NATIONAL EXPERT-BASED ASSESSMENTS: AUSRTRIA

REPORT FOR THE AUSTRIAN NARRATIVE ON FOREST RESTORATION

SUPERB
Upscaling Forest Restoration

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INTRODUCTION: HISTORICAL EVOLUTION OF FOREST RETORATION AUSTRAIA

Throughout history, the borders of Austria have undergone changes. While this report pertains to the current territory of the Austrian Federal Republic, which spans 83,882.56 km², it is important to consider that the text sources may refer to regions beyond present-day state borders, particularly prior to 1918 (Figure 1). Therefore, it is crucial to take historical context into account while interpreting the information presented.

In summary, the history of forest restoration and adaptation in Austria can be divided into three distinct periods. The first period (>1914) from the 18th and 19th century was marked by the need to address the negative impacts of excessive timber use. This led to the implementation of legislative frameworks and a focus on artificial afforestation using conifer species. The second period (1914–1990) was characterized by intense silviculture and forest management, improved education, and capacity building, as well as a growing debate on near-natural restoration measures and concerns regarding monoculture forest stands. The third period (>1990) saw forest restoration activities aimed at mitigating and adapting to the effects of climate change while also addressing societal expectations for combating biodiversity loss. This period has seen the emergence of forest restoration as a well-established scientific discipline, integrated into operational management practices. The history of forest restoration in this region can be traced back to the 16th century when the booming mining industry (mainly iron and salt) in Tyrol, Styria, Carinthia and Upper Austria led to an unprecedented demand for wood, endangering the forest stands. This situation prompted the first forest assessments and inventories to estimate the available resources (Figure 2). Based on these assessments, local and regional forest ordinances were published to secure a sustainable supply of energy (at this time charcoal and fuel wood were the only sources) and to balance supply and demand. First, they addressed the exclusive use of certain mountain forest areas by the neighbouring mining industries. To ensure sustainable management of the forest and prevent shortages of wood and fuel that could lead to production standstills, forest dedications were established for mining companies, and the regulations were put in place to ensure long-term stability (Feichter, 1995). Other prescriptions concerned the ban of clearing of forests with protective functions (above traffic routes or settlements) or the prohibition of forest pasturing of goats to support natural rejuvenation. In forests dedicated to the mining industry, the legally prescribed logging method was systematically clear cutting to gain as much charcoal as possible. Reforestation after clear-cutting did not take place although some seed trees were left over to promote natural regeneration. Forests in the ownership of farmers or used by them according to ancient rights were managed by coppice systems, coppice with standards or in high forests by single tree felling of different species and diameter according to the demand of the farmstead. The outcome was a mixed uneven-aged forest with a variety of different tree species including broadleaves. Despite regulations being implemented, due to the high demand for energy the variety of prescriptions was unable to slow down forest degradation. Local forest regulations of the 16th century, such as those in Tyrol, Styria and elsewhere in the mining districts of Austria regulated logging but did not address reforestation, indicating a lack of understanding about the consequences of clear-cutting in high mountains (Maier, 2019).

In the 17th and 18th centuries, artificial regeneration activities became more common, particularly in regions with a high demand for charcoal and timber. However, it was not until the late 18th century that forest restoration became a matter of political, economic, and scientific interest, to safeguard the supply of timber for energy production, mining industries, and export.

In the mid-18th century, during the rule of Maria Theresa, the crown-lands of the Austrian monarchy implemented new forest regulations. These regulations were motivated by an active trade and commerce policy that followed the principles of mercantilism and relied on significant state intervention. (Feichter, 1995). However, the safeguarding of the forest area and the maintenance of a sustainable energy supply were the central focus of all these ordonnances.

In the 19th century, Austria experienced a significant decline in forest cover due to intensive logging and forest grazing mainly by goats and sheep. Depending on the available resources and demographic development the intensity varied among regions. This widespread trend had several negative consequences, including a loss of protection against avalanches, flooding, and landslides. To address these issues, forest restoration activities and capacity-building efforts were institutionalized and implemented on a large scale throughout Austria (Wildbachverbauungsgesetz (Gesetz zur unschädlichen Ableitung von Gewässern) 1884). Moreover, the transition from wood and charcoal to fossil fuels and the facilitation of transport caused by the implementation of an extended railway network reduced the pressure on the forest and drove the demand for valuable timber for domestic and export use. Thus, afforestation activities became an increasingly important business with trade across the Austrian-Hungarian Empire and beyond. To support reforestation efforts during this period, particular focus was placed on fast growing and easy reproducing species such as Norway spruce (*Picea abies*), pine (*Pinus nigra*), and larch (*Larix decidua*) (Johann, 1985). Particularly, Norway spruce became a high demanded timber and in consequence, market conditions initiated the conversion of former coppice forests or mixed forests dominated by broadleaf trees to conifer forests, dominated by Norway spruce. The earliest restoration activities focused on seeding and remedying over-thinned stands.

In addition to the factors mentioned earlier, the second half of the 19th century saw a significant shift in land use in Austria, known as the agrarian revolution. This period saw the afforestation of forest pastures and abandoned agricultural land, which provided another motivation for forest restoration activities. The conversion of these areas to forest not only helped to stabilize the soil, prevent erosion, and protect against landslides, but also provided valuable wood resources for the growing economy (Johann et al., 2004).

The year 1852 saw the introduction of the Forestry Act, which created a comprehensive legal framework for forest management in Austria. This legislation provided clear guidelines for the granting of clearing permits, the obligation to afforestation of cleared areas, and the prohibition of forest desolation (Johann, 1985; Stoerk, 1903). Additionally, the act required the regeneration of windstorm destructed stands to ensure soil and water conservation. These measures represented a significant step towards the sustainable management of Austria's forests and helped to ensure the long-term viability of forest restoration (Johann, 1985; Johann et al., 2004).

The implementation of the 1852 Forestry Act was supported by the establishment of forestry associations, the promotion of scientific research, and the development of specialized training facilities. This was necessary because the implementation of the act faced challenges due to a lack of knowledge and availability of suitable seedlings. To address this issue, incentives such as forestry association memberships and reforestation awards were introduced as well as one of the world's first forest seed laboratory was established. However, the success of reforestation efforts was often hindered by intense grazing and game pressure, which had already been noted as a problem in the late 19th century. Despite these challenges, efforts to restore Austria's forests continued.

In the early 1900s, the state of forestry in Austria worsened due to economic and political factors, as well as natural disasters. In Salzburg and Upper Austria, the replacement of forest and pasture servitudes resulted in fragmentation and the sale of peasant estates for speculative transactions, which had a negative impact on forest stands (Feichter, 1995; Hillgarter & Johann, 1994). Large state forest areas were sold to private owners, which induces a shift in the ownership structure.

Furthermore, an inconsistent customs tariff caused issues in the timber trade. These challenges were compounded by wildlife damage, insect infestations, forest fires, and increased grazing pressure, which hindered many restoration efforts (Johann, 1985). To address these issues, premiums were awarded for successful afforestation, and high-quality forest reproductive materials were distributed. Despite these efforts, there was a significant imbalance (1:5) between demand and production of forest plants, resulting in afforestation being carried out at the wrong time with poor quality plants or from unsuitable provenance.

In 1908, approximately 2,816 hectares of land in Upper Austria and 977 hectares in Salzburg were reforested with spruce, larch, and stone pine plants obtained from state nurseries. The government also introduced several official measures to promote reforestation, such as mandatory logging permits, subsidies, premiums, and the distribution of forest plants by state forestry administrations and large landowners. Despite these efforts, forest grazing and litter extraction remained significant challenges for forest stands. Moreover, in addition to afforestation, silvicultural measures aimed at restoring forest stands were also increasingly developed and implemented on a large scale (Johann et al., 2004). One of the most used techniques was thinning, which improved storm resistance and facilitated growth in spruce stands. Such silvicultural measures were essential for stabilizing forests and ensuring their long-term survival.

Until the beginning of the World War I, the forestry objectives in Austria were focused on securing a sustainable supply of wood to produce tanning agents and roe deer antlers, as well as promoting economic ties with foreign partners. During the war years from 1914 to 1918, the priorities of forest owners shifted towards the procurement of raw materials essential to the war effort. This included the harvesting of Norway spruce trees to meet the demand for tanning agents used in the production of leather, as well as the supply of firewood to urban areas.

In the post-war years of World War I, financial difficulties led to cutbacks in funding for reforestation measures. The economic crises of the time made it difficult to justify the costs of forest management in relation to the returns, which further hindered initiatives for forest restoration. Despite these challenges, restoration and reforestation remained relevant forestry policies and were discussed, for example, at the "Wald-in-Not" (Forests in Need) conferences in 1927 and 1931.

The precarious economic situation made it particularly difficult for small forest owners to implement measures for forest conservation and restoration. After catastrophic snow pressure damage and large-scale wind throws in the 1930s, small-scale forestry and natural regeneration were adopted. Highly thinned mixed stands, such as spruce with beech, which were particularly used for reforestation after wind damage to reduce soil degradation, became increasingly established. The newly developed methods for forest conservation were put on hold during the war years (1938 to 1945). During the World War II, large-scale clear-cutting and forest devastation dominated.

The prolonged overuse of forests in the lowlands and hills (<900 m above sea level) led to extensive forest restoration initiatives in the 1950s. The primary objectives during this period were to intensify forest management, increase yields, improve forest access, and ensure sustainable profits. In the post-war decades, the availability of suitable seeds relied on imports from abroad. In 1954 alone, 6 million forest plants were imported to Austria. In the 1960s, the establishment of seed plantations and parent tree selection were improved through dedicated local initiatives. A particular challenge was communication and knowledge transfer to small forest owners. The enormous number of forest owners with an area of less than half a hectare, dating back to the first settlements, had caused a fragmentation of forest ownerships.

The long-term trend reveals that in the first post-war business census conducted in 1951, a total of 432,848 agricultural and forestry businesses were identified, which is approximately the same as in the 1930 census. However, since then, the number of these businesses has continuously dwindled over time and is around 140,000 at present (Statistik Austria, 2016). Improved income prospects in alternative economic sectors have prompted some to sell or neglect their forests. Moreover, the agricultural and forestry enterprises had to meet a certain minimum size to remain competitive (Figure 3).

The main goal of restoration efforts since the 1960s until the 1980s was the transition from large clear-cut areas and monoculture spruce stands to small-scale management, selective cutting, and the establishment of mixed forests through natural regeneration. In addition to forest conversion, the possibilities of soil improvement, wildlife management, forest engineering techniques such as tending and thinning, were also topics of forest restoration. Starting in the 1970s, conflicts of use with tourism and recreational functions of the forest were discussed. The consideration of environmental protection began to be incorporated into forestry planning in the 1980s, driven by forest dieback due to air pollution.

The Forestry Act of 1975 still provides the legal framework for measures, duties, and responsibilities for reforestation, forest protection, and forest management. Snow-break disasters (in Upper Austria) and avalanches (in Vorarlberg and Tyrol) as well as infestations of forest pests led to an intensive discussion of afforestation and tree species selection, with mixed forest stands being considered as a basis for stable forests. In the 1980s, nature conservation aspects came increasingly into focus through the nature conservation movement. The protection of species-rich forest habitats, such as riparian forests, process protection in nature reserve forests, and the restoration and promotion of biodiversity in near-natural forests are among the restoration goals of this period.

After 1990, forest restoration activities have been influenced by three main drivers, resulting in three major temporal trends. In the 1990s, the most common trend was reforestation using site-appropriate and adapted tree species to maintain multifunctional forests. The primary focus was on sustainable forest management for economic interests.

However, after the forest fires in 2008 and the drought in 2016, the increasing impact of climate change has shifted the focus on forest restoration that promotes diversity in terms of tree species selection and genetics, structures, and habitats. This approach aims to safeguard forest functions after damaging events and establish high structural resilience of newly established stands. The drivers for this change were the visible environmental changes caused by global warming, large-scale damages from pests and diseases, bark beetle outbreaks, snow pressure calamities, and regionally increasing game populations, mainly ungulates. The spatial occurrence of this trend correlates with the bark beetle (*Ips typographus*) outbreak, which has caused the dieback of Norway spruce (*Picea abies*) forests. This trend is still ongoing today (Figure 4).

Moreover, there has been a small-scale trend in the last decade of the period, focusing on the restoration of forest habitats with high nature conservation value, such as riparian forests, bog forests, and other rare forest communities, strongly supported by the EU fundings. Financial support in the form of co-financing and subsidies has been provided by the Austrian Rural Development Programme (during the periods 2007–2013 and 2014–2020) as well as the national Forest Fund (covering the years 2019–2025) to numerous forest restoration initiatives. The Forest Fund (Waldfonds) was initiated by the Austrian federal government in 2020 with a volume of 350 million euros. It supports the Austrian forestry and wood industry by promoting nationwide measures such as reforestation, the establishment of climate-resilient forests, forest protection measures, forest fire management, and actions to increase connectivity and promote biodiversity in forests (Figure 5).

Figure 1. Map of the reference territory in green (the area of today´s Austrian Federal Republic) on the historic map of the Austrian-Hungarian Empire in the end of the 19th century.

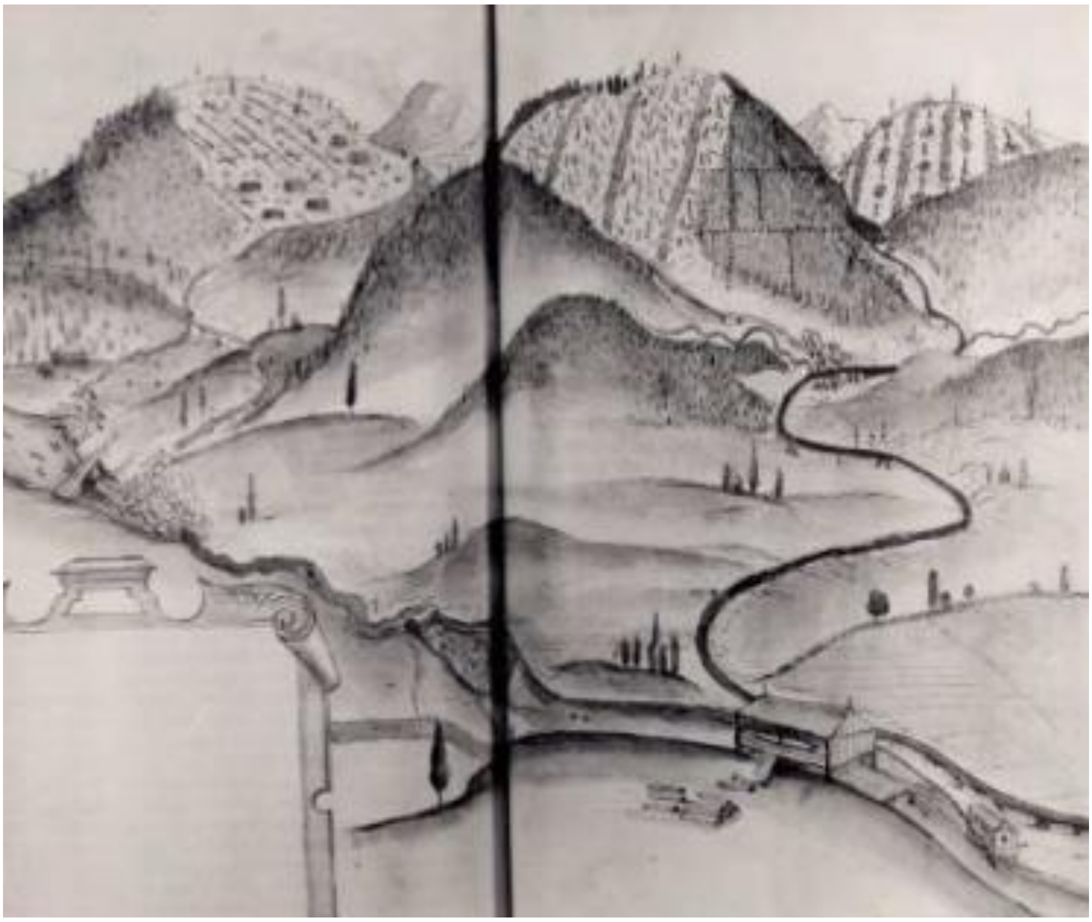

Figure 2. Deforestation of the Salzkammergut in the 17th century (Johann, 2012).

Table 1. Development of the forest cover and tree species composition through human interventions. After the restoration efforts, the ecological situation of the forest manifested itself in different ways for individual tree species. The proportion of Norway spruce (*Picea abies*) increased by one and a half times, while the proportion of larch (*Larix decidua*) and pine (*Pinus* spp.) increased fourfold. However, the proportions of fir (*Abies alba*), beech (*Fagus sylvatica*), and oak (*Quercus* spp.) declined significantly (Hafner, 1994; Hillgarter & Johann, 1994). Consequently, coniferous trees became more dominant than deciduous trees. This shift in tree composition had significant consequences for the forest communities and their associated biodiversity until the 1980s.

	1000	1600	1800	1900	1926	1988	2000	2021
Tree cover %	75%	26%	30%	32%	1926%	45%	47%	48%
Tree species								
Picea	36	50				65	59	55
Abies	26	15–20				5	3	3
Larix	2					8	5	6

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Pinus	4					16	6	5
Fagus	20					9	11	12
Quercus	8					1	2	2
Other trees	4					5	14	15
Conifers	68	65				85	74	70
Deciduous	32	35				15	26	29

Table 2. Development of the ownership structure on average across the Periods (Johann, 2002; ÖWI, 2016). Approximately 80% of forests in Austria are privately owned, with only 15% being national forests and 3% being municipal forests.

