NATURE-POSITIVE ARCHITECTURE: A REGENERATIVE DESIGN PROCESS FOR A WINERY USING OAK BARRELS

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ABSTRACT

Sustainability in its development is increasingly focusing on nature. However, this research shows that through positive development, benefits are not only gained in nature, but are actually viewed as a common good. From this emerged regenerative development and design, in which there is a judgement from a whole system perspective. Through the knowledge of place, a strategy is first developed within the design process, in which oak regeneration can respond to the respective site patterns. This knowledge should then be used to design in harmony with the larger patterns of place. This is achieved through a partnership between the place (as a living being) and other various living systems. Herein, such a partnership is presented between place, humans and oak forest regeneration. This partnership brings forth new activities and growth through co-evolution, and is made permanent by bridging with viticulture. The regeneration of wood is passed down over several generations, using it not only as a building material, but also with the manufacture of wine barrels. In doing so, this research shows how this material works and is produced, and what other uses, if any, are available at the time the material depreciates.

KEYWORDS

Local resources, Nature-positive, Renewable materials, Regenerative design, Oak, Wine barrels, Winery

I. INTRODUCTION

1.1. Problem analysis

Nature has been significantly transformed in most of the world due to a variety of human factors. The harvest of raw timber has increased by 45% compared to 2017 to about four billion cubic metres, more than 85% of wetlands have been lost and 75% of land use has been drastically changed (IPBES et al., 2019). The most widespread form of this land-use change is due to the strong measures of expansion of farmland (Brink & CGN, 2015). In this, more than a third of the land area was converted for agriculture or animal farming. This expansion, together with a doubling of the urban area since 1992 and an unprecedented expansion of infrastructure related to growing population and consumption, has largely been at the expense of forests and grasslands (Van Dyck et al., 2018). All this while the formulated definition of sustainable development coming from 1987 precisely describes development that meets the needs of the present generation without compromising the needs of future generation, both here and in other parts of the world (United Nations, 1987).

Besides agriculture and high population growth, the building sector's share of destroying nature is also significant. This is mainly due to the large amount of nitrogen emissions, coupled with the 'over' extraction of construction materials and raw materials. Technical development in this, combined with growing transport infrastructure and trade opportunities, has meant that materials are no longer tied to local availability or regional traditions (Röstlund & Björling, 2020). This has

led to many innovations and higher living standards in many parts of the world, but as a side effect it has also given the illusion of endless resources (Borden & Meredith, 2012). The rationalised and centralised production process has since continued on that path, resulting in a 'disconnect' between resources, communities and landscapes. However, the fact is that we only have one planet with both finite and renewable resources that we over-consume. The contemporary use of materials and the logic of the construction industry are largely the result of a modernist approach to buildings and landscapes. The tabula rasa approach of this modernist view sought a universal civilisation, a kind of " one size fits all" methodology. This contributed to the emergence of a phenomenon of placelessness, especially in the Western world (Framptom, 1983)

1.2. Problem statement

The way we build now is about "extracting" materials in places where we don't build. And building in the places where we do not "extract" materials. In addition, little or no attention is paid to renewing the material in question. Just "extracting" materials naturally gives a negative effect on nature and our living environment. A new approach is needed where it is envisaged that through positive development, both humans and nature will benefit. This will create a synergy between these different life forms. In addition, it is important to maintain this positive development over future generations, and thus be able to continue providing regenerative materials and raw materials.

1.3.Context

This research aims to explore the theme of nature-positive architecture within the local context. Given the renewal/regeneration of materials, this mainly concerns plant species. However, not every plant species lends itself as a suitable building material. Therefore, this research will focus on trees, with the oak in particular. This is because oak is the second most common tree species in the Netherlands (Algemene Vereniging Inlands Hout, n.d.). Here, the most common oak is *Quercus robur* (pedunculate oak), but in addition, *Quercus petraea* (sessile oak) is the other autochthonous oak species of the Netherlands. It can therefore be said that oak wood is truly a local product. Moreover, oak is a hardwood species and therefore lends itself particularly well as a building material, such as: structural elements, window frames and as a facade finish. This research is linked to the design of a winery that fits within the local context and the associated soil conditions and environment. What is understood by a winery is a building or complex within which wine is produced. This process includes the fermentation of fruit, as well as the blending and aging of the juice. Besides a building, this winery will also have available land to grow the grapes itself. Since producing wine is closely linked to nature, other natural products are used besides grapes, namely wooden wine barrels. This is also a good use of oak, and therefore the focus of this research. It will look at how barrels can be regenerated, and how they can, for example, be used (after use) as building materials.

Figure 1: Quercus robur (pedunculate oak), Groen! natuurlijk

A second important point when it comes to the local context is the actual project location. Where better than in the very place that has become the result of resource depletion (negative impact). An example of such a site is a quarry, in this particular case a marl quarry (mergel). This quarry is located near the Belgian border on the south side of the city of Maastricht. This city gets its name from the river Meuse (Maas), which flows on the east side of the quarry. The quarry itself is excavated from a 100-metre-high hill plateau called the Sint-Pietersberg. Sint-Pietersberg is a table mound composed mainly of limestone. Limestone is a chalk rock, an organically formed sedimentary rock (deposited rock) that has been built up layer by layer over millions of years. The fossil remains come from larger and smaller marine organisms with an external or internal calcium skeleton composed of calcium carbonate. After their death, these calcium skeletons sank to the sea floor and accumulated in thick layers. When the Cretaceous Sea retreated ± 65 million years ago, a huge package of this limestone deposits, hundreds of metres thick, came to the surface (Janssen & Naturalis, 2012). This limestone package is what we now know as Sint-Pietersberg (Mount St Peter).

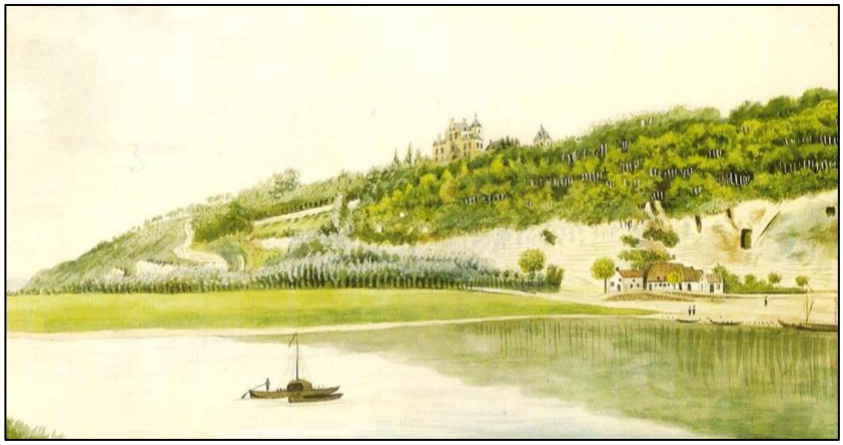

Figure 2: View of Sint-Pietersberg and castle Caestert ca. 1830, Philippe van Gulpen

The mountain's eventful history has left visible scars. Before the mass excavations, the hill already served as an extraction site for limestone. However, this was done underground. As early as the 17th century, the landowners, the farmers of the time, extracted marl blocks by digging tunnels. The marlstone blocks were then used as building material in the immediate surroundings. However, this 'small-scale' material extraction was taken over by the 'large-scale' excavations in

the 20th century. This was done by the "First Dutch Cement Industry" (ENCI). Here, marlstone was no longer used as a direct building material, but served as a raw material to make concrete (as this required cement). This material extraction ultimately caused the greatest disruption to nature and biodiversity at Sint-Pietersberg. What was formed over millions of years was destroyed only within decades.

