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FOREST MANAGEMENT (M WATT, SECTION EDITOR)

The Evolution of Forest Restoration in Europe: A Synthesis for a Step Forward Based on National Expert Knowledge

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Abstract

Purpose of review We are amid a historical momentum encouraging forest restoration, yet the translation of ambitious targets into reality is hindered by poor documentation and understanding of the success and failure of past restoration efforts. This review aims to evaluate the ecological, social, political and economic characteristics of forest restoration across Europe, their development over time and key lessons learned to guide future restoration initiatives. The analysis is based on the synthesis of expert assessments from 18 European countries.

Recent findings Early restoration initiatives in central and southern Europe were largely reactive to natural disasters or timber shortages, and while effective in erosion control and timber production, their ecological benefits were often limited due to monoculture plantations and short-rotation systems. Geopolitical crises intensified timber production, with nationalized and centrally managed forests in several countries, but often at the cost of biodiversity. Since the 1990s, a shift toward multifunctionality has emerged driven by the convergence of environmental, social, political and economic events.

Summary Forest restoration in Europe has transitioned from disaster reduction and production-driven efforts to a more multifunctional approach that promotes biodiversity. Changes have been driven by a combination of environmental (e.g., catastrophic consequences following natural disasters), political (e.g., wars, forest nationalization and management centralization), legal (e.g., strict and ambitious national and international policies), social (e.g., rural abandonment and changes in societal values) and economic (e.g., new funding mechanisms or market fluctuations) events. Despite the development, conflicting goals, insufficient funding, climate change and short-term thinking persist as key barriers.

Keywords Afforestation · Drivers of change · Ecological recovery · Economy · Historical · Obstacles · Political · Social · Success

Introduction

While human influence is and has been at the root of most forest degradation, humankind also has a long history of stimulating the recovery of degraded forests. The practice of forest restoration can be traced as far back as the Chou dynasty (1100–256 BC), when a forest service was established to protect forests and restore bare land in China [1] or to the Mauryan dynasty when Emperor Ashoka (268–232

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BC) ordered wide-scale afforestation and conceived the first concept of a national park to restore forests in ancient India [2]. Documented efforts to increase forest cover in Europe date back to the Middle Ages, with large-scale planting to reforest a highly degraded area around Nuremberg (Germany) being reported as early as the thirteenth century [1].

Despite this long history, it is only recently that we are experiencing an unprecedented momentum that encourages forest restoration at the global, national and regional scales [3]. The growing recognition that functional forests are key to tackling many of humanity's challenges (e.g., biodiversity, water and climatic crises) has elevated forest restoration to the forefront of environmental agendas. Initiatives such as the declaration of the UN Decade on Ecosystem Restoration [4], the Bonn Challenge/New York Declaration on Forests aiming to restore 350 million ha of degraded land by 2030 [5] and the Convention on Biological Diversity's call to restore at least 30% of degraded ecosystems by 2030 (target #2 in the Kunming-Montreal Global Biodiversity Framework) [6] underscore the global commitment to this endeavor. Europe´s willingness to materialize restoration wishes is evidenced by the ambitious goals and targets highlighted in the recently approved European Nature Restoration Law, which aims to restore at least 20% of land and sea by 2030 by mandating Member States to develop National Restoration Plans. Moreover, the growing attention to forest restoration within the global political arena parallels its exponential growth in scientific literature, exemplified by a 50-fold increase in publications between 2000 and 2013 [7].

However, translating these ambitious goals into tangible outcomes continues to pose significant social, financial, political and technical challenges, which are exacerbated by the uncertainty inherent to a changing climate and disturbance regimes [8, 9]. A pivotal and over-arching obstacle hindering current forest restoration ambitions lies in the insufficient documentation and dissemination of both successes and failures from past restoration initiatives [10]. Hence, there is a clear need to capitalize upon past experiences in forest restoration to minimize mistakes and maximize the efficient use of resources in the future [3], especially considering the wealth of untapped knowledge generated by past initiatives [11].

In this article, we address this limitation by collecting and synthesizing detailed information on the major practices and on the historical evolution of forest restoration in Europe to provide insights into the factors for successful (and unsuccessful) forest restoration. Specifically, we aim to: 1) examine the ecological, social, political and economic characteristics of the main forest restoration initiatives across Europe, 2) understand how the nature of these initiatives has evolved over time and what the main drivers of change have been, and 3) synthesize the lessons learned from past and present restoration practices to make recommendations for the implementation of the European Nature Restoration Law. This has been achieved by analyzing and synthesizing the detailed information provided by 32 forest restoration national experts from 18 European countries in the form of national narratives.

Methods

Narrative analysis is a type of qualitative data analysis that involves the documentation and analysis of narratives from a study group to understand events and phenomena [12]. Although this approach has mostly been used in social sciences, it has also been successfully applied in environmental research [e.g., [13]. To conduct this study, national experts on forest restoration were selected following a systematic approach and asked to develop a narrative on the development of forest restoration in their country using a pre-defined template. The narratives were then systematically analyzed, and the main patterns were identified and synthesized. This study was developed as part of the European Green Deal H2020 Project SUPERB on upscaling forest restoration.

National Expert Identification

To make sure that different sociopolitical and economic contexts as well as different biomes and ecoregions were represented, a sub-sample ($n = 18$) of countries covering all five European regions was selected: 1) North – Finland, Sweden and Denmark, 2) Central-West – Germany, France, Belgium, Netherlands, Switzerland, Austria and UK, 3) Central-East – Hungary, Poland and Romania, 4) South-West – Spain and Italy, and 5) South-East – Greece, Croatia and Slovenia (Fig. 1). Potential expert candidates from these countries were identified following two complementary approaches. On the one hand, considering that many of these countries are represented within SUPERB, we used all the experience and knowledge within the consortium by asking partners to propose national experts. In parallel, we conducted a literature search in Google Scholar for each country using the following keywords: forest restoration AND country OR forest regeneration AND country OR reforestation AND country. When a relevant publication was found, a first screening of the authors of the publication was conducted. If their previous/current work was related to forest restoration and relevant to the narratives, they were identified as potential experts for that particular country. After harmonizing the information obtained from both approaches, we compiled a list of 120 potential experts.

All the candidates identified during the previous step were assessed and ranked based on how related their previous work was to the contents of the narrative (see next section). Specifically, their suitability was quantified based

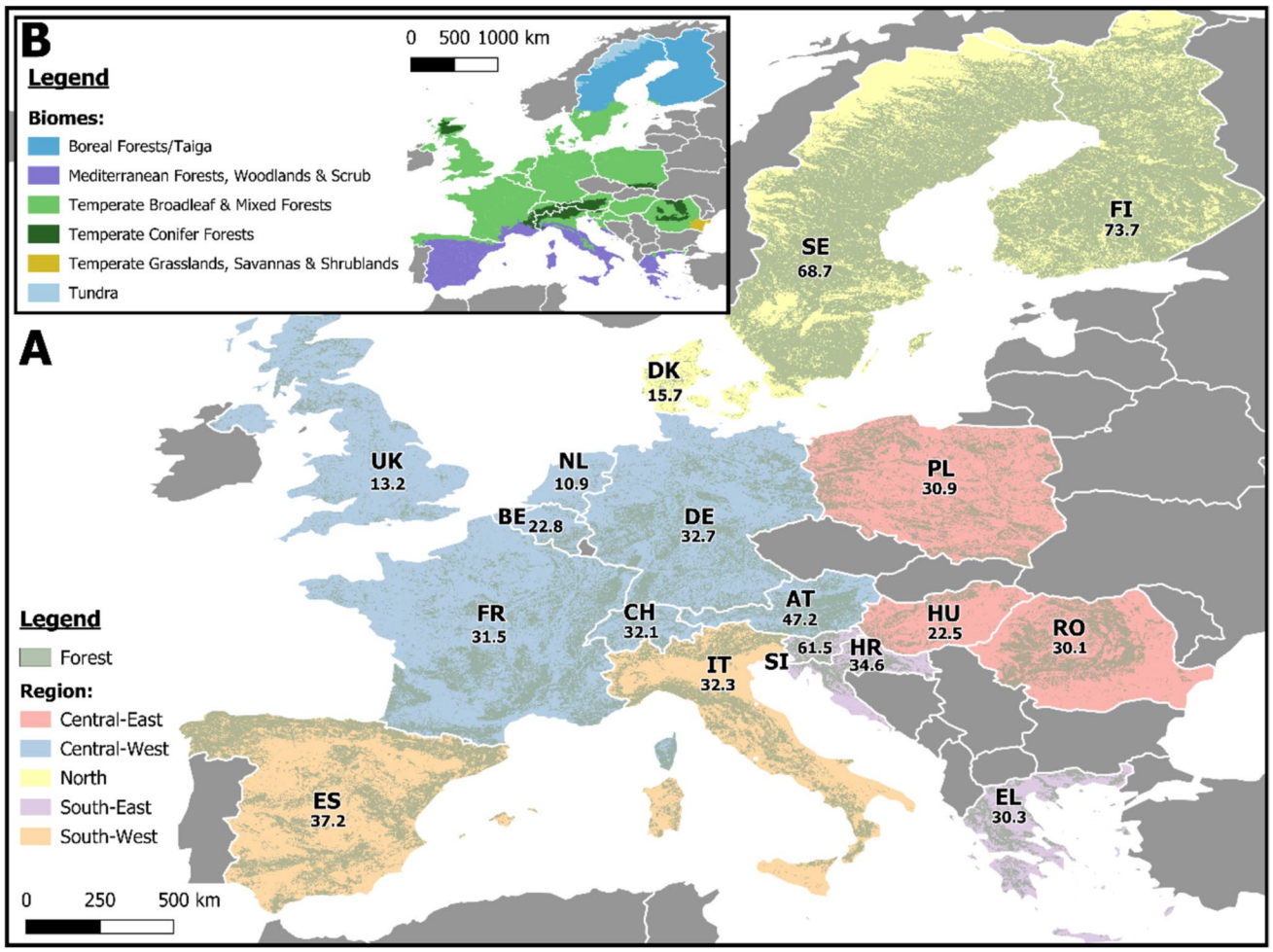

Fig. 1 The 18 European countries included in this study, as well as **A** the five regions they represent (colors) and the % forest area relative to total land area as reported by the FAO (numbers) [14], and **B** the terrestrial biomes they cover [15]

on five criteria that defined the profile we were looking for: (1) forest restoration related work – 2 points, (2) historical perspective – 1 point, (3) national scope – 1 point, (4) other aspects indirectly related to forest restoration – 0.5 points, and (5) seniority and network of subject-matter experts – 0.5 points. After assessing each candidate's background based on these five criteria and assigning a score (0–5), the potential experts were ranked, and the two with the highest score were identified and invited to collaborate and write the national narrative for their country. This process resulted in the participation of 32 experts from 18 European countries (Fig. 1).