Forest ownership type	Period 1	Period 2	Period 3
Small private forest owner (<200ha)	-	44%	54%
Private forest owner (200ha–1000ha)	-	16%	9.6%
Private forest owner >1000ha	-	26%	18.3%
Municipal forests	-	-	3.3%
State forest	-	14%	14.8%

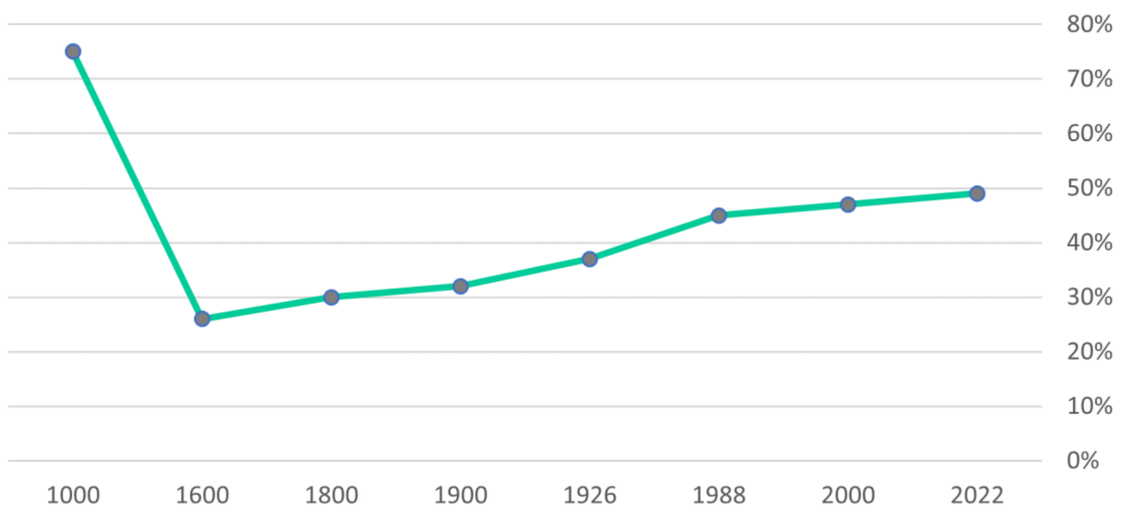

Figure 3. Development of the forest cover in Austria (referring to today´s Austrian territory) after *Feichter, 1995 and NFI, 2022.*.

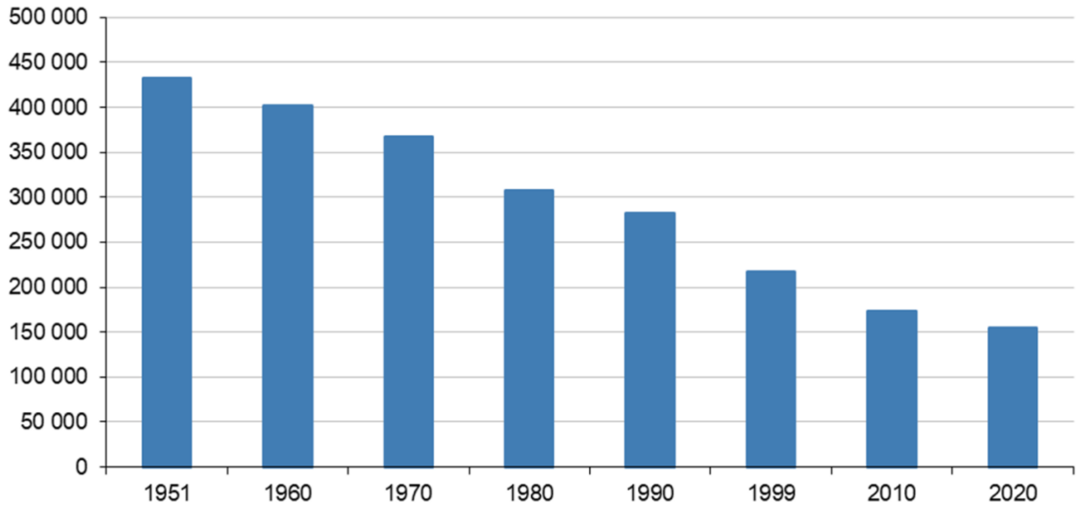

Figure 4. Agricultural and forestry holdings in Austria 1951 to 2020 (Statistics Austria, 2020).

1851 — **Assemblies of forester associations**

Farmers and foresters began to assemble and form forest associations, which played a crucial role in promoting reforestation initiatives. These associations were instrumental in raising awareness about the benefits of forest restoration and mobilizing support for the cause. Their efforts helped to drive significant progress in the restoration of degraded lands across the country.

1852 — **Imperial Forest Act of 1852**

Legal regulation of the principles of forest conservation, reforestation obligations, and the prohibition of forest destruction;

1860 — **Afforestation initiatives**

Natural disasters in Austria raised awareness of the positive effects of forest restoration and helped to convince the population of the importance of afforestation.

1884 — **Torrent and avalanche control Act**

Start of the institutional establishment the protection of mountain streams and other flowing bodies of water as well as restoration measures for protective forests.

1908 — **Progress in research and experimentation**

The involvement of various stakeholders, in the restoration project increased during the afforestation process.

1975 — **The Austrian Forest Act of 1975**

The objective of the 1975 Forest Act is to maintain forests and the forest soil and to ensure forest effects and sustainable forest management.

1982 — **Establishment of near-nature practices**

The forest restoration initiatives are beginning to implement the use of near-nature practices, which aim to mimic the natural processes that occur in forests. This approach can lead to an increase in the diversity of tree species, as well as the structural diversity of the forest at both the stand and landscape levels.

1995 — **Ecological forest restorations**

Several ecological restoration projects were to be carried out with the aim of enhancing biodiversity in endangered and rare forest habitats, utilizing the funding provided by EU programs such as ERDF, LIFE, and INTERREG.

2020 — **Waldfond**

Reforestation with site-appropriate and climate-suitable planting material and the promotion of tree species diversity; Conservation, improvement and restoration of areas of conservation value that contain habitat types or species worthy of protection, as well as the preparation of scientific or practice-oriented principles related to biodiversity-relevant topics.

Figure 5. Key milestones in the evolution of forest restoration in Austria.

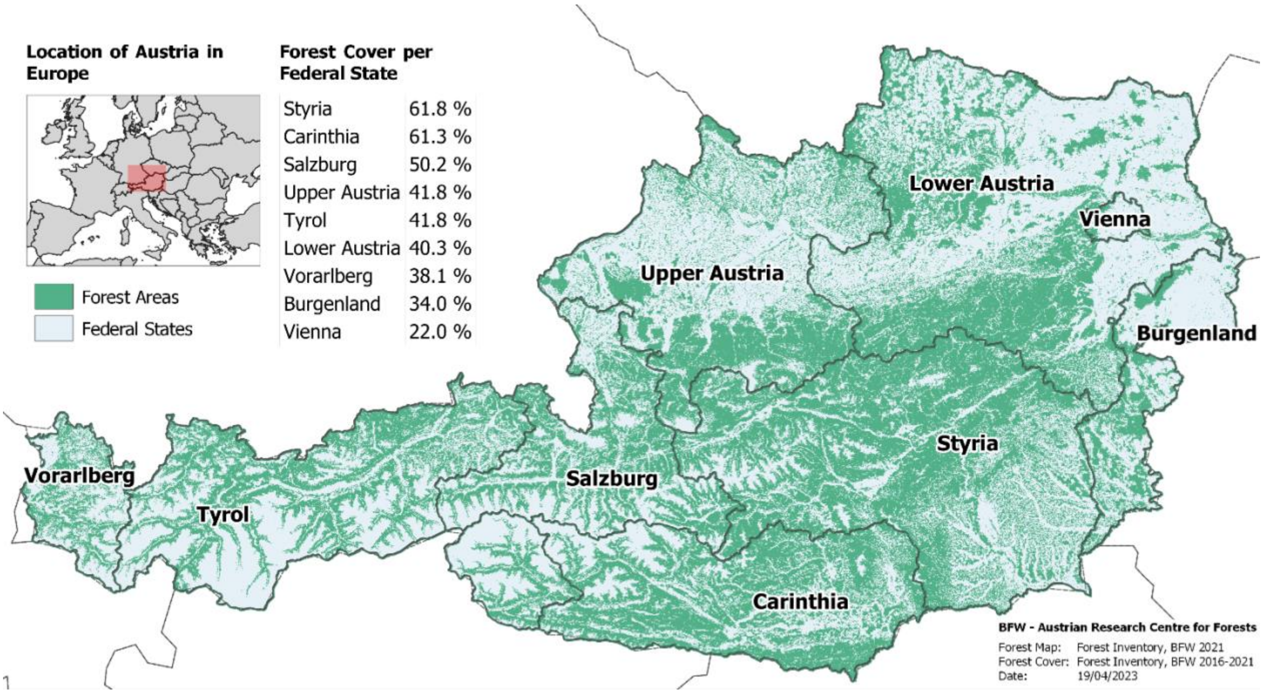

Figure 6. Map of the forest cover in Austria (NFI, 2023)

PERIOD 1: <1914

Section 1: General overview – how much, when and where

Deforestation in certain regions has resulted in the creation of wastelands, which are completely unproductive and ecologically degraded areas. Examples of wastelands include bare mountain ridges, slopes, drifting sands, inland dunes, and uncultivated heaths. By 1898, between 430,000 to 970,000 hectares of wasteland were identified, mostly in mountainous areas. Forest restoration initiatives have primarily focused on reclaiming these wastelands, particularly in the northern edge of the Alps, the drifting sand areas of the Marchfeld in the northeast of Vienna, the mountain wastelands in the Central Alps, and the karst areas in the southern peripheral Alps (Johann, 2001; Weigl, 2001b).

The increasing deterioration and reduction of forest areas led to numerous initiatives for the restoration of forests in the 19th century, which were supported by the passing of the Forest Act of 1852 (Figure 7). The objectives of the restoration measures were primarily the reforestation of secondary forest areas in the high mountains through mainly through seeding and later planting seedlings, the reforestation of abandoned pastures and agricultural areas achieved through consolidation, as well as the establishment of nurseries for the production of plant material for reforestation (Hillgarter & Johann, 1994).

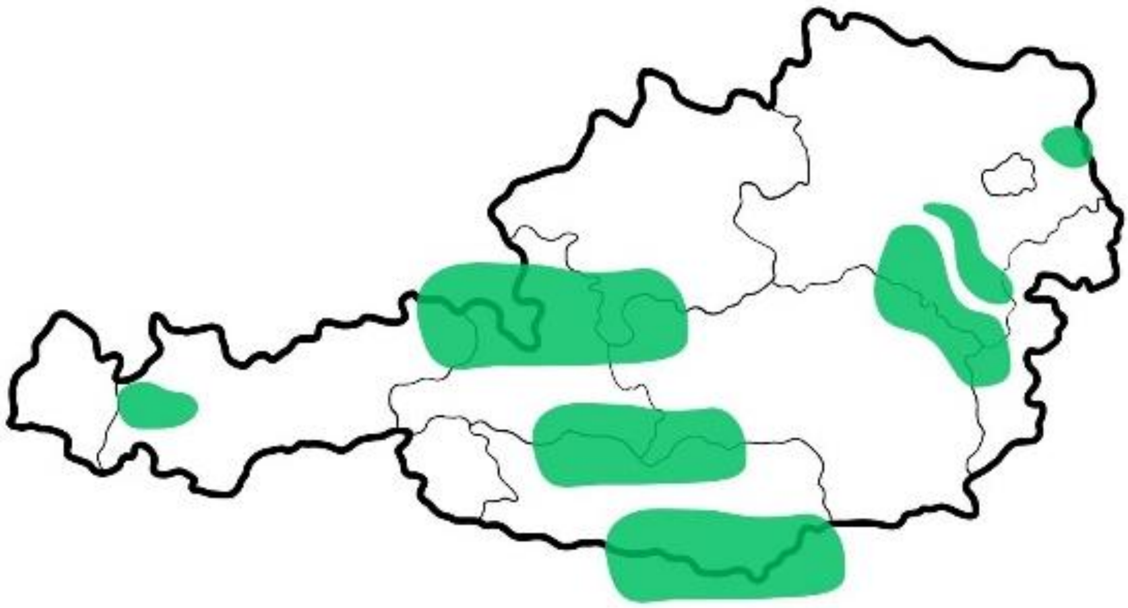

Figure 7. Schematic map of the location of the main forest restoration projects focusing on the afforestation of wasteland area within the country in Period 1 (<1914).

Section 2: Conditions prior to the interventions

The increase of natural hazard due to deforestation was the main driving force behind forest restoration initiatives. The land use management regime in place pre restoration were grassland, abandoned areas, forest pastures (mainly in the mountain regions), and sandy soils (in the east of Austria). The main driving forces for degradation can be divided in three groups (Figure 8) (Johann et al., 2004).

Socio political

- mining (iron, copper, salt) *
- provision of energy ressources *
- demand for fire wood
- increasing population
- changing market demands

Ecological

- game browsing*
- Pests and diseases
- forest grazing
- litter harvesting
- understocked forest stands
- wasteland
- snow-break, windthrow, avalanches *

Management

- land-use conflicts (agricultural production, hunting sector) *
- felling methods
- poorly adapted species/provenances
- lack of silvicultural capacites

Figure 8. Main drivers of degradation in the Period 1 (<1914) – focusing on the overall situation in the beginning of the 18th century, after Johann et al. (2004, p. 29). Drivers with high impacts at large scale are marked with (*).

During the 18th century in Austria, the abiotic conditions of forests were influenced by a variety of factors, including the local climate, topography, soil, and geology. The climate was characterized by seasonal variations in temperature and precipitation, with colder winters and warmer summers, and annual precipitation ranging from 500–1200 mm, depending on the region. The topography of the land varied from mountainous regions with steep slopes to lower lying areas with gentler hills, valleys, and plains. The soil quality and composition also varied significantly across the country, ranging from fertile loamy soils to less productive sandy or rocky soils. The geology of the region played a role in the soil composition, with different types of rocks and minerals contributing to variations in soil fertility and drainage. In addition to these abiotic factors, human activities such as clear-cutting, logging, and grazing also had significant impacts on the abiotic conditions of Austrian forests during the 18th century. Overall, the abiotic conditions of Austrian forests in the 18th century were shaped by a complex interplay of factors and varied considerably across different regions of the country.

Based on pollen analysis and historical resources, it is estimated that the composition of tree species before intense forest management activities in 1000AD consisted of 68% conifers and 32% broadleaf species (Hillgarter & Johann, 1994; Johann et al., 2004). However, considerable differences in species compositions can be assumed between the eastern lowlands and mountainous regions. The forest cover in Austria prior to the intervention in this period (<1800) was around 26% of the territory but varied significantly across different regions. It should be noted that these estimations were made in the absence of drivers of degradation, which could have further impacted the composition and distribution of forest species.

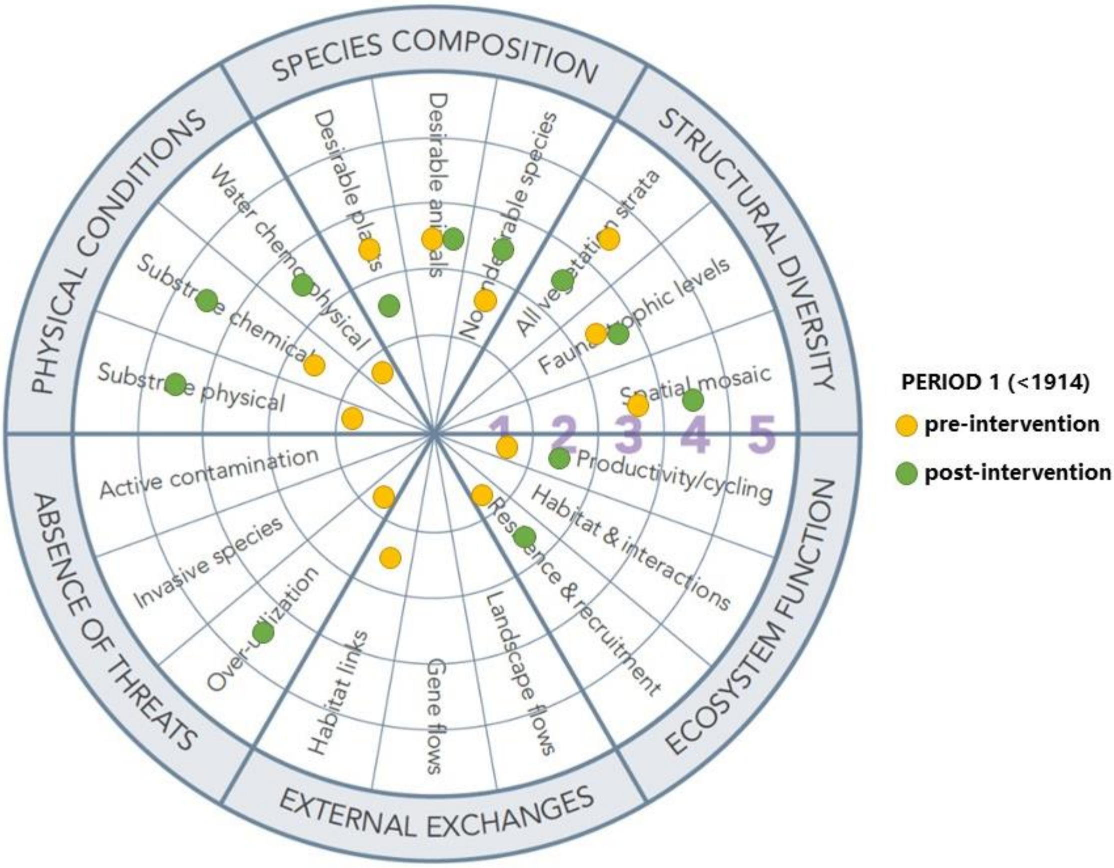

Figure 9. Estimation of the overall ecological conditions, pre-intervention and post-interventions in the Period 1 (<1914) in Austria. Each attribute was rated from 1 (deteriorated) to 5 (comparable to reference ecosystem) based on the summary of overall ecological conditions.