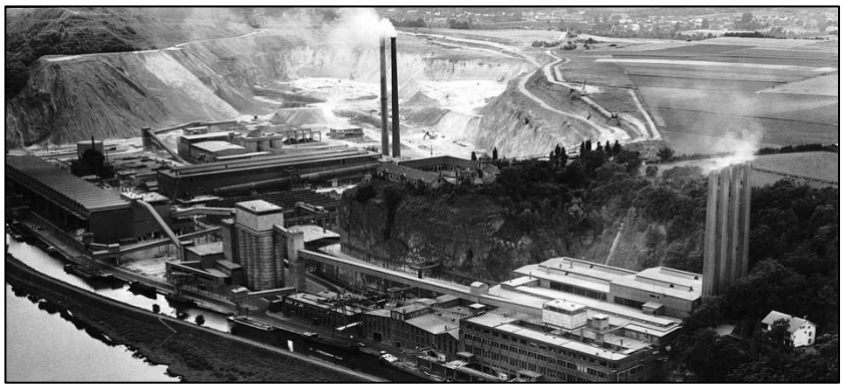

Figure 3: ENCI quarry, Stichting Ontwikkelingsmaatschappij ENCI-gebied

1.4.Research question

The overall research question for this paper is:

> How can a regenerative design process for a winery, using oak wood as a premise, be applied in the local context to facilitate nature-positive architecture?

The sub-questions that will be addressed to answer the main question are:

1. What is a regenerative design process?
2. What is needed from the local context (place) to facilitate material regeneration?
3. What are the general properties, qualities and specific applications of oak?

II. METHOD

The research will be conducted in the chronological order of the sub-questions formulated above. First, in paragraph 3.1, there will be a literature research on what exactly a regenerative design process is. This will be done to first of all examine to what extent it differs from present-day 'sustainable' design processes. Qualitative data will be collected to arrive at different starting points/key premises. Paragraph 3.2, again through a literature review, will look at how such a regenerative design process can work from a particular site/place. From this, relevant conditions, boundaries and opportunities can then be formulated for oakwood regeneration. And how this process can zip in/merge with existing sustainable techniques from surrounding forests. For this purpose, qualitative and quantitative data will be collected to firstly get a picture of what is needed from the context. And then how such "sustainable" forests function, in order to ultimately identify which forests can be found in the immediate vicinity of Maastricht. The last paragraph (3.3) will use a literature study and information from databases to map the character properties of oak, such as chemical properties, strength, tangibility and durability. This is therefore a quantitative study. However, specific research will also be done on how regenerated oak wood can be applied within the design of a winery. This will include research into the properties and further applications of wine barrels in addition to some already mentioned specific applications (see 1.3).

III. RESULTS

3.1.Regenerative design and development

When it comes to defining a regenerative design process, it will first be necessary to review what systems/processes have developed over time. This chapter will look at what approaches there are, how these approaches came about, how each approach affects nature and our environment, and what its key premises are.

3.1.1. The ‘less bad’ approach

First in line comes the Green Building approach. It is so termed to indicate that these buildings have better environmental performance than more 'normal' buildings. This approach mainly addresses issues such as resource use, emissions and waste, health and comfort aspects. It primarily aims to improve the health and comfort of people and the building while reducing the adverse environmental impacts of human activities on ecological systems (Cole, 2012). In doing so, this approach is single-minded because it takes little or no account of interrelatedness (Reed, 2007). In doing so, this approach does not close cycles, does not encourage creative synergies and does not respond to local ecological and social contexts.

Within Green Building, eight key characteristics are identified (Cole, 2012): Namely, (1) Reducing damage to natural or sensitive areas; (2) Reducing the need for new infrastructure; (3) Reducing the impact on natural features and ecology of the area during construction; (4) Reducing potential environmental damage from emissions and outflows; (5) Reducing contributions to global environmental damage; (6) Reducing resource use (such as: energy, water, materials); (7) minimising the discomfort of building occupants; and (8) minimising pollutants and irritants in the building interior.

3.1.2. The ‘neutral’ approach

In a sense, the second approach is similar to Green Building, but more with an emphasis on reaching a point where the health of the planet's organisms and systems can be maintained over time (Reed, 2007). This came primarily from a need to counterbalance the predatory practices of industrialisation. A basis was established for utilitarian concepts, such as an ecological economy and ecosystem services, which stood up for the conservation and protection of natural resources, natural areas and endangered species (du Plessis, 2012). This makes this approach the neutral approach because the idea of sustainability leads to the understanding that sustainability will be achieved if the earth's capital - financial, human, social, productive and natural - remains the same or does not decline.

Since the publication of the Brundtland Commission report, Our Common Future (United Nations, 1987), "sustainability" and "sustainable development" have emerged as widely accepted and necessary requirements to guide all future human actions (Cole, 2012). Although the two concepts (sustainability and sustainable development) are similar, a difference can be noticed. Sustainable development maintains an anthropocentric view and favours incremental change that does not challenge existing established powers/privileges, institutional reforms and technological advances. By contrast, sustainability promotes a biocentric view that places human presence in a larger natural context, focusing on constraints and fundamental value and behavioural change (Cole, 2012). The goal of sustainability from this perspective is to cultivate relationships that sustain the capacity of the global social-ecological system to create not only life-supporting but also life-improving conditions for the global community of life. To achieve this, human efforts should be aligned with those of nature, resulting in activities, technologies and human habitats that are embedded in and contribute to natural processes of creation, evolution and regeneration (Hes & du Plessis, 2015). Although it has become common practice, however, it seems inappropriate to consider buildings as "sustainable". Whereas in the Green Building approach, what is literally meant that way is different in this approach. A building is an element that is part

of wider human endeavours and necessarily depends on its context. A building can therefore support sustainable lifestyles, but cannot be sustainable on its own (Gibberd, 2001).

3.1.3. The ‘doing something’ approach

The third approach deals with design in terms of using design and construction activities to restore the capacity of local natural systems to a healthy state of self-organisation. (Reed, 2007). The term for this is restorative design, which goes for a primary basis to restore the health of a subsystem of an ecosystem, such as wetlands, forests, riparian corridors, beach dunes, etc. While it does take a biocentric approach that brings only minor environmental effects and organic forms, it excludes the role of humans. Once the self-organising capacity of the system is initiated, "humans leave the process (Kellert, 2008). This makes this approach insufficient to achieve a fully restorative environmental design, hence the designation "doing something". A next step is needed, balancing culture, history and ecology, to make design and development permanent and truly sustainable.

3.1.4. The ‘reconnecting’ approach

This approach recognises that humans are an integral part of nature and that human and natural systems are one. Even more so, humans have an evolutionary affinity with nature and an innate need to connect with life and life-like processes (Wilson, 1984). From this has emerged a term called: Biophilia. Biophilic design is an approach to sustainable development that integrates human needs to connect with natural systems and processes into the design of the built environment, hence the 'reconnecting' approach.

From biophilic design, six elements and several principles have been formulated (Kellert, 2008): (1) To design with environmental characteristics. These are the characteristics and features of the natural environment such as natural colours, water, fire, fresh air, sunlight, plants, animals, natural materials such as wood and stone, views, green facades, soil, landscapes, habitats and ecosystems; (2) To apply natural forms, which simulate and mimic the forms found in nature. These include botanical and animal forms such as leaves, shells, trees, foliage, ferns, honeycombs, insects, other animal species and body parts; (3) Using natural patterns and processes. This means the functions, structures and principles that characterise the natural world, especially those that have played a role in human evolution and development; (4) Provide light and space, where spatial and lighting features can evoke the feeling of being in a natural environment. These include natural lighting, filtered and diffuse lighting, shadows, warm light, a sense of spaciousness, spatial variability, and more subtle manifestations such as sculptural qualities of light and space, the integration of light, space and mass; (5) Contributing to place-making. This refers to the links between buildings and the distinctive geographical, environmental and cultural characteristics of particular places and locations. This can be achieved by connecting place to its geographical, historical, ecological and cultural characteristics, the use of indigenous materials, the spirit of place (genius loci) and countering placelessness. (6) Making use of evolved human relationships with nature. Which deals with the above-mentioned basic innate tendencies to connect with nature, such as the feeling of being in a coherent and legible environment, the sense of prospect and refuge, the order and complexity, which generates the sense of curiosity and seduction, provides safety and protection and gives the sense of autonomy.