The Template for the Narratives

The template (51 pages) defined the structure and the indicators to be developed to ensure that all experts followed a similar flow and to facilitate the integration and synthesis of the information (Figure S1). In the introduction section, the experts were provided with the contextual information needed to develop the narratives. In the main body of the template, the structure and indicators to be developed were specified. To trace the historical evolution of forest restoration in Europe, we initially divided the template into two time periods (pre-1990 and post-1990, coinciding with the implementation of pivotal European environmental policies). However, experts were encouraged to move beyond this division and pinpoint the most significant periods in the evolution of forest restoration specific to their country. Within each period, the narrative was guided by 38 indicators distributed into 6 sections (see Table S1). An imaginary narrative for a fictitious country was presented as an example to facilitate comparable narratives across countries (Figure S2). To complement the qualitative and descriptive nature of the narratives and facilitate quantitative analyses, some of the indicators were included in a table format to encourage sharing concise and quantitative information on the indicators. The experts were provided with the template

in December 2022 and given 9–12 months to write the narratives.

Data Analysis and Synthesis

Once the experts submitted the first draft of the narrative, the quality was assessed by checking whether the template had been followed, all sections had been completed and every indicator had been addressed. Additionally, once all the narratives had been received, a harmonization exercise was done to ensure that all the narratives were as consistent as possible regarding definitions (e.g., interpretation of the term restoration) and content (e.g., level of detail provided). Based on this, experts from each country were provided with specific feedback that included major and/or minor comments. This revision process was repeated until the quality of the narrative was sufficient based on information availability and ended in March 2024.

We systematically analyzed and categorized the final versions of the 18 national narratives following thematic analysis techniques [16]. Each sentence or group of sentences was tagged in Excel with a country, period, type of initiative, section, indicator and keyword(s) to facilitate the thematic analysis of the narratives. Then, using the filtering function according to the theme of interest, the results of the different countries on a specific topic (e.g., main drivers of degradation in the second period, funding mechanisms in the first period) were compared and synthesized to extract the main patterns. The results provided by the narratives were complemented by the information available in the literature.

What is Forest Restoration – Solving Discrepancies

Responding to this question was one of the main challenges when harmonizing the narratives, as different experts had diverging perspectives on the broad definition provided: "*any activity within the restorative continuum that aims to improve the biodiversity, ecological integrity and provision of services in forest ecosystems"* [17]. In particular, Sweden and Finland differed from others as they only considered purely ecological restoration in their narratives. This is understandable considering that, unlike in other countries, the trigger for restoration in these boreal countries has not been a critically low forest cover, but a critically high share of simplified clearcut rotation forests with single age and species plantations. Therefore, while countries in temperate and mediterranean biomes initiated their narratives by describing the afforestation (i.e., establishment of forest through planting or deliberate seeding on land that was under a different land use) or reforestation (i.e., re-establishment of forest on land classified as forest) [18] that started a couple of centuries ago, the Swedish and Finnish narratives emphasized the biodiversity-oriented ecological restoration over the last few decades.

This question was also key when deciding how to interpret the 1940–1990 period characterized by an overwhelming focus on increasing wood biomass provision at the expense of other forest ecosystem services. This slightly deviates from the chosen definition of forest restoration, and although most did, some experts did not feel comfortable with including these initiatives in the narratives. This is understandable, considering that some of these purely productive initiatives resulted in ecological degradation or decreased biodiversity. But, according to Gann et al. [17] definition of the restoration continuum, rehabilitation is included and refers to a management activity conducted to reinstate a level of ecosystem functioning to ensure the provision of ecosystem services. This also aligns with the importance that the United Nations Agenda 2030 places on the socioeconomic aspect of sustainable development. Additionally, understanding this period is crucial to comprehending the problems that European forests face these days as well as to learning from past decisions and outcomes. Therefore, although the provision of a single ecosystem service was targeted, and this often compromised the provision of other services, these initiatives are also discussed. The collected information, thus, better reflected the following definition: *any activity within the restorative continuum that aims to improve the biodiversity, ecological integrity and/or provision of services in forest ecosystems*. To work with it, a clear distinction was made between restoration success, understood as the achievement of the restoration goals (e.g., timber production, erosion control, job creation, biodiversity conservation), and ecological recovery, understood as the improvement in biodiversity, ecological integrity (composition, structure and function) and the provision of multiple ecosystem services.

Development of Forest Restoration in Europe

Despite the sociopolitical, ecological and economic differences of the countries studied in the narratives, most of them depicted a similar story regarding the development of forest restoration, with three main restoration periods identified (Figure S3): 1) disaster reduction focused period (< 1940), 2) production focused period (1940–1990), and 3) multifunctionality focused period (> 1990). Below, we describe the main environmental, technical, social, political and economic characteristics of each of the three periods based on the response to the indicators provided by the experts.

First Period (< 1940): Disaster Reduction

Main Drivers of Change, Goals and Types of Initiatives

European forests experienced centuries of overexploitation as the growing human population increasingly used forests to extract a wide variety of subsistence products as well as cleared them for livestock grazing and agriculture. Thus, the main drivers of degradation during this period were overgrazing, overharvesting and erosion, with litter raking, fire, agriculture and browsing also mentioned by some countries (Fig. 2). These led to a deficient ecological condition, with very poor soil conditions, low productivity and historically low levels of forest cover (Figure S4). This, in turn, triggered natural disasters such as floods (e.g., Spain, Croatia, France, Austria, Greece, Italy, Switzerland, Slovenia), avalanches (e.g., Austria, Switzerland) and shifting sands (e.g., Belgium, Denmark, Spain, Poland, Hungary, Netherlands) that had dramatic effects on the human population. Additionally, this depletion of forests led to wood shortages for the expanding mining and iron industries, which incentivized some countries to re-stock degraded forests and deforested lands. Hence, the main restoration goals in this first period across the 18 countries were the reduction of disaster risk, protection against erosion and production of timber, but improving water quality and creating jobs were also mentioned by several countries (Fig. 3).

Afforestation represented the main forest restoration initiatives in the nineteenth century and the first half of the twentieth century (Table 1). This included mountain slope afforestation to halt the problems resulting from torrential rains on bare slopes (flooding, avalanches…) in countries such as Spain, Italy, Greece, France, Austria and Switzerland, heathland afforestation to boost productivity and/or to stop the disasters caused by drifting sands (Belgium, Denmark, Netherlands, UK, Germany), Karst afforestation to protect from the harsh conditions and erosion that resulted from deforestation (Slovenia, Croatia, Austria), and afforestation of plains on sandy soils to reduce erosion (Hungary, Romania, Austria).

Restoration Activities and Species Used

To achieve these goals, countries reported a combination of passive and active approaches. The main passive activity was the cessation or attenuation of the degrading factor in the form of regulations that prohibited or limited forest grazing, litter raking or overharvesting, such as the Croatian Forestry Ordinance from 1775, the Danish Forest Act from 1805 or the Belgian Forest Code from 1854. Because of the high degree of degradation, natural regeneration was failing in most cases and, thus, active approaches that involved planting or sowing in high densities as well as labor-intensive soil preparation were common during the first period.