The initial ecological situation of Austrian forests was shaped by historical forms of forest use. For instance, the widely used agricultural practice of litter raking within forests led to extreme nutrient depletion and soil acidification due to repeated biomass removal. The widespread use of fodder trees, where the leaves and young twigs were used as cattle feed, resulted in impaired seed production and wood quality. Chipping for the use of litter led to a decrease in the share of deciduous trees and an increase in bark beetle damage. In some cases, the area was also used for grain and beet cultivation for 2 to 3 years after clear-cutting, which had consequences for forest development such as the encroachment of tree species composition, browsing, soil erosion, and an increase in pH values. One of the biggest challenges was grazing livestock in forests, which led to nutrient depletion, soil compaction, selective root damage, and, in the case of horse and goat grazing, damage to the bark of young trees (Hillgarter & Johann, 1994; Johann, 2022; Weigl, 2001b).

Section 3: Technical aspects of the interventions

During the initial phase of the Austrian restoration initiatives before 1914, the primary objectives were to rehabilitate degraded land resulting from overexploitation, with the aim of mitigating the risk of disasters, increasing timber production, and providing erosion protection.

The restoration initiatives during the 19th century aimed to increase the forest cover and promote the sustainable use of timber as a natural resource. However, these initiatives did not refer to any specific reference ecosystems. It wasn't until the late 1870s that large-scale restoration case studies were showcased within a reward program, which provided a framework for reference ecosystems to be used as a guide for future restoration efforts (Johann, 2001). These case studies demonstrated the effectiveness of different restoration methods and provided a framework for reference ecosystems to be used as a guide for future restoration efforts. This allowed for more targeted and effective restoration initiatives that focused on restoring specific ecosystems and their associated site conditions, rather than just increasing forest cover and promoting sustainable timber use in a general sense.

During the 18th century, the growing demand for wood led to concerns about potential wood shortages. Both popular scientific literature and legislation of the time reflected these concerns. However, simply preserving existing forests by banning logging and regulating timber sales was no longer sufficient. Instead, positive forestry measures became the focus of forest regulations, such as regulations on natural regeneration and reforestation through sowing or planting. The reforestation of barren forest areas was deemed a necessary state policy, and the cultivation of "wild" trees was recognized as a science equal to that of planting cultivated and fruit trees. While previous forestry measures had mainly focused on logging, reforestation was now accomplished through skilled management of felling areas and the preservation of seed trees. This shift led to the establishment of tree nurseries, experiments with forest plants, and the implementation of planned reforestation efforts (Feichter, 1995).

The prevalent method for forest restoration was assisted artificial regeneration, encompassing the cessation of degradation and active interventions (*such as plantation and the obstruction of torrents, landslides and avalanches) to remedy abiotic and biotic damage, and facilitate the process of recovery. This approach was particularly useful in cases where ecosystems have been severely degraded or damaged, as it allowed for targeted and effective interventions to restore the ecosystem to a more stable state. Assisted regeneration interventions included measures such as replanting native tree species and controlling erosion. These interventions were tailored to the specific needs of the ecosystem and varied in intensity depending on the severity of the damage. At this point non-native tree species where not used for forest restoration although pioneer experiments took place in the eastern part of Austria initiated by National Research institutions (Hillgarter & Johann, 1994).

According to the classification by Gann et al. (2019), forest restoration interventions can be categorized into three types: reduced impacts, remediation, and rehabilitation. Forest restoration initiatives involved various activities such as sowing native tree species, regulating wildlife, selecting retention trees during logging, preparing planting sites, constructing fences, and addressing degradation factors. As a result of these measures, the management of afforestation activities, especially in mountain regions and intensive lowlands, resulted into a significant increase of forest cover.

The main native tree species used for restoration activities were Norway spruce (*Picea abies*), followed by the European larch (*Larix decidua*), and various pine species (*Pinus spp*) (refer to Table 1 for details). To restore wasteland areas in the eastern part of the country, pine was used to stabilize sandy soils. In the mountain regions, such as Tyrol, Styria, Salzburg, and Carinthia, spruce and larch were primarily used for afforestation. Complementary measures included promoting artificial regeneration (planting and artificial seeding activities) and prohibiting pasturing of sheep and goats in forest areas. The planting material for most restoration activities was provided by local nurseries, both state and private owned.

Section 4: Socioeconomic and political aspects of the interventions

Section 4: Socioeconomic and political aspects of the interventions

The forest degradation had both direct and indirect negative impacts on the national economy. However, it took a collective effort to raise awareness about the importance of forests and their benefits. This effort gained momentum after the flood disasters that occurred in the late 19th century, which helped convince people across the country and the regions of the positive effects of restoring forests. Despite the challenges posed by poverty and lack of education, the implementation of forest restoration measures was successfully achieved (Johann, 2001).

The government made efforts to encourage the population towards reforestation by implementing a range of measures. These measures included incentivizing personal involvement in state-run activities through labour, as well as offering cash prizes, medals, state subsidies, and tax exemptions. Furthermore, the government initiated intensive programs in educational institutions and daily newspapers to raise awareness and promote participation (Johann, 2001; Weigl, 2001b).

The Forestry Act of 1852 played a significant role in promoting restoration initiatives. The act required forest owners to reforest newly cleared areas within five years and maintain older stands and clearings every year. Failure to comply with these obligations is treated as forest devastation and could result in coercive measures. The act also banned activities that could harm the forest or surrounding areas, such as buildings, land, connecting roads, and water sources, due to landslides, avalanches, rock falls, floods, windstorms, and other natural disasters. These measures aimed to preserve the forest soil and stand while protecting against any detrimental changes to water, vegetation, or land (Feichter, 1995).

Another non-legally binding policy instrument that was mainly used in mountain restoration projects was the payment of rewards for successful afforestation. Under this scheme, the Ministry of Agriculture and Mining paid up to 1000 Dukaten (which, in today's value, is approximately 22,200 EUR according to the historical currency converter https://www.eurologisch.at/docroot/waehrungsrechner/#/, 09.04.2023) to eligible restoration projects. To qualify for the reward, the afforestation area had to be in the mountain region and at least eight years old, and it had to be monitored for at least 12 years to ensure its success (Johann, 2002). The aim of this initiative was to establish case studies that demonstrate the successful restoration of debt-ridden Alpine regions. The rewarded forest restoration areas were, on average, 20 hectares in size and located above 1500 meters above sea level.

In addition, targeted tree planting initiatives were implemented, particularly in municipalities and for small-scale forest owners. For instance, in 1879, as part of the celebration of Her Majesty's silver wedding anniversary, people were encouraged to plant wedding trees, which resulted in the planting of 22,808 trees in 61 areas and the creation of 400 hectares of young forest. These initiatives were instrumental in promoting public awareness of the importance of reforestation and encouraging local communities to take an active role in forest restoration efforts (Johann, 2002).

In the 19th century, the renaturation initiatives played a vital role in improving the training of specialized personnel, including forest workers, forest technicians, and forest protection personnel. The forestry associations of the federal provinces, then crown provinces, were instrumental in imparting knowledge and taking on essential tasks in this context (Johann, 1985).

Funding for the reforestation of wasteland was made available through state and regional subsidies, a reforestation fund, and a reforestation commission. Both small and large forest owners were eligible for subsidies. Afforestation projects and their state subsidies were justified by the financial benefit and economic advantage of the protective forest, but in some cases, aesthetics and ethical considerations also played a role. The afforestation created income opportunities for the local population, not only in the afforestation process itself but also in the use of the reforested areas, such as handicrafts, carts, road construction, and torrent control (Johann, 2001). These efforts were not just about restoring degraded landscapes but also about creating sustainable livelihoods for the people living in those areas. The reforestation of wasteland helped to bring back the natural beauty of the landscape, which, in turn, attracted tourists to the region in the later decades from 1920s onwards, boosting the local economy further. Therefore, the subsidies provided were not just an investment in the environment, but also in the prosperity of the people living in the region.

The restoration projects involved various stakeholder groups, including private forest owners, national, regional, and local administrations, local communities, wood-processing industries, forest associations, agricultural schools, and research institutions. Stakeholder involvement was higher during the afforestation process than before the restoration initiative. The chemical industry was also crucial; pine resin served as a significant foundation, especially in southern Austria, ensuring income. However, after the afforestation activity was completed, citizen involvement decreased, resulting in lower success rates. The overall level of participation of stakeholders was moderate because stakeholders were involved but only during one stage of the afforestation process. The local population reverted to traditional management practices, such as cattle grazing in forest stands, which were prevalent before the afforestation. The successful reforestation efforts, e.g., in the Karst Region of the South-Eastern Alps, have generated increased interest among local foresters and rural communities in the positive ecological and economic effects of these upgrades. However, it should be noted that this process of awareness building is slow and requires continued effort on the part of the population.

Section 5: Results, successes and challenges

The overall level of success achieved through restoration activities in the Period 1 (< 1914) was good. The primary objective of forest restoration initiatives has been to increase forest cover up to 35% with specific focus on the mountain areas, and this goal has been successfully achieved by 80%. However, there is no significant improvement of biodiversity reported. although we may assume that specialized forest species might have increased while species from former pastures and open land can be expected to have decreased. Moreover, the provision of ecosystem services such as water, timber, fiber productions as well as soil protection and natural hazard minimization. Increased. . Throughout the restoration process, stakeholders have been involved, and their participation has been remarkable, thanks to the efforts of forest associations. The ecological outcomes of the restoration efforts, especially concerning biodiversity and ecosystem services, warrant closer examination Nevertheless, the restoration intervention has positively influenced the governmental organization and administration at the provincial level.

On the other hand, the limited access to forest areas and the shift towards promoting conifers single-species forests caused significant social inconvenience, particularly for rural people from lower classes. This was due to the restrictions on collecting firewood, the exclusion from forest grazing and litter harvesting, and prohibitions on gathering berries and mushrooms. The focus on wood production led to both the promotion and regional elimination of certain tree species. For instance, beech was locally eradicated, either considered undesirable when charcoal was the main product (Austrian Alps). This management approach resulted in a depletion of the diverse functions that woodlands can offer. To exacerbate matters, reforestation efforts on infertile farmland and barren land, predominantly with spruce or pine, gained momentum around 1820. This trend was driven by market changes, with an increasing demand for valuable timber, which further led to the conversion of former coppice forests into high stands of only few tree species, mostly conifers.

The extensive single species plantations of Norway spruces have led to an increase in the forested areas of Austria since the depression of 1800. This increase is noticeable in almost every province, but especially in the mountainous regions of the Southwestern and Eastern parts of the northern Alps.

The alteration of the natural composition of tree species is less significant for mixed mountain forests at higher altitudes, compared to Alpine forests in the valleys and basins. In the inner Alpine region, Norway spruce plantations have increased by 30 to 40%, corresponding to a 20 to 25% increase in Norway spruce over a period of 350 years prior to the restoration intervention (Johann et al., 2004).

One of the primary obstacles of the period has been the provision of forest reproductive material for afforestation, a problem that was particularly acute starting in 1880 (Johann, 1985).

At the end of this period, the rapid implementation of reforestation measures has achieved significant local success. For instance, the proportion of forested areas in the karst regions of the southern peripheral Alps increased from 15% to 50%. The reforestation of the karst regions in the southern peripheral Alps had significant political, socio-economic, and administrative consequences. Reforestation measures were officially recognized as being of great importance, resulting in four key actions: the reforestation of degraded lands, the preservation of existing forested areas, the introduction of stall feeding and dairy farming, and the prohibition of sheep and goat grazing in forested areas. These measures were instrumental in promoting sustainable forest management practices, preserving the ecological balance of forested areas, and improving the socio-economic conditions of rural communities (Johann, 2002). The success of these efforts has since inspired similar initiatives in other regions, further reinforcing the importance of responsible forest management practices. Similarly, afforestation efforts in the Marchfeld led to a near-complete reduction of wasteland areas.

The intervention triggered changes in the overall forest management of Austria. The land use management regime shifted towards protecting forests from degradation and erosion, which led to the regulation of cattle grazing in forest areas. The growing population's overexploitation of forests was no longer accepted by legal administrations and influential forest associations. Although clear cuttings remained a common practice, afforestation measures were now more commonly implemented to support sustainable forest management.

PERIOD 2: 1914 TO 1990

Section 1: General overview – how much, when and where

During and after the World War I, timber production played a crucial role in Austria's economic development. However, the effects of the economic crisis in the 1930s resulted in a significant decline in afforestation and forest maintenance. Any afforestation that did occur during this period was limited to Norway spruce (*Picea abies*). The primary goal of forestry during this time was to ensure sufficient wood production for both the domestic market and export, which also influenced forest restoration activities in the years leading up to the World War II. Intensive afforestation and restoration were carried out in forest areas that were favorable for timber transport, and which had been heavily impacted by clear-cutting during and after the World War II. The decades of the 1950s and 1960s witnessed remarkable advancements in technology, politics, and economy, which spurred a discourse on the need to ensure the sustainable utilization of forests. Approximately 200,000 hectares had been restored in the first part (until 1930s) of the Period 2 (Johann, 2002). Until the mid-1960s, the annual newly afforested areas increased to up to 6000 hectares per year.

Already at the beginning of the 20th century, the impact of forest management on natural processes was discussed, which have been intensified in the second half of Period 2. Close-to-nature practices have been established as an instrument of forest restoration. However, until the period of economic reconstruction after 1945, forest restoration initiatives remained oriented towards timber production. The public's growing interest in nature and environmental protection issues drove the discussion of naturalness and ecosystem services (Weigl, 2001a). From the 1950s onwards, near-natural silvicultural measures were added to forest restoration activities alongside afforestation.

In the 1980s, the phenomenon of forest dieback caused a surge in environmental consciousness among the public in Austria, leading them to scrutinize forestry practices critically. The escalating pollution of Austria's forests has spurred both the Austrian Forest Association and forestry policy to take action aimed at reducing the emissions of harmful substances and implementing measures to restore these valuable natural resources. This heightened awareness of nature and environmental protection prompted the development of competencies in forest management and conservation, as well as the study of forest ecology.

Since the beginning of the 20th century, extensive high-altitude afforestation has taken place in Austria. A large part of this afforestation was and is directly related to measures to protect against natural hazards. Especially, after several severe avalanche catastrophes with many fatalities took place in the early 1950s, mountain communities and provinces demanded large scale protection by means of technical measures combined with large reforestation actions, which were then supported and implemented by the federal government with the support various scientific institutions. The warming climate also opens the possibility for mountain forests to expand upwards beyond the previous forest boundary. This can happen naturally, but also in the context of targeted afforestation at or above the current forest boundary.

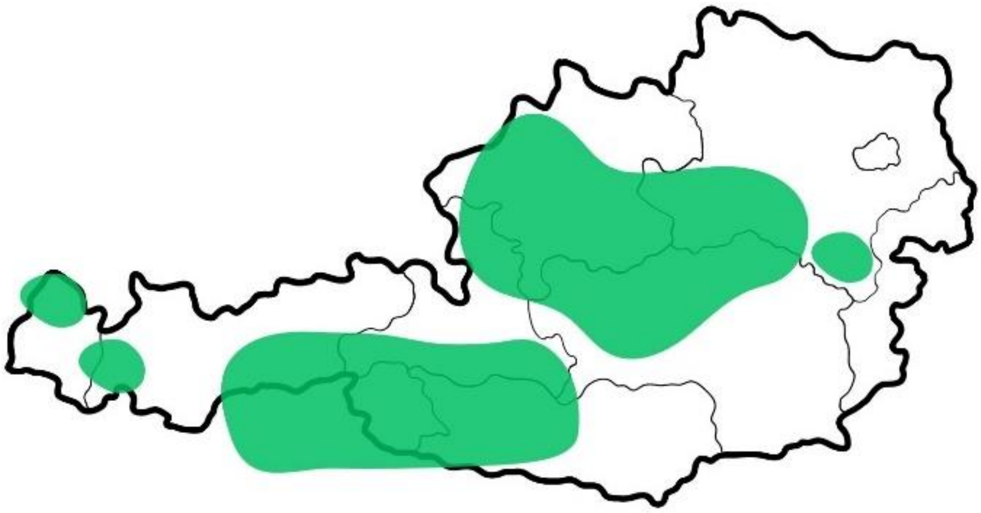

Figure 10. Schematic map of the location of the main forest restoration projects including afforestations and ecological forest restoration initiatives in Period 2 (1914–1990).