The biophilic design approach illustrates how the built environment can be designed in such a way to promote a greater connection with nature. But the goal of regenerating our world, increasing its health and potential, requires a more active role. All this in communion with nature, by reintegrating man-made environments with natural processes and systems. This will ultimately result in an environment to be created where all species find a home, cherish and rejoice (Hes & du Plessis, 2015).

3.1.5. The ‘making it better’ approach

Within the previous approaches, it refers to how connection with nature provides psychological and physical health benefits to humans, and how the quality and efficiency of human habitats and industrial processes can be improved by learning from and collaborating with nature, and even letting nature do the work. However, the question of this approach is whether humans can also benefit nature. Can humans not all design 'with' or 'like' nature, but also 'for' nature? A very dated quote immediately bridges the gap between what is good for nature, as well as can be good for humans:

> *“Ces arbres qu’il plante et à l’ombre desquels il ne s’assoira pas, il les aime pour eux-mêmes et pour ses enfants, et pour les enfants de ses enfants, sur qui s’étendront leurs rameaux.”* (Hyacinthe Loyson, 1866)

This quote reads, "These trees he plants and in whose shade he will not sit, he loves for himself and for his children and for his children's children, over whom their branches will spread". The concept of 'positive development' fits perfectly into this. In fact, this concept suggests that humans can increase the quality of life for all while increasing sustainable choices for future generations, through development that makes everyone benefits from and expands future options (Birkeland, 2008; ‘\;////////////////////???2012). Within this concept, opportunities are actively sought to create net positive outcomes, not less bad or neutral ones. This is to expand and even improve the ecological base beyond what it was before their settlement. The aim is not merely to offset the physical footprint of development, but rather to completely reverse the ecological footprint (Hes & du Plessis, 2015).

To do this, it is first necessary to look at examples from nature from which humans already experience positive effects. These examples from nature are also called 'ecosystem services', and it distinguishes four categories: providing, regulating and cultural services that directly affect people; and supporting services that are needed to maintain the other services. People already experience these positive impacts through (Zari, 2012): (1) consciously providing habitat for species other than humans; (2) contributing to soil formation and fertility through careful cycling of biodegradable waste and recycling of non-biodegradable waste; (3) purifying the air, water and soil; (4) regulating the climate with limiting greenhouse gas emissions or possibly sequestering carbon; (5) producing renewable energy; and (6) collecting rainwater.

Subsequently, consideration can be given to developing this further where everyone benefits from it. Here, the concept of 'positive development' offers a number of design criteria (Birkeland, 2014): (1) Transcend 'resource autonomy' (self-sufficient energy production, water and waste treatment), by creating positive impacts on-site and/or off-site that enhance ecology and eco-services; (2) Create synergies and shared spaces for natural and human habitats (through multifunctional design and integrated indoor/outdoor spaces) and increase resources wherever possible; (3) Improve human and environmental health (not just reduce toxins), by creating opportunities for social interaction, physical activity, semi-outdoor spaces and local food production; (4) Support the bioregion and native biodiversity, by acting as a gene bank and incubator for the restoration of the region's ecology and/or the remediation of rural monocultures (5) Use natural systems and forces to maximise heating, cooling and ventilation before adding active systems, even when the latter are powered by renewable energy sources; (6) Improve ambient microclimate and reduce impacts of heat island effect and carbon emissions to create public open spaces and greenery; (7) Reduce land area while increasing natural capital, habitats and biodiversity in urban areas and developments by creating "ecological space" (or even sky parks where possible) (8) Design reversible, demountable and adaptable wherever possible, as permanent development may not reduce impacts on distant ecosystems; (9) Use organic, compostable, adaptable and renewable resources and materials wherever possible instead of mined materials with high levels of built-in waste or toxic binders, solvents, etc.

3.1.6. The ‘regenerative’ approach

The last approach is essentially a continuation of the aforementioned approach, as it addresses the positioning of nature and habitat. But as a complement, these approaches embed the ability to keep improving performance over time and under changing environmental conditions. This then refers to the approach "regenerative development and design. This approach assumes that people, human developments, social structures and cultural interests are an inherent part of ecosystems', making people integral and particularly influential participants in the health and fate of Earth's web of living systems." (Mang & Reed, 2020).

An important aspect of a regenerative approach is to see design as "designing the 'capacity' of the built world to support the positive co-evolution of human and natural systems, rather than "designing things" (read: buildings, infrastructure, etc.). In doing so, it is important to define "sustainable" buildings as "buildings that can support sustainable lifestyles". This emphasises that buildings are no longer seen as "products", but rather "play a role in positively supporting human and natural processes". As it were, buildings are positioned as "central to creating higher levels of order and, as such, creating greater variety and complexity", either as part of and connected to a larger system. All this changes "the current emphasis from individual self-sufficient buildings" to "opportunities for positive connection and creative synergies with adjacent buildings and surrounding ecosystems (Cole in Mang & Reed, 2020). However, a difference can also be noted. This approach sees development and design as two separate synergistic processes. Both these processes play a crucial role in ensuring greater reach, with neither being sufficient without the other. However, the main difference between the two processes is that regenerative development deals with generating a patterned understanding of the whole system of a place. It 'develops' strategic and systemic thinking capacities of stakeholders and interested parties to achieve maximum regenerative influence and support (Mang & Reed, 2020). In other words, this involves the larger scale of a place/site. In contrast, regenerative design acts more from the uniqueness of a place rather than a more universal system. It works at different scales to integrate flows and structures of the built and natural environment. Whereby the smaller scales affect the larger ones and vice versa.

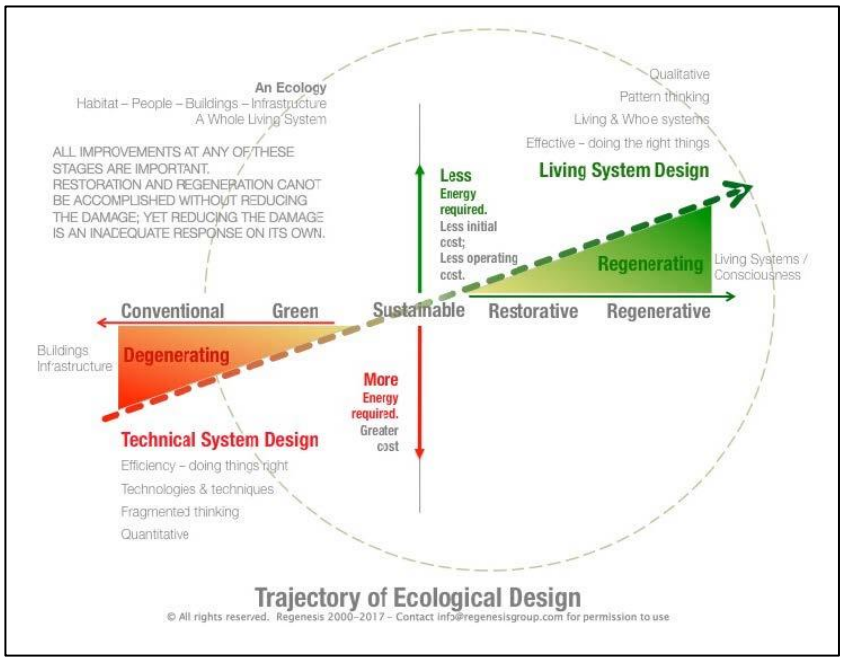

Figure 4: Trajectory of Ecological Design. Regenesis Group

3.2.The capacity of its locality

In this paragraph, the factors of a particular place are explored in order to actually foresee oak regeneration. First, it clarifies the definition of place, and explains how such a regenerative process is applied in three different phases. To then make this specific to oak regeneration. In this, place is defined as the unique, multilayered network of living systems within a geographical region that results from the complex interactions, over time, of natural ecology (climate, mineral and other deposits, soil, vegetation, water and fauna, etc.) (Mang & Reed, 2012). Place is seen within the regenerative process as 'living', like a living system or entity.

