.6. Common regulation framework

Inspections, monitoring and measures will be taken in the scope of the same jurisdictional framework. Regulations are defined at European level by the European Commission. See sections *2.2.*, *2.3.* and *2.4.* for more precisions on regulations.

#### 6.2.7. New funding opportunities

Stakeholders following the method can benefit from EU funding and support programs.

### 6.3. Social benefits

#### 6.3.1. Gives voice to people

Developed around a common EU regulation framework, the method improves forest governance by increasing monitoring and reducing the impacts of industries in the fields.

#### 6.3.2. Deforestation free wood products

Providing timber traceability, the transparency of the method throughout the whole process allows to control and ensure that all wood products have not been produced on deforested lands.

#### 6.3.3. Landscape

Avoid deforestation and land degradation favours the preservation of traditional landscapes. These landscapes carry local history and often represent the identity of a place.

### 6.3.4. Tourism

Specificities of traditional landscapes mentioned above section *6.3.3.* also favour tourism and eco-tourism. Tourism brings its dynamics and plays an important role in rural places' life.

### 6.3.5. Well-being and healthy living

Healthy forests provide a natural structure that supports outdoor recreation activities, favouring well-being and healthy living of society.

### 6.3.6. Forests partnerships

The method promotes forests partnerships within Europe, leading to the development of projects, tourism, and opening international opportunities for European rural areas.

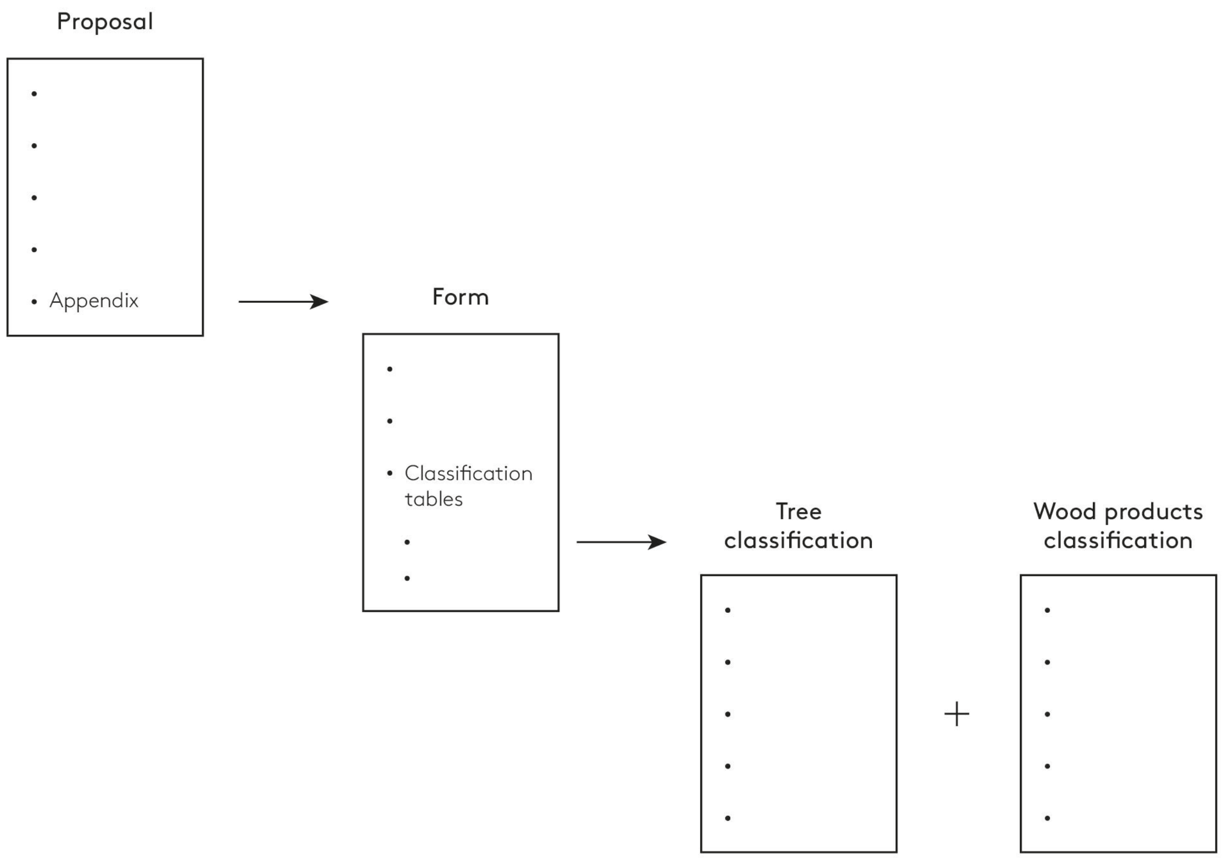
## 7. Stepwise approach of implementation

This section looks at how the general principles developed section *4. General principles* are reported for monitoring in practice through the process of implementation.

The method provides a form (annexe 1) that will be filled at the start of the architectural project. The form is articulated in four different sections in relation to the main components that are forestry, architecture and industry. Each chapter seeks to detail specific variables involved in the process in order to provide relevant data to ensure clear transparency.

The *Forest* section will be detailed based on the *Tree classification* table's classification keys (annexe 2). The *Architecture*, *Primary processing* and *Secondary processing* sections will be detailed based on the *Wood products classification* table's classification keys (annexe 3).





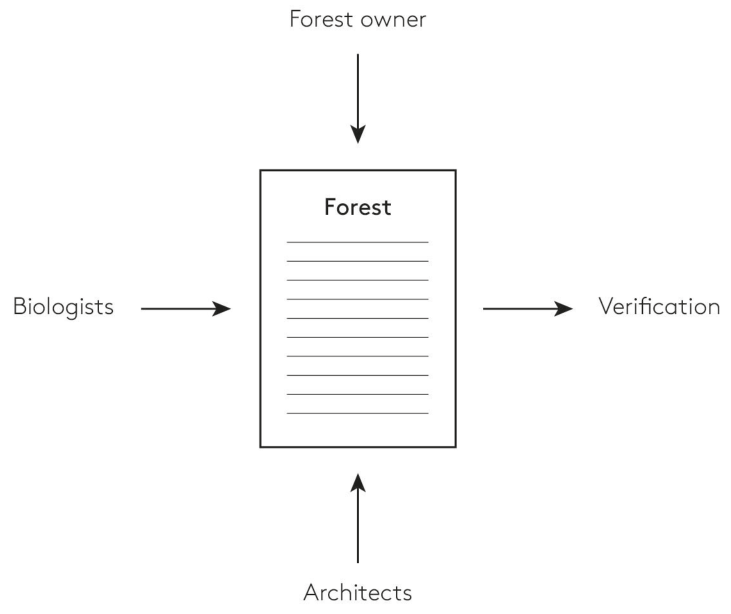

Proposal's branching diagram.

Source: Author.

### 7.1. Forest

This section of the form gives indications on the harvested forest. Information regarding its location, ownership and management are reported by the forest owner. In addition to this, mapping and inventory is done by architects and biologists. Mapping reports forest's past, current and future states after harvesting. Pictures, plans, sections and 3D models will be provided as part of mapping, as graphical descriptions of the forest's state.

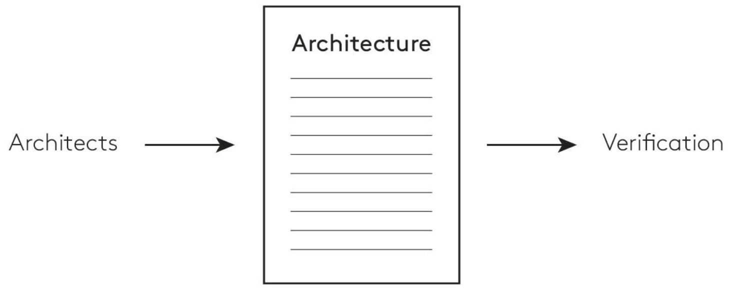
Inventoring is done based on tree classification keys, from the *Tree classification* table (annexe 2). These keys give specifications on tree species, conditions, growth stage, and on environmental and harvesting qualities.




Form's Forest section inputs diagram.
Source: Author.

### 7.2. Architecture

This section of the form gives indications on the architectural project. Information regarding the architecture agency and project description are provided by the architectural agency working on the project. The data include identification and location of the agency, as well as responsibilities in the project, needs in wood and project's carbon evaluation.




Form's Architecture section inputs diagram.
Source: Author.

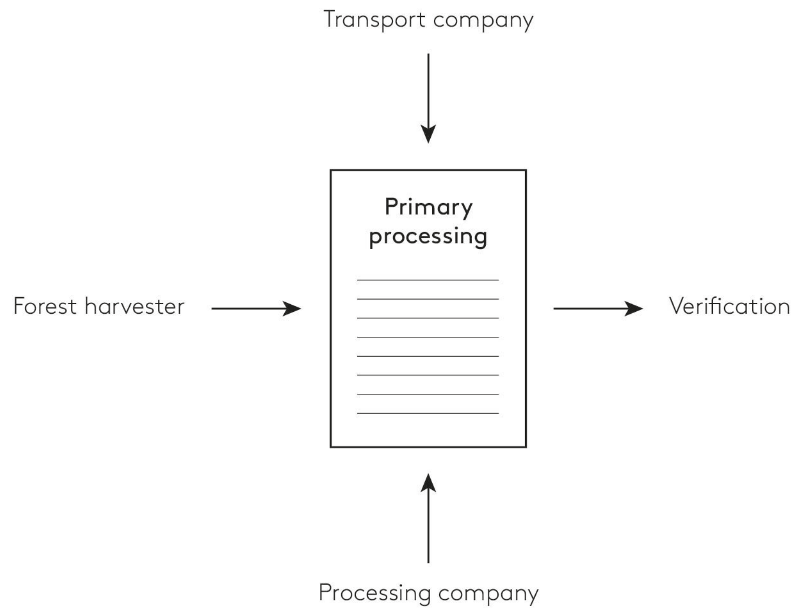
### 7.3. Primary processing

This section of the form gives indications on the primary processing stage. It details the process from the marking of harvested logs in the forest to the primary processing outcomes. The section includes information regarding transport company, ways of



transport, and material outcomes from processing (wastes and products). Data is provided by forest harvesters, transporters and processing companies.