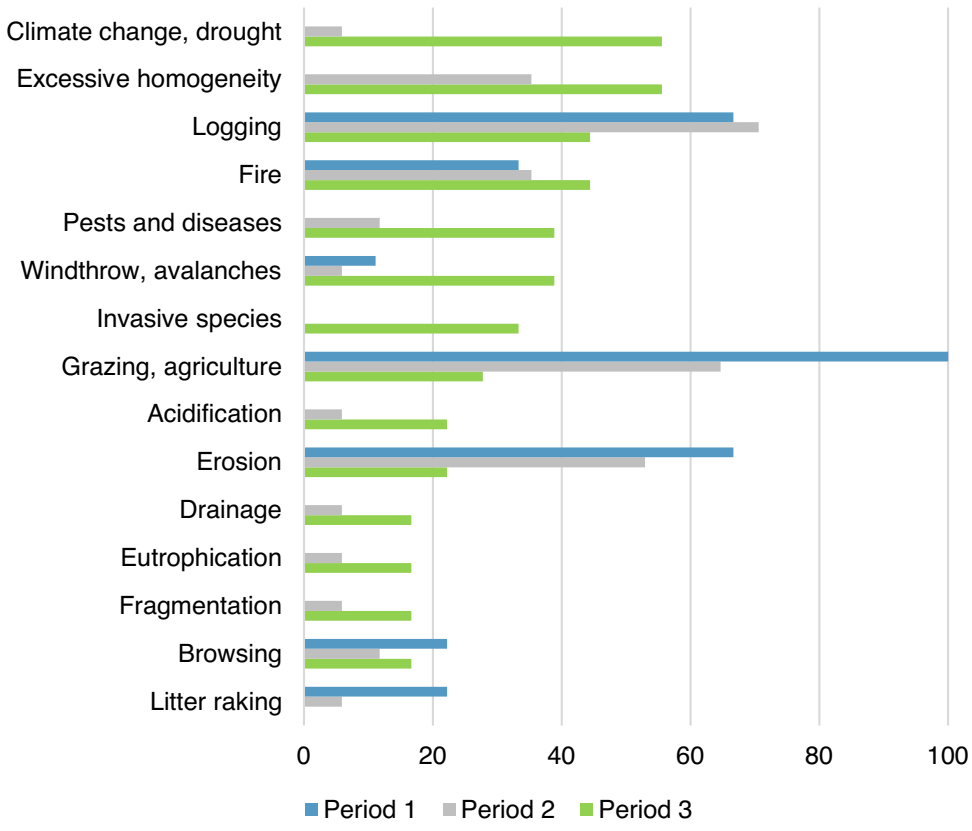

Fig. 2 The percentage of countries that include these drivers of forest degradation in the first (before 1940), second (1940–1990) and third (after 1990) periods of the narratives

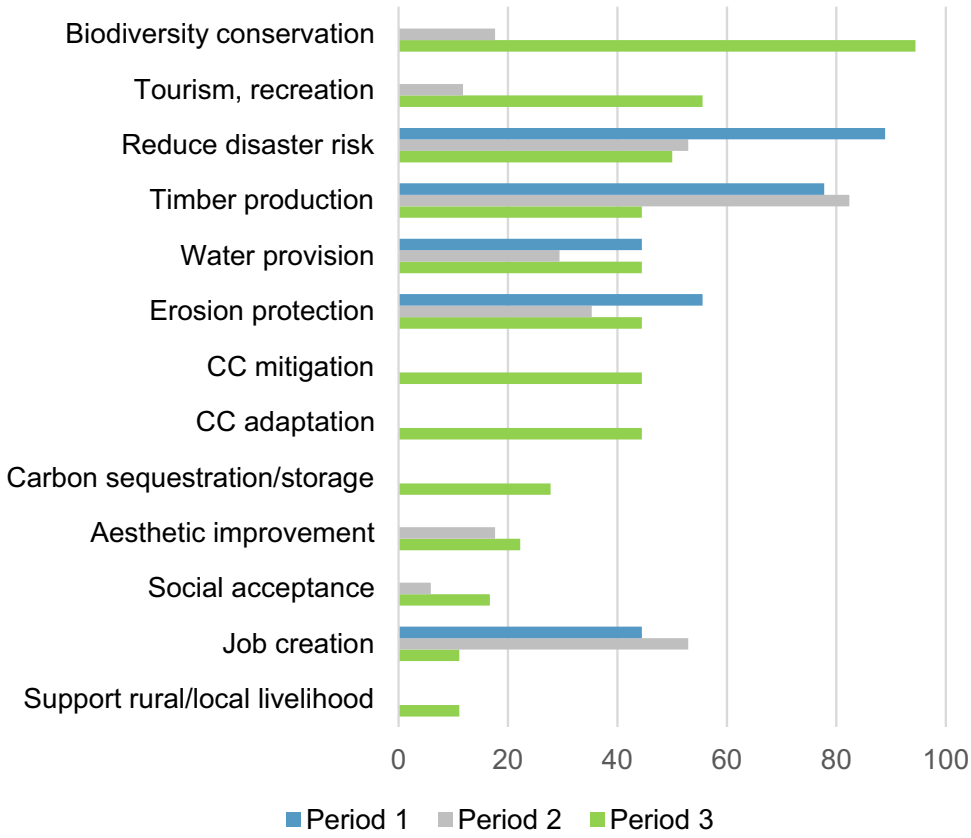

Fig. 3 Forest restoration goals and the proportion of countries identifying them as important during the first (before 1940), second (1940–1990) and third (after 1990) periods of the narratives

In the case of mountain afforestation, steep slopes had to be stabilized before planting by reshaping slopes, using fascines, sowing herbs, etc., while in wet forests draining was commonly applied before planting. A common follow-up activity was building fences to protect the young trees from livestock grazing.

The tree species used in afforestation varied across countries, but mostly fast-growing pioneer tree species were chosen, with pines (*Pinus* sp. L.) being the preferred trees in many initiatives because of the challenging site conditions in degraded areas (see Table S2 for details on pine species used). Norway spruce (*Picea abies* H. Karst) was mostly used in the subalpine areas of Switzerland and Austria, where it is native, but also in out-of-range areas in countries such as Germany, Denmark, Slovenia, Italy and the UK due to its economic value, wood quality and high growth rate. European larch (*Larix decidua* Mill.) was marginally used in countries such as Austria, Switzerland, the UK and France. Broadleaved trees (oaks, poplar and ash) were used to a lesser extent in countries such as Croatia, Spain, Switzerland and the UK, and private initiatives with the exotic eucalypts (*Eucalyptus* sp.) are reported during this first period in Spain, Italy and Greece. The exception to this dominance of conifer tree species was found in the afforestation of sandy soils in Hungary and Romania, where the non-native and invasive black locust (*Robinia pseudoacacia* L.) was widely used (> 80% in Romania) [18]. In Hungary, besides black locust, other invasive exotic species such as box elder (*Acer negundo* L.), tree of heaven (*Ailanthus altissima* Swingle) and black cherry (*Prunus serotina* Ehrh.) were used in the afforestation of the Great Hungarian Plain, with thousands of hectares of non-native invasive species remaining in forests to this day [19].

Governance and Funding

Most of the afforestation was promoted and funded by the State and regional administrations during the first period. However, the land to be afforested was not only state-owned but also community-owned or private, especially in countries and regions with a high share of privately owned land. Therefore, the public administration in several countries had to either encourage private owners and communities to afforest their lands (e.g., by offering tax exemptions, technical support or forest reproductive material) or acquire their land by buying, expropriating or establishing agreements. Acquiring land represented a considerable expenditure of the total budget (e.g., 23.8% of the expenditure of the UK Forestry Commission 1920–1933).

The governments spent considerable funds on these initial afforestation initiatives (Figure S5): the French government allocated 10 million francs (44 million constant euros$_{2023}$)

Table 1 The main types of forest restoration initiatives (columns) described in each of the 18 national narratives (rows) for each time period (1: < 1940, 2: 1940–1989, 3: > 1990). The last three rows show the total number of countries that report a given initiative in a given time period

	Afforestation for erosion control	Afforestation for production`	Agricultural afforestation	Afforestation for carbon sequestration	Urban/periurban afforestation	Conversion to plantation	Reforestation for productivity	Mining rehabilitation	Post nat. disturbance restoration	Designation of protected areas	Close-to-nature forest management	Ecological restoration for biodiversity	Rewilding, reintroductions	Riparian restoration	Diversification of plantations	Prestoration	Deming	Invasive control	Forest hydrology restoration
Austria	1,2						2		3	3	3		3		3			3	
Belgium		1	3			2	1,2			3	3							3	
Croatia	1,2						2		3		2,3				3	3	3	3	
Denmark	1,2	1,2	3						3	2,3	3	3							3
Finland							1,2,3			2,3	3	3							
France	1	2					2		2,3	3	3			3					
Germany		1,2	2			1,2			3	2,3	3				3				
Greece	1,2,3	2,3	3		1,2			2,3	1,2,3	1,2,3				3					3
Hungary	1,2,3	2	3		2					2,3	3	3			3				
Italy	1	2			3					3	3					3			
Netherlands	1	1,2								2,3		3			3				
Poland			1,2,3					2,3	3	2,3					3				
Romania	1		2,3				2,3			3	3								
Slovenia	1,2,3		1				2		3			3			1,2,3				
Spain	1,2,3			3		2	1,2	3				3	3	3					
Sweden		1,2					1,2			2,3	3	3	2						
Switzerland	1,2	2				2			3	2,3	2,3	3	2			3		3	3
UK		1,2,3	2	3	3	2	2	2,3		2,3	3	3	3	2,3	2,3			3	
Total Period 1	12	6	2	0	1	1	4	0	1	1	0		0	0	1	0	0	0	0
Total Period 2	8	10	4	0	2	5	10	3	2	10	2		2	2	2	0	0	0	0
Total Period 3	4	2	6	2	2	0	2	4	9	15	13		3	4	8	3	1	5	4

for afforestation during the 10 years following the promulgation of the 1860 law on mountain afforestation, and in Romania, 150 million lei (30 million euros, without considering inflation) from the state budget were spent between 1882 and 1887 for the afforestation of the southern degraded lands. Still, insufficient funding was one of the main constraints. The establishment of administrative units specialized in restoration to conduct the work and provide technical assistance (e.g., the Reforestation Commissions (1888, Spain), the Karst Afforestation Commissions (1881, Slovenia), the Forestry Commissions (1919, UK)) was key in the success of these large-scale, state-led initiatives.

Restoration Success and Ecological Recovery

Most of the forest restoration initiatives were classified as having a moderate to good level of success in achieving the objectives, especially considering the degree of land degradation. Tree plantations successfully halted or reduced erosion and related problems in most countries. For example, in Hungary, stabilizing the shifting sands after afforesting 65,000 ha was an important achievement. In France and Spain, the erosion problem was mostly halted, and in Croatia, the last devastating flood hit the country in 1856 (i.e., no more floods after 19,000 ha of Karst were afforested). The economic objective of increasing timber production was also achieved in countries such as Germany, Denmark and Belgium, as degraded former farmlands were turned into productive plantations. Job creation was also successful in countries such as Spain, where it is estimated that one million working days were created in relation to restoration during this period [20].