3.2.1. Understanding the place with its unique patterns

The first phase of the regenerative process is to understand the relationship with place. The aim of this phase is to understand the inherent dynamics and potential of sites, projects and communities in relation to their environments, and how projects can become regenerative forces through appropriate relationships (Mang & Reed, 2012). The traditional project process begins by collecting individual sets of knowledge from experts in the fields of water, energy, soil and more. Without an overall systematic context, this knowledge can be fragmented and misleading (Reed, 2007). The best means of understanding the essence of a place is what is called "story of place". In this, it refers to an actual story, as it allows us to understand and share complex wholes, to create a collective representation of the future. After all, stories have been formed over the course of human history, using these narratives to hold on to the integrity of a culture and its connection to a place over thousands of years. Examples include song lyrics, poems and myths (Mang & Reed, 2012). Besides forming stories, exploring patterns is also very important. Patterns are forms of relationships that reoccur again and again. Reading or understanding patterns reveals the fundamental, actual and potential energy flows that make up a system, e.g. wind, water, foot traffic, etc.

The following core patterns are formulated and explained (Mang & Reed, 2020): (1) the ecological, social and cultural patterns, these create and manage the conditions that determine how life in a place is represented; (2) the potential value-added patterns that life in that place engages in, and how those conditions may influence each other; and (3) the development implications and possibilities for how people and buildings seek to enable the health and continued evolution of place.

One such example of mapping patterns is a map where it is visible what type of soil there is at the particular place (see Figure 5). The story around this would then be about its origins and any alteration. For oak regeneration, it is also very important to look at patterns, such as soil type. Oak trees are found on soils with different cation exchange capacity and nutrient supply, from gravel substrates to limestone soils, but grow best with moderate growing conditions or on sites with somewhat more extreme water conditions (Annighöfer, 2015). In the case of *Quercus robur* (pedunculate oak), sites can be moist or wet, and even survive flooding to some extent. The soils at these sites are then often alkaline and nutrient-rich loam or clay soils. In contrast, *Quercus petraea* (sessile oak) is more likely to be found on well-drained shallow, stony and rocky, dry soils. This is because the species is more sensitive to high groundwater levels and stagnant wet, and therefore more tolerant of drought (Bréda, 1993). However, research shows that soil conditions nevertheless have two influences on the abundance of seedlings (a plant raised from seed). The first influence has to do with very fertile soil. On this soil, the competition from other tree species increases as the soil fertility is also high. Whereas the second influence, on the contrary, deals with less fertile soil. This soil lends itself as very suitable for growing mature oaks. Here, the second influence is more valuable for growing oak trees, this because no other tree species can grow on these nutrient-poor sites (such as maple, ash, cherry and sorbus species) (Annighöfer, 2015). In terms of regeneration, this competition from secondary tree species is the most crucial factor. Here, little or no competitive pressure is not immediately undesirable or unhelpful, but determines the success of oak regeneration (Mölder et al., 2019).

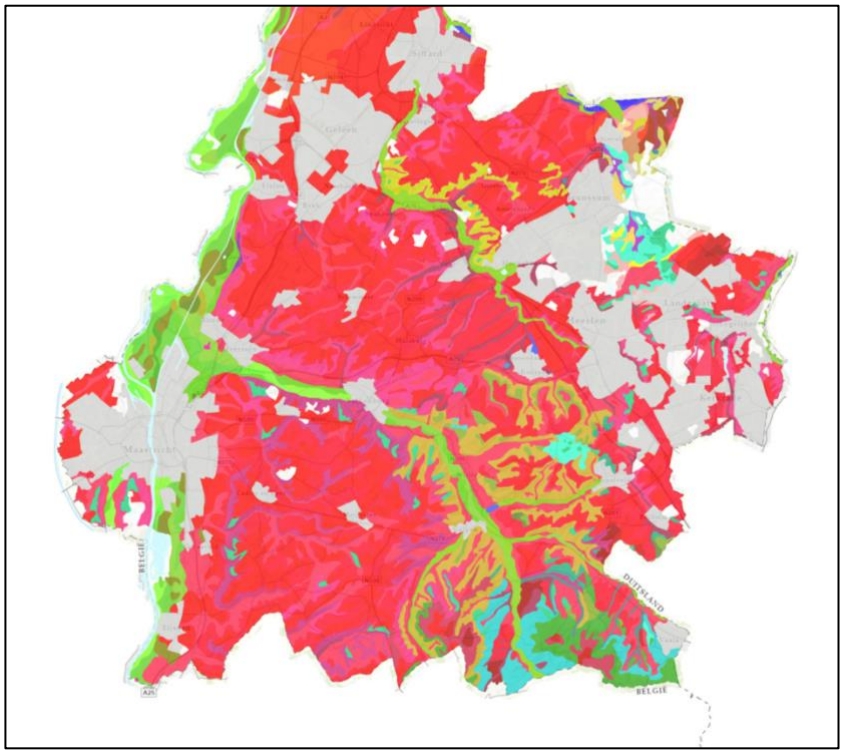

Figure 5: Soil map of the south of Limburg, Esri Nederland

3.2.2. Design the place with harmony

The second phase is about translating those aforementioned findings (from the "story of place" and the unique patterns) into design principles and systemic, integrated plans, designs and construction processes. Here, human presence in a landscape will need to be optimised to harmonise human activities with the larger pattern of place (Mang & Reed, 2020). In this, the design of a building should not be built in isolation, but should also repair and/or improve with the world around it. This creates a so-called 'pattern harmony' in which the specific place becomes more one with the world outside it. However, this harmony is not permanent. A good solution can turn into a bad solution over time, so it requires a more progressive rather than one-off harmonisation where the pattern is constantly rearranged (Mang & Reed, 2020).

The principle of reconfiguring patterns in harmony works the same in relation to maintaining oak woodland regeneration. For example, forest planning objectives must take into account the impacts of climate change, as well as Europe's consequent habitat regulations (Natura2000). But above all, forest managers must also take into account the conditions present. These conditions will require different measures the moment a tree grows bigger. The method of planting in this is a very important starting point. In practice, different ways are followed for planting such an oak forest. However, this study prefers a way that focuses on the maximum achievable production of high-quality oak wood. This is because in this way a harmony can be created in the regenerative design process within the life-cycle (see Figure 6) of mainly the oak. This method of planting is started by planting 2000 seedlings per hectare (Mölder et al., 2019). During the first year, seedling growth is mainly due to the weight and size of the acorn. Therefore, oak seedlings often survive in large numbers and adverse conditions. But soon after this stage, other requirements come into play that affect the survival of oak saplings. This shows that the development stage has a strong influence on resource requirements (Annighöfer et al., 2015). Within this method of planting, early thinning is recommended to remove unwanted tree species. At the age of 30 to 40 years, when trees are then about 10 to 15 metres tall and tree density has been reduced to 500 trees per hectare, 60 to 100 potential future trees per hectare are selected. These potential trees will be

increasingly encouraged to grow on during further thinning. If other tree species do not interfere with the oak crowns, they can be preserved as an undergrowth. However, this undergrowth can then be dominated by broad-leaved tree species or spruces to prevent the development of epicormal shoots (Löf et al., 2016). To give this undergrowth, as well as the newly planted oak trees a good chance and to maintain it, light should be made available over time. This is done to prune the canopy/ crown tops (the openings between the leaf tops). In the process, this pruning wood can be used as fencing or fuel. Under different conditions, different studies refer to an average felling/ crown opening (openings between the leaf tops) of 0.1 to 0.3 ha (Kohler et al., 2020). After a rotation period of 120 to 150 years, about fifty to seventy span the crown, and will remain for the foreseeable future. Besides light, there are many other factors that can contribute to regeneration success, but this is difficult to determine due to the uniqueness of a site.