Specifications on processing outcomes are based on wood products classification keys, from the *Wood products classification* table (annexe 3). These keys determine the categories of the final wood products after primary processing: roundwood, fuelwood, sawnwood, panel, pulp, paper, cork...

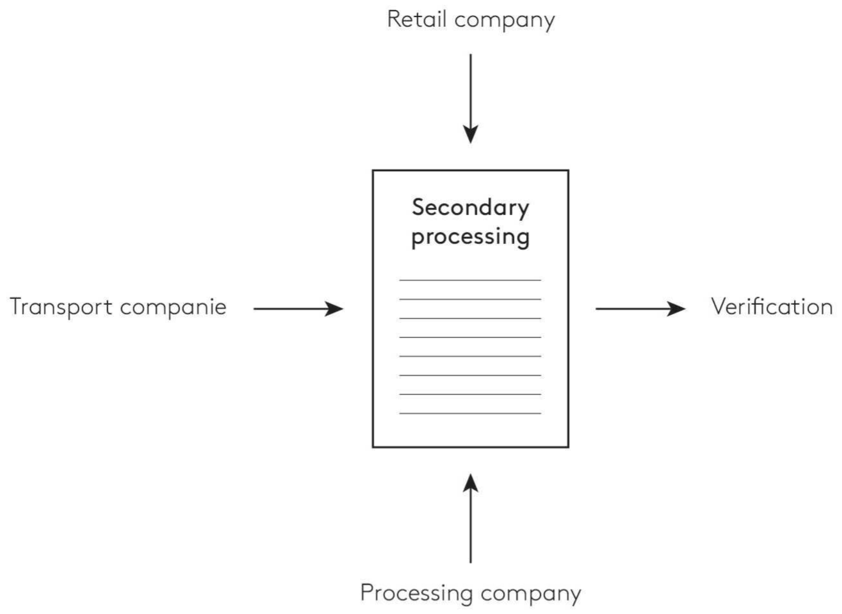



Form's Primary processing section inputs diagram.
Source: Author.

### 7.4. Secondary processing

This section of the form gives indications on the secondary processing stage. It details the process from the moment wood products leave the primary processing site to secondary processing site and retailing. The section includes information regarding transport company, ways of transport, and material outcomes from processing (wastes and products). Data is provided by transporters, processing and retail companies.

Specifications on processing outcomes are based on wood products classification keys, from the *Wood products classification* table (annexe 3). These keys determine the categories of the final wood products after primary processing: roundwood, fuelwood, sawnwood, panel, pulp, paper, cork...




Form's Secondary processing section inputs diagram.
Source: Author.

## 8. Ownership

The method developed in this proposal identifies steps in the process of wooden building construction and helps to name stakeholders involved in each of these. Internal audit is crucial at each steps to allow for evaluation and improvement. However, timber industry can be at risk for corruption thus measures in timber traceability have to be taken for transparency and impartiality. In addition to internal audit, external audit will be conducted throughout the whole process at every stages.

Since the method lies on the latest European forest policies, external audit will be ensured by European government-owned first party audit body. All data collected, audited and shared will be under the ownership of European government.

## 9. Guidelines

This section defines guidelines for good practices in forestry, architecture and during the industrial processes, aligned with the proposal method. It specifies quantitative and qualitative delimitations of the criteria (section *2.5.*), quality variables (section *2.6.*) and general principles (section *4.*).

### 9.1. Guidelines for forestry

• Species diversity: All species present before harvesting will be present after harvesting. Special attention will be given to native species. Non-native tree species will not be



removed if they do not significantly disturb ecological processes.

• Canopy cover: Canopy cover will be maintained at 50% minimum over the global surface of the harvested forest. Gaps created from harvesting will not exceed 0.05 ha. The gaps are varied in shapes and sizes, will not affect forest's stability, and be based on light-access needs of surrounding tree species to allow natural regeneration.

• Biomass volume: Do not harvest more than 50% of a same species in terms of above-ground biomass. Below-ground biomass of harvested trees will not be excavated.

• Structural complexity: Do not harvest more than 75% of a same tree range. Tree range is defined by a tree's trunk diameter at breast height and tree's canopy height.

• Regeneration patches: When 0.025 ha or more and composed of 5+ years old saplings, regeneration patches will not be altered by harvesting processes.

• Deadwood: The method aims to find a minimum of 20 $m^3$/ha of deadwood, including lying and standing deadwood.

• Resilient trees: Resilient trees will be identified before harvesting. An area of 0.015 ha centered at its trunk will not be altered by harvester machines.

• Habitat trees: Habitat trees will be identified before harvesting. An area of 0.015 ha centered at its trunk will not be altered by harvester machines.

• Old or large trees: A tree that has reached 100 years old or half of its species life expectancy on the specific site will not be harvested.

• Stand origin: The method favours natural regeneration but allows for plantations. When plantation is done, it will be limited to local species and will respect local species diversity and forest's current stage of growth.

• Indicator species: Tree species of late-seral developmental phases and species listed on the red list of the International Union for Conservation of Nature (IUCN) will not be harvested. Special attention for protection to these will be given during harvesting.

• Seed bearing trees: When found on site, seed bearing trees' distribution will be preserved across the whole harvested area.

• Harvesting frequency: 10 years should separate two harvestings of a same tree range.

• Compact and light tracked skidder and harvester machines. Manual tree falling and horse skidding being considered as the lowest impact interventions in a forest.

### 9.2. Guidelines for architecture and industry

• Forest capacity: Forest mapping will evaluate forest's final capacity in terms of wood availability, taking into consideration biodiversity and carbon cycles.

• Project's carbon footprint: Carbon emissions resulting of the project will be balanced by the harvested forest(s) in 10 years maximum.

• Forest mapping roles: Forest mapping will be done by a team of biologists and architects with the aim of sharing knowledge between the fields. In addition, by taking part in the mapping process, architects will be exposed to practical situations, thus get a better understanding of relations between the tree, the material of wood and its final use. This should help in opening possibilities within the forestry industry.

• Iterations: Forest mapping will enable iterations between project, forest and industry, thus will deepen understanding and possibilities of what a natural forest can offer to the architectural project within its ecological boundaries.

• Design: Architects and engineers will work in cooperation on alternative structural wood products research projects. These projects will feed a database of alternative structural wood products. As references, architects will look in the database after the mapping of a forest to seek for alternative design elements to use in the project. Industries will use the database to develop flexible industrial processes of production of the alternative structural wood products listed.

• Wood products inventory: The design process of a wooden building will provide a wood products inventory regarding the needs (types and amounts) for the building to be constructed. The wood products listed in the inventory will refer to the alternative structural wooden products database mentioned above.

• Graphical clarity: Forest mapping allows inventory and classification, thus should clearly show graphically the criteria listed section *2.5.* and quality variables listed section *2.6.*.



## Appendix

*Annexe 1*

## Reporting Form

## Forest

| | |
|---|---|
| **Identification** | |
| Parcel's administrative code | |
| Surface | |
| Address | |
| GPS coordinates | |
| City | |
| Country | |
| Code | |
| Owner | |
| Address | |
| Street, No. | |
| City | |
| Country | |
| Code | |
| Contact person | |
| Telephone | |
| E-mail | |
| **Characterisation** | |
| History | |
| Origins | |
| Current forest's stage of growth | |
| Current state | |
| Plans | *Refer to annexe 1.1 - Criteria and Quality variables mapping* |
| Sections | *Refer to annexe 1.2 - Criteria and Quality variables mapping* |
| Species inventory | |



| | |
|---|---|
| Targets | |
| Annual growth (biomass) | |
| Carbon footprint | |
| Annual | |
| Projected (10y) | |
| Photographic report before harvesting | *Refer to annexe 1.3* |
| **Management** | |
| Regime | |
| Day of harvesting | |
| Method of harvesting | |
| Logger company | |
| Address | |
| Street, No. | |
| City | |
| Country | |
| Code | |
| Contact person | |
| Telephone | |
| E-mail | |
| Website | |
| Harvested trees marked on plan | *Refer to annexe 1.4* |
| Plans after harvesting | *Refer to annexe 1.5* |
| Sections after harvesting | *Refer to annexe 1.6* |
| Photographic report after harvesting | *Refer to annexe 1.7* |