Overall, most countries experienced an increase in forest cover during this period, but several countries (e.g., Romania, Hungary, France) fell short of meeting the defined targets and some even experienced no net gain (e.g., northern Belgium, the UK) as afforestation efforts were 'counterbalanced' by further deforestation, mainly on fertile soils for agriculture and infrastructure. Regarding the quality of the forests, most countries reported a marginal or moderate ecological recovery. The established forests were mostly even-aged plantations managed with relatively short-rotation clearcut systems (namely in the temperate biome) and, thus, deficient in biodiversity compared to reference ecosystems. For example, the black pine plantations established in the Slovenian Karst and in France should be considered as an intermediate stage in the successional development of the forest towards oak woodlands, but most of the stands were poorly managed/thinned, so the return of native vegetation has been rather slow. In Hungary, black locust plantations were often created on former grasslands, which could mean a significant deterioration in ecological terms. Similarly, in Belgium and the Netherlands, the afforestation of transformed (i.e., resulting from previous deforestation) yet valuable open habitats such as heathlands and grasslands with conifer monocultures is considered to have resulted in a decline in biodiversity, and in Switzerland, clearcut prohibitions and continuous cover forest management put pressure on light-demanding species for decades. In several countries, species that were introduced as nurse species or productive species in forest restoration (e.g., black cherry) also became challenging invasive species.

Main Obstacles

One of the main obstacles to successful restoration reported by several countries for this first period was conflicting goals and local opposition (Fig. 4). The subsistence nature of the economy in rural areas made forest restoration work difficult as neighbors lost their rights to the communal use of forest resources (generally grazing, crops and firewood) and hence showed resistance to the land use change in countries such as Spain, Austria, Switzerland, Belgium, France, Hungary, Croatia and Slovenia. This was aggravated by related factors such as poverty, lack of enforcement and lack of stakeholder involvement. Another common obstacle was limited knowledge or lack of trained staff, which led to problems such as poor planting techniques or poor choice of species or provenances. Although the shortcomings of the contemporary forest management approaches started to become evident (e.g., low resilience towards biotic and abiotic disturbances), large-scale alterations did not ensue [21]. This was in part due to other obstacles such as insufficient funding, political instability, grazing/browsing and lack of post-restoration management, which prevented the successful implementation of emerging ideas such as close-to-nature forest management. Country-level examples of all these obstacles can be found in Table S3.

Second Period (1940–1989): Production

Main Drivers of Change, Goals and Types of Initiatives

The beginning of the second period was marked by a geopolitical crisis accompanied by changes in the wood market that strongly influenced the type and amount of forest restoration. The two World Wars led to significant forest degradation through direct destruction (e.g., shelling) and indirect overexploitation (Fig. 2), as wood was needed for military and household purposes due to coal shortages. Post-war reconstruction further drove deforestation, and many early 20th-century restoration efforts were halted due to shifting priorities. Additionally, deforestation for agriculture was exacerbated by the difficult socioeconomic conditions. The combination of these resulted in a marked decline in forest cover in the countries that were more actively involved in the

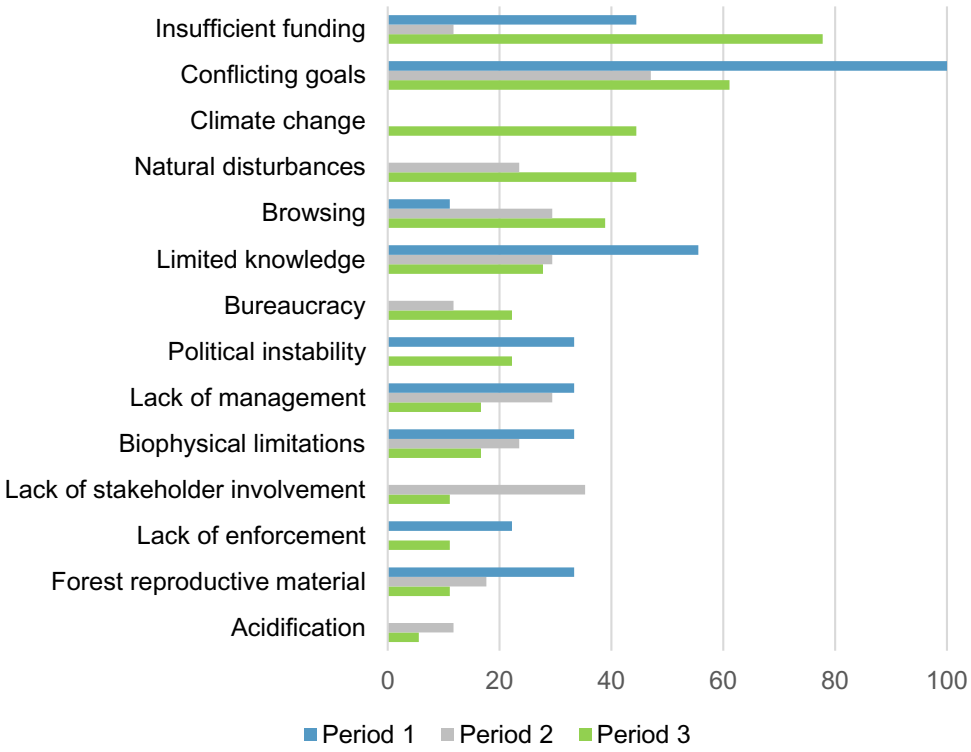

Fig. 4 Main obstacles for successful restoration and the proportion of countries identifying them as important during the first (before 1940), second (1940–1990) and third (after 1990) periods of the narratives

wars (e.g., Germany, UK, Belgium, Spain, Austria, Poland) and a renewed interest in the restoration of forests for timber production. Additionally, timber production became integral for the economic growth and flourishing industry between the 50 s and 70 s, and the new wave of rural abandonment following the socioeconomic crisis post World War II further facilitated many large-scale afforestation/reforestation initiatives. Thus, the main restoration goal shared by most countries during this second period was timber production, followed by the reduction of disaster risk and job creation as reported by half of the countries (Fig. 3).

To achieve these goals, large-scale afforestation and reforestation efforts, particularly on abandoned or marginal farmland, grasslands, peat bogs and degraded forests, characterized the first half of this period. Although afforestation for protective purposes remained important, the period saw a shift toward productive purposes, including the conversion of low-productivity forests (e.g., beech or oak coppice) into monoculture plantations (Table 1). However, this period was not only about disaster reduction and production, but other ecosystem services such as aesthetics, recreation, hunting or the provision of drinking water were also increasingly valued and protected by taking some forests out of harvesting and designating protected areas. Other initiatives that were not discussed in the previous period but that a few countries include in this one were the restoration post natural disturbances (e.g., fire, windthrow), post mining or rewilding by reintroducing extinct animal species.

Restoration Activities and Species Used

Most afforestation and reforestation initiatives followed an active approach, but passive approaches became increasingly common by the end of the period as natural regeneration was encouraged and facilitated by rural abandonment and the designation of protected areas gained momentum. Passive approaches were also favored post-fire in countries such as Spain, Greece and France due to the fire-tolerant nature of the mediterranean vegetation. Restoration activities were similar to those employed in the previous period, including soil preparation (ploughing, draining…), planting and fencing. Soil preparation was increasingly mechanized throughout the period. Planting was still done in relatively high densities, although densities tended to decline over time. Weeding, herbicide/pesticide application and thinning were also used in many countries during this period to boost tree growth. While in many countries draining was a prerequisite for afforestation, in mediterranean countries, water retention was key for successful establishment.

Conifer tree species, namely spruce and pine, were widely planted in all countries. Norway spruce became very popular due to its economic value, easy and cheap establishment, and rapid growth: not only was this the dominant species in countries within its natural range (e.g., Sweden, Austria and Switzerland), but it was also artificially expanded to sites outside its natural growth area in Switzerland (lowlands), Italy, Croatia, Denmark, France, Germany, Hungary, Slovenia, Romania, Netherlands, Sweden and the UK. Spruce

was usually planted in higher soil quality sites, whereas pines were used in poor quality sites. All pine species mentioned in the previous period (Table S2, mostly Scots pine and black pine, but also Aleppo pine, maritime pine, mountain pine, Turkish pine and lodgepole pine) continued to be used during this period, as well as new conifers such as Silver fir (*Abies alba* Mill.), European larch, Sitka spruce (*Picea sitchensis* Carr.), Douglas fir (*Pseudotsuga menziesii* Franco) and Nordmann fir (*Abies nordmanniana* Spach).

Among deciduous tree species, the fast-growing poplar hybrids became popular for the afforestation/reforestation of riparian areas due to their economic value in the expanding paper industry in several countries (e.g., Hungary, Belgium, Greece, France, Spain, Netherlands). The invasive and fast-growing black locust was still popular in the afforestation of barren and sandy areas in Hungary, Greece, Croatia or Romania. By the end of the period, once the vulnerability of conifer monocultures became obvious, enrichment planting with beech (*Fagus sylvatica* L.) or black cherry became more common in countries such as Germany and the Netherlands. In the afforestation efforts of Slovenian Karst, increasingly greater numbers of native broadleaves such as oaks (*Quercus* sp. L.), sycamore (*Acer pseudoplatanus* L.), the European nettle tree (*Celtis australis* L.) and chestnut (*Castanea sativa* Mill.) were used in enrichment planting. Finally, in addition to tree species, extinct animal species that assisted forest restoration were also re-introduced in countries such as Switzerland (lynx – *Lynx lynx* (Linnaeus, 1758) and beaver – *Castor fiber* (Linnaeus, 1758)) and Sweden (beaver).