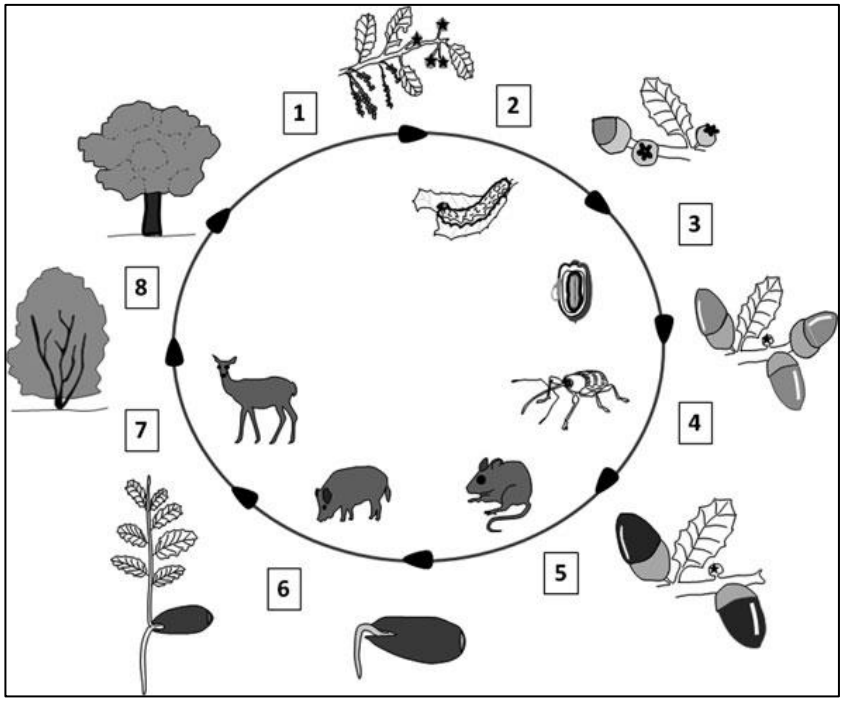

Figure 6: Life cycle of an idealized oak species, F. Pulido in Campos et al. (2013), Numbers refer to the processes linking differentstages: 1 flowering, 2 fertilization, 3 acorn growth, 4 acorn maturation, 5 acorn dispersal andgermination, 6 seedling emergence 7 sapling establishment, and 8 growth from juvenile to adulttree. Organisms interacting in these processes are: 2 insect defoliators, 3 bacterial pathogenscausing the drippy nut disease, 4 acorn borers, 5 acorn dispersers, 6 acorn consumers 7 browsingmammals.

3.2.3. Design the place for co-evolution

The third and final phase is a result of the efforts from the previous two phases. In it, what emerges most strongly is that the role of an architect is not seen as a person who makes drawings and delivers a project, but rather as a gardener. A gardener who sees himself as a partner in a co-evolution with the living system (place) in which work is performed, cultivating growth by providing the right environment (as a gardener does for his plants) (von Hayek, 1974). The responsibility of a regenerative designer becomes one as a facilitator of processes and methods that maintain the ongoing capacity of a project, by enabling owners, managers, contractors and stakeholders over time to recognise and integrate new social, economic and ecological opportunities. With this, the design of a building is not an end product, but a catalyst of positive cooperative ventures to enable co-evolution. If successful, its effects can be noticed even before final construction (Mang & Reed, 2012, 2020).

One strategy to enable such co-evolution is to further expand social opportunities. This is then mainly seen from a cultural point of view, as it has implications for social relations and is a non-material benefit whereby the sense of place is enhanced. Examples include religious values, inspiration, aesthetics and recreational values. Several studies suggest that the recreative value of a place is enhanced by temperate deciduous trees, such as oak stands (Norman et al. 2010; Johansson et al. 2014). But even since the earliest times, oaks have played an important role in the human culture of Europe. It provided wood for fuel, acorns for livestock, bark for tanning and timber for construction. From the Greeks to the Germans, the Slavs and the Celts, the oak was a sacred tree, which is why the oak is often a national or regional symbol, for example on German, Croatian and British coins and in the coat of arms of Bulgaria (Ealton et al., 2016). In addition, funnily enough, the oak is also included within the culture of Limburg, due to the incorporation of oak within the national anthem.

> *"Waar in 't bronsgroen eikenhout, 't nachtegaaltje zingt.*
> *Over 't malse korenveld, 't lied des leeuweriks klinkt.*
> *Waar de hoorn des herders schalt, langs der beekjes boord.*
> *Daar is mijn vaderland, Limburgs dierbaar oord!"*
> (Gerard Krekelberg, 1864-1937)

Another and much larger example of how an oak forest can survive over hundreds of years can be found within the viticulture of France. This is because French oak is of utmost importance to the winemaking process. Oak is usually chosen for its hardiness, permeability, contribution to characteristic aromas, its ability to inhibit fungi and yeasts, its mechanical properties and its tradition of use (Carpena et al., 2020). However, some French oak forests were initially planted not for this viticulture, but to supply a powerful marine industry of France. In the year 1670, several oak forests were planted at the command of Louis XIV (and later Napoleon) for the benefit of the republic (Office National des Forêts, 2018). However, these plans stagnated so these forests were not used for war, but for producing wine barrels (see Figures 7 and 8, shown in brown). This tradition still lives on, and the surplus of these oak forests are now even under protection and conservation for ongoing barrel production. This principle can therefore potentially be passed on to other oak forests in several countries within Europe. Especially given the upcoming changes regarding the climate. As a matter of fact, a change is already taking place regarding the planting of oaks (Bontemps et al., 2011). Whereas in some places *Quercus robur* (pedunculate oak) used to grow faster and was more suitable for planting, *Quercus petraea* (sessile oak) is now increasingly chosen for planting. This is because of the increasingly warmer and drier conditions in which sessile oak grows better (see 3.2.1.). Figure 7 shows how a new ecological opportunity may emerge in terms of the regeneration of pedunculate oak (*Q. robur*), and Figure 8 shows this for sessile oak (*Q. petraea*). Sessile oak will increasingly be planted in pedunculate oak areas, and pedunculate oak will be planted further north. Here, the different wine regions are indicated in red. With this, this principle is a direct example of such co-evolution between humans and oak regeneration.