*Annexe 1.1*

## Plans - Criteria and quality variables mapping



*Annexe 1.2*

## Sections - Criteria and quality variables mapping

*Annexe 1.3*

## Photographic report before harvesting



*Annexe 1.4*

## Harvested trees marked on plan

*Annexe 1.5*

## Plans after harvesting



*Annexe 1.6*

## Sections after harvesting

*Annexe 1.7*

## Photographic report after harvesting



## Architecture

| | |
|---|---|
| **Organisation** | |
| Organisation's name | |
| Organisation's representative | |
| Address | |
| Street, No. | |
| City | |
| Country | |
| Code | |
| Website | |
| Contact person | |
| Telephone | |
| E-mail | |
| Website | |
| **Project** | |
| Project name | |
| Project's leader | |
| Project brief | |
| Project location | |
| Street, No. | |
| City | |
| Country | |
| Code | |
| Needs | |
| Product's name | |
| Product's code | |
| Product's species | |
| Volume | |
| Product's name | |

| | |
|---|---|
| Product's code | |
| Product's species | |
| Volume | |
| Product's name | |
| Product's code | |
| Product's species | |
| Volume | |
| Building's lifespan | |
| Building's carbon footprint | |



## Primary processing

| | |
|---|---|
| **From forest to primary processing site** | |
| Transport company | |
| Address | |
| Street, No. | |
| City | |
| Country | |
| Code | |
| Contact person | |
| Telephone | |
| E-mail | |
| Website | |
| Vehicle | |
| Model | |
| Year | |
| Itinerary from depot to the forest | |
| Itinerary from forest to primary process site | |
| Loads (kg) | |
| Itinerary from process site to depot | |
| **Primary processing site** | |
| Production (see product classification) | |
| Product name | |
| Product code | |
| Product species | |
| Volume ($m^3$) | |
| Waste (see product classification) | |
| Product name | |
| Product code | |
| Product species | |

| | |
|---|---|
| Product species | |
| Volume ($m^3$) | |
| **From primary processing site to retail** | |
| Transport company | |
| Address | |
| Street, No. | |
| City | |
| Country | |
| Code | |
| Contact person | |
| Telephone | |
| E-mail | |
| Website | |
| Vehicle | |
| Model | |
| Year | |
| Itinerary from depot to secondary process site | |
| Itinerary from secondary process site to retail | |
| Loads (kg) | |
| Itinerary from retail to depot | |
| **Retailing** | |
| Retail company | |
| Address | |
| Street, No. | |
| City | |
| Country | |
| Code | |
| Contact person | |
| | |



| | |
|---|---|
| Telephone | |
| E-mail | |
| Website | |
| Inventoring | |
| Product name | |
| Product code | |
| Product species | |
| Volume | |

| | |
|---|---|
| Volume (m³) | |



## Secondary processing

| | |
|---|---|
| **From primary to secondary processing site** | |
| Transport company | |
| Address | |
| Street, No. | |
| City | |
| Country | |
| Code | |
| Contact person | |
| Telephone | |
| E-mail | |
| Website | |
| Vehicle | |
| Model | |
| Year | |
| Itinerary from depot to primary process site | |
| Itinerary from primary to secondary process site | |
| Loads (kg) | |
| Itinerary from process site to depot | |
| **Secundary processing site** | |
| Production (see product classification) | |
| Product name | |
| Product code | |
| Product species | |
| Volume (m³) | |
| Waste (see product classification) | |
| Product name | |
| Product code | |

*Annexe 2*

## Tree classification table

| Categories | X | Code |
|---|---|---|
| Specie | | 01000 |
| Evergreen | | 01010 |
| Deciduous | | 01011 |
| Endemic | | 01020 |
| Non-endemic | | 01021 |
| Invasive | | 01030 |
| **Specie key** | | XXXXX |
| Condition | | 02000 |
| Lying deadwood | | 02010 |
| Standing deadwood | | 02011 |
| Scenescent | | 02020 |
| Resilient | | 02030 |
| Healthy | | 02040 |
| **Condition key** | | XXXXX |
| Dynamic | | 03000 |
| Sapling | | 03010 |
| Understory | | 03011 |
| Open light | | 03012 |
| Stem exclusion | | 03020 |
| Maturity | | 03030 |
| Old growth | | 03040 |
| **Dynamic key** | | XXXXX |
| Environmental qualities | | 04000 |
| Seed bearing | | 04010 |
| Habitat tree | | 04020 |
| Cavity | | 04021 |
| Cavity with mould | | 04022 |
| Canopy deadwood | | 04023 |
| Fruit bodies of saproxylic fungi | | 04024 |
| Root buttress cavity | | 04025 |
| Cracks | | 04026 |
| Fork split | | 04027 |
| Burr | | 04028 |
| **Environmental qualities key** | | XXXXX |
| Harvesting qualities | | 05000 |
| Structural | | 05010 |
| Pulp | | 05020 |
| Energy | | 05030 |
| **Harvesting qualities key** | | XXXXX |

*Annexe 3*

## Wood products classification table

| Categories | X | Code |
|---|---|---|
| Roundwood | | 01000 |
| Sawlogs and veneer logs | | 01010 |
| Pulpwood | | 01020 |
| Chips and particles | | 01030 |
| Wood residues | | 01040 |
| Other industrial roundwood | | 01050 |
| **Roundwood key** | | XXXXX |
| Fuelwood and charcoal | | 02000 |
| Fuelwood (incl. chips, residues, pellets, brickets, etc.) | | 02010 |
| Charcoal | | 02020 |
| **Fuelwood and charcoal key** | | XXXXX |
| Sawnwood and sleepers | | 03000 |
| Railway sleepers | | 03010 |
| Sawnwood | | 03020 |
| **Sawnwood and sleepers key** | | XXXXX |
| Engineered wood products | | 04000 |
| Laminated Lumber Products | | 04010 |
| Finger Jointed Lumber | | 04020 |
| Glue Laminated Products (Glulam) | | 04030 |
| Laminated Veneer Lumber (LVL) | | 04040 |
| Parallel Strand Lumber (PSL) | | 04050 |
| I-Joists/I-Beams | | 04060 |
| Trusses & Engineered Panels | | 04070 |
| Other | | 04080 |
| **Engineered wood products key** | | XXXXX |



| | | |
|---|---|---|
| Wood based panels | | 05000 |
| Veneer sheets | | 05010 |
| Plywood | | 05020 |
| Particle board | | 05030 |
| OSB | | 05031 |
| Other particle board | | 05032 |
| Fibreboard | | 05040 |
| MDF | | 05041 |
| HDF | | 05042 |
| Softboard | | 05043 |
| Hardboard | | 05044 |
| Insulating board | | 05045 |
| **Wood based panels key** | | XXXXX |
| Pulp | | 06000 |
| Mechanical | | 06010 |
| Semichemical | | 06020 |
| Dissolving | | 06030 |
| Chemical | | 06040 |
| Unbleached sulphite pulp | | 06041 |
| Bleached sulphite pulp | | 06042 |
| Unbleached sulphate (kraft) pulp | | 06043 |
| Bleached sulphate (kraft) pulp | | 06044 |
| Recovered paper | | 06050 |
| **Pulp key** | | XXXXX |
| Paper and paper board | | 07000 |
| Graphic papers | | 07010 |
| Newsprint | | 07011 |
| Uncoated mechanical | | 07012 |
| Uncoated woodfree | | 07013 |

| | | |
|---|---|---|
| Coated papers | | 07014 |
| Household and sanitary paper | | 07020 |
| Packaging materials | | 07030 |
| Case materials | | 07031 |
| Folding boxboards | | 07032 |
| Wrapping papers | | 07033 |
| Other papers mainly for packaging | | 07034 |
| Other paper and paperboard | | 07040 |
| Converted paper products | | 07050 |
| Printed matter | | 07060 |
| **Paper and paper board key** | | XXXXX |
| Wood manufacturers | | 08000 |
| Packaging, cable drums, pallets | | 08010 |
| Packaging and crates | | 08011 |
| Cable drums | | 08012 |
| Pallets | | 08013 |
| Furniture | | 08020 |
| Builders carpentry | | 08030 |
| Windows | | 08031 |
| Doors | | 08032 |
| Shingles and shakes | | 08033 |
| Floors | | 08034 |
| Others | | 08035 |
| Decorative wood | | 08040 |
| Tools and  turned wood | | 08050 |
| Tools | | 08051 |
| Children toys | | 08052 |
| Sport goods | | 08053 |
| Musical instruments | | 08054 |



| | | |
|---|---|---|
| Other | | 08055 |
| Other | | 08060 |
| **Wood manufacturers key** | | XXXXX |
| Exterior products | | 09000 |
| Buildings and their parts | | 09010 |
| Garden Furniture/Outdoor products | | 09020 |
| Garden furniture | | 09021 |
| Playground equipment | | 09022 |
| Decking | | 09023 |
| Other | | 09030 |
| **Exterior products key** | | XXXXX |
| Cork and cork products | | 11000 |
| Natural cork and cork waste | | 11010 |
| Cork manufactures | | 11020 |
| **Cork and cork products key** | | XXXXX |
| Energy | | 12000 |
| Non-wood products | | 13000 |
| Other | | 14000 |

## C. Reporting form

*Annexe 1*

## Reporting Form

## Forest

| | |
|---|---|
| **Identification** | |
| Parcel's administrative code | 084 A 32; 084 A 41 |
| Surface | 00 ha 20 a 00 ca |
| Address | |
| GPS coordinates | 44°49'00.3"N 3°39'59.6"E |
| City | Chams |
| Country | FRANCE |
| Code | 48600 |
| Owner | Bernard LAFONT |
| Address | |
| Street, No. | 224 Rue des 4 Estrades |
| City | Chams |
| Country | FRANCE |
| Code | 48600 |
| Contact person | Lucas LAFONT |
| Telephone | +33 6 47 71 72 31 |
| E-mail | lucas.lafont@yahoo.com |
| **Characterisation** | |
| History | |
| Origins | Sylvopastoralism prior to the 60s. |
| Current forest's stage of growth | Mature for harvesting |
| Current state | |
| Plans | *Refer to annexe 1.1 - Criteria and Quality variables mapping* |

Table 11: Annexe 1, *Forest* section of the proposal's reporting form.