Governance and Funding

Like in the previous period, forest restoration happened in public and private lands, and it was promoted mainly by the government that aimed for higher self-sufficiency and provision of raw materials after the war. However, unlike the previous period, the second period is characterized by a considerable nationalization of privately owned forests post World War II in Romania, Croatia, Slovenia, Hungary and Poland, as well as by a strong and centralized state control of forest management (in these and other countries such as Greece, Spain and Italy). These changes in ownership and governance facilitated the efficient implementation of the projects and, thus, large-scale afforestation/reforestation goals were mostly achieved. In countries where private ownership was still prevalent, the motivation to plant trees was often economically driven as timber demand and prices were high during this period. Similarly, state funding mechanisms were often derived from the sale of timber, including the French National Forestry Funds (*Fonds Forestier National* or NFF) or the Slovenian biological depreciation fund [22, 23].

The main restoration goal of this period (i.e., timber production) was reflected in policies (e.g., the 1952 German Forest Law, the 1951 UK Forestry Act) and was enacted through regulations (e.g., obligation to replant after felling – e.g., the 1962 Dutch Forest Act) or financial incentives (e.g., tax benefits). However, policies reflecting environmental conservation became increasingly common throughout the period as well, which were instrumental in promoting the declaration of protected forest areas. Also, legal frameworks supporting multifunctional and close-to-nature forest management (e.g., the Slovenian Forest Act 1949, the Austrian Forest Act 1975, the Romanian Forest Law 1976) started to be published throughout this period.

Restoration Success and Ecological Recovery

This tight and centralized state control and funding resulted in large areas being afforested/reforested in many countries during the second period (Fig. 5), which contributed to forest cover increasing in most countries (e.g., by 7% in Switzerland, Poland and the UK). From an economic perspective, these initiatives can be considered successful as the new plantations delivered profitable goods to the industrial market (see Table S4 for country-specific examples). The afforestation for protective functions was also considered successful in countries such as Spain, the Netherlands, Italy, Slovenia and Hungary, where erosion and related problems (floods, drifting sands) were reduced. The restoration goal of job creation was also successful in countries like Spain and Romania, but in the Netherlands, harsh working conditions and insufficient salaries led to strikes and consequent dismissals [24].

Much of this socioeconomic success came at a high ecological price. Many of the initiatives did not result in a clear ecological recovery, but to the contrary, were a driver of ecological degradation as structurally and compositionally poor plantations replaced habitats of high ecological value. Examples of such replacements include the plantation of Norway spruce in mixed beech-coniferous stands (e.g., Switzerland, Romania), the expansion of acacia in oak-favorable sites (e.g., Hungary, Romania), the substitution of native species-rich meadows and riparian forests with hybrid poplar plantations (e.g., Belgium, Spain, Greece), the creation of conifer monocultures for cellulose production in biodiverse heathlands and grasslands (e.g., Netherlands, Belgium), and the drainage of functionally important wetland forests (e.g., Sweden, UK). The use of exotic invasive species oftentimes prevented the establishment of native species (e.g., Italy, Hungary), and the even-aged single species plantations showed low resilience to disturbances in later periods (e.g., Germany, France). Additionally, this period saw a marked shift in the European tree composition, with a considerable increase in the share of coniferous trees (Table S4) and

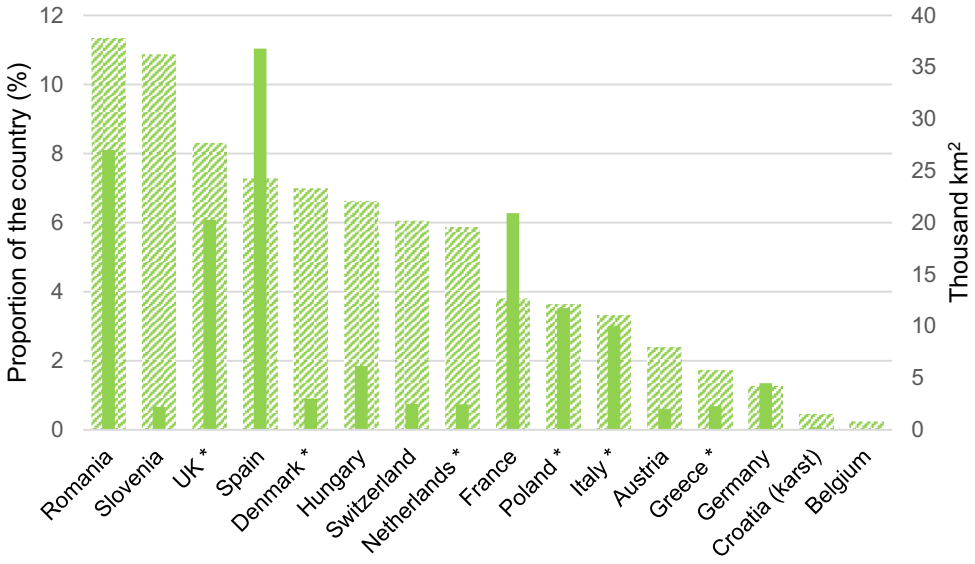

Fig. 5 Afforested/reforested area (solid bars, secondary y-axis) and percentage of the country (stripped bars, primary y-axis) reported by different countries in the narratives for the second period (~ 1940–1990). The countries that report the area for the first and second periods combined (< 1990) are shown with an asterisk

associated consequences for the forest communities and their biodiversity. However, it is important to note that there were also examples of good ecological recovery (e.g., by the end of the period, spruce monocultures as well as black pine plantations were diversified with a broadleaved tree understorey in Slovenia) and the increasing number of protected areas in most countries during this period meant that some forests (albeit limited in space) were being spared from degradation (Table S4).

Main Obstacles

The main obstacles during this period were conflicting goals, browsing, severe degradation, lack of knowledge, issues with the forest reproductive material, lack of management and lack of stakeholder involvement (Fig. 4). As it was the case in the previous period, conflicting goals between agriculture/farming and forest restoration led to limitations in the land available for afforestation in countries such as Spain, Romania, Greece and the UK. Additionally, in this second period, conflicts between forestry and nature conservation stakeholders emerged, as reported by Hungary, Sweden and Austria. Despite a reduction in livestock grazing, the density of wild ungulates surged during this period, posing a challenge to the natural regeneration of deciduous and fir tree species due to intensive browsing in countries like Austria, Germany, Hungary and Slovenia. Also, in these and other countries, the lack of initial knowledge and adequate forest reproductive material for restoration with deciduous tree species contributed to their failure [25–29].

Severe stages of degradation and harsh abiotic/biotic conditions were also reported to negatively affect restoration initiatives in Croatia, Denmark, Greece and Hungary. In countries such as Spain, Italy, France and Poland, a lack of post-restoration management has been reported to hinder the success of afforestation/reforestation. The lack of tending of the established forests (e.g., thinning) has resulted in dense stands of single pioneer species that are vulnerable to natural disturbances (e.g., pests and fire). In fact, disturbances such as fire (e.g., Slovenia, Greece), pests (e.g., pine processionary (*Thaumetopoea pityocampa* (Denis & Schiffermüller, 1775) – Slovenia, Greece), acid rain (e.g., Belgium, Netherlands) and windthrow (e.g., Poland) were reported to be another common obstacle to the success of the initiatives during this period. Finally, several narratives also described the lack of stakeholder involvement (Greece, Italy, Romania, Spain, UK and Sweden) and bureaucracy (Greece and France) as obstructing or delaying forest restoration.

Third Period (> 1990): Multifunctionality

Main Drivers of Change, Goals and Types of Initiatives

This period marks a shift in the focus of restoration efforts from increasing forest quantity to improving quality, alongside the diversification of key aspects like degradation sources, restoration goals and activities, promoted forest functions, funding sources and stakeholders. This shift was facilitated by the coming together of several environmental, social, political and economic drivers of change between the 1970s and the 1990s: 1) severe disturbances hit the forests, leading to huge economic losses that highlighted the vulnerability of monospecific even-aged plantations to acid rain, drought, wildfires, windthrow or bark beetle (*Ips typographus* L.) outbreaks, which were and are being exacerbated by climate change, 2) societies started to demand change based on a growing interest in recreation and tourism, as well as growing environmental concerns, 3) the value of timber

decreased due to a lower demand (e.g., closure of mines) and the opening of the international timber market, and 4) the increasing influence of international and EU environmental policies (e.g., the Convention on Biological Diversity 1992, the EU Habitats Directive 1992) elevated the significance of biodiversity conservation on national political agendas. Thus, although the goals from previous periods (i.e., timber production, erosion control and reduction of disaster risk) remained relevant, biodiversity conservation took center stage and was highlighted by most countries, followed by restoration for tourism and recreational uses (Fig. 3). Restoration for climate change-related issues (mitigation, adaptation and carbon sequestration/storage) was also a new goal driving forest restoration in several countries.

Considering the diversification of restoration goals, a multifunctional forest restoration approach was increasingly undertaken. The level of multifunctional uptake, however, varied across countries and was done following both segregative (designation of protected areas) and integrative (close-to-nature forest management) strategies (sensu [30]) (Table 1) with varying ratios across countries. Afforestation and reforestation initiatives for productive purposes were mostly absent from the narratives, while initiatives for protective purposes were not discussed as much as in previous periods. Instead, ecological restoration initiatives for biodiversity conservation and the diversification of plantations were commonly included. Finally, new types of initiatives that aimed to address current challenges were described and included: post-natural disturbance restoration, forest hydrology restoration, invasive species control, riparian restoration, initiatives of rewilding or nature-based solutions, afforestation for carbon sequestration, urban/periurban forest restoration and prestoration.