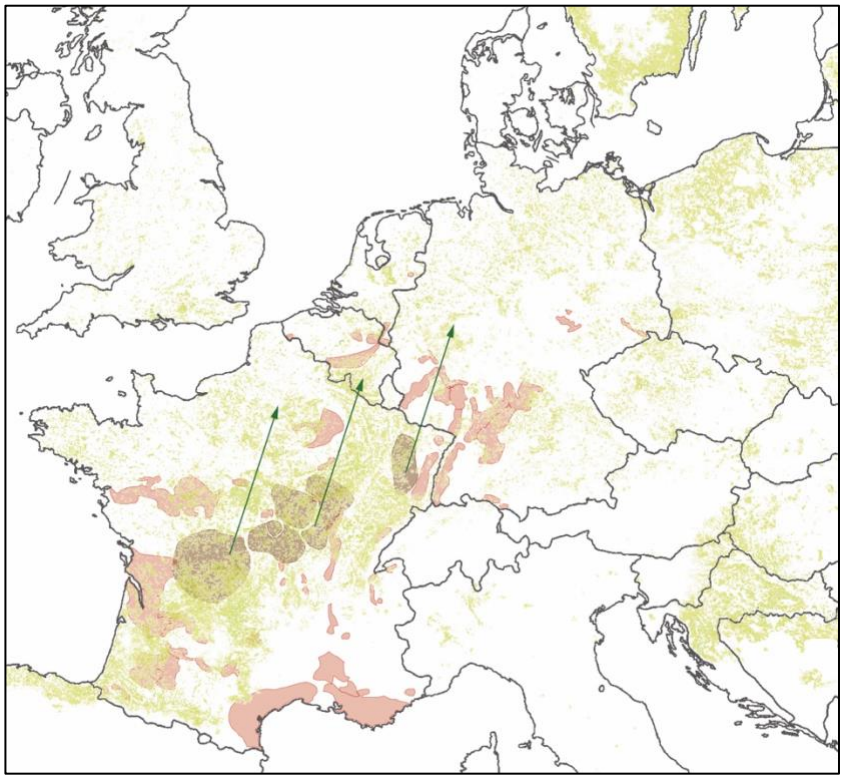

Figure 7: The relative probability of presence and development for *Quercus robur*, adapted map created by the author based on the maps of Eaton et al. (2016)

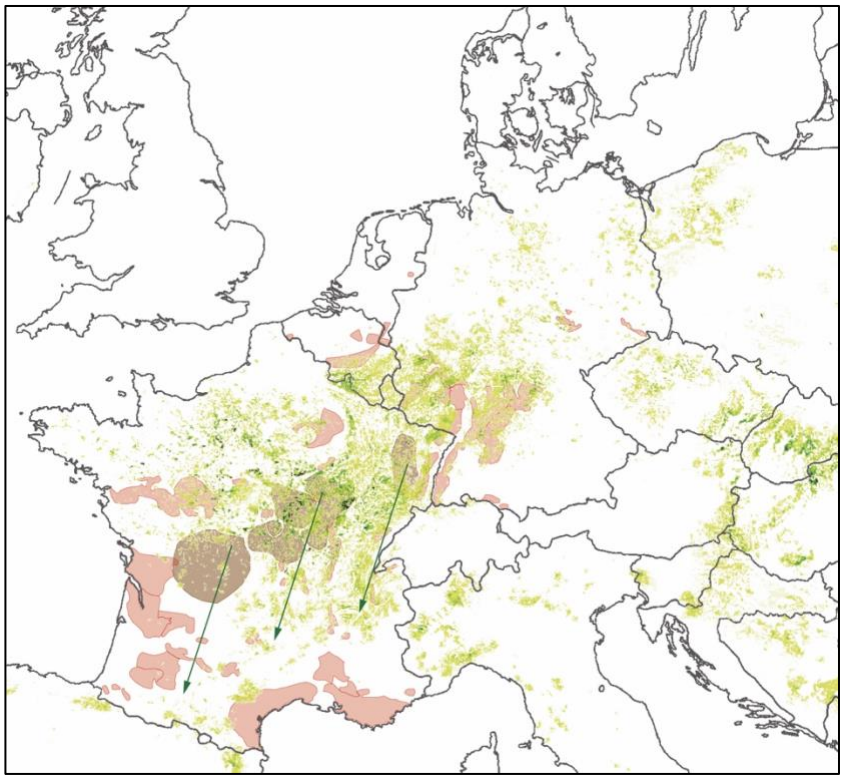

Figure 8: The relative probability of presence and development for *Quercus petraea*, adapted map created by the author based on the maps of Eaton et al. (2016)

3.3.The application of oak wood

The previous section already showed how such oak tree species grow and under what conditions. First, this section will investigate the generic properties of *Quercus robus* (pedunculate oak) and *Quercus petraea* (sessile oak). The continuation of this is to investigate the forms of application of wood as a direct building material. This research will mainly focus on two applications, namely: (1) as a construction element and (2) as an exterior shell (either window frames or façade finishing). A third application is not directly a building material, but rather an application within the winery. As mentioned earlier, namely as a wine barrel. Here, this subparagraph will identify the possible further potential of the oak planks (derived from the barrel), and whether this material can be used as a building material.

3.3.1. General properties of *Quercus*

The *Quercus* has been closely associated throughout human history. The species was around before the arrival of Homo sapiens and has acquired many basic resources for humans ever since. The genus *Quercus*, which has more than 400 species, including 275 in Europe, are found throughout the northern hemisphere (Gil-Pelegrín et al., 2017). Between the 45th and 50th latitudes, the *Quercus*' growing range stretches across the earth like a band, being a little higher in Europe due to its maritime climate and a little lower in North America due to its terrestrial climate. However, Europe was fortunate that, after becoming partly deforested, many oak forests were established for shipbuilding. However, not everywhere this remained intact, and therefore did not ensure good regeneration. In the Golden Age, for example, the Netherlands squandered almost its entire oak forest stock on the construction of the famous VOC fleet (VVNH & Centrum Hout, 2004).

The structure of oak is composed of several cells, with growth rings being identified in the transverse plane. In the same transverse plane, the description of structural aspect can also be observed. This consists of two parts, namely the newly formed part, which forms the outer layer, and the darker coloured part in the middle. Here, the outer shell is called the sapwood and the middle part the heartwood. The transition of these two parts ultimately determines the texture of the material, resulting in heterogeneity (dissimilarity) (Santos et al., 2012). Oak is a ring-pore wood species, which means it has vessels (pores) that can be read within each annual ring. These vessels form each year in the early wood (growing season: spring) much larger/wider in size than in the late wood (growing season: summer). The function of these vessels is to process or store (nutritional) substances.

Table 1: The average physical and mechanical properties of *Quercus* species (Santos et al., 2012)

Species	Q. robur	Q. pyrenaica	Q. alba	Q. rubra	Q. faginea	Q. ilex
Physical properties						
Density (kg.m^{-3})	710	774	680	750	890	900
Tangential shrinkage (%)	10.7	10.5	8.8	11.0	14.9	9.5
Radial shrinkage (%)	4.9	5.8	4.4	4.4	9.5	5.3
Volumetric shrinkage (%)	16.8	17.4	12.7	16.3	25.0	16.0
Fiber saturation point (%)	31	30	n.a.	32	n.a.	27
Mechanical properties						
Transverse compression (MPa)	n.a.	14.5	7.4	n.a.	n.a.	n.a.
Transverse tension (MPa)	3.9	8.3	5.5	4.3	4.9	4.6
Rolling shear (MPa)	n.a.	12.8	n.a.	n.a.	n.a.	n.a.
Parallel tension (MPa)	n.a.	84.0	n.a.	n.a.	n.a.	n.a.
Bending strength (MPa)	135	138	105	152	150	147
AME (MPa)	n.a.	11500	12300	n.a.	n.a.	n.a.
Parallel shear (MPa)	n.a.	19.1	13.8	n.a.	n.a.	n.a.
Parallel compression (MPa)	50.5	54.3	51.3	54	53.0	50.0

The physical properties of oak wood are measured on three aspects: (1) density, expressed in kg/m3; (2) shrinkage coefficient; and (3) moisture content. Mechanical properties are measured on seven aspects: (1) transverse tensile strength; (2) transverse compressive strength; (3) parallel tensile strength; (4) parallel compressive strength; (5) shear strength; (6) flexural strength; and (7) modulus of elasticity (AME). All mechanical properties are expressed in N/mm2, which converted is equivalent to MPa (Megapascal). Below is a summary of all properties of the different types of *Querus*.