Section 2: Conditions prior to the interventions

Land use and management regime pre-restoration was characterized by large clear-cuts and monoculture plantations of Norway spruce (*Picea abies*), Austrian pine (*Pinus nigra*) and the European larch (*Larix decidua*) (Feichter, 1995; Johann, 2002). Many areas had been clear-cut and replanted, and some of them were heavily grassed over, which hindered natural regeneration. As a result, many of Austria's forests were in a degraded state, with low biodiversity, poor soil quality, and increased susceptibility to pests and diseases.

Before intervention, the sociopolitical conditions were shaped by changing social values, particularly after World Wars I and II. In many European countries, the population once again began to recognize and demand the various goods and services that forests could offer. There was a growing need for protection and recreational functions, leading to the view that utilization, protection, and recreation were interconnected and should be optimized together (Dieterich, 1944). This approach later extended to include ecological targets as well. However, although the society expressed its demands for further environmental services, foresters and forest owners were and are still dependent on income from wood production, because so far, the society refused to recognize the requirement to value and eventually to pay for other ecosystem services other than timber production and hunting. This continuing emphasis on wood production and the missing markets for other ecosystem services increasingly creates conflicts with the social environment.

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Socio political

- forest attractiveness
- intensive timber production
- timber market developmen* (decreasing timber prices) with limited revenues for investiations

Ecological

- game browsing*
- pests and diseases
- snowbreaks, windthrow, avalanches*
- pollution
- eutrophication
- climate change
- low biodiversity

Management

- land-use confticts
- know-how
- harvesting methods
- poorly adapted species/provenances
- monotypic stands*

Figure 11. Main drivers of degradation in the Period 2 (1914–1990).

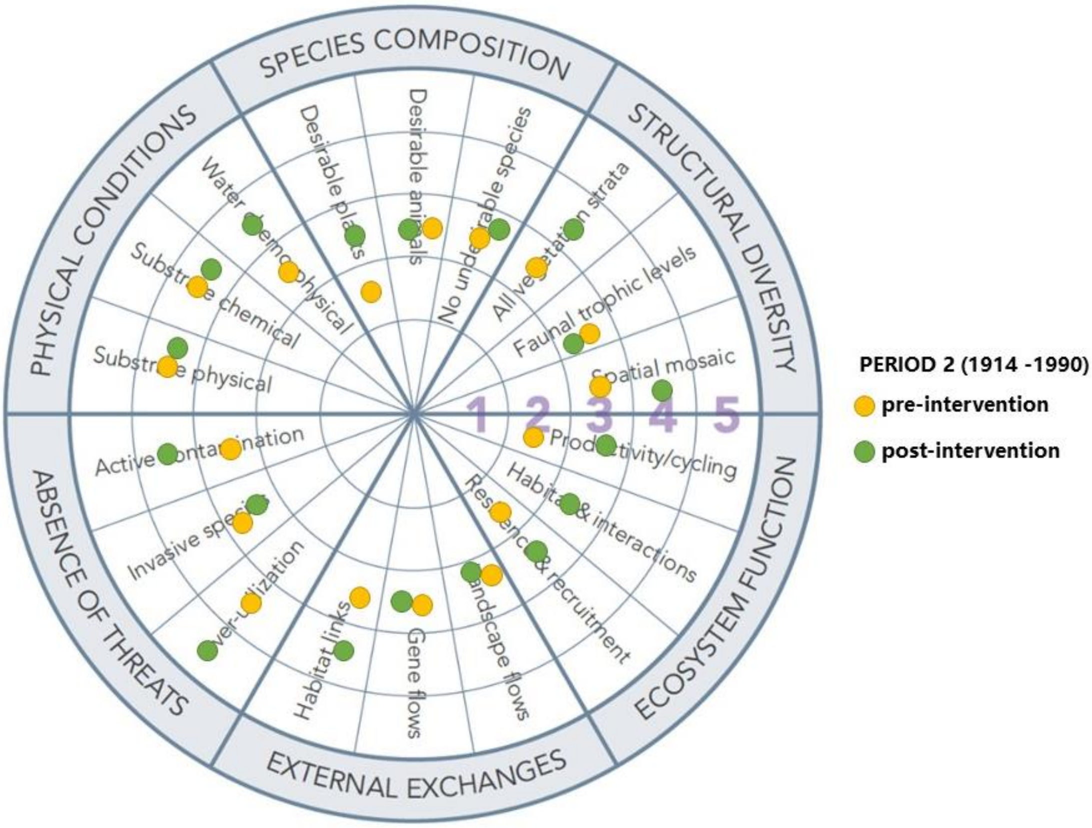

Figure 12. Estimation of the overall ecological conditions pre-intervention and post -interventions in the Period 2 (1914–1990) in Austria. Each attribute was rated from 1 (deteriorated) to 5 (comparable to reference ecosystem) based on the summary of overall ecological conditions.

Section 3: Technical aspects of the interventions

During Period 2, the forest restoration goals can be broadly categorized into two main interest groups. The first group focused on afforestation initiatives on clear-cutting areas using coniferous tree species to meet the demand for natural resources, including the protective function. The restoration goals of this group included improving water quality, increasing timber production, and erosion protection. Between the mid-1950s and mid-1960s, the annual area of newly afforested land grew by as much as 6,000 hectares per year. The implementation of large-scale afforestation also involved technical processes such as fertilization and drainage. This first type of forest restoration intervention utilized an approach of artificial regeneration, which involved techniques such as active tree planting, soil amendment, to facilitate the regrowth of the forest. During Period 2, the technical interventions in forest restoration primarily focused on coniferous species, with *Picea abies* (Norway spruce) being the dominant species. Following *Picea abies*, the interventions also included the planting of *Larix decidua* (European larch) and *Abies alba* (European silver fir) to complement the forest ecosystem. These selections were based on their good growth rate and timber production capabilities, contributing to the overall restoration effort.

The second group focused on restoration measures in forest stands of near-natural silviculture, using combined methods of natural and artificial regeneration of different tree species while considering site-specific conditions. The restoration goals of this group included protecting biodiversity in terms of species, habitat, and genetic diversity, promoting tourism, enhancing recreation opportunities, improving forest attractiveness, ensuring social acceptance, and mitigating pollution. This second type of forest restoration intervention utilized a combination of assisted regeneration and natural regeneration following the cessation of drivers of degradation.

The technical groundwork for high-elevation afforestation initiatives was laid in the 1950s through comprehensive ecological studies conducted in the subalpine region at Poschach, near Obergurgl, Tyrol. These studies were conducted by the former 'Forschungsstelle für Lawinenvorbeugung' (Research Center for Avalanche Prevention) of the Forest Technical Service of Torrent and Avalanche Control (WLV), which later became part of the current BFW (Federal Research and Training Centre for Forests, Natural Hazards and Landscape). In the early 1970s, the research site at Poschach was closed, and new meteorological and biometric investigations were initiated in the afforestation near Haggen in the Sellrain valley, Tyrol, founded in 1963. Significant findings regarding site conditions and microclimatic factors influencing tree development in the timberline ecotone, as well as the response of afforestation sites to thinning interventions, were published by researchers such as Hensler (1972), Neuwinger (1972), Stern and Hopf (1988), Kronfuss (1972, 1980, 1985, 1995, 1997), Kronfuss and Havranek (1999), Markart (2000), and others.

end of the an emerging To address the issues arising from low biodiversity, poor soil quality, and increased susceptibility to pests and diseases, forest restoration initiatives in Austria focused on promoting more sustainable management practices that prioritize the health and resilience of forest ecosystems. This included the adoption of mixed-species forests, which provide greater ecological diversity and resilience than single-species plantations, as well as the implementation of low-impact harvesting techniques that minimize damage to the forest floor and surrounding ecosystems. Therefore, the restoration activities aimed at promoting near-natural forest management focused on various aspects such as selecting appropriate tree species, considering the natural forest community, promoting mixed tree species that included rare or endangered ones, avoiding clear-cutting, and allowing for minimal natural regeneration with long periods of limitation. Additionally, the establishment of uneven-aged stands and the promotion of genetic diversity within deciduous and coniferous species were emphasized. The ultimate goal of these activities was to ensure that timber harvesting was carried out in a way that protected the forest stand and maintained productive forest soils (Weigl, 2001a).

In the context of semi-natural silviculture, forest restoration activities are often aimed at restoring the natural state of ecosystems before they were impacted by human activities. This involves an in-depth understanding of the ecological processes that underpin forest ecosystems, as well as the ability to identify the reference ecosystems that provide a blueprint for restoration efforts (Grabherr, 1998; Von Hanns Kirchmeir & Grabherr, 2008). Reference ecosystems were considered those that were thought to be close to the natural state of an ecosystem prior to human intervention. They were characterized by the presence of a diverse range of native species, natural disturbance regimes, and complex ecological interactions (Willner & Grabherr, 2007). Reference forest ecosystems were characterized by native tree species combinations and low levels of disturbance on the ground vegetation, resulting in minimal deviation from the potential natural forest community.

In conclusion, according to the classification by Gann et al. (2019), forest restoration interventions can be categorized into three types: reduced impacts, remediation, and ecological recovery. Intervention activities of this type typically included:

1. Mitigating factors that degrade the environment, such as:

- Cessation or reduction of harmful practices, such as deposition of waste, such as garbage, debris, and sewage sludge, exacerbates the degradation, any activity leading to a significantly weakened or entirely destroyed forest floor, exposing it to risks of landslides or erosion § 16 Forstgesetz 1975 (Forestry Act 1975),.
- Attenuation of pollution (Air pollutants)
- Restoration of degraded habitats

2. Enhancing ecosystem function and productivity, through:

- Sowing of seeds or planting of vegetation
- Mulching to reduce soil erosion and retain moisture
- Fertilizing to improve soil fertility
- Pest and disease control to maintain plant health
- Hydrological interventions to manage water resources
- Regulation of wildlife populations to maintain ecological balance

3. Managing vegetation and land use, including:

- Planting to restore or enhance vegetation cover
- Fencing to control grazing or prevent damage
- Thinning to improve forest health and structure
- Soil amendments to enhance soil quality and nutrient availability
- Weeding
- Logging to support sustainable forestry practices

Section 4: Socioeconomic and political aspects of the interventions

It was not until the 1950s that civil society was more actively integrated into education programs of administrations and forest owner associations, which helped to strengthen citizen participation in forest management (Johann, 1985, 2002). Government bodies and public administration allocated funds for forest restoration and management. These funds were often derived from the national budgets or specific environmental programs aimed at promoting forest conservation and ecosystem restoration. Landowners who owned and managed forested areas were direct beneficiaries of restoration activities as it improved the health and productivity of their forests. The involvement of public administration during this period was significant. They played a central role in formulating forest policies, regulations, and legislation that encouraged sustainable forest management, restoration, and protection. The public administration was responsible for overseeing the allocation of funds and implementing restoration projects at regional and national levels.

A characteristic result of the increasing multifunctional use of forests in the Period 2 – caused by the changing demands and values of society – is the dedication of forest areas to certain forest function sometimes also including the leaving out of other functions. This tendency can be observed in forest legislation (Schuster, 1987). The Forest Act of 1975, which came into effect on January 1 of that year, provided a legal framework for forest management in Austria that is still in force today. This legislation guarantees the effects of the forest, including its use, protection, welfare, and recreational benefits. It also regulates aspects such as reforestation, selection of tree species, forest endangerment bans, and frost protection obligations, as well as restrictions on forest use. The Forest Act of 1975 responded to threats to the forest with concrete measures for the protection of the forest against harmful air pollution, including effective threshold values. The Forest Act of 1975 was a significant milestone for forest restoration initiatives in Austria. These initiatives aimed to preserve or develop species-rich and genetically diverse forests, while considering local conditions. The goal of these initiatives was to ensure the long-term productivity and renewal capacity of forest ecosystems, while also enhancing their vitality and resilience. Through the Forest Act of 1975, forest restoration initiatives gained importance in Austria. This legislation provided a legal basis for sustainable forest management practices that promote the conservation of biodiversity and the restoration of degraded forest ecosystems. By prioritizing the preservation and restoration of forests, Austria has taken an important step towards achieving long-term ecological sustainability.

The Farmers' Union and the Chamber of Agriculture have been influential lobbyists for various forestry disciplines since 1935. The Forest Association, along with other associations of forest owners, played a key role in facilitating loans for forestry interventions and providing standardized, high-quality planting material. These efforts were aimed at supporting sustainable forest management practices that promote the long-term health and productivity of forest ecosystems. By providing access to affordable loans, forest owners could invest in activities such as reforestation, thinning, and selective harvesting, which are critical for maintaining healthy and resilient forests. In addition, the provision of standardized, high-quality planting material was essential for ensuring successful reforestation and regeneration of degraded forests. This ensured that the newly planted trees were genetically diverse, well-adapted to local conditions, and had the potential to thrive in the long-term. Through these efforts, the Forestry Association and other associations of forest owners have played an important role in promoting sustainable forest management practices in Austria, even though conifer species were often preferably recommended and planted

Another example of active stakeholder participation were the "Forest in Need" (“Wald in Not”) conferences held in 1927 and 1931. One of the issues discussed was the impoverishment of forests as a result of economic developments. Due to the financial challenges, maintaining the protective role against floods and avalanches was not feasible for many forest owners (Johann, 2002).

In the early 1950s, a movement emerged that promoted near-natural forest management, which later became known as the "Green Front." This movement advocated for the conservation of biodiversity and the restoration of degraded forest ecosystems through sustainable management practices.

The nature conservation movement of the 1970s brought about significant changes in the understanding of forest restoration activities. The Austrian Forest Conference of 1977 and other events involving stakeholder groups discussed the tension between business objectives and ecological goals for forests. Among the stakeholders were not only the Nature Conservation Association and the Austrian Alpine Club, but also tourism associations, and the Center for Environment and Nature Conservation.

The stakeholder groups involved in restoration projects included national, local and regional administrations, private forest owners, state forests, research institutions, hunters, and forest managers. The level of participation of these stakeholders during project’s design, implementation and monitoring of this period 2 was overall good, with most (~75%) stakeholders participating in most or all stages of the project, or all stakeholders being involved but only during one stage of the projects implementations. The level of engagement varied, depending on the stakeholders' roles, responsibilities, and resources.

Section 5: Results, successes and challenges

Through strategic prioritization of sustainable forest management, Austria has successfully restored a significant number of degraded forests to a healthier and more resilient state by the end of Period 2. Austria's commitment to sustainable practices has revitalized its forest ecosystems, ensuring continued provision of essential ecological services.

At the end of the period, the forest restoration initiatives have achieved a moderate level of success overall. The first goal of afforesting mountain areas abandoned agricultural land, and wasteland has been successfully accomplished, with the deforest cover of Austria reaching 45% in 1988. In the 1970s, a significant topic was afforestation of arable and grassland areas in structurally challenged regions like Mühlviertel and Waldviertel. However, at the end of the second period, objectives such as the improvement of the ecological integrity and the full provisioning of all ecosystem services through silvicultural restoration activities faced several obstacles, including conflicts of interest with NGOs and nature conservation administration, lack of research results and their application in restoration practices, and the acceptance of stakeholder groups.

Forest owner satisfaction showed a notable shift from being dissatisfied before 1950 to becoming more satisfied from 1950 to 1990. The increase in satisfaction can be attributed to several factors. One crucial aspect was the active involvement of stakeholders (mainly forest owners) in the forest legislation process. The formation of unions and consultations with Land & Forst Betriebe (agricultural and forestry enterprises) allowed stakeholders to voice their concerns and contribute to decision-making. Moreover, the implementation of restoration initiatives, particularly those involving Norway spruce and other conifers, played a significant role in improving stakeholder satisfaction. These initiatives not only contributed to ecological improvements but also provided income opportunities in rural areas of Austria, further strengthening stakeholder support for forest restoration efforts.

The management of forest areas faced a significant challenge as no systematic information was collected. To address this issue, the Austrian National Forest Inventory was established in 1961, with the aim of long-term monitoring of the development of wood supply, increment, felling, and afforestation, as well as investigating the forest structure and species compositions. With the implementation of ecological forest restoration activities, the objectives of the Austrian Forest Inventory expanded to include additional parameters such as the recording of regeneration, expansion of the protection forest, monitoring of vitality and stability, and recording of species diversity through tree and shrub species (Gabler & Schadauer, 2006; Ledermann, 2002; Schadauer, 1994).

The successes of the "closer to nature" restoration measures in forest management are evident from key figures in the Austrian Forest Inventory. The proportion of clear-cuts over 500 square meters has decreased indicating a reduction in the number of areas where entire sections of the forest are cut down. The increased use of natural regeneration was primarily an economic question. With declining timber prices in the 1980s, the profitability of companies plummeted, and afforestation became something they could no longer afford or were willing to invest in. Another encouraging trend is the rise in the proportion of hardwoods from 4.8% in 1960 to 25.4% in 1990, indicating a shift towards a more diverse and sustainable forest composition. However, high game populations remain a significant challenge, as they hinder the establishment of standard mixed forests. Storm catastrophes like the one that occurred in 1990 have also presented challenges to forest restoration efforts, especially in spruce monocultures. It is worth noting that in 1990, approximately 300,000 hectares of forest were designated as protective forests, which accounts for about one third of Austria's total forest area. Restoration initiatives in the protection forest, such as worldwide stand maintenance to increase stability, the initiation of regeneration, and the regulation of weeds, were identified as needing rehabilitation in 1990 (Hillgarter & Johann, 1994). Overall, the restoration measures of forest management closer to nature have shown promising results, as evidenced by the increase in natural regeneration forests and the proportion of hardwoods. However, continued efforts are required to address challenges such as high game populations and storm catastrophes and to ensure that restoration initiatives in protective forests are effectively rehabilitated.