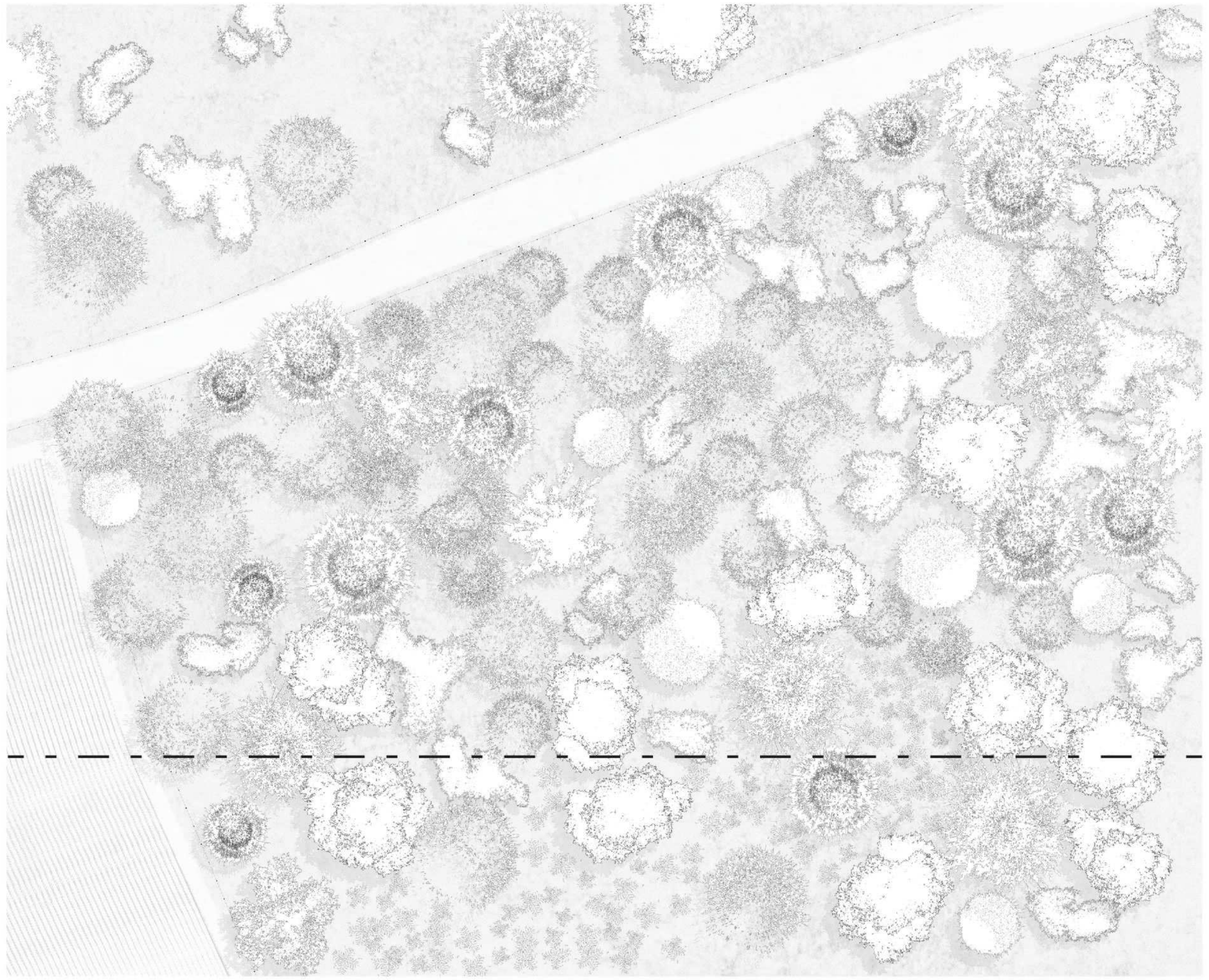


| | |
|---|---|
| Sections | *Refer to annexe 1.2 - Criteria and Quality variables mapping* |
| Species inventory | Scot pine, silver fir, spruce, beech, rowan, white beam, ash, cherry tree, birch. |
| Targets | 5.1, 5.2, 5.4. |
| Annual growth (biomass) | |
| Carbon footprint | |
| Annual | |
| Projected (10y) | |
| Photographic report before harvesting | *Refer to annexe 1.3* |
| **Management** | |
| Regime | Closer-to-Nature FM |
| Day of harvesting | |
| Method of harvesting | |
| Logger company | |
| Address | |
| Street, No. | |
| City | |
| Country | |
| Code | |
| Contact person | |
| Telephone | |
| E-mail | |
| Website | |
| Harvested trees marked on plan | *Refer to annexe 1.4* |
| Plans after harvesting | *Refer to annexe 1.5* |
| Sections after harvesting | *Refer to annexe 1.6* |
| Photographic report after harvesting | *Refer to annexe 1.7* |

Table 11 (continued).

*Annexe 1.1*

## Plans - Criteria and quality variables mapping



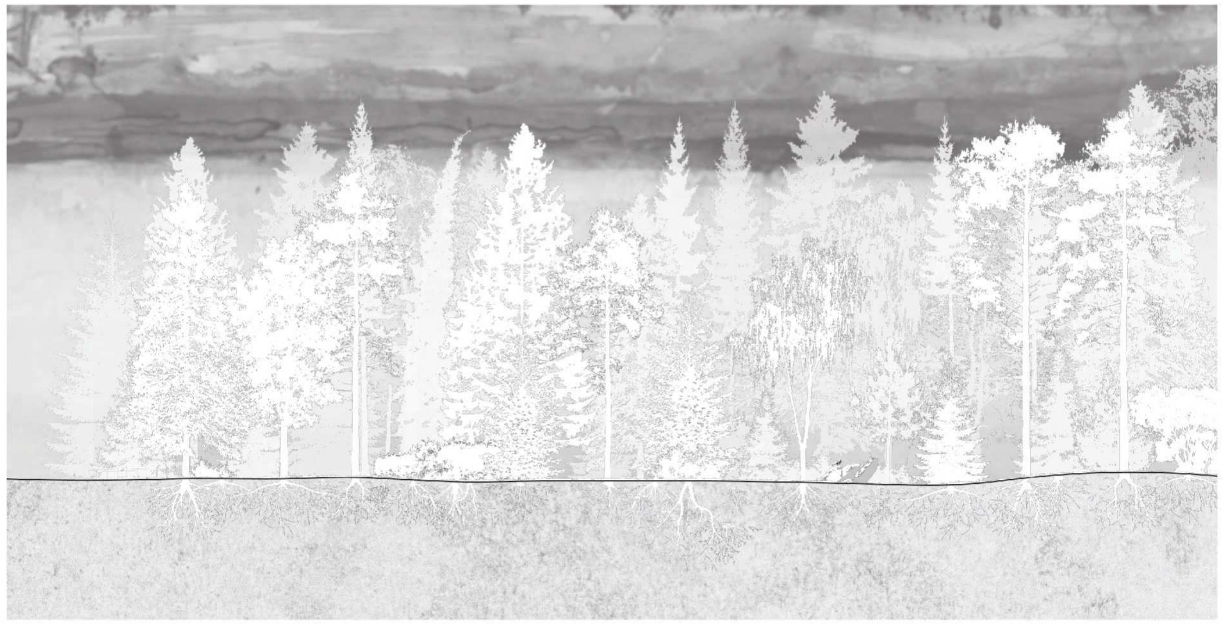
1:200 (A0)

Figure 58: Annexe 1.1, *Forest* section of the proposal's reporting form.



*Annexe 1.2*

## Sections - Criteria and quality variables mapping



1:200 (A0)

Figure 59: Annexe 1.2, *Forest* section of the proposal's reporting form.