3.3.2. *Quercus* as building material

To actually use oak as a building material, the wood must first be sawn. There are different sawing techniques for this, for different applications. However, before it can be sawn, it is necessary to dry the wood properly. This is the most important stage in wood processing as it ensures better gluing, finishing and preservation. Because of its defects and unevenness, both morphological and structural, drying oak is a slow and precarious operation (Santos et al., 2012). After the wood is dried, and before it can be sawn, it is still important to equilibrate (balance to equilibrium condition) and dimensionally stabilise the wood. Sawing is the next most important factor in wood processing. The logs of oak can be badly shaped, and if this is the case, it is more difficult to saw long pieces. Therefore, there are two ways of sawing: by (1) planing, which involves sawing lengthwise (along with the fibres); and by (2) cross-cutting, which involves sawing widthwise (crosswise to the fibre). For cutting boards or beams, the first method is used. However, depending on the intended application, the log can be sawn in different ways. Herein, three main directions are indicated: (1) radial; (2) tangential; and (3) axial.

The first way of sawing wood is "flat" sawing. This is done in the tangential direction parallel to the annual rings. This way of sawing is the most effective way of cutting a log into planks. Each plank is cut straight from the trunk in one direction, without changing the orientation of the trunk. This method produces boards with a full range of angles from the rings of the trunk. However, this method of cutting can cause warping or cracking due to the difference in shrinkage of the different wood directions. A variant of "flat" sawing, namely "plain" sawing. This is again done in the tangential direction parallel to the annual rings, only in this way care is taken that the annual rings do not come to a greater angle of 35 degrees. Cutting out beams and columns in this way is quite possible because variation in the direction of cutting is allowed. The second way of sawing wood is “quarter" sawing. This is done in the radial direction perpendicular to the annual rings; the annual rings thus show parallel lines. In this case, the log is first divided into four pieces (quarters), To then saw perpendicularly in the direction of the annual rings, and the adjacent board is sawn parallel. In this way, too, it is quite possible to saw out beams and columns with it, because the first quadrant division can ensure a suitable size. The third and last way is then again, a variant of "quarter" sawing, namely "rift" sawing. This also involves first sawing the log into four parts, then ensuring that each board has parallel lines in the annual rings. However, this does create many unusable pieces for use as building materials.

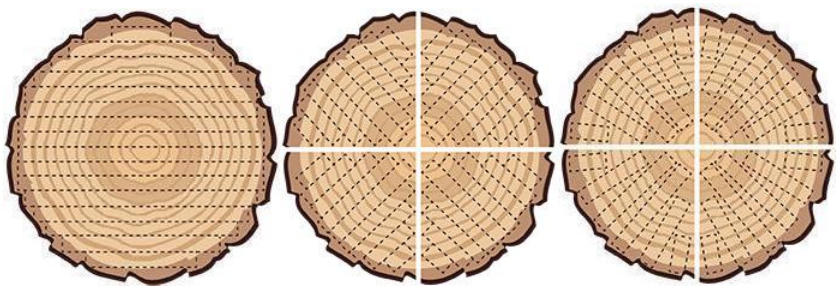

Figure 9: The different sawing techniques, from left to right: live, quarter and rift, collected by author from Swanerhardwood.com

After sawing, an initial quality selection takes place. Freshly sawn oak is first air-dried for six months to a moisture content of 35-40%. This is done out of the sun, shielding the wood from excessively dry or strong winds. It is then artificially dried to the desired moisture content. For furniture wood and parquet, this is 8-10 and 7-9% respectively. In hydraulic engineering, logically, non-dried wood is used. Drying in two stages is necessary, because accelerated drying in one go easily leads to deformations, cracks or collapses. Both radially and tangentially the wood shrinks strongly, but very differently. Once dried, oak is quite dimensionally stable (VVNH & Centrum Hout, 2004). Oak comes in many forms. It can be used both indoors and outdoors and, because it is a hardwood species, lasts a long time. For the correct application of the specific wood, an application guide has been developed (see table 2).

Table 2: Application guide of oak wood (VVNH & Centrum Hout, 2004)

Application guide oak wood			
Vein:	Rough	Medium	Fine
Growth:	Fast	Normal	Slow
Annual rings:	large, more than 3 mm	Between 1-3 mm	Very fine, >1 per mm
Details:	Very large	Nice mirrors	Flawless wood for veneer
Works:	Most	Less	Least
Suitable for:	Outside	Outside and inside	Inside
Application:	Construction timber, beams, columns, chair legs, and back posts, water construction, sleepers	Window frames, doors, furniture	Sculpture, panelling, mouldings, veneers

One such example of how different parts of an oak trunk can be used within the design of a building is visible in Figure 10, in which the "plain" sawing method is applied. It can be seen that the structural parts come mainly from the heartwood, the supporting structural parts mainly from where the transition from the core to the outer layer and the finishing elements even more towards the outside.

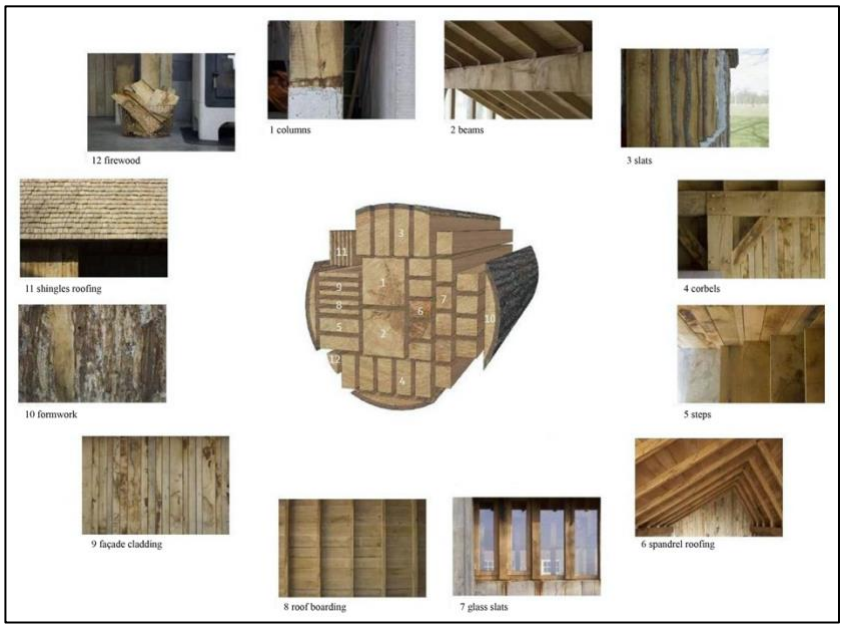

Figure 10: A design of the "sixteen oak barn" in Berlicum involved cutting down oaks locally and determining which part of the tree trunk could best be used for which part of the barn, Hilberinkbosch Architecten (2018)

3.3.3. *Quercus* as wine barrel

Besides oak being widely used in construction, another important application can be found in viticulture. This, as mentioned earlier, is common in France. Wine storage and ageing is a practice that has been used since ancient times, as it is resilient, flexible and relatively impermeable to liquids (Alamo-Sanza & Nevares, 2019). It is crucial that the wood has a straight grain, it should not give off unpleasant flavours, it should be free of defects that can cause leaks and should also be thermoplastic. This is because the wood must be able to be bent by heat, and this is essential for the shape and manufacture of the barrel. For this, oak proved to be very suitable. The value of the barrels especially comes into its worth in the maturation process. During barrel maturation, the extractables of the oak start to mix with the grape juice. With this, aromas are modified/added, including notes of vanilla, brioche/sweet bread, coconut, spices, smoky toast aromas, coffee and caramel (Prida, 2012). But at the same time, controlled oxidation of the substances, caused by the penetration of oxygen through the barrels/pores, gives a beneficial effect on the sensory characteristics of the wine (such as colour, flavour and aroma).