There was also a diversification of the main drivers of degradation addressed. The main sources of degradation from previous periods (i.e., agriculture, overgrazing, erosion, overharvest) were still reported by several countries, but new ones (many of which, interestingly, derived from the type of restoration conducted in the previous period) appeared and attracted much attention in forest restoration post-1990 (Fig. 2). Excessive homogeneity and its negative effect on biodiversity and resilience became a source of concern, which resulted from either intensive rotation forestry (e.g., Finland, Netherlands), the abandonment of diversifying silvicultural treatments such as thinning (e.g., Spain, Italy) or the suppression of natural diversifying elements such as fire (e.g., Finland, Spain). Other current drivers of degradation related to past forest management activities include drainage and invasive species. For example, black cherry, which was introduced in the previous period to enrich pine plantations (e.g., Netherlands, Belgium, Poland), turned out to be an invasive alien species that dominated the understorey of thousands of hectares, obstructing the natural development of a native admixture.

Natural disturbances were reported as an important driver of degradation during this period as well, which were related to both the vulnerability of homogeneous plantations derived from past afforestation/reforestation campaigns, and to the increasing frequency and intensity of natural disasters due to climate change. Extreme drought events, windthrows and wildfires started to become increasingly common and caused large-scale forest damage in most countries. Pests (e.g., bark beetle, pine processionary) and diseases (e.g., ash dieback caused by an invasive fungal pathogen) also raised concern and attracted much attention and resources in restoration. Finally, forests degraded due to acidification and eutrophication resulting from various industry activities and pollution were restored in countries such as Belgium, Netherlands, Germany and Poland. However, note that the disturbance of plantations also created opportunities for restoration and that it can lead to increased biodiversity [31, 32].

Restoration Activities and Species Used

The types of activities also diversified in response to the diversification of threats and goals. Passive approaches gained relevance and included activities that range from landscape-level protection (e.g., restriction of active management in strictly protected forest reserves) to tree-level protection (e.g., retention of habitat trees during forest management). Assisted forest restoration also became very prevalent during this period, with techniques such as management for old-growth forests and the emulation of natural disturbances being employed in ecological forest restoration initiatives. The creation and retention of deadwood were some of the most commonly used techniques to favor species that depend on deadwood (e.g., white-backed woodpecker), which was usually done by felling trees and leaving downed logs or by girdling trees and leaving standing dead wood. Some of the first experiments to restore deadwood by girdling trees were carried out in 1994 in the Finnish Mäntsälä region. Because the suppression of natural disturbances negatively impacted light-demanding species in uniformly dense plantations, restoration techniques that emulate these disturbances (e.g., gap creation, prescribed burns) were increasingly used namely in boreal countries.

Several countries increasingly adopted close-to-nature forest management throughout this period, promoting aspects that favour forest restoration. The cessation/attenuation of degrading factors as a restoration activity became increasingly incorporated into forest management, including the prohibition to use hazardous pesticides or intensive soil preparation, the obligation to retain habitat trees and deadwood, or the limitations on clearcutting. The diversification of plantations was a widespread objective that was pursued

through the promotion of natural regeneration in forest management when possible, or by planting more native – often deciduous – tree species. Because of the growing browsing pressure, fencing, tree protectors and regulating wildlife populations became very common assisted restoration activities (especially when broadleaved species were being promoted). Sanitary fellings also became an increasingly important (albeit controversial) post-disturbance restoration technique in countries such as Germany, Poland, Croatia and Slovenia and could represent a high percentage of the total annual harvest due to the growing incidence of pests and diseases. Hydrological interventions such as rewetting forests by blocking or filling ditches to restore the original species association were reported by several countries such as Sweden, Denmark and Switzerland.

Although planting was less prevalent than in the previous period, active approaches that involved the introduction of biota were still common in the third period. In general, planting densities decreased, but the most common tree species from previous periods (i.e., pines, spruce, black locust) continued to be planted despite their shortcomings. However, there has been a clear shift towards promoting native deciduous tree species. For example, beech was widely planted to enrich spruce plantations in Germany, and oak species (namely holm oak (*Q. ilex* L.) in Spain; pedunculate oak (*Q. robur* L.) and sessile oak [*Q. petraea* (Matt) Liebl. in Poland) were commonly planted in pine stands during this period. Other deciduous tree species that were increasingly incorporated to enrich forests include sycamore, rowan (*Sorbus aucuparia* L.), wych elm (*Ulmus glabra* Huds.) or linden (*Tilia* sp. L.). Additionally, fruit-bearing tree and shrub species are increasingly being favored to support animal biodiversity, and native riparian tree species to replace exotic poplar hybrid plantations from the previous period. It is also worth noting that recently attention has been paid to the selection of tree species that are adapted and resilient to anticipated climate change impacts (i.e., prestoration), but, beyond policy recommendations and research, very little progress has been made on the ground in most countries. However, provenances are increasingly being taken into account when planting, with decision support tools being developed to help foresters decide the best alternatives for the current and future site conditions. Finally, several countries reported that animals were also introduced as part of restoration, including birds (capercaillie), wild species valued as game (deer, roe deer, fallow deer, mountain goat), large domestic herbivores (e.g., cows and mares) and predators (e.g., bears, wolves, lynx).

Governance and Funding

The governance and funding of the initiatives also diversified during this period. If before 1990 almost all the work was centralized in the state forestry administration, after 1990, not only did the administration fragment (i.e., decentralization) into regional and local administrations (e.g., Spain, UK, Netherlands, Belgium, Greece), but new actors emerged which, on occasions, became as important or even more so (e.g., associations, foundations, companies, research centers, neighborhood communities). In addition, the beginning of the third period was characterized by ownership privatization in countries that nationalized forests during the second period (e.g., Slovenia, Romania, Hungary). These two movements generally slowed down the implementation or led to regional divergences in policies, approaches and implementation.

However, strong national regulatory policies that became very important for the implementation of multifunctional forest restoration were also developed, including the Romanian Law on the Conservation, Protection and Development of forests (1986), the Flemish Forest Decree (1990), the Swiss Forest Law (1991), the Polish Forest Act (1991) and the Danish Nature Protection Act (1992). Additionally, a very influential new actor entered the restoration arena and elevated the importance of biodiversity conservation in national and regional policies: the EU. In particular, the EU Habitats Directive (1992) and its key instrument (i.e., the Natura 2000 network) were mentioned by several narratives to have been a cornerstone for nature conservation in their countries.

The lack of available public land for restoration was perceived as an obstacle due to the fragmentation of holdings, the large number of owners and their perceived disinterest in forest restoration [33]. In this third period, three financial policy instruments became very relevant to overcome this limitation and encourage private owners to restore forests: subsidies or payments for ecosystem services, certification and EU funding. In several countries (e.g., Finland, Belgium, Austria, Germany UK), landowners that adhered to higher ecological standards (e.g., prohibition on clearcutting and the use of fertilizers and pesticides, or the promotion of native deciduous species and deadwood) received a greater subsidy to compensate for potential income loss or increased costs.

Contracts between forest owners and the administration also became increasingly common in countries such as Switzerland, Finland, Sweden and Spain. The goal of these contracts is to encourage the consideration of nature conservation values on top of legal requirements within a certain time period and with a certain level of economic compensation. The introduction in the 1990s of soft voluntary regulations in the form of market-based certification schemes (PEFC

and FSC) also required the involved forest owners to take biodiversity and ecological aspects into consideration in forest management.

Finally, EU funds are a new source of funding that has been shaping the type of restoration conducted in the third period. The European Agricultural Fund for Rural Development (EAFRD), which is implemented by EU countries and co-financed by national/regional budgets, funded multiple restoration programs across most countries, but also gave rise to conflicts (agriculture vs. conservation) [34]. LIFE and Interreg programs funded ~ 700 projects aiming at ecological forest restoration over the past 20 years [35, 36]. For countries such as Greece, although spatially limited, this type of EU funding was pivotal for supporting a new line of restoration with new objectives and stakeholders.

Restoration Success and Ecological Recovery

Evaluating the success of restoration actions during this last period is challenging because of the diversification of goals and because ecological recovery takes time. Most experts assessed it more positively than in previous periods, but there are still multiple examples of moderate success. The most positively evaluated initiative, overall, was the adoption of close-to-nature forest management, especially in the temperate forest biome. Such a statement was based on National Forest Inventory data and indicators that showed an upward trend in the amount of deadwood, in the proportion of deciduous species and mixed stands, in the use of natural regeneration or in stand age. In boreal countries, although the awareness of the need to diversify the widespread even-aged rotation forestry is increasing, uneven-aged management practices would need to upscale dramatically in practice to have the needed ecological impact.

Similarly, diversification efforts have been largely successful, evidenced by the increasing share of broadleaved species and mixed stands. Nonetheless, challenges persist, especially in post-fire restoration efforts in some mediterranean countries, where the use of deciduous species has proven difficult (see obstacles below). In central Europe, the widespread use of beech as a diversification species has raised concerns due to unexpectedly high mortality rates following recent droughts, highlighting limitations in its use for prestoration. On a more positive note, natural post-disturbance (e.g., windthrow) regeneration has shown the potential for the development of diverse and resilient forest communities with minimal human intervention in several countries.