*Annexe 1.3*

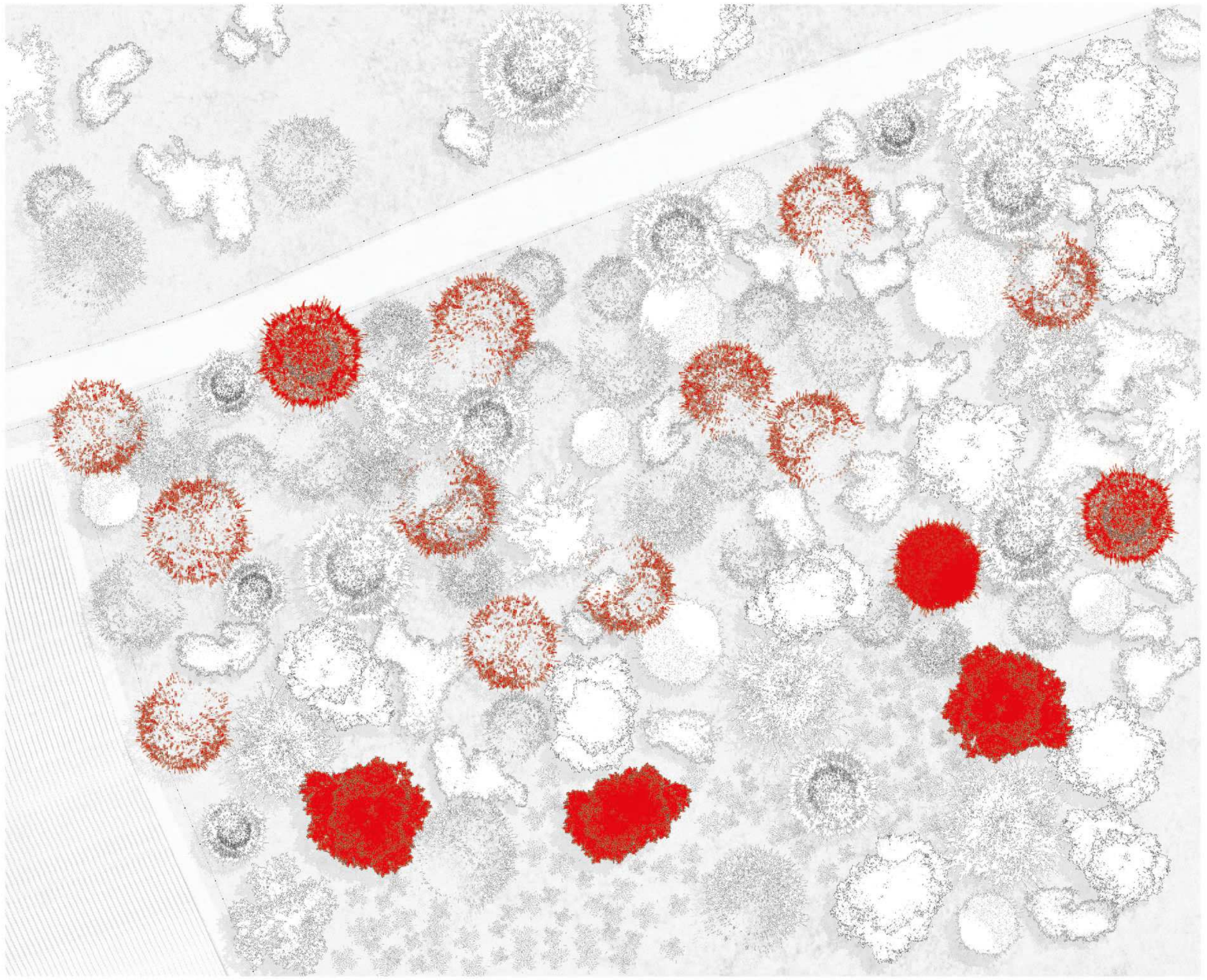
## Photographic report before harvesting

Figure 60: Annexe 1.3, *Forest* section of the proposal's reporting form.



*Annexe 1.4*

## Harvested trees marked on plan

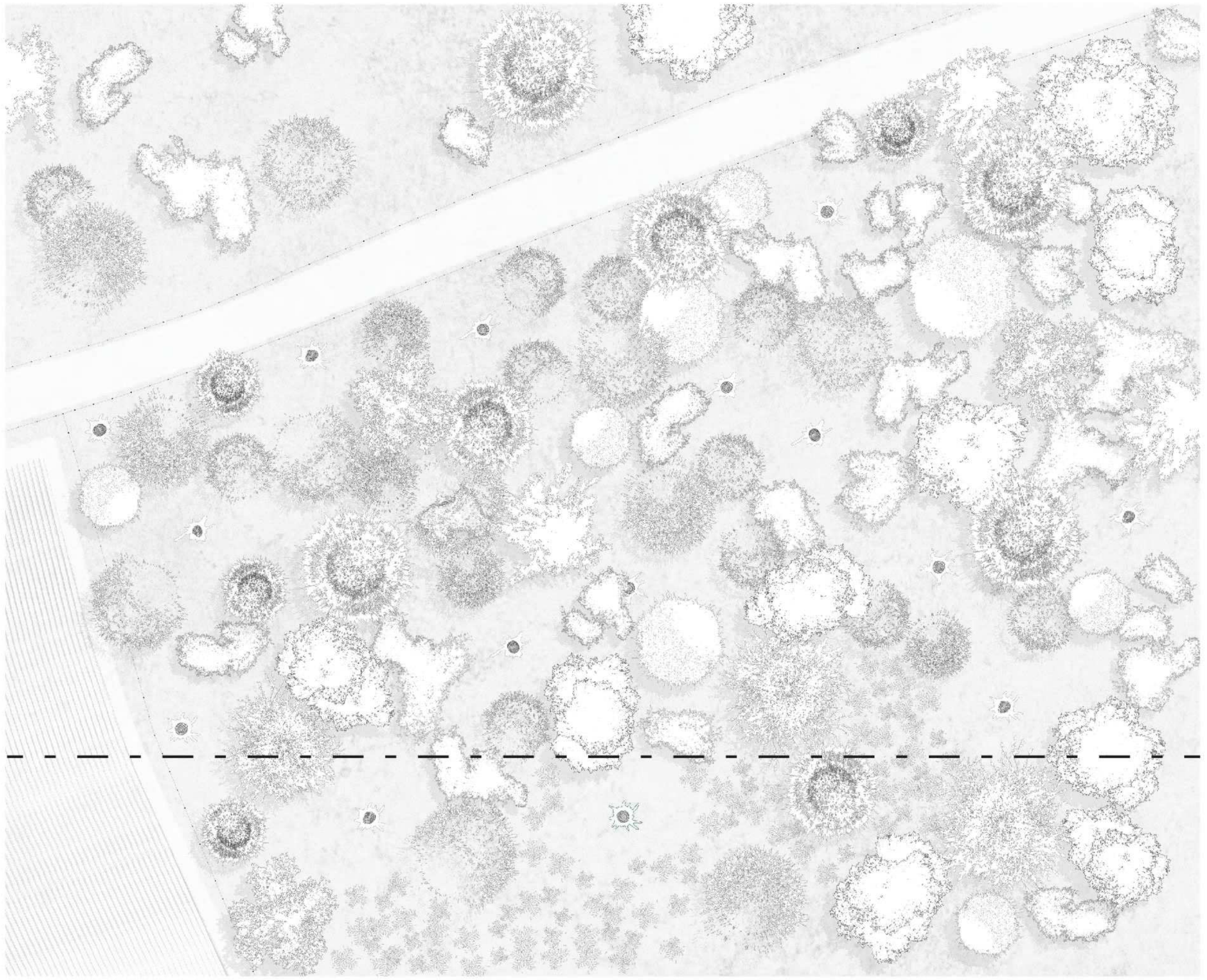


1:200 (A0)

Figure 61: Annexe 1.4 *Forest* section of the proposal's reporting form.

*Annexe 1.5*

## Plans after harvesting



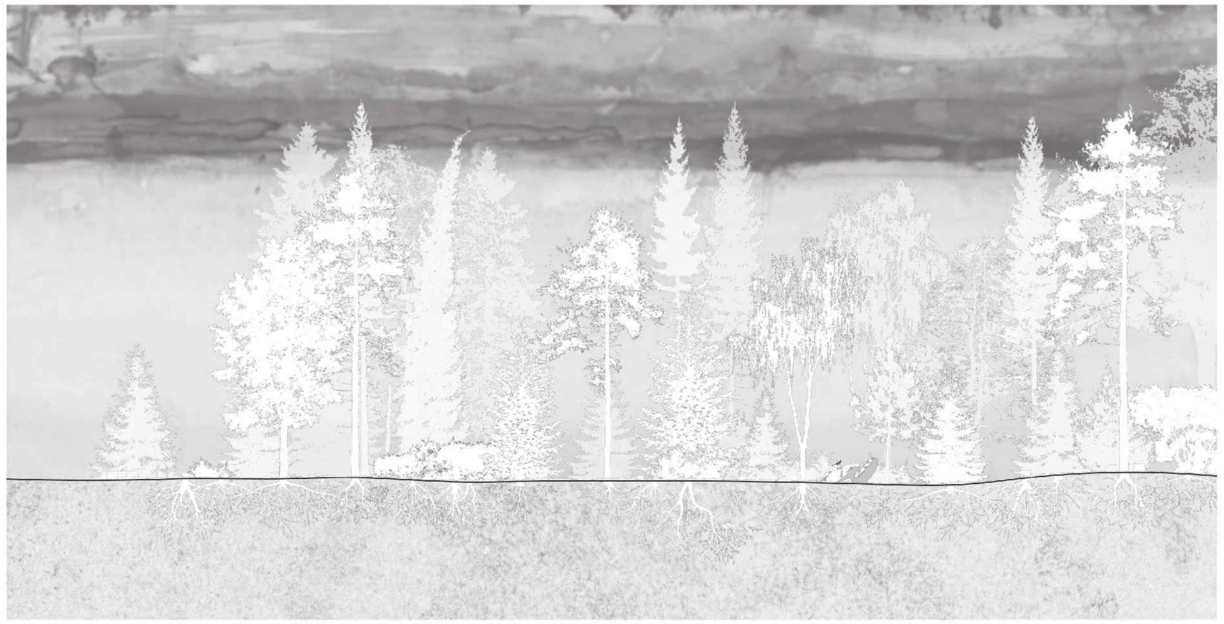
1:200 (A0)

Figure 62: Annexe 1.5, *Forest* section of the proposal's reporting form.



*Annexe 1.6*

## Sections after harvesting



1:200 (A0)

Figure 63: Annexe 1.6, *Forest* section of the proposal's reporting form.

## D. Scenario 2 of implementation

### D.1. Principles and expectations

The implementation of the method is here proposed on an arable land (land type 2A). Today, no trees are to be found on the parcel. However, the neighbouring parcels are scot pines forests. On the east side of the arable land is a natural forest which is also part of the farm. The choice to convert an arable land to a dynamic forest has been made to approach this implementation as an experimental case. Starting from an arable land will help to identify the main steps and cycles throughout the implementation, both natural and operational.