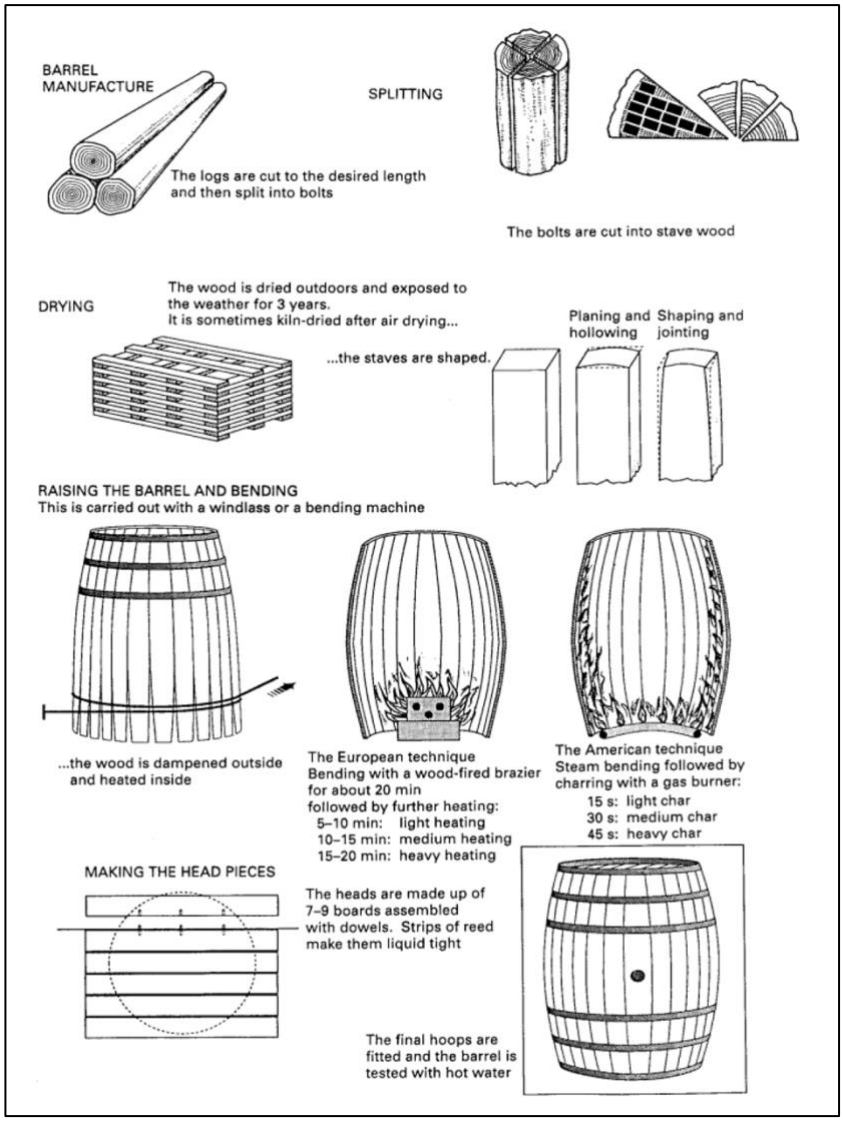

Figure 11: Diagram of barrel manufacture (Jackson, 2008)

Making a wine barrel is a complicated process (see Figure 11). As described earlier, the wood must first dry after being selected. The wood is then quartered/ rift sawn, and staves are determined based on the wood grain. In the case of Querus robur or petraea, the wood is split, following the direction of the medullary rays to ensure the density of the wood and avoid the risk of leakage. After splitting, the staves have to dry again in the open air for a certain time. The staves are then shaped according to the characteristic shape of the barrel. Bending the wood therefore requires heat and moisture. Heat in the form of a fire pit, which is placed in the staves shaped cone. This is held for about 20 to 30 minutes until the temperature inside the cone reaches 200 to 220 degrees Celsius. This is followed by a second heating process called toasting. Toasting is one of the most influential operations on the composition of oak in which the formation of flavour compounds is promoted. Here, the intensity and duration is an important factor. Lastly, the lid is made which makes it completely liquid-proof (Rubio-Bréton et al., 2012; Carpena et al., 2020).

It takes an oak tree, at its youngest 60 to 80 years, and at its oldest 150 to 200 years, to be suitable for making wine barrels. Subsequently, a wine can lie in the barrel for only six to 18 months. This can be done, with interim cleanings up to three times before the wine barrel has lost its vigour and is thus discarded. For larger barrels, the lifespan can be further extended by removing the a thin layer on the inside of the barrel. Still, a wine barrel has an average lifespan of only three to six years (Stadler & Fischer, 2020). Of course, in its immediate function, these barrels are used even further in distillers, for example. Other possibilities include making the barrels into furniture or decorative pieces as, for example, a pot to hold plants (Canas et al., 2022).

IV. CONCLUSION

Over the years, many approaches have been conceptualised with nature always playing an increasingly prominent role in people's lives. Therefore, a sequence can be discerned in which it eventually ends up with an entirely new systems thinking. This started from the conviction that when human beings saw positive development as a common good, and therefore not only to their own advantage. This provided new insight for a further expansion, namely that of the regenerative system. This development starts with an assessment of the whole system, looking at a wide range of patterns and ecosystems. This directly acquires knowledge of the site that is a resource for in every stage of a design. The conditions studied where oak forests grow best is a single example of how oak regeneration can respond to such site patterns. It is safe to say that there are many more patterns to be found in the given site, and this will require further research into: (1) the patterns to be found within the site; and (2) how oak trees fit within these patterns. This knowledge, in turn, can ensure that the patterns being regenerated are again in harmony with the larger patterns of the site. For this to be possible, and sustained for future generations, a partnership must be created between the place (as a living being) and other living systems (a human, a tree, an animal). The fact of such an oak regeneration strategy (3.2.2) is just to illustrate how this applies between human life in harmony with growing oak trees. When growing oak trees, many more life forms will be brought along. However, further research is required to further bridge how this partnership can be in harmony with other life forms and place. This partnership has a permanent and distinctive role in bringing forth activity, growth and co-evolution. An example of such co-evolution can be found within viticulture, where regeneration strategies have evolved over time to continue providing oak, for the manufacture of wine barrels. Partly for this reason, a winery design strategy is a desirable option. Oak regeneration will have to adapt due to the impact of climate change, paving the way for new ideas. This oak wood can be used directly at the local level as a building material, and at the same time for the manufacture of wine barrels. For this, a life-cycle strategy needs to be developed that allows the regeneration of oak wood to fit into the maintenance and replacement of such building elements and wine barrels. However, it would be also interesting for a winery design if these wine barrels, after their depreciation, could be used as building materials. Here, there are two factors that make it interesting to actually enable

this. The first factor is about the impermeability of the material. This is made possible by its shape, but also especially by its toasting. Similar techniques are used to make wood suitable as a facade material (read: Shou sugi ban). This makes this material potentially suitable as an outer shell of a building. In doing so, it is not clear what the effect of the layer of grape juice that has soaked into the wood is. This introduces the second factor, as it is precisely this layer that is seen as undesirable within the process of winemaking (Pidra, 2012). This is because the layer is very susceptible to attracting microflora and potentially becoming an enrichment on biodiversity. However, again it is not known what effect this will have on the wood when applied as a façade material. For both of these unknowns, further studies and experiments are needed that map the effects of this saplayer, and to find out what fungi and bacteria will be attracted. Such studies can be found within microbiology (Roos et al., 2019), but this will have to be translated to the use as a building material.

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