Regarding forest quantity, although several countries saw increases in forest cover during this period, such increases mostly resulted from natural regeneration, which was facilitated, in some cases, by rural abandonment. In fact, countries such as the UK, Belgium, Romania and Denmark reported failures in meeting annual afforestation and forest expansion targets, and the Netherlands even experienced a decrease in forest cover over the past decade. Finally, the area of protected forests increased in most countries during this period, but the level of success differs depending on the type of protection and country.

Main Obstacles

The main obstacle reported by all countries during this third period was insufficient funding (Fig. 4) as shown in the country-level examples in Table S5. Even when the financial compensation was adequate, the lack of trust in whether subsidies would be maintained in the long term discouraged many owners from engaging in restoration (e.g., Belgium, Denmark). In fact, subsidies, as a financial policy instrument, have shown several shortcomings in the context of forest restoration, including uncertainty on the long-term implications, the external financial dependency that it creates, the bureaucracy it entails and the burden for the administration due to the high budget that has to be committed for an extended period.

Conflicting goals was another obstacle which was again reported by most countries in this period. The main two conflicts were between agricultural and forest land covers and between timber production and nature conservation, and they were present at both the social (i.e., conflicts among stakeholders) and political (i.e., inconsistent cross-sectoral policies) dimensions (Table S5). Several experts raised concerns about the recent polarization of perspectives and how they hinder successful restoration. There were also growing concerns that climate change mitigation and bioenergy policies, such as the EU Renewable Energy Directive focused on accumulating carbon through tree planting, can contradict forest biodiversity policy objectives and lead to policy fragmentation and ecological degradation [37, 38].

Furthermore, the dissolution of the unitary organization of forest management and the reprivatization of the forests continued to challenge forest restoration in several countries (Table S5). In fact, the lack of silvicultural knowledge (e.g., missing thinning treatments to facilitate the establishment of target species) and ecological understanding of private forest owners was reported as an obstacle by several countries. Finally, climate change, the consequent intensification of natural disturbances, the growing browsing pressure (which especially hinders the establishment of deciduous species) and excessive bureaucracy that make measures unattractive to applicants were also reported as major obstacles by several countries.

Conclusions – 10 Lessons Learned

Analyzing expert national narratives is a valuable tool for deriving long-term, large-scale practical knowledge, enabling us to extract lessons and general guidelines to successfully navigate the UN Decade on Ecosystem Restoration and implement the European Nature Restoration Law. Results show that changes in forest restoration over the last two centuries as well as the success or failure of national initiatives have been driven and/or conditioned by a combination of environmental, technical, political, legal, social and economic factors. Below, we highlight these factors and summarize the main conclusions extracted based on the 18 national expert narratives in the form of 10 lessons learned to help guide future restoration.

1. **Natural disasters trigger change:** Some of the first large-scale forest restoration initiatives in several countries were a response to catastrophic natural disturbances (e.g., floods, avalanches, shifting sands) that resulted from centuries of overexploitation and deforestation. The changes in forest restoration observed after 1990 were also triggered, in part, by growing environmental disasters (e.g., acid rain, large-scale windthrow, bark beetle outbreaks, fires) and global environmental crises (the climate change and biodiversity crises, and to a lesser extent, the water crisis). Sound ecological understanding and strong political will to act upon it are crucial to prevent such catastrophic tipping points.
2. **Geopolitical turmoil forces change:** Wars have strongly influenced forest restoration in Europe in an ambivalent way. On the one hand, wars acted as strong drivers of degradation by directly destroying forests or sharply increasing timber demand. Wars also represented clear obstacles to restoration by halting previous efforts and forcing changes in objectives, priorities and funding. Finally, the geopolitical vulnerability resulting from timber shortages during the war encouraged many countries to initiate strong afforestation/reforestation campaigns with a focus on timber production, with clear legacy effects on the structure and composition of forests decades later.
3. **Forest ownership and governance accelerate or decelerate change:** The nationalization/privatization of forests and centralization/decentralization of forest competencies have been some of the most influential political decisions for forest restoration. Some narratives show that the centralized management and funding of state forests usually led to efficiency and success in meeting large-scale targets, whereas the fragmentation of property into many private owners and forest governance into many administrations slowed down progress. Throughout history, governments have tried different mechanisms with different levels of success to deal with the lack of available public land for restoration (e.g., expropriation, purchase, contracts, tax benefits, in-kind support), and currently, certification and subsidies are popular choices. However, they all have shortcomings, and thus, property fragmentation continues to be a burning issue in forest restoration. On the bright side, there are many examples of successful local initiatives [11]; therefore, innovative governance solutions that catalyze the upscaling of these good practices are essential.
4. **Funding mechanisms support change:** One of the most common obstacle throughout time has been the lack of funding, whereas most successful initiatives reported in the narratives are based on strong and stable funding mechanisms (e.g., state funding of the Karst afforestation program based on the sale of forestry products). The shift in the type of forest restoration experienced in the third period has been possible partly due to EU funding programs such as the European Agricultural Fund for Rural Development (EAFRD) or LIFE programs. Still, all countries report insufficient funding as a main obstacle to successful restoration nowadays and shortcomings of some financial instruments (e.g., subsidies), highlighting the urgent need for innovative funding mechanisms and regulations that are as resistant as possible to political and market fluctuations.
5. **Market fluctuations drive change:** Changes in the demand and value of different forest products (e.g., charcoal, fuelwood, timber) and services (e.g., tourism, carbon sequestration) over time have strongly influenced the type of restoration. For example, the decreased demand for fuelwood following the introduction of fossil fuels and the growing timber demand for the mining industry led to the conversion of many deciduous coppice forests to coniferous high forests. This highlights the importance of ensuring that future forest restoration initiatives provide marketable benefits (e.g., non-timber products such as truffles, wildlife tourism, payments for carbon sequestration), as this will encourage landowners to engage in long-lasting restoration (especially considering the reluctance of many to depend on subsidies).
6. **Sociodemographics and societal values demand or enable change:** Rural abandonment has facilitated restoration in some cases by reducing the conflict between agricultural and forest land uses and enabling natural forest regeneration. However, the lack of forest management resulting from this abandonment can also lead to forest degradation (e.g., overly dense stands with

high flammability), showing that the involvement of an active rural population can contribute to successful forest restoration. Shifts in societal values can also drive change, as exemplified by the crucial role of the increased environmental awareness of the population and demand for the recreational use of forests in diversifying restoration objectives after 1990, highlighting the need for effective communication and education of society.

7. **Policies guide change:** Although a policy analysis is not within the scope of this review and the myriads of policies included in the narratives cannot be captured, it can be said that some of the most successful and influential policies have been national forest laws that were strict (not overly autocratic, not overly soft) and sought to balance socioeconomic benefits and ecological protection. The creation over time of administrative units and institutions specialized in forest restoration as well as the nationally centralized education of foresters have also been instrumental in the success of restoration in many countries. Forward-looking and ambitious international and European environmental policies have also been reported to exert a strong influence on national strategies.
8. **Convergence of multidimensional drivers accelerates change:** Drivers of change do not act in isolation but synergistically (or antagonistically). Usually, several drivers of change have to come together to have a real impact, showing the interrelation of social, environmental, economic and political aspects of forest restoration. For example, at the beginning of the twentieth century, the limitations of even-aged monocultural conifer plantations started to show, and some forest managers and researchers advocated for continuous cover forestry. However, this movement did not materialize in most countries (Slovenia could be considered an exception) because the geopolitical and economic situation of the time prioritized maximizing wood supply. It was not until the 1970s to 1990s that the convergence of social, political, economic and environmental factors enabled this change.
9. **Conflicting goals impede change:** One of the main obstacles to successful forest restoration based on the narratives has been conflicting goals, both at the socioeconomic (e.g., among stakeholders) and political (e.g., among policy sectors) levels. The most recurrent conflicts are those between agricultural and forest land uses (e.g., agricultural subsidies are much more attractive than afforestation subsidies), and between timber production and biodiversity conservation goals. Moreover, new conflicts (e.g., between climate change mitigation and forest biodiversity policies) are raising growing concerns.
10. **Short-term solutions can cause long-term problems:** The final general lesson that we have extracted based on the narratives of these 18 countries is that when solutions to a particular problem are taken based on short-term thinking or without considering other interconnected components of the system, these solutions can become the source of future problems. For example, the fixation of sandy soils or enrichment of conifer plantations with invasive exotic species has caused the unintentional introduction of new threats. The afforestation/reforestation of degraded land with conifer monocultures has resulted in increased vulnerability to natural disturbances such as fire and windthrow. The complete suppression of past drivers of degradation (e.g., fire, grazing, harvesting) has led to simplified forests lower in biodiversity. Some experts have expressed concerns that current approaches to solve immediate problems such as climate change and biodiversity crises may lead to a type of restoration (e.g., afforestation with monocultures of fast-growing species to sequester carbon or prohibitions on timber harvest to create forest reserves) that threatens the system in the future (e.g., loss of biodiversity, lack of sustainably grown wood for the green transition).

Therefore, we conclude that a shift in how we view and manage the landscape may be necessary as: "some problems consistently resist solution … These are the problems for which a new way of looking is required" [39]. Specifically, our perception of the landscape should evolve from an aggregation of static and isolated patches towards understanding the landscape as a dynamic and interconnected socioecological mosaic of different habitats that vary in space and time. A holistic landscape approach to forest restoration (in research, policy and practice) may be the only way to minimize tradeoffs and conflicts among sectors and stakeholders and to simultaneously address the many challenges that all habitats on the planet face. Additionally, innovative funding mechanisms, as well as restoration initiatives that provide marketable benefits are crucial to engage landowners and address both property fragmentation and rural abandonment issues. Finally, long-term thinking that is aware of the interconnectedness of the system is key for successful forest restoration. As Donella Meadows [39] wrote, "The world is a complex, interconnected, finite, ecological-social-psychological-economic system. We treat it as if it were not, as if it were divisible, separable, simple, and infinite. Our persistent, intractable global problems arise directly from this mismatch".