After comparing the pre- and post-intervention ecological conditions of the areas where restoration projects were conducted, some improvements in ecological recovery have been observed in Austria. Additionally, there have been considerable socioeconomic improvements in three to four aspects such as conflict resolution, economic development, or community engagement. Overall, the results have been positive and have indicated that ecological restoration efforts have contributed to improved ecological and socioeconomic conditions in Austria.

PERIOD 3: >1990

Section 1: General overview – how much, when and where

The forest area in Austria increased from 3.8 million hectares in 1990 to 4.1 million hectares in 2020. Furthermore, it has been observed that since 1990 the area of deciduous and mixed forests increased steadily. Towards the end of the period, the forest area in Austria has continued to grow, reaching 4,0150,000 hectares, which accounts for 47.9% of the country's total land area. Styria is the most heavily forested province, with 62% forest cover, followed by Carinthia with 61%, Salzburg with 52%, and Upper Austria with 42%. In the last ten years, the forest area has increased at a rate of six hectares per day, which is equivalent to nine football fields per day. Of the total forest area, 81% is privately owned, with about 145,000 owners, and a quarter of the forest area in Austria is owned by women (BML, 2020). The share of hardwood species increased from 15% in 1990 to 29% in 2021, promoting biodiversity, and enhancing the climate resilience of the forests, while the share of spruce decreased from 57% to 46% in the last decade. The forest ecosystem's habitat for animals and organisms has been fortified, leading to further improvements in biodiversity, as standing deadwood has increased by 18% within the last decade (BFW/ÖWI, 2019; Bundesministerium für Land- und Forstwirtschaft Umwelt und Wasserwirtschaft, 2023; ÖWI, 2016, 2023). The trend towards more hardwoods continues in 2022, with coniferous pure stands decreasing by 6%, and mixed hardwood stands increasing by 6% over the last decade. There has also been a significant 8% rise in hardwood pure stands, improving biodiversity and climate adaptability in the forests (ÖWI 2023).

However, forest damage caused by felling remains at a high level, and it is clearly increasing in the protective forest, undermining its protective functions for settlements and infrastructure. In the rest of the forest, there has been a slight decrease in the amount of damage caused by shearing, which may be attributed to twice as many peeled logs being removed during thinning. On the other hand, damage due to browsing on young plants has increased, as the number of cloven-hoofed game such as deer and roe deer has been continuously increasing for many decades, which is too high for healthy forest regeneration (ÖWI, 2023).

Austria has implemented various programs and initiatives to restore and protect its forests, while facilitating the promotion of sustainable forest management practices. That includes, for example, the use of selective logging techniques, protection of forest biodiversity, and monitoring of forest health. Trends of this period refer to several initiatives to restore degraded forest ecosystems, such as the LIFE+ project, which aims to restore and conserve valuable forest habitats, and the Forest Landscape Restoration (FLR) program, which focuses on restoring degraded forest ecosystems. Additionally, emphasis was put on increasing public awareness about the significance of forests and encouraging public engagement in forest restoration endeavours. This has involved implementing educational programs, public outreach campaigns, and actively engaging local communities in forest restoration initiatives. The specific amount of forest area restored in future depends on various factors such as national and regional policies, funding, climate change, and natural disasters.

Forest fires have historically been a relatively minor concern for forests and forest restoration in Austria. However, experts predict that these events may become increasingly common in the future because of climate change. To address this issue, a team of researchers is currently investigating how forest fires can be more accurately predicted in order to improve preventative measures. Regional climate models and various studies have indicated that Austria will experience longer heat waves and more intense dry periods in the years ahead. Unfortunately, recent summers have already shown that these conditions are often accompanied by an increase in forest fire incidents. Despite the best efforts of volunteer fire brigades and well-established infrastructure, firefighting efforts have often faced coordination, water supply, air support, and strategy issues. The restoration of forests with a focus on reducing fire hazards has become a goal of restoration measures of increasing attention. This includes reducing fuel loads, slowing down the spread of fires, and decreasing ignition potential.

However, this report does not specifically indicate the amount of forest area that was restored during this time period, as it also includes natural forest regrowth and afforestation efforts.

Forest restoration initiatives can be categorized into three types: EU co-funded projects, nationally funded projects, and private restoration initiatives. The scale of the restoration initiatives ranged from 0.5 to 2600 ha. Currently, there are 32 main forest restoration initiatives, including 27 projects funded by the EU LIFE Programme and five projects funded by the Interreg Programme. The total budget for the EU co-funded projects is €250 million, with an average project budget of €4.5 million. The forest restoration goals of these projects are diverse and include the development of forest edges and dynamic forest gap systems, restoration of river landscapes and riparian forests, restoration and management of the alluvial flood plain of the River Danube, bog forest and peatland restoration, risk management, climate adaptation measures, and the transformation of spruce-dominated montane forests.

In an assessment of local and regional restoration activities of the recent years, a variety of efforts could be observed.

Important players in restoration efforts are the national parks. Within their boundaries, they initiate and bring forward a big amount of restoration efforts as well as intense monitoring, often with close collaboration with research at universities and nature management of the State Forest Management Organizaion (ÖBF). Österreichische Bundesforste ÖBF (State Forest Management Organizations) manage about 1/10 of the forest (510;000 ha) in Austria. More than half of the area is under nature protection and require specific managements and consultation for protected areas for example on neobiota management in Wienerwald and best-practice action guides to increase biodiversity. Activities also include compensatory measures for infrastructure projects, but also the combat of invasive species such as knapweed (*Impatiens glandulifera*), black locust (*Robinia pseudoacacia*), knotweed (*Reynoutria* spp.) and giant hogweed (*Heracleum mantegazzianum*).

There are several private companies that invest in renaturalizaion projects. An example is viadonau with significant investments in river restoration along the Danube.

Citizen science projects empower the engagement of many people through mapping initiatives and public planting activities organized by local communities can be found in scales between 0.05 until 63 hectares.

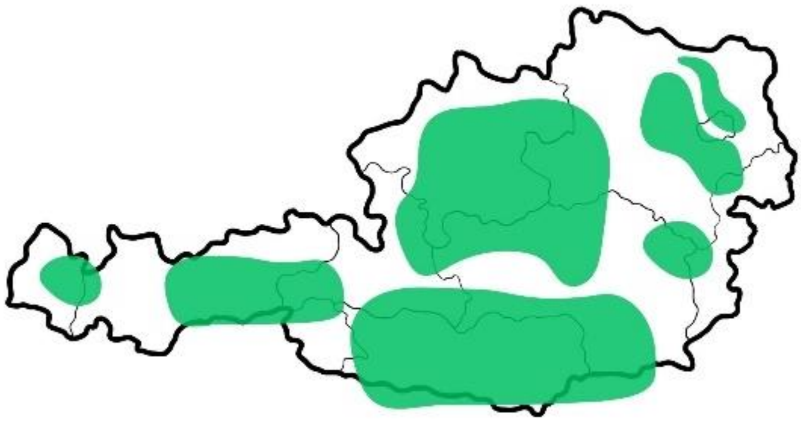

Figure 13. Schematic map of the location of the main forest restoration projects including afforestations and ecological forest restoration initiatives in Period 2 (1914–1990).

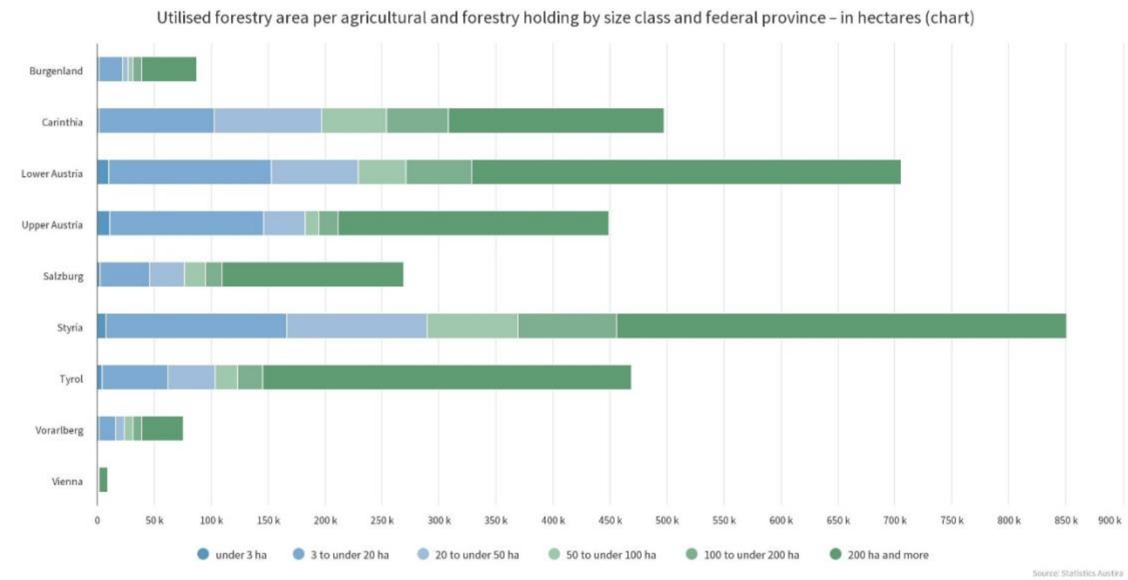

Figure 14. Forest area by federal state and size class of agricultural and forestry holding in Period 3 (> 1990) (Statistics Austria, 2022).

Table 3. Holdings and their forest area, comparing 2010 to 2020 (Statistics Austria, 2022).
STATISTIK AUSTRIA, agricultural structure surveys. Compiled on 14.10.2022. - Rounding differences due to technical reasons. 1) 2010: Mountain Farm Cadastre (BHK); from 2020: Farms with natural handicaps subdivided into severity point groups. A comparison with earlier classifications (e.g., mountain farms) is not possible.

Structural characteristics	Farms/holdings		forest area in hectares	
	2010	2020	2010	2020

Größenklasse der Waldfläche				
< 5 ha	68,959	58,874	164,124.42	157,933.22
5 to under 10 ha	33,537	35,644	235,211.44	252,328.80
10 to under 20 ha	22,101	21,743	305,656.11	304,054.52
20 to under 30 ha	7,806	7,793	188,514.72	189,419.07
30 to under 50 ha	5,883	5,904	222,013.62	224,385.51
50 to under 100 ha	3,524	3,528	240,688.86	242,302.05
100 to under 200 ha	1,960	1,947	266,971.55	266,775.04
200 ha and more	1,537	1,523	1,779,960.91	1,774,796.22
Total	**145,307**	**136,956**	**3,403,141.63**	**3,411,994.43**
In mountain areas	87,319	85,608	2,736,466.37	2,742,539.76
Federal states				
Burgenland	5,836	5,309	85,536.46	87,441.37
Kärnten	16,938	17,381	486,986.57	497,542.71
Niederösterreich	31,037	30,294	695,051.54	704,798.24
Oberösterreich	30,031	27,484	443,706.44	448,771.12
Salzburg	8,720	8,553	283,508.99	269,025.27
Steiermark	36,792	31,648	851,355.50	850,153.20
Tyrol	12,496	12,386	476,064.49	468,822.13
Vorarlberg	3,416	3,614	71,419.48	75,708.75
Wien	41	287	9,512.16	9,731.64
Austria, total	**145,307**	**136,956**	**3,403,141.63**	**3,411,994.43**

Section 2: Conditions prior to the interventions

Norway spruce (*Picea abies*) is the dominant tree species in Austria, with pure spruce stands being natural in the subalpine region. However, monospecific stands of Norway spruce below 700 m elevation are often human made and prevalent in many parts of the country due to their high productivity and good timber prices (Hasenauer, 2000; Hasenauer & Sterba, 2000; Schmidt-Vogt et al., 1989). Despite their short-term economic success, such pure spruce stands can cause, especially under changing climate conditions, forest site degradation, low stability, and increased risks from windthrow and pests, leading to reduced profitability in the long term (Berger & Hager, 2000). As a result, there is an ongoing trend to convert secondary spruce stands to mixed species stands.

Forest management in Austria is transitioning from wood production to ecosystem management, sparking heated debates. While wood production has traditionally been prioritized, conservation values are gaining prominence. Separating areas for specific goals (conservation or production) will greatly impact the future forest development, as well as the restoration goals (Johann, 2001).

Three restoration scenarios were investigated at the beginning of the period to mitigate the drivers of degradation. The first scenario involves a change in species composition by planting broadleaved species to improve soil conditions in secondary coniferous stands suffering from a lack of nutrition. The second scenario involves fertilization to affect soil processes, but it also carries positive and negative side effects such as a reduced susceptibility to phloem feeders and fungi infections while possibly contaminating groundwater due to leaching and runoff. The third scenario is stand treatment, which assumes that decreasing stand density will increase tree vigour and stability, but it also carries negative side effects such as decreasing stand stability immediately after treatment and causing higher runoff rates (Hasenauer & Sterba, 2000).

Most forest restoration initiatives in Austria are a response to large-scale damage caused either by windthrows or snow-break or later also by bark beetle attacks (especially since 2015). They are mostly responding to direct consequences of the disturbances. Recent infestations have, for example, resulted in damaged areas of 20,000 ha across Austria, with 13,000 ha in the Waldviertel region of Lower Austria requiring urgent reforestation. Private forest owners are primarily responsible for these affected areas, which are typically up to 0.5 ha in size (Landwirtschaftskammern Österreich, 2022; ÖWI, 2023).

Socio political

- management expectations
- conflicting policy targets (climate change adaptation & biodiversity
- disconnected small forest ownership structure
- low and highly fluctuating timber prices low and highly fluctuating timber prices with limited revenues for investiations

Ecological

- browsing
- Pests and diseases *
- snow-breaks, windthrow, avalanches
- eutrophication
- climate Change *
- invasive species
- drought
- fires

Management

- availability of forest reproductive material
- delayed or missing thinning measures

Figure 15. Main drivers of degradation in the Period 3 (>1990).

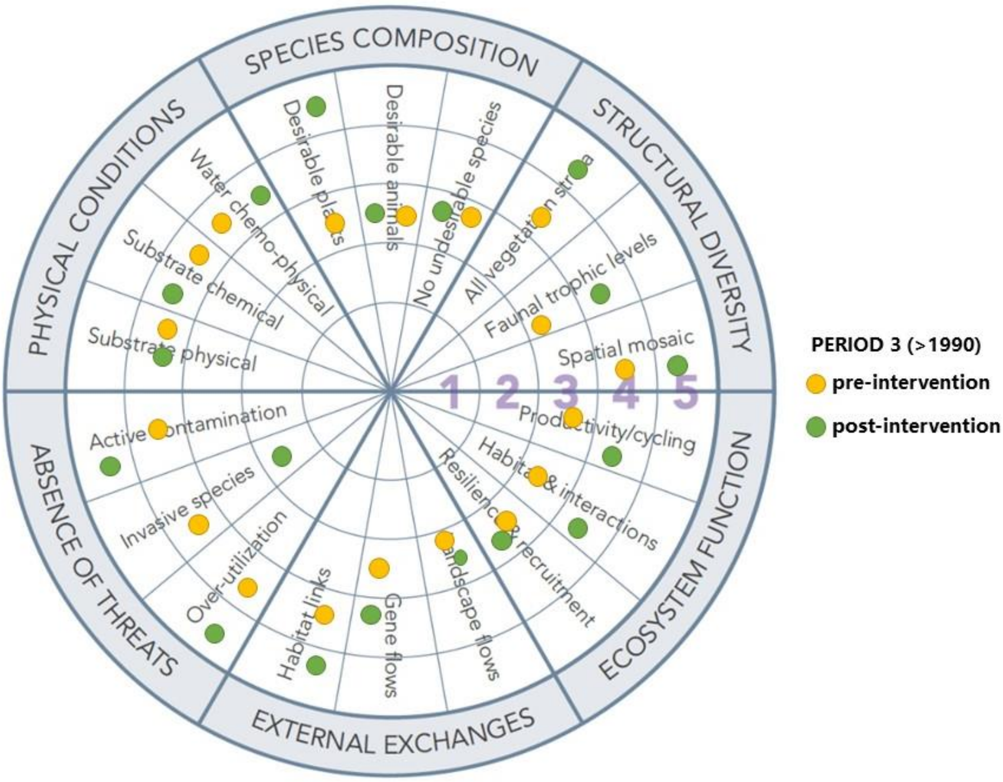

Figure 16. Estimation of the overall ecological conditions pre-intervention and post -interventions in the Period 2 (> 1990) in Austria. Each attribute was rated from 1 (deteriorated) to 5 (comparable to reference ecosystem) based on the summary of overall ecological conditions.