In this chapter, four periods are highlighted. The first one is year 0, where the conversion of the land starts. The second one is year 10, the third one is year 30 and finally the fourth one is year 60. In the course of these four periods, the forest will grow various types of trees of different ages. From year sixty, it is considered that the forest will be able to provide mature trees for timber production, while still growing types of trees that have been already observed at Y10 and Y30.

The planning behind implementation follows the guidelines defined in the proposal. The same applies for monitoring. The chosen targets are targets *5.2. Develop forest structure diversity*, *5.3. Tree cover extension* and *5.4. Increase old or large trees ratio*. In fact, beneficiating from neighbouring forests, the afforestation of this parcel will use the local flora as an initiator to the establishment of a dynamic, heterogeneous forest.

The description of the implementation is based on the reporting form provided with the proposal. Figures 63 to 70 show plans and sections extracted from the form. Y0 starts with filling the *Forest* section of the reporting form. Y10 gives an update on the forest state and a first report on harvesting. Y30 fills the *Architecture* section of the reporting form, and gives an update on the forest state and a second report on harvesting. This is the first period where the forest can provide timber suitable for structural wood products. Y60 gives an update on the forest state and a third report on harvesting. Y10, Y30 and Y60 will be reported in their respective time. Figures 65 to 70 are a representation of what could likely happen. In the appendix of the booklet can be found the report corresponding to Y0.

Tables 12 and 13 aim to be used as references for evaluation of the implementation from an economic perspective. Table 12 results from the harvest of the farm's arable lands in 2023. Table 13 shows the results of an economic study conducted over more than 573 hectares of forests managed in continuous cover forestry in the north of France[26]. This two summary tables can also help to highlight variables on which farmers can choose to focus on in their land use practices, in order to increase the values of their forests.

(26): Forêt Nature. (2022, May 10). *Bilan économique de 40 années de gestion Pro Silva en forêt privée - Evrard de Turckheim* [Video]. YouTube. https://www.youtube.com/watch?v=7j7kErYSiOo

**Y0**

Planning
• Target 5.2
• Target 5.3
• Target 5.4

Mapping
• Annexe 1 (Forest)
• Annexe 1.1
• Annexe 1.2
• Annexe 1.3

Carbon evaluation

**Y10**

Monitoring

Mapping
• Annexe 1.1
• Annexe 1.2
• Annexe 1.3
• Annexe 1.4
• Annexe 1.5
• Annexe 1.6
• Annexe 1.7

Carbon evaluation

**Y30**

Monitoring

Planning

Mapping
• Annexe 1 (Architecture)
• Annexe 1.1
• Annexe 1.2
• Annexe 1.3
• Annexe 1.4
• Annexe 1.5
• Annexe 1.6
• Annexe 1.7

Carbon evaluation

**Y60**

Monitoring

Planning

Mapping
• Annexe 1 (Primary and secondary processing)
• Annexe 1.1
• Annexe 1.2
• Annexe 1.3
• Annexe 1.4
• Annexe 1.5
• Annexe 1.6
• Annexe 1.7

Carbon evaluation

**Y60+**

Monitoring

Planning

Mapping
• Annexe 1 (Primary and secondary processing)
• Annexe 1.1
• Annexe 1.2
• Annexe 1.3
• Annexe 1.4
• Annexe 1.5
• Annexe 1.6
• Annexe 1.7

Carbon evaluation

Figure 64: Main steps of method's implementation.

## D.2. Economic overview

| | | | | |
|---|---|---|---|---|
| Parcel | Arable land | | | Total surface: 0 ha 91 a 63 ca |
| Structure | Cultivation | Harvested in | Number of parcels | Access conditions |
| | Oat | 08/2023 | 3 | Machineable |
| Harvesting | Straw harvested (in kg of DM) | Profitability (in kg/ha) | Seeds harvested (in kg of DM) | Profitability (in kg/ha) |
| | 1 T 408 kg | 1 T 537 kg /ha | 1 T 650 kg | 1 T 801 kg /ha |
| Turnover | Sales price of oat straw | Turnover for oat straw | Sales price of oat seeds | Turnover for oat seeds |
| | 60€/T | 84.50€ = 92.22€/ha | 360€/T | 594€ = 648.26€/ha |
| Total | | | | 678.50€ = 740.48€/ha |
| Operational costs | Seeds | Plowing | Harvest | |
| | 2€/kg (100 kg/ha) | 110€/ha | 120€/ha | |
| Total | 183.26€ | 100.80€ | 109.96€ | 394.02€ = 430€/ha |
| Operating result | | | | 284.48€ = 310.46€/ha |

Table 12: Case study farm’s operating result from 2023 harvesting.

| | | | | |
|---|---|---|---|---|
| Parcels | Heterogeneous forest | | | Surface: 573 ha 50 a 00 ca |
| Structure | Management regime | Harvested in | Number of parcels | Access conditions |
| | Continuous cover forestry | 10/2020 to 09/2021 | 185 | Machineable |
| Harvesting | Species harvested | | | |
| | Oak, beech, pine, spruce, silver fir, douglas fir | | | |

Table 13: Operating result from 2023 Continuous Cover Forestry.

| | | | | |
|---|---|---|---|---|
| Turnover | Roundwood | Firewood | Other (hunting rent…) | |
| | 121 501.70€ | 4 144.26€ | 34 486.59€ | |
| Total | | | | 160 132.85€ |
| Operational costs | Harvesting | Silviculture | Maintenance | Other |
| | 40 610.96€ | 7 538.45€ | 18 437.19€ | 53 007.14€ |
| Total | | | | 119 593.73€ |
| Operating result | | | | 40 539.12€ = 70.69€/ha |
| Non-wood forest products | | | | 77.80€/ha[27] |
| Carbon | Absorption | Credit | Income from credits | |
| | 3.5T/ha/year[28] | 53.33€/T[29] | 186.65€/ha/year | |
| Total income | | | | 335.14€/ha/year |

Table 13: (continued).

## C. Application

Plan delimitations

Section line

Figure 65: Chosen parcel for implementation, to which relate figures XX, XX, XX and XX. (Scale 1:2000 - A4)

(27): European Commission. (2021). *New EU forest strategy for 2030. COM. (2021) 572 final. Communication from the commission to the European parliament, the council, the European Economic and social committee and the committee of the regions.* https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52021DC0572

(28): Brown, S., Sathaye, J., Cannell, M. G. R., & Kauppi, P. E. (1996). Mitigation of carbon emissions to the atmosphere by forest management. *Commonwealth Forestry Review, 75*(1), 80–112. https://www.cabdirect.org/abstracts/19960604718.html

(29): *Carbon Price Tracker | Ember*. (n.d.). Ember. https://ember-climate.org/data/data-tools/carbon-price-viewer/

Figure 66: Plan, year 0 (Scale 1:200 - A3)

Figure 67: Section, year 0 (Scale 1:200 - A3)



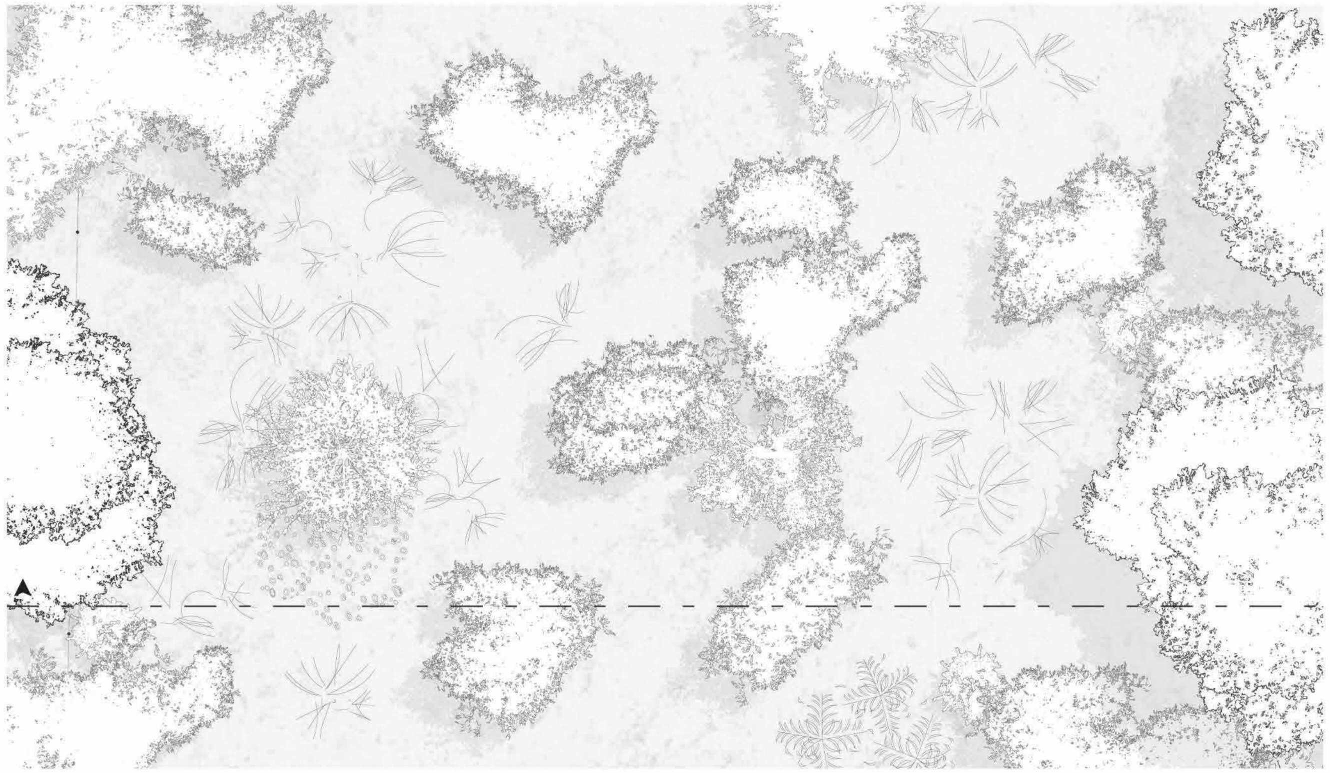


Figure 68: Plan, year 10 (Scale 1:200 - A3)