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Author Contribution M.E. and S.dM. conceptualized the research study, supervised the development of national narratives, analyzed and synthesized the results, led the writing of the manuscript, and developed the methodology with the collaboration and contribution of I.A., I.C., M.M.M., L.W., K.L. and J.H. A.A. prepared maps and figures. The rest of the coauthors contributed through the development of the corresponding national narratives. All authors reviewed the manuscript.

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References

1. Evans J. Planted Forests – Uses, impacts and sustainability. Cambridge, Massachusetts, USA and FAO, Rome, Italy: CAB International; 2009.
2. Roy A, Fleischman F. The evolution of forest restoration in India: The journey from precolonial to India's 75th year of Independence. Land Degrad Dev. 2022;33(10):1527–40.
3. Jacobs DF, Oliet JA, Aronson J, et al. Restoring forests: What constitutes success in the twenty-first century? New Forest. 2015;46:601–14.
4. UN (United Nations). About the UN decade 2019. https://www.decadeonrestoration.org/about-un-decade (accessed 2023.10.21).
5. Verdone M, Seidl A. Time, space, place, and the Bonn Challenge global forest restoration target. Restor Ecol. 2017;25:903–11.
6. UN (United Nations), 2022. Press Release: Nations Adopt Four Goals, 23 Targets for 2030 In Landmark UN Biodiversity Agreement. https://www.un.org/sustainabledevelopment/blog/2022/12/press-release-nations-adopt-four-goals-23-targets-for-2030-in-landmark-un-biodiversity-agreement/ (accessed 2024.02.21).
7. Nunez-Mir GC, Iannone BV, Curtis K, et al. Evaluating the evolution of forest restoration research in a changing world: a "big literature" review. New Forest. 2015;46:669–82.
8. Höhl M, Ahimbisibwe V, Stanturf JA, Elsasser P, Kleine M, Bolte A. Forest Landscape Restoration—What Generates Failure and Success? Forests. 2020;11(9):938.
9. Hering D, Schürings C, Wenskus F, Blackstock K, … Pe´er G. Securing success for the Nature Restoration Law. Science, 2023;382:1248–1250.
10. Sabogal C, Besacier C, McGuire D. Forest and landscape restoration: Concepts, approaches and challenges for implementation. Unasylva. 2015;66:3.
11. Krumm F, Rigling A, Bollmann K, Brang P, Dürr C, Gessler A, Schuck A, Schulz-Marty T, Winkel G. Synthesis: Improving biodiversity conservation in European managed forests needs pragmatic, courageous, and regionally-rooted management approaches, in: Krumm F., Schuck A., Rigling A. (Eds), How to balance forestry and biodiversity conservation – A view across Europe. European Forest Institute (EFI), Swiss Federal Institute for Forest, Snow and Landscape Research (WSL), Birmersdorf, Switzerland, 2020;608–633.
12. Riessman CK. Narrative methods for the human sciences. Thousand Oaks, CA: SAGE Publications; 2008.
13. Jepsen MR, Kuemmerle T, Müller D, Erb K, Verburg PH, et al. Transitions in European land-management regimes between 1800 and 2010. Land Use Policy. 2015;49:53–64.
14. Food and Agriculture Organization of the United Nations (FAO). 15.1.1 Forest area as a proportion of total land area (Primary series). 2024. https://de-public-statsuite.fao.org/?tm=forest%20area&pg=0&snb=16. Accessed 2024.05.12
15. Dinerstein E, Olson D, Joshi A, Vynne C, Burgess ND, Wikramanayake E, Hahn N, Palminteri S, Hedao P, Noss R, Hansen M, Locke H, Ellis EC, Jones B, Barber CV, Hayes R, Kormos C, Martin V, Crist E, Sechrest W, Price L, Baillie JEM, Weeden D, Suckling K, Davis C, Sizer N, Moore R, Thau D, Birch T, Potapov P, Turubanova S, Tyukavina A, de Souza N, Pintea L, Brito JC, Llewellyn OA, Miller AG, Patzelt A, Ghazanfar SA, Timberlake J, Klöser H, Shennan-Farpón Y, Kindt R, Lillesø JB, van Breugel P, Graudal L, Voge M, Al-Shammari KF, Saleem M. An ecoregion-based approach to protecting half the terrestrial realm. BioScience. 2017;67(6):534–45.
16. Silverman D. Interpreting qualitative data: Methods for analyzing talk, text and interaction. 3rd ed. London, UK: Sage Publications Ltd.; 2006.
17. Gann GD, McDonald T, Walder B, Aronson J, Nelson CR, Jonson J, Hallett JG, Eisenberg C, Guariguata MR, Liu J. International principles and standards for the practice of ecological restoration. Restor Ecol. 2019;27:S1–46.
18. Food and Agriculture Organization of the United Nations (FAO), 2020. Global Forest Resources Assessment 2020 – Terms and Definitions. Food and Agriculture Organization of the United Nations, Rome, Italy.
19. Korda M. A Magyarországon inváziós fafajok elterjedésének és elterjesztésének története (*History of the spread and expansion of invasive tree species in Hungary*) (Doctoral dissertation). Sopron, Hungary: University of Sopron; 2019.
20. Elorrieta O. La política que puede y debe hacerse en España. Reconstitución económica de España y problemas de la tierra. Montes e Industrias. 1934;42:143–5.
21. Johann E. Historical development of nature-based forestry in Central Europe. In: Diaci J, editor. Nature-based forestry in Central Europe. Ljubljana, Slovenia: University of Ljubljana; 2006. p. 1–18.
22. Cottin C. Bilan quantitatif et impacts de l'action du Fond forestier national. Réflexion sur l'évaluation du Fond forestier national. Direction de l'Espace rural et de la Forêt, Paris, France. 1995.

23. Winkler I, Krajčič D. Zagotavljanje gozdne reprodukcije. Gozdarski Vestnik. 1998;56:18–24.
24. Stolk C. De hel van Jipsinghuizen. 1924–1939: werkverschaffing in Groningen. Meinders, Groningen, Netherlands. 1988.
25. Zundel R, Schwartz E. 50 Jahre Forstpolitik in Deutschland (1945 bis 1994). Landwirtschaftsverlag, Münster-Hiltrup, Germany. 1996.
26. Miklavžič J. Melioracija smrekovih monokultur na Pohorju. Gozdarski inštitut Slovenije, Ljubljana, Slovenia. 1958.
27. Mlinšek D. 40 Jahre Überführung von Monokulturen. Österreichische Forstzeitung. 1990;101:36–8.
28. Diaci J. Nature-based silviculture in Slovenia: origins, development and future trends. In: Diaci J, editor. Nature-based forestry in Central Europe. Ljubljana, Slovenia: University of Ljubljana; 2006. p. 119–31.
29. Bartsch N, von Lüpke B, Röhrig E. Waldbau auf ökologischer Grundlage. 8th ed. Stuttgart, Germany: Verlag Eugen Ulmer; 2020.
30. Müller J, Bußler H, Goßner M, et al. The European spruce bark beetle Ips typographus in a national park: from pest to keystone species. Biodiv Conserv. 2008;17:2979–3001.
31. Viljur ML, Abella SR, Adámek M, Alencar JBR, Barber NA, Beudert B, Burkle LA, Cagnolo L, Campos BR, Chao A, Chergui B, Choi CY, Cleary DFR, Davis TS, Dechnik-Vázquez YA, Downing WM, Fuentes-Ramirez A, Gandhi KJK, Gehring C, Georgiev KB, Gimbutas M, Gongalsky KB, Gorbunova AY, Greenberg CH, Hylander K, Jules ES, Korobushkin DI, Köster K, Kurth V, Lanham JD, Lazarina M, Leverkus AB, Lindenmayer D, Marra DM, Martín-Pinto P, Meave JA, Moretti M, Nam HY, Obrist MK, Petanidou T, Pons P, Potts SG, Rapoport IB, Rhoades PR, Richter C, Saifutdinov RA, Sanders NJ, Santos X, Steel Z, Tavella J, Wendenburg C, Wermelinger B, Zaitsev AS, Thorn S. The effect of natural disturbances on forest biodiversity: An ecological synthesis. Biol Rev. 2022;97(5):1930–47.
32. Kraus D, Krumm F. Integrative approaches as an opportunity for the conservation of forest biodiversity. European Forest Institute, Freiburg, Germany. 2013.
33. UN and FAO. Who owns our forests? Forest ownership in the ECE region. United Nations Publication, Geneva, Switzerland. 2019.
34. Sarvašová Z, Ali T, Đorđević I, Lukmine D, Quiroga S, Suárez C, Hrib M, Rondeux J, Mantzanas KT, Franz K. Natura 2000 payments for private forest owners in Rural Development Programmes 2007–2013 - a comparative view. Forest Policy Econ. 2017;99:123–35.
35. EC (European Commission). LIFE Public Database. 2023. https://webgate.ec.europa.eu/life/publicWebsite/search (accessed 2024.04.29).
36. Interact. Keep.eu: Interreg projects and documents. 2023. https://keep.eu/projects/ (accessed 2024.04.29).
37. Sotirov M, Arts B. Integrated Forest Governance in Europe: An introduction to the special issue on forest policy integration and integrated forest management. Land Use Policy. 2018;79:960–7.
38. Stevens N, Bond WJ. A trillion trees: carbon capture or fuelling fires? Trends Ecol Evol. 2023;39(1):1–4.
39. Meadows DH. Whole earth models and systems. CoEvol Q. 1982;34:98–108.

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