Section 3: Technical aspects of the interventions

Restoration goals

The forest restoration goals in Austria of Period 3 are guided by various objectives of forest management. The foremost objectives include sustainable timber production and near-natural forest management, which aim to balance economic interests with ecological sustainability. The condition of forests is to be maintained and improved to ensure their long-term viability and productivity. Another important objective is to increase the stability, vitality, and adaptability of forest stands to climate change as a basis to ensure also the future provision of forest ecosystem services and the maintenance of biodiversity. Forest management also aims to increase the resistance of forests to pests, which is particularly important given the recent outbreaks of bark beetle infestations in Europe. Forest management also seeks to safeguard forests as recreational areas for the public, and to preserve forest genetic resources. Moreover, safeguarding and improving biodiversity and habitats for animals and plants is a crucial objective of forest restoration initiatives in Austria. Forests provide habitat for a wide range of flora and fauna, and their conservation is critical for the long-term survival of many species. Finally, forest management aims to safeguard traditional forest management practices, such as coppice, coppice with standards, and small-scale plenter management (e.g., in Vorarlberg Bregenzerwald), which are an important part of Austria's cultural heritage.

In the 1990s, sustainable forest management was guided by the principle of multifunctionality, which has also become the overall goal of restoration activities. This approach, also known as multipurpose or multiple-use forestry, seeks to achieve various objectives, including timber production, protection against natural hazards, recreation, and more (Glück, 1994; Weiss, 2000). These objectives can be seen as modern societal demands placed on forest management since the Industrial Revolution. As such, sustainable forest management must balance these diverse objectives, while ensuring the long-term health and productivity of forest ecosystems.

In the second half of the Period, sustainable forest management has been guided by the principle of multifunctionality, which has also become the overall goal of restoration activities. This approach, also known as multipurpose or multiple-use forestry, seeks to achieve various objectives, including timber production, protection against natural hazards, recreation, and more (Glück, 1994; Weiss, 2000). These objectives can be seen as modern societal demands placed on forest management since the Industrial Revolution. As such, sustainable forest management must balance these diverse objectives, while ensuring the long-term health and productivity of forest ecosystems. While in the past, afforestation at high altitudes was mostly planned to protect specific objects (i.e., settlements, infrastructure, etc.) directly, in the context of climate change, carbon sequestration can be expected to play an increasing role today – the upward expansion of the forest could sequester considerable amounts of CO_2 due to the increase in aboveground tree biomass, provided that the carbon content in the soil does not decrease at the same time (Hasenauer, 2012). Near-natural areas that have been lightly used are often considered as reference ecosystems. In the second period, it was found that one-third of the native forests had been heavily modified or were artificial in comparison to the reference ecosystems (Grabherr, 1998).

Reference ecosystem

In Austria, the reference ecosystem used for restoration initiatives can vary depending on the restoration model, but can generally be classified into three main categories: active climate change adaptation, close-to-nature forestry, and restoration of forest habitats with high nature conservation value. As a result, all three approaches were implemented during the Period 3. These approaches can be broadly classified into three types: passive, assisted regeneration, and active. Passive restoration involves allowing natural regeneration to occur after the cessation of the driver of degradation. Assisted regeneration involves actively intervening to correct abiotic and biotic damage and to stimulate recovery. Active restoration involves correcting biotic and abiotic damage and reintroducing biota after the cessation of degradation. By utilizing a combination of these approaches, restoration initiatives in Austria aim to achieve resilient forest ecosystems that can be sustainably managed.

Approach & Intervention activities

In Austria, there are various intervention activities aimed at protecting and enhancing forest ecosystems. These include protecting old-growth forests in patches, especially for the Trittsteinbiotope programme, which seeks to increase ecological connectivity (Oettel, 2022). Pest and disease control measures are taken to maintain the health of the forest ecosystem, and hydrological interventions are carried out in the Danube Floodplains to maintain a healthy water balance. Regulations are in place to manage wildlife populations, and fencing is used to protect forest areas. Management for old-growth forest attributes is carried out in the Eastern and Central regions, and retention trees are selected during logging to ensure continuity. Planting and maintenance activities are done to change the tree species composition and ensure the health and growth of trees. Finally, control measures are implemented mainly in lowlands to prevent invasive species from damaging the forest ecosystem.

In Period 3, the planting of coniferous species continues to play an important role, but many forest managers modified the reforestation design and lowered the seedling densities to wide spacings of 2 x 3 m to 2 x 2 m and a density of 1,700 to 2,500 trees per hectare. Hardwoods are typically planted in partial afforestation. An alternative approach is to use groups of 15 to 25 trees per group with a spacing of 1x1m or 2x2 m within groups and a spacing of 10 to 15 meters between groups. Alternatively, three closely spaced rows of the target tree species (2 x 1 m) can be planted between eight to twelve meters apart from the next rows. This method allows for mechanical maintenance and good quality selection on sites that can be driven over. To ensure the quality of the target tree species, filler trees such as hornbeam can be planted around the edges or left untouched (Landwirtschaftskammer Steiermark, 2023). Moreover, such wide-spaced rows allow a good integration of natural regeneration into the stand development.

Species used

In Austria, there has been a significant decline in the area planted with spruce in commercial forests since the 1980s. The latest survey conducted in 2016/18 indicates a further decrease of 48,000 hectares, with spruce now accounting for only 46% of the productive forest area (ÖWI, 2022). The area of Scots pine and other conifers has also declined, while the total area of coniferous in the sustainably managed forest has decreased by 3,000 hectares compared to the previous survey. However, given the actual age distribution of Austrian forests, coniferous growing stocks still accounts for approximately 79% of the total stocks, while hardwood stock accounts for 21%. The share of pure coniferous stands has decreased in favour of pure hardwood and mixed stands, and the share of hardwood in the stock has also increased disproportionately. The most common tree species in terms of area are spruce, beech, larch, pine, fir, and oak.

Forest owners in accordance with §13 of the Forest Act are required to reforest cleared areas and bare lands. The forest owners are given a time limit of five years for afforestation and ten years if natural regeneration is possible. Natural regeneration is preferred, because it preserves genetically valuable stands, allows good selection for maintenance measures, and saves costs for planting material and working time. However, afforestation is often necessary, due to the lack or poor quality of seed trees, to replace coniferous stands with broadleaved tree species, the need for increasing tree species and genetic diversity, uneven regeneration density, and the increasing harvests of young premature forests stands due to biotic and abiotic disturbances The forest restoration initiative are initiated using artificial regeneration techniques. The following tree species are widely used for afforestation of mixed forest stands across Austria (Bundesforschungszentrum für Wald (BFW), 2023; Landwirtschaftskammer Oberösterreich, 2021; Landwirtschaftskammern Österreich, 2022; LIECO GmbH & Co KG, 2023; ÖWI, 2023):

- Abies *alba* (Silver fir)
- Acer *campestre* (Field maple)
- Acer *platanoides* (Norway maple)
- Acer *pseudoplatanus* (Sycamore)
- Alnus *glutinosa* (Black alder)
- Alnus *incana* (White alder)
- Betula *pendula* (Birch)
- Betula *pendula* var. *carelica* (Linden-leaved birch)
- Carpinus *betulus* (Hornbeam)
- Castanea *sativa* (Sweet chestnut)
- Corylus *colurna* (Tree hazel)
- Fagus *sylvatica* (Red beech)
- Fraxinus *excelsior* (Common ash)
- Juglans *nigra* (Black walnut)
- Juglans *regia* (Walnut)
- Larix *decidua* (European larch)
- Larix x *eurolepis* (Hybrid larch)
- Picea *abies* (Common spruce)
- Pinus *cembra* (Swiss stone pine)
- Pinus *nigra* (Black pine, Corsican black pine)
- Pinus *sylvestris* (Scots pine)
- Populus *nigra* (Black poplar)

- Populus x *canescens* (Hybrid poplar)
- Prunus *avium* (Sessile cherry)
- Pseudotsuga *menziesii* (Douglas fir)
- Quercus *petraea* (Sessile oak)
- Quercus *robur* (English oak)
- Quercus *rubra* (Red oak)
- Robinia *pseudoacacia* (Common robinia)
- Salix *alba* (Silver willow)
- Sorbus *domestica* (Service tree, Speierling)
- Taxus *baccata* (European yew)
- Tilia *cordata* (Small-leaved linden)
- Ulmus *glabra* (Mountain elm)

The majority (>98%) of all restoration initiatives targeting afforestation are using native tree species (Landwirtschaftskammer Oberösterreich, 2021). The overall use of non-native trees in Austria is below 0.2% of the forest cover, and is not increasing much over the Period 3 (Brus et al., 2019; Lapin et al., 2023).

Furthermore, decision support tools have been developed for the selection of tree species and seed provenances in Austria. One of them is the so-called tree species traffic light which provides an initial assessment of suitable tree species for climate-smart forest. The tool uses a color-coding system to indicate the suitability of a tree species, with green indicating high suitability, yellow indicating medium suitability, and red advising against using the tree species. However, site factors should still be considered when making the final decision on which tree species to choose. Another tool is the provenance recommendation system www.herkunftsberatung.at, where user may select the best suited provenances for regeneration.

Section 4: Socioeconomic and political aspects of the interventions

Landowner and land manager, Stakeholder groups & Stakeholder involvement

Almost half of Austria is forested. This corresponds to an area of about four million hectares. About 80% of the forest area is shared by about 145,000 private owners and 2% are municipal forests. The remaining 18% is state forest (ÖWI, 2016). The stakeholder groups involved in restoration projects include national, local and regional administrations, private forest owners, state forests, research institutions, NGOs, hunters, and forest managers.

In Austria, mountain forest restoration is handled by two institutions: the provincial forest authorities and the torrent and avalanche control service WLV. Each has a distinct restoration concept – the forest authority emphasizes a multifunctional management approach that prioritizes forest owners' interests, while the WLV focuses on maintaining and improving the protective function of forests to protect settlements and infrastructure form natural hazard such as avalanches, rockfall and torrents. These activities often involve local beneficiaries in financing and planning. However, the forest authority's approach, which is less focused on hazard protection, may favour forest owners over the public interest (Weiss, 2004).

The level of stakeholder participation during project design, implementation, and monitoring has increased during Period 3. Forest owner associations have played a crucial role in involving stakeholders in policy-making and setting restoration goals, particularly due to the high number of private forest owners. Research institutions, such as the Austrian Research Centre for Forests (BFW) and the University of Applied Life Sciences (BOKU) have supported research-based decision-making and provided input for forest restoration policies and practices.

The level of stakeholder involvement in different projects is generally good, with around 75% of stakeholders participating in most or all stages, or all stakeholders involved but only during one stage of the project. However, the participation of small forest owners in restoration projects is challenging, because small forest owners often own only parts of the restoration area and need specific motivation and support. This is particularly true for non-agricultural forest owners that live more likely in urban areas, have non-agricultural professions, and rely on sources of income other than primary production (Hogl et al., 2005; Jandl, 2020; Mostegl et al., 2019). A qualitative study showed that the forestland owned by non-agricultural forest owners is rather viewed from a socially oriented perspective, with concerns for recreation and utilization of timber for their own needs and future generations (Kvarda, 2004).

Another stakeholder group are forest certification schemes (Fischer et al., 2005; Maesano et al., 2018; Mikulková et al., 2015). PEFC Austria is a forest certification scheme maintained by global and national associations that was founded in 1999 and since then has developed certification standards for the domestic forest and the downstream value chain. Two-thirds of Austria's total forest area is certified, with standards that include the protection of ecologically valuable areas, avoidance of clear-cutting, preservation of deadwood, soil protection during machinery use, avoidance of pesticide use, and consideration of protected biotopes and endangered species (PEFC, 2023).

Sources and amount of funding & funding beneficiaries (Costs & Budget)

The approaches of forest restoration initiatives are supported by national and regional policies, for example, the reforestation focus of the Forest Fund subsidizes a restoration approach that emphasizes the transformation to mixed species stands and the "mother tree campaign" aims to protect rare tree species. In addition, reforestation efforts should ensure that more than 75% of the plants used are oriented towards the native tree species community. It is also crucial to consider future climate change, when selecting tree species for reforestation. The Forest Fund also supports the use of non-native species such as Douglas fir and red oak; however, it restricts its funding to a share of 25% of the restoration area at maximum. These measures aim to promote sustainable reforestation practices that are resilient to the challenges of a changing climate and help to preserve and improve forest biodiversity.

From 2007 to 2020, the Austrian Rural Development Programme (ARDP) and the national Forest Fund provided financial support through co-financing and subsidies for numerous forest restoration initiatives. Their emphasis on adopting mixed-species forests has boosted ecological diversity and resilience, while low-impact harvesting techniques minimized disruptions to forest floors and surrounding ecosystems. While the goals of these measures, such as conservation and improvement of ecologically valuable forest stands, were undisputed, their implementation in Natura 2000 areas fell far short of expectations due to administrative rules and requirements that made the measures unattractive to applicants. In mountain regions, restoring forestry potential was crucial for conserving, improving, and restoring the protective, ecological, and social functions of the forest, including stabilizing soil against erosion and maintaining the forests as a carbon sink and renewable resource. Additionally, funding in the following period focused on ecology-related forestry activities, such as conserving old growths, deadwood/biotope wood, and rare tree species, to maintain the forest's habitat functions. Actions to maintain multifunctional forest management across 164,700 hectares of woodland were found to have a beneficial effect on biodiversity. However, the programmes lacked a dedicated measure for climate protection, although they supported cooperation projects, logistic chains, investments in machinery, and the promotion of wood and biomass use through targeted forest management measures, forest road construction, and forest rejuvenation.

The Austrian Rural Development Programme, as part of the European Agricultural Fund for Rural Development (EAFRD) within the EU's Common Agricultural Policy (CAP) within of the period 2007–2013, Measure 221 (M211) on afforestation of non-forested land had allocated 1.56 million euros of public funds for initial afforestation of agriculturally used land. However, this only accounted for a small percentage (0.027%) of the overall budget allocation for axis 2 of the programme. Despite this, the funds were fully utilized for replanting 239 hectares of deciduous and mixed forests through 472 projects by 336 applicants. It's worth noting that a significant portion of the budget was already tied up by payment obligations from the previous programme period, LE 00-06.

Policies and instruments supporting restoration

In the last decade, the Austrian Rural Development Programme as part of the EAFRD was offering investments for forests. This measure (known as M8) includes several initiatives such as afforestation and establishment of forests, restoration of forests after disasters, and strengthening the ecological value of forest ecosystems. Under 8.1 of M8, the afforestation of non-forest land and compensation for agricultural yield loss are supported. The measure helps to increase the forest cover and compensates for the loss of agricultural yield caused by the establishment of forests. It contributes to the protection of the soil against erosion, improvements in the local water balance, and the beautification of the landscape. In the event of natural disasters, such as fires or storms, forests may suffer significant damage. In such cases, 8.4 of M8 provides funding for the restoration of forests. This measure aims to restore the ecological value of the forests by replanting trees, maintaining the forest, promoting biodiversity, and preserving forest genetics. Strengthening the ecological value of forest ecosystems is another important aspect of M8. Under 8.5, afforestation, including preparatory measures such as soil cultivation and the provision of water is supported. Forest maintenance, promotion of biodiversity, and forest genetics are also encouraged under this measure. The goal is to strengthen the ecological value of the forest and its functions, such as carbon storage, water regulation, and habitat provision. M15 is another initiative under the Austrian Rural Development Programme that focuses on area-specific forest environmental measures. The aim of this measure is to improve forest management practices, contribute to climate change mitigation, and protect the environment. The measure includes initiatives such as forest management planning, sustainable forest management, and the promotion of the use of renewable resources.

Given that nearly half of Austria's national territory is already covered by forest, M221, which supports the afforestation activities on non-forested land, is of minor importance in the overall context of the rural development programme and at the national level. However, the measure is still relevant at the local and regional level in under-forested regions of Austria, where it contributes to improving forest ecosystem service (Federal Ministry of Agriculture Forestry Regions and Water Management, 2016). According to the WIFO study (Sinabell et al., 2016), forest restoration measures aimed at improving the ecological value of forests have induced a gross value added of approximately 179 million euros at the enterprise and supra-company/economic level. This estimate takes into account the value added by the supported enterprises, demonstrating the significant economic benefits of investing in forest restoration initiatives. These findings highlight the importance of preserving and promoting sustainable forestry practices to boost local economies and mitigate the impact of environmental degradation.

Table 4. Payments of the Austrian Rural Development Programme for agriculture and forestry by year and restoration measure (in million euros)(BML, 2023a).