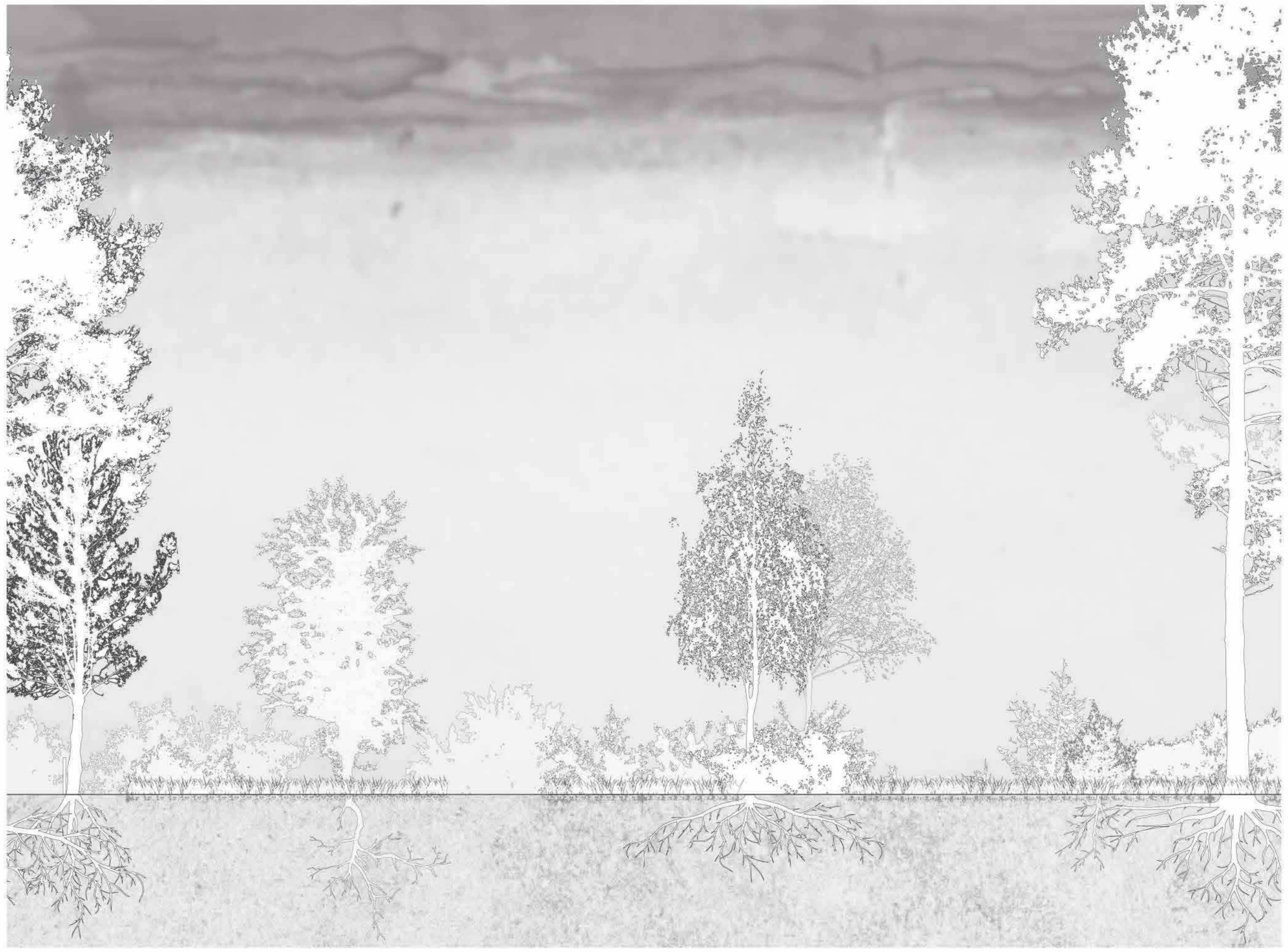


Figure 69: Section, year 10 (Scale 1:200 - A3)

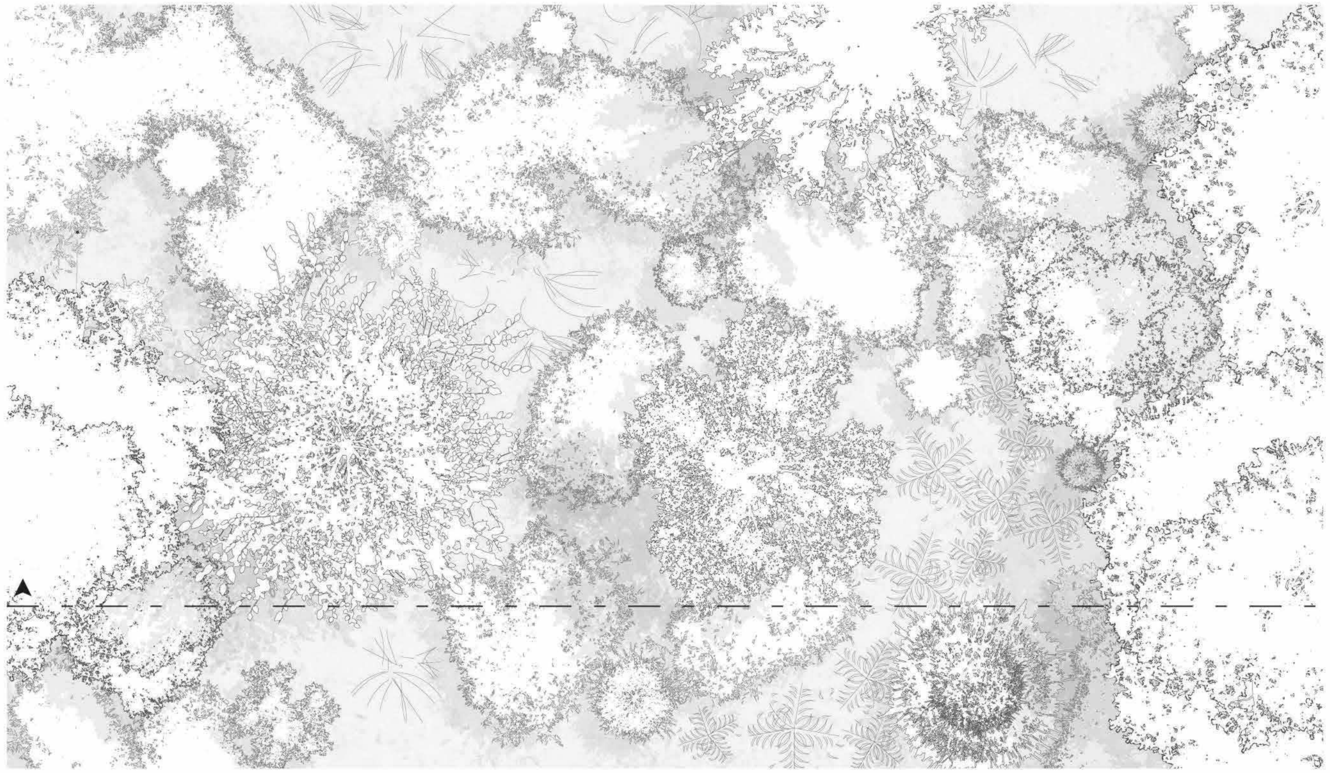


Figure 70: Plan, year 30 (Scale 1:200 - A3)

Figure 71: Section, year 30 (Scale 1:200 - A3)