Year	Level	Reforestation and establishment of forests	Restoration of forests after disasters	Strengthening the ecological value of forest ecosystems.	Forest environmental and climate services
2000		0.85		14.09	
2001		0.58		17.38	
2002		0.49		13.04	
2003		0.76		15.28	
2004		0.63		17.23	
2005		0.41		14.07	
2006		0.29		21.43	
2007		0.15	1.01	14.68	
2008		0.24	6.84	18.99	
2009		0.22	6.79	18.63	
2010		0.26	2.75	19.05	
2011		0.09	4.74	14.15	0.07
2012		0.14	3.19	11.66	0.01
2013		0.14	1.53	6.83	0.04
2014		0.12	2.55	7.79	0.04
2015		0.21	1.03	4.94	
2016		0.09	0.07	3.58	
2017		0.08	0.34	9.24	0.02
2018		0.05	0.44	11.73	0.22
2019		0.07	1.03	12.50	0.10
2020		0.06	3.29	17.04	0.06
2021		0.06	4.03	22.88	0.10
2022	EU	0.04	1.31	9.07	
	State	0.02	0.80	5.43	
	Federal	0.01	0.54	3.62	
	Total	**0.07**	**2.65**	**18.12**	**0.67**

The Forest Fund, with an investment volume of 350 million euros, is the most significant package of measures taken for domestic forests in recent years (from 2020 to 2026). Its measures aim to develop climate-resilient forests, promote biodiversity, and increase the use of wood as an active contribution to climate change mitigation. Forest owners are compensated for the loss of value caused by bark beetle infestation, and forest protection measures such the establishment of dry and wet deposits for damaged wood, and mechanical debarking to reduce further infestations. Also, reforestation and tending measures of damaged forest sites are supported. Reforestation efforts prioritize promoting diversity in tree species, genetics, structures, and habitats, as well as ensuring sustainable safeguarding of forest functions after damaging events and establishing high structural resilience of the newly established stands. To access the 80 million euros available for this purpose, more than 75% of afforested plants must be oriented towards the natural tree species community and comply with funding requirements in the respective province. Additionally, farms with a forest area of 100 hectares or more are required to submit relevant information on sustainable forest management from a forest management plan or equivalent instruments to be eligible for funding. The Forest Fund is a significant step towards promoting sustainable forest management and mitigating the impacts of climate change in Austria (BML, 2023b).

Protection designation

Intervention activities in the Period 3 also included full protection in the sense of restriction of active management. The total area of IUCN and Natura 2000 protected areas is 24,092 square kilometers, adjusted for overlapping areas. Of this total area, 51.5% are covered by forests, which equals to 12,512 square kilometers. As a result, 31.25% of Austria's forest area is protected under these conservation schemes. In addition to these protected areas, the BFW's Trittstein (Oettel, 2022) and Naturwaldreservate (BFW (Bundesforschungszentrum für Wald), 2018) programme will soon add numerous areas that will better connect habitats and increase biodiversity in the forest. Many of these protected areas rely on voluntary contract nature conservation, where forest owners not only receive compensation for putting their land out of use, but also actively collaborate with the BFW in long-term monitoring. Twice a year, these forest owners report on the state of biodiversity on their land, and work with the BFW to delineate and identify new areas for protection.

Section 5: Results, successes and challenges

Level of success

The level of success in achieving restoration goals in Austria during Period 3 is moderate, with strong indications of progress towards a good status. The restoration initiatives faced moderate success due to additional challenges like widespread deforestation and bark beetle attacks, which hindered resources for restoration efforts.

In 2016, approximately 30% of Austria's forested area was designated for the primary purpose of mitigating gravity-driven natural hazards. However, this was not always the case. The extensive reforestation project undertaken in the late 1960s (WIFO, 1963) played a pivotal role in the restoration of devastated forests. In the Alpine regions, significant attention was given to high-elevation afforestation, either within avalanche release zones with the aim of complementing or even replacing technical avalanche mitigation structures (Heumader, 2000; Schönenberger, 2001), or to reduce intense runoff events due to increased rainfall interception and enhanced transpiration during dry periods (e.g., Bosch and Hewlett, 1982; Calder, 1990; Cornish, 1993; Rowe and Pearce, 1994; Stednick, 1996; Fahey and Jackson, 1997; Bruijnzeel, 2004).

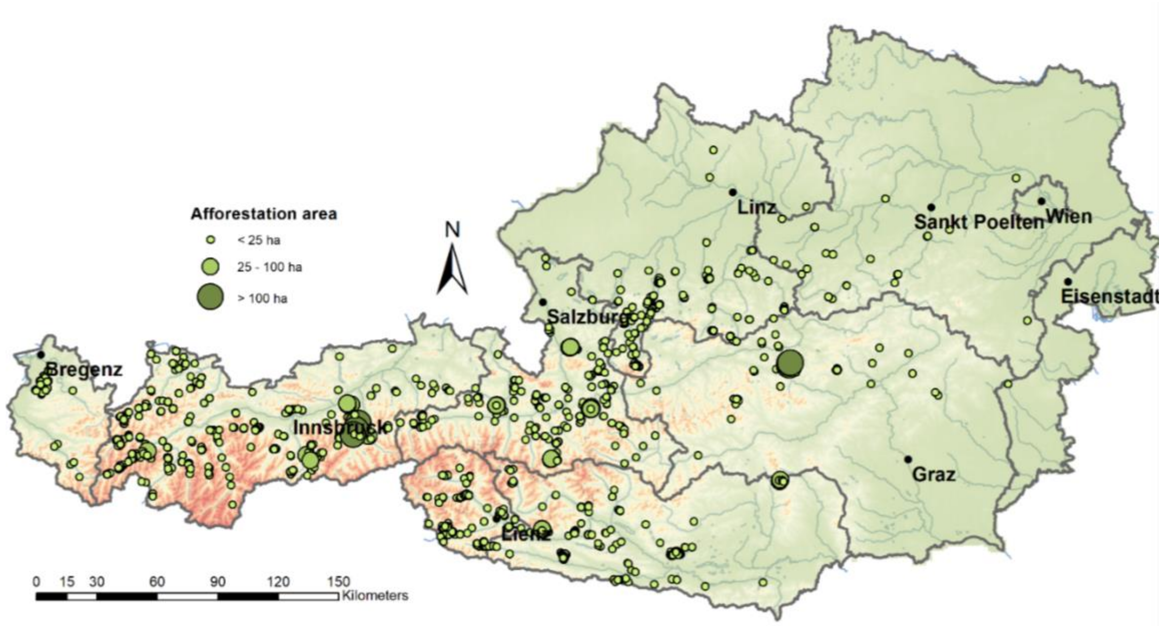

Figure 17. Austrian afforestation sites at the timberline, respectively in high-elevation, in order to establish protection forests. In total 5360 afforestation sites on ~15,000 ha were established between 1906 and 2017. (Source: Forest Technical Services Torrent- and Avalanche Control, 2016).

In 2022, a total of 7.26 million solid cubic meters (Efm) of damaged wood as harvested, accounting for 37.5% of Austrias's annual cut, and showing an increase of 20.1% compared to 2021. Compared to long-term averages, the 2022 damage was 17.27% below the 5-year average (7.26 million Efm) and 1.91% above the 10-year average (7.12 million Efm). The main factors contributing to the damages in 2022 were bark beetles (48%), storms (32%), and other calamities (20%) (BML, 2023c). However, regional strategies and transregional restoration goals are lacking in some forest restoration initiatives. Tradeoffs and synergies between climate change adaptation measures and biodiversity conservation exist but are poorly discussed in terms of their impact on the success of restoration initiatives. To improve restoration efforts, it is important to develop regional strategies and set transregional restoration goals, as well as to have a more comprehensive discussion on the tradeoffs and synergies between climate change adaptation and biodiversity conservation.

Land use and management regime post-intervention

Restoration initiatives targeting the restoration of large-scale damage caused by bark beetle attacks, have resulted in an increase in tree species diversity and a change in silvicultural practices towards mixed forests, including both coniferous and broadleaved tree species.

Ecological condition post-intervention & ecological recovery

Improved ecological conditions have been observed in areas where restoration interventions have taken place. Forest restoration efforts have led to the regeneration of native plant communities, tree species diversity and an increase in biodiversity, particularly in areas, where Norway spruce stands have been transformed to mixed forest stands. Overall, restoration interventions have contributed to the recovery of ecological functions and services in degraded forest ecosystems.

The area successfully restored by restoration projects in Austria during Period 3 cannot be precisely determined due to the different approaches and indicators used to monitor them.

The promotion of close-to-nature practices through restoration initiatives, which combine different close-to-nature forestry approaches, increasing and promoting natural tree species composition, and improving the management of deadwood and forest structure diversity, were found to benefit the conservation status of beech forests in Austria. This includes the replacement of planted spruce forest stands in the lower montane altitudinal range with native broadleaved tree species. According to ÖWI (National Forest Inventory), the area covered by beech trees has increased from 309,000 to 380,000 hectares since 1990. Additionally, the beech stock has increased from 91 million to 122 million cubic meters.

Local ecological restoration initiatives have resulted in a post-intervention regime that has improved the habitat quality of forest features. For example, hydrological restoration actions have been taken in floodplain forests, and ex-situ and in-situ measures have been implemented for specific endangered species, which have been included in forest management plans afterwords.

Socioeconomic improvement, Level of stakeholder satisfaction & Main obstacles

Climate change is having a significant impact on forests in Austria, with rising temperatures and changing precipitation patterns making it more challenging to implement effective restoration measures. Furthermore, the ownership of forests in Austria is often fragmented, with many small private owners. This can make it challenging to coordinate restoration efforts and implement measures consistently across different areas.

Protective forests require intensive site-specific care to withstand the effects of natural hazards and climate change. Lack of care and extreme events, such as avalanches, storms, forest fires, or bark beetles, can destroy protective forests, rendering them ineffective for decades. Rapid restoration of the protective effect is required in such cases and is often accompanied by technical protection measures. In 2022, 15.7% of Austria's forests provide direct protection to specific objects (mainly infrastructure and settlements) and are being defined as forests with direct object protective function. Moreover, additional 26.1% of forests provide indirect protection for specific objects and the forest sites itself being referred to as indirect protective forests. In total, 42% of the country's forests have a protective function. Almost every fourth Austrian benefits from protective forest and its ecosystem services, such as protection against avalanches, rockfall, erosion, and floods (BML, 2022). There is a significant need for better regeneration of the protective forests. Only 59% of the protection forest is classified as "stable," while 33% is classified as "stable to unstable," and 8.3% is classified as "critically unstable to unstable," with a consistent trend (BML, 2008).

The effectiveness of policy tools utilized is influenced by the actors who participate in policy networks. These actors include national and regional authorities, scientists, interest groups, and the target population of political programs. The development of restoration concepts is shaped by the interests and belief systems of these actors, which heavily influences the implementation of policies (Weiss, 2004).

Monitoring

With the data collected in the national forest inventory, it is possible to describe the overall impact of passive, assisted and active restoration initiatives. The Statistisches Informationssystem (Statistical Information System) of the national forest inventory has been in operation since 1961, and since 1981, a permanent sampling grid has been used. The system has been enhanced with increased integration of remote sensing data, including digital aerial images and orthophotos with high spatial resolution, as well as Sentinel 2 data. These data have become essential for monitoring and assessing the most crucial parameters for restoration initiatives, such as forest growth, tree species occurrences, tree microhabitats, regeneration, soil, lichens, and deadwood. Through the national forest inventory, these data enable an overall assessment of the impact of active and passive restoration efforts (ÖWI, 2023).

However, one of the challenges of ecological restoration initiatives at local sites is the lack of funding for long-term monitoring. This can make it difficult to track progress and make necessary adjustments to ensure the success of the project. Additionally, afforestation and subsidized restoration initiatives are often only monitored during the funding period. Consequently, there are often limited data on the long-term impact of restoration initiatives. To ensure the success of forest conservation/restoration efforts, it is essential to prioritize long-term monitoring and funding. By doing so, it will be possible to track progress, identify areas for improvement, and make necessary adjustments to ensure the continued success of these initiatives.

PART 2: SUMMARY TABLE

Indicators	<1914	1914–1989	>1990
Forest area restored (afforestation, minimum area)	800,000 ha	67,105,600 ha	84,400 ha
Number of projects/initiatives	Private and public initiative; >350,000	Private and public initiative; >130,000	Private and public initiative; >140,000
Geographical distribution	In all regions of the country; Mostly mountain areas,	In all regions of the country	In all regions of the country
Spatial scale	>2 ha/project	>0.5 ha/project	>0.5 ha/project
Land use/management regime pre	Woodland pasture, wasteland, abandoned farmland, coppices forests	Coniferous forest, abandoned farmland, coppices forests	Coniferous forest, degraded forests, agricultural land
Abiotic conditions		-	-
Forest category and type	-	-	-
Main driver(s) of degradation]	game browsing, snowstorms, windthrow, avalanches, land-use conflicts	Monotypic stands, soil erosion, Game browsing	Bark beetle outbreaks, climate change;
Ecological condition pre (1-5)]	1: Bad	2: Poor	3: Moderate
Restoration goals	reduce disaster risk, timber production, Food provision	reduce disaster risk, timber production, Water quality, job creation,	Biodiversity protection, Carbon storage/sequestration, Climate change adaptation and mitigation
Approach	Active	Active, assisted regeneration,	Assisted regeneration, passive, active
Type	reduced impacts, remediation, and rehabilitation	reduced impacts, remediation, and Ecological recovery	Rehabilitation, Ecological recovery, and Rewilding, and Prestoration
Activities	Planting after clear cut, sowing native tree species, regulating wildlife, selecting retention trees during logging, preparing planting sites, constructing fences;	Natural and artificial regeneration, preparing planting sites, constructing fences, increasing tree diversity;	Habitat restoration, plantation after outbreaks; Fencing, individual tree protection
Species used	*Picea abies, Larix decidua, Pinus nigra*	*Picea abies, Larix decidua, Pinus nigra, Quercus rubra*	>30 different species;
Genetically modified organisms [+]	No	No	No
Management for old-growth forest [+]	No	yes	yes

Land owner/manager [+]	national, regional or local administration, public company, private company, association, cooperative	national, regional or local administration, public company, private company, association, cooperative	national, regional or local administration, public company, private company, association, cooperative
Sources of funding [+]	national, regional or local administration	national, regional or local administration, private investments	national, regional or local administration, EU funding, private investments
Funding beneficiary [+]	Private forest owner	Private forest owner, state forests	Private forest owner
Budget [+]/cost [+]	-	-	-
Socioeconomic benefits [+]	Timber production and protective function of forests against rockfall	Timber production and protective function of forests against rockfall,	Increase of ecosystem services, biodiversity conservation, Timber production and protective function of forests against rockfall
Stakeholder groups [+]	including private forest owners, national, regional, and local administrations, local communities, wood-processing industries, forest associations, agricultural schools, and research institutions.	Private & public Forest owner, hunters, forest owner associations, administrations, industry, research institutions;	Private & public Forest owner, forest owner associations, administrations, industry, infrastructure provider, NGOs, environmental engineers, research institutions; hunters, and forest managers; Forest Certifications (PEFC)
Stakeholder involvement (1-5) [+]	3: Moderate	4: Good	4: Good
Level of success (1-5) [+]	3: Moderate	3: Moderate	3: Moderate
Land use/management regime post [+]	clearcut forest management, reduction of forest pastures;	Mostly continuous cover forest management	Mostly continuous cover forest management in sensu of close-to-nature forestry, mixed-forest
Ecological condition post (1-5) [+]	3: Moderate	3: Moderate	3: Moderate
Ecological recovery (1-5) [+]	2: Marginal	3: Moderate	3: Moderate
Socioeconomic improvement (1-5) [+]	3: Moderate	3: Moderate	4: Good
Main obstacles [+]	provision of forest reproductive material for afforestation, browsing;	conflicts of interest, lack of research results, browsing;	implement effective restoration measures, , extreme climatic events, browsing;
Monitoring (yes/no) – Indicators [+]	No	Yes (NFI only)	Yes (NFI only)
Stakeholder satisfaction (1-5) [+]	3: Average	2: Dissatisfied (<1950), 4: Satisfied (1950–1990)	4: Satisfied

FINAL REQUEST

Finally, please identify practitioners, landowners and/or restoration project managers in your country to assist us in our efforts to compile unpublished information and regional and local knowledge and experience on forest restoration:

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REFERENCES

Berger, T. W., & Hager, H. 2000. Physical top soil properties in pure stands of Norway spruce (*Picea abies*) and mixed species stands in Austria. *Forest Ecology and Management*, *136*(1–3), 159–172.

BFW/ÖWI. 2019. *Österreichische Waldinventur*.

BFW (Bundesforschungszentrum für Wald). 2018. *NWR (Naturwaldreservate) Programm*. http://www.naturwaldreservate.at/index.php/de/nwr-programm

BML. 2008. *Nachhaltige Waldwirtschaft in Österreich Österreichischer Waldbericht 2008*. chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/https://info.bml.gv.at/dam/jcr:902064b7-7dfb-4161-b41e-f81ffa7da9a1/Waldbericht_2008_1_neu.pdf

BML. 2020. *Daten, Zahlen und Fakten 2019/2020, Forstwirtschaft, S., pp. 58–75*.

BML. 2022. *Zahlen und Fakten 2022*. https://info.bml.gv.at/service/publikationen/allgemeine-themen/zuf2022.html

BML. 2023a. *Bundesministerium für Land- und Forstwirtschaft, Regionen und Wasserwirtschaft Sektion III - Forstwirtschaft und Nachhaltigkeit Abteilung III/3 - Waldschutz, Waldentwicklung und forstliche Förderung*.

BML. 2023b. *FOrst Fund*. https://info.bml.gv.at/en/topics/forests.html

BML. 2023). *Holzeinschlagsmeldung 2022 – Steigerung des Gesamteinschlags*. https://info.bml.gv.at/themen/wald/wald-in-oesterreich/wald-und-zahlen/holzeinschlagsmeldung-2022.html

Brus, R., Pötzelsberger, E., Lapin, K., Brundu, G., Orazio, C., Straigyte, L., & Hasenauer, H. 2019. Extent, distribution and origin of non-native forest tree species in Europe. *Scandinavian Journal of Forest Research*, 34(7). https://doi.org/10.1080/02827581.2019.1676464

Bundesforschungszentrum für Wald (BFW). 2023. *Klima-fitter Wald*. https://www.klimafitterwald.at/baumarten/

Bundesministerium für Land- und Forstwirtschaft Umwelt und Wasserwirtschaft. 2023. *Österreichischer Waldbericht 2023*. https://info.bml.gv.at/themen/wald/wald-in-oesterreich/oesterreichischer-waldbericht-2023.html

Dieterich, V. 1944. *Vorbedingung bestmöglichen Ausgleichs zwischen angespanntestem Holzbedarf und nachhaltiger Forstwirtschaft. On:* Mitteilungen der Hermann-Göring-Akademie der Deutschen Forstwissenschaft, BD IV/1, : 39.

Federal Ministry of Agriculture Forestry Regions and Water Management. 2016. *LE 07-13 EX-POST-EVALUIERUNG Evaluierungsbericht 2016 Teil B Bewertung der Einzelmaßnahmen*.

Feichter, H. 1995. Waldbewirtschaftung im Spannungsfeld zwischen privaten und öffentlichen Interessen: aktuelle Probleme im Spiegel der Geschichte. *Arbeitsberichte. Internationale Reihe*, 1995(3).

Fischer, C., Aguilar, F. X., Jawahar, P., & Sedjo, R. A. 2005. *Forest certification: toward common standards?*

Gabler, K., & Schadauer, K. 2006. Methoden der Österreichischen Waldinventur 2000/02. *BFW Berichte*, *135*, *132*.

Glück, P. 1994. Entstehung eines internationalen Waldregimes. *Centralblatt Für Das Gesamte Forstwesen*, *111*(2), 75–92.

Grabherr, G. 1998. *Hemerobie osterreichischer Waldokosysteme*. Universitätsverlag Wagner.

Hafner, F. 1994. Mehrfachnutzung des Waldes. *Österreichs Wald-Vom Urwald Zur Waldwirtschaft. Österreichischer Forstverein; Eigenverlag: Vienna, Austria*, 108–128.

Hasenauer, H. 2000. Forest ecosystem restoration: ecological and economical impacts of restoration processes in secondary coniferous forests. Proceedings of the International Conference, Vienna, Austria, 10-12 April, 2000. *Forest Ecosystem Restoration: Ecological and Economical Impacts of Restoration Processes in Secondary Coniferous Forests. Proceedings of the International Conference, Vienna, Austria, 10-12 April, 2000.*

Hasenauer, H., & Sterba, H. 2000. The research programme for the restoration of forest ecosystems in Austria. *Spruce Monocultures in Central Europe. Problems and Prospects*.

Hillgarter, F.-W., & Johann, E. 1994. Österreichs Wald–Vom Urwald zur Waldwirtschaft. 2. völlig überarb. und erweiterte Auflage. *Wien, Eigenverlag Autorengemeinschaft*, 544.

Hogl, K., Pregernig, M., & Weiss, G. 2005. What is new about new forest owners? A typology of private forest ownership in Austria. *Small-Scale Forest Economics, Management and Policy*, 4, 325–342.

Jandl, R. 2020. Climate-induced challenges of Norway spruce in Northern Austria. *Trees, Forests and People*, 1, 100008.

Johann, E. 1985. *Der Forstverein für Oberösterreich und Salzburg und die Entwicklung der Forstwirtschaft: ein Rückblick auf 130 Jahre fruchtbringender Wechselbeziehungen*. Forstverein für Oberösterreich u. Salzburg.

Johann, E. 2001. *Zur Geschichte des Natur-und Landschaftsschutzes in Österreich. Historische „Ödflächen" und ihre Wiederbewaldung*. na.

Johann, E. 2002. *Zukunft hat Vergangenheit: 150 Jahre Österreichischer Forstverein*. Österreichischer Forstverein.

Johann, E. 2012. *Über den Aufwachs des jungen Gehölz*. https://www.yumpu.com/de/document/view/2105454/uber-den-aufwachs-des-jungen-geholz-bfw/53

Johann, E. 2022. Wälder in den Alpen–Nutzung und Schutz. In *Wald in der Vielfalt möglicher Perspektiven: Von der Pluralität lebensweltlicher Bezüge und wissenschaftlicher Thematisierungen* (pp. 201–221). Springer.

Johann, E., Agnoletti, M., Axelsson, A.-L., Bürgi, M., Östlund, L., Rochel, X., Schmidt, U. E., Schuler, A., Skovsgaard, J. P., & Winiwarter, V. 2004. History of secondary Norway spruce forests in Europe. In *Norway Spruce Conversion* (pp. 25–62). Brill.

Kvarda, M. E. 2004. 'Non-agricultural forest owners' in Austria–a new type of forest ownership. *Forest Policy and Economics*, 6(5), 459–467.

Landwirtschaftskammer Oberösterreich. 2021. *Bauamrtenliste - Aufforstungen*. https://ooe.lko.at/waldfonds-fördert-aufforstung-und-den-kulturschutz+2400+3370912

Landwirtschaftskammer Steiermark. 2023. *Jetzt ist Zeit zum Aufforsten: Waldfonds unterstützt*. https://stmk.lko.at/jetzt-ist-zeit-zum-aufforsten-waldfonds-unterstützt+2400+3376309

Landwirtschaftskammern Österreich. 2022. *Standort- und klimaangepasste Verjüngung des Waldes*. https://www.lko.at/verjüngung-die-zum-standort-passt+2400+3624790

Lapin, K., Bindewald, A., Brundu, G., Marinšek, A., Chakraborty, D., Oettel, J., Konrad, H., La Porta, N., Alagić, A., & Berger, F. 2023. Transnational strategy on the sustainable management and responsible use of non-native trees in the Alpine Space. *Central European Forestry Journal*, 69.

Ledermann, T. 2002. Ein Einwuchsmodell aus den Daten der Österreichischen Waldinventur 1981–1996. *Centralblatt Für Das Gesamte Forstwesen*, 119(1), 40–76.

LIECO GmbH & Co KG. 2023. *Sortimentskatalog*. chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/https://www.lieco.at/wp-content/uploads/2023/01/Folder_LIECO_2023_DS-Ansicht.pdf

Maesano, M., Ottaviano, M., Lidestav, G., Lasserre, B., Matteucci, G., Scarascia Mugnozza, G., & Marchetti, M. 2018. Forest certification map of Europe. *IForest-Biogeosciences and Forestry*, 11(4), 526.

Maier, A. 2019. *Die Waldordnungen des Bergbaubezirks Kitzbühel von 1554 und 1556 im Kontext der Gesetzgebung und des Bergbaus der Frühen Neuzeit Inklusive einer geschichtsdidaktischen Ausarbeitung*. chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/https://diglib.uibk.ac.at/ulbtirolhs/download/pdf/3395236

Mikulková, A., Hájek, M., Štěpánková, M., & Ševčík, M. 2015. Forest certification as a tool to support sustainable development in forest management. *Journal of Forest Science*, 61(8), 359–368.

Mostegl, N. M., Pröbstl-Haider, U., Jandl, R., & Haider, W. 2019. Targeting climate change adaptation strategies to small-scale private forest owners. *Forest Policy and Economics*, 99, 83–99.

Oettel, J. 2022. *Projekte „Connect For Bio" und „ConnectPLUS"*. https://trittsteinbiotope.at/impressum/

ÖWI. 2016. *Wem gehört Österreichs Wald?* https://www.bfw.gv.at/pressemeldungen/folder-waldbesitz/

ÖWI. 2023. *Waldinventnur*. https://waldinventur.at/#/

PEFC. 2023. *PEFC*. https://www.pefc.at/jahresberichte/

Schadauer, K. 1994. *Baumartenatlas für Österreich: die Verbreitung der Baumarten nach Daten der Österreichischen Waldinventur; FDK: 181.1: 174.7: 176.1:(436):(084.42)* (Issue 76). Forstliche Bundesversuchsanstalt, Waldforschungszentrum.

Schmidt-Vogt, H., Keller, T., Klimetzek, D., Schoenhar, S., Tesche, M., & Vite, J. P. 1989. *The spruce. Vol. II/2*.

Schuster, E. 1987. *Multifunktionalität des Waldes und Mehrprodukt-Waldwirtschaft am Beispiel der Forstgeschichte. In: : News of Forest History 25/26. Proceedings of the Symposium Multiple Use*.

Sinabell, F., Pennerstorfer, D., Streicher, G., & Kirchner, M. 2016. Wirkungen des Programms der Ländlichen Entwicklung 2007/2013 in Österreich auf den Agrarsektor, die Volkswirtschaft und ausgewählte Bereiche der Lebensqualität. *WIFO Studies*.

Statistics Austria. 2020. *Agrarstrukturerhebung 20 Landund forstwirtschaftliche Betriebe und deren 20 Strukturdaten Endgültige Statistik im Fokus Ergebnisse* 1.17. https://www.statistik.at/services/tools/services/publikationen/detail/1414

Statistics Austria. 2022. https://www.statistik.at/en/statistics/agriculture-and-forestry/forest-timber/wooded-land

Statistik Austria. 2016. *Agrarstrukturerhebung 2016*.

Stoerk. 1903. *Geschichte der österreichischen Land-und Forstwirtschaft und ihrer Industrien 1848–1898. Festschrift zur Feier der am 2. Dezember 1898 erfolgten fünfzigjährigen Wiederkehr der Thronbesteigung*. JSTOR.

Von Hanns Kirchmeir, G. K., & Grabherr, G. 2008. *Die Naturnähe der Kärntner Wälder*.

Weigl, N. 2001a. Die Frage der naturnähe in der österreichischen Forstwirtschaft im 20. Jahrhundert. In *Faszination der Forstgeschichte*, 79–130.

Weigl, N. 2001b. *Faszination der Forstgeschichte : Festschrift für Herbert Killian*. https://d-nb.info/963787063/04

Weiss, G. 2000. The principle of sustainability in Austrian forest legislation-analysis and evaluation. *Forging a New Framework for Sustainable Forestry: Recent Developments in European Law. IUFRO World Series*, 10, 39–57.

Weiss, G. 2004. The political practice of mountain forest restoration—comparing restoration concepts in four European countries. *Forest Ecology and Management*, 195(1–2), 1–13.

Willner, W. & Grabherr, G. 2007. *Die Wälder und Gebüsche Österreichs*.

ADITIONAL FOTOS

This historical resource, titled *"Vom Umstocken des Waldes"* ("On the Stumping of the Forest"), documents traditional forestry practices related to the removal of tree stumps as part of woodland clearing or conversion. The image was captured 1927, by Woldemar Pelleter and is part of the archives of the Austrian Federal Research Centre for Forests (BFW). The photograph was digitized using an HP Scanjet G3110 and is openly accessible. As a rare visual record of early 20th-century forestry methods, it offers valuable insight into historical forest management and wood utilization techniques.

This openly accessible historical resource (ID 1579), titled *"Vom Umstocken des Waldes"* ("On the Stumping of the Forest"), was created by Woldemar Pelleter in 1927, and is preserved by the Austrian Federal Research Centre for Forests (BFW). It relates to forest engineering, timber harvesting, and historical felling techniques, featuring tools such as the sapine and sappel. The image was digitized using an HP Scanjet G3110.

This openly accessible historical resource (ID 2049) documents traditional winter timber extraction in Upper Austria on February 7, 1963. Captured by Ottokar Baschny and archived by the Austrian Federal Research Centre for Forests (BFW), the image shows horse-drawn sled timber transport—known as *Pferderückung*—along snow-covered forest trails. It highlights historical logging practices and the role of forestry workers during winter operations. The original photograph was digitized using a CanoScan LiDE 220.

This openly accessible historical resource (ID 2049) captures winter timber hauling in Upper Austria on February 7, 1963. Taken by Ottokar Baschny and archived by the Austrian Federal Research Centre for Forests (BFW), the image shows traditional log transport using sleds (*Blochschlitten*) and draft horses along forest sled trails (*Schlittweg*). It illustrates key elements of historical logging practices, including the use of traction sleds, locking chains (*Sperrkette*), and the manual labor of forestry workers. The original photograph was digitized using a CanoScan LiDE 220.

historical photo, taken on June 6, 1957, by Baschny and archived by the Austrian Federal Research Centre for Forests (BFW), shows a DKW off-road vehicle during a forestry equipment demonstration held by the Austrian Forest Association in the Gahns district, Vienna. The image highlights mid-20th-century forest technology and its practical applications in rugged terrain. It was digitized using a CanoScan LiDE 220.

This openly accessible historical resource (ID 2586) features a photograph taken on May 2, 1890, by Carl Böhmerle, documenting a thinning trial plot (7/IV) in Gablitz, Austria. It forms part of a three-volume collection titled *Photographic Views of Selected Experimental Plots by the Imperial-Royal Forest Research Directorate*, held by the Austrian Federal Research Centre for Forests (BFW). The image, listed as photo 16 of 21 in the first volume, captures the site one year after a clearing of 0.8 of the basal area in plot 7/I, with further reduction to 0.5 planned following undergrowth establishment. The photo illustrates early forest inventory and growth measurement methods, with a person included as a visual scale reference. The original print was scanned from an ensemble of images (ID 2570–2595) and is part of a significant documentation of historical forest monitoring in Austria.

This openly accessible historical resource (ID 1464) depicts timber transport via forest railway in the Kalkalpen region of Upper Austria. Taken on July 8, 1982, by Herbert Haberl and archived by the Austrian Federal Research Centre for Forests (BFW), the photograph shows forestry workers operating on the *Waldeisenbahn Reichraming*, a key transport system within the area now known as the Kalkalpen National Park. It highlights the role of narrow-gauge forest railways in historical logging practices. The image was digitized using a CanoScan LiDE 220.

This openly accessible historical resource (ID 2875) shows a view from the Jubiläumswarte looking northwest toward Exelberg in the Vienna Woods (*Wienerwald*), captured on June 1, 1968, by Handrich and Mader. Archived by the Austrian Federal Research Centre for Forests (BFW), the image reflects the recreational value of forests and documents landscape changes following clear-cutting (*Kahlschlag*). It is part of a broader record on forest history and the role of urban woodlands in public recreation. The photo was digitized using a CanoScan LiDE 220 and corresponds to index card no. 3037/195009.

This openly accessible historical resource (ID 2863) documents pest control operations in the high mountain region of Zirbitzkogel, Styria, Austria. Captured 1962 by Ottokar Baschny and archived by the Austrian Federal Research Centre for Forests (BFW), the image shows the use of the AS 1 motorized backpack sprayer for forest pest management.

It forms part of the archive of the Institute for Forest Protection and illustrates mid-20th-century plant protection methods in alpine forestry. The photo was digitized using a CanoScan LiDE 220 and is referenced under card number 414.22/1363/197699.

This openly accessible historical resource (ID 2854) was captured on September 4, 1955, by the Institute for Forest Protection and is archived by the Austrian Federal Research Centre for Forests (BFW). The photograph shows the last stands of Swiss pine (*Pinus cembra*, right) and European larch (*Larix decidua*, left) in the Murwinkel region of Styria, Austria. Taken from Stickleralm looking up the valley toward Jagerspitzen and Nebelkareck, the image documents typical mountain forest types and treeline dynamics in the Austrian Alps. The photo was digitized using a CanoScan LiDE 220 and is part of the Institute's forest history archive.

This openly accessible historical resource (ID 1450) features a photograph taken on July 7, 1927, by Woldemar Pelleter and archived by the Austrian Federal Research Centre for Forests (BFW). It documents growth characteristics of ash trees (*Fraxinus excelsior*) as part of early forest growth studies. The image relates to forest history, silviculture, and hardwood development, highlighting interest in timber yield and site productivity. It was digitized using an HP Scanjet G3110.

This openly accessible photo, taken on August 4, 2022, by Anna-Maria Walli (BFW), documents bark beetle damage (*Ips typographus*) in South Tyrol, Italy. It highlights forest damage caused by the spruce bark beetle and relates to forest protection and insect impact monitoring. The image was captured using a VOG-L29 camera.

This openly accessible photo, taken on June 5, 2020, by Anna Walli (BFW), shows young forest plants protected by browse guards during reforestation efforts in Hitzendorf, Styria, Austria. The image relates to silviculture and plant cultivation, illustrating measures against wildlife browsing. It was captured with a VOG-L29 digital camera.

This openly accessible historical photo, taken on July 1, 1946, by Scheuble and archived by the Austrian Federal Research Centre for Forests (BFW), documents storm damage and salvage logging in Carinthia, Austria. It shows a windthrow area and relates to forest protection, disturbance history, and post-storm timber recovery. The image was digitized using a CanoScan LiDE 220.

photo, taken on November 10, 2022, by BFW / FAST Ossiach, documents storm damage and windthrow in a forested area. It relates to forest protection and highlights the impact of severe wind events on forest stability. The image was captured using a digital camera.

This openly accessible photo, taken on June 9, 2005, by Ruhm, Englisch, Starlinger, Geburek, Perny, and Neumann (BFW), shows a group of advance-growth sycamore maple (*Acer pseudoplatanus*) within a spruce stand on permanent research plot 920 near Gerolding. The image illustrates formative pruning and branch removal measures applied for high-value timber production. It relates to silviculture, stand tending, and natural regeneration, and was captured using a Canon PowerShot G2.

FIGURES

TABLES

SUPERB
Upscaling Forest Restoration