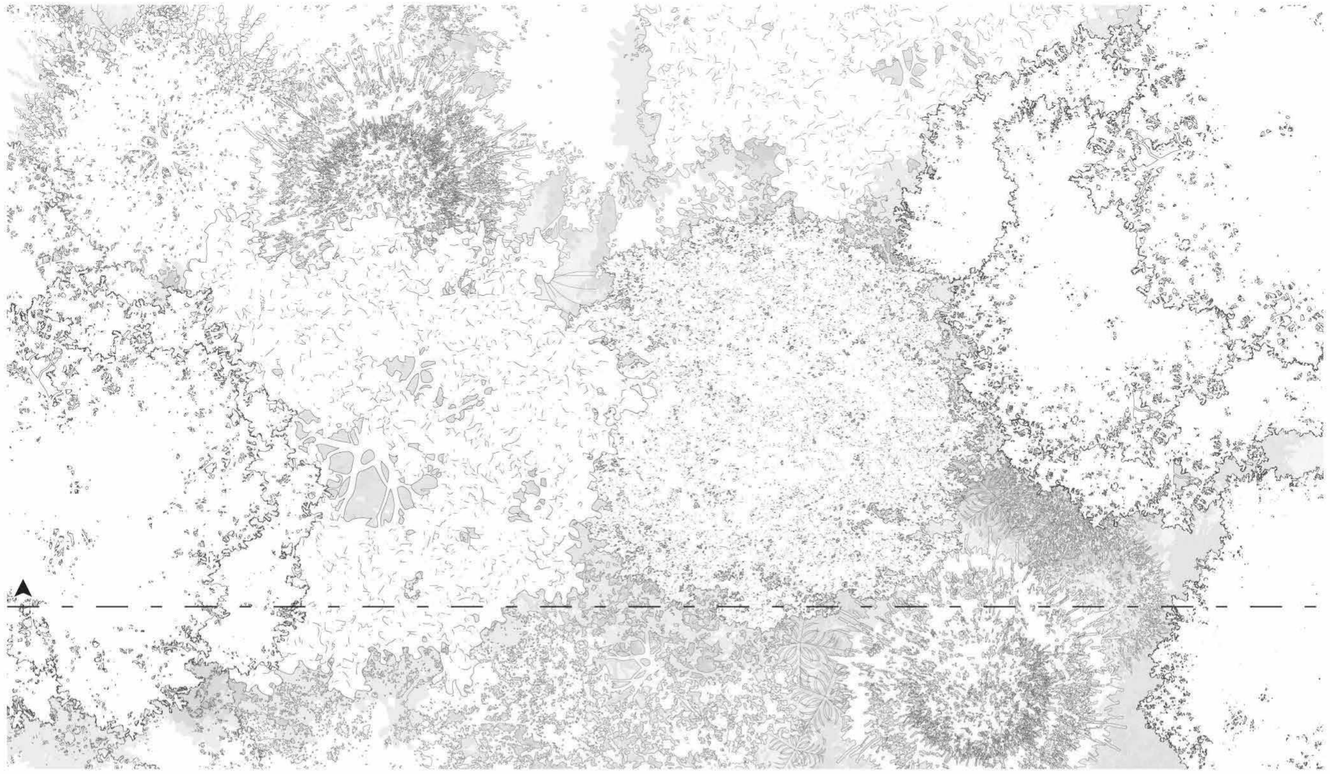


Figure 72: Plan, year 60 (Scale 1:200 - A3)

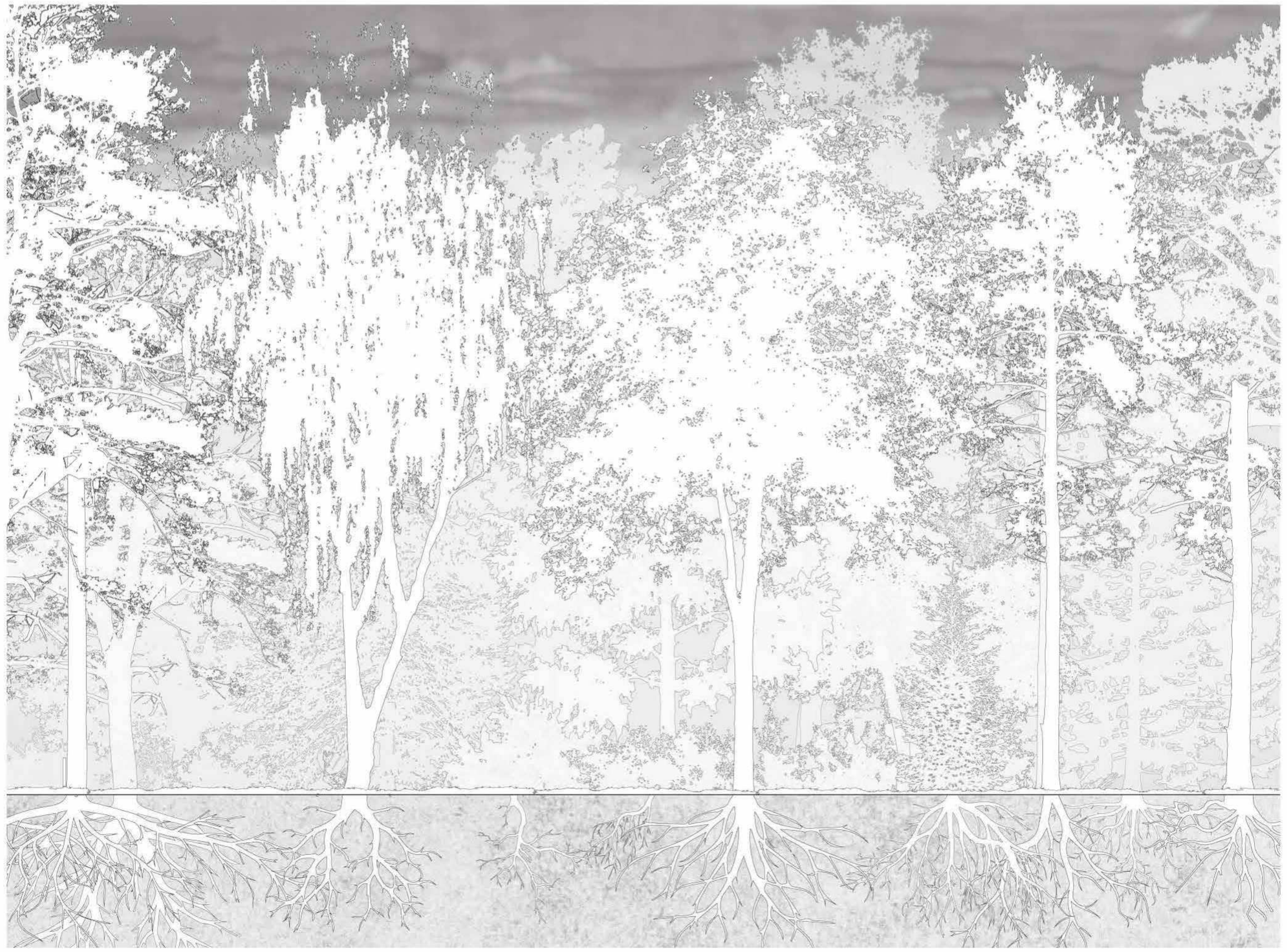


Figure 73: Section, year 60 (Scale 1:200 - A3)

## D.3. Results

This section seeks to highlight the main expected outcomes from the theoretical implementation of the proposal's method on an arable land. The results come from a speculative scenario. However, they are based on the local environment, its structure, dynamics and composition, with the scot pines forest on the east of the parcel as a reference. To this has been added the layer of human activities, with forest management practices such as thinning or havesting.

The *Forest* section of method's annexe *1. Reporting Form*, as well as annexes *1.1 Plans - Criteria and quality variables mapping*, *1.2 Sections - Criteria and quality variables mapping* and *1.3 Photographic report before harvesting* have been completed at Y0. They can be found in the thesis appendix. The rest of the reporting form will have to be completed throughout the years, along with the forest growth and forest management practices such as harvesting.

The main objective behind this implementation is to enhance the different values of the (future) forest, while ensuring that the material needs from the farm will be fulfilled. In fact, the farm has not been operating between 1979 to 2023. New needs will emerge with the farming activity development, such as buildings for storage of machines and crops for instance. The method will be implemented within that frame. In the case of the arable land presented section C. of this chapter, the three targets mentioned section *A.* orient land use practices to reach the guidelines defined section *9. Guidelines* of the method. That taken into account, land use practices will have to be done along the different successional stages of the forest growth. Then, it becomes very important to work specifically with identified tree species. The following table presents the main tree species in relation to the parcel, their forest's succession stage group, as well as their final destination from a material perspective depending on their trunk's diameters.

The implementation starts here with a stand (re)initiation at the scale of the whole parcel. This stage leads to the establishment of preparatory stands, with an increase in woody and foliage biomass. It provides favourable conditions for a forest to grow. These stands are composed of pioneer tree species which can grow on poor soils and under direct sunlight, and that for most of them show a fairly short life span. This stage is very polyvalent since it provides a large range of wood types, suitable for structural wood products, furniture or pulp production. Scot pines and birches are pioneer species. However, maintain a forest at an early successional stage is a challenge, when it is often easier to work with later stages. Following this successional stage comes the understory reinitiation with seral tree species. This stage usually follows tree mortality that leads to gap in the canopy. The forest starts to get mixed, with the apparition of tolerant species such as spruces and silver firs. The final stage of this forest will be old-growth with oaks and beechs that will start to take over the land. These species show a great potential in construction, with higher resistance properties than spruce for instance.

In the end, it is important to follow and be aware in which successional stage the forest currently is. This determines the species that will be found, wood types, and ultimately wood products that this forest can provide.

| | ∅ (cm) | Roundwood | Fuelwood | Sawnwood | Engineered wood products | Panels | Pulp |
|---|---|---|---|---|---|---|---|
| Betula (pioneer) | 5 apex | | × | | | | × |
| | 20 DBH | × | × | × | × | × | × |
| | +50 DBH | × | | × | × | × | |
| Populus tremula (pioneer) | 5 apex | | × | | | | × |
| | 20 DBH | × | × | × | × | × | × |
| | +50 DBH | × | | × | × | × | |
| Pinus sylvestris (pioneer) | 5 apex | | × | | | | × |
| | 20 DBH | × | × | × | × | × | × |
| | +50 DBH | × | | × | × | × | |
| Picea abies (seral) | 5 apex | | × | | | | × |
| | 20 DBH | × | × | × | × | × | × |
| | +50 DBH | × | | × | × | × | |
| Abies alba (seral) | 5 apex | | × | | | | × |
| | 20 DBH | × | × | × | × | × | × |
| | +50 DBH | × | | × | × | × | |
| Fagus sylvatica (climax) | 20 DBH | × | × | × | × | × | × |
| | +50 DBH | × | | × | × | × | |
| Quercus petraea (climax) | 20 DBH | × | × | × | × | × | × |
| | +50 DBH | × | | × | × | × | |

Table 14: Tree species and trunk diameters in relation with wood products.