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Coppice forests: Between management, conversion and restoration

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Abstract: Coppice is the oldest form of systematic and sustainable use of forests, and is currently applied on about 29 million ha (about 14% of total forest land area) in Europe. It had its maximum spread in the 16th century, when an estimated 36% of all forested land in Europe was managed for coppice. Coppice forests were the most important source of fuelwood until the mid-19th century, when firewood and charcoal were substituted by alternative fuels, and the demand for construction wood increased. Consequently, coppices (both low and coppice-with-standards) started to be converted to high forests, and the process was driven by national policies and/or subsidies, which is still the situation in some European countries. During the 20th century, coppicing was abandoned in many places across Europe due to the abandonment of the countryside and population migration into cities, as well as changes in socio-economic conditions, technical advances and political restrictions. However, coppicing is still important in many European countries as the main source of firewood for the rural population, who has limited access to other sources of energy. In this context, this paper presents the most important characteristics of this complex abandonment/management/conversion picture, emphasising the pros and cons for the future of coppices across Europe.

Keywords: biodiversity; coppice conversion; coppice restoration; firewood vs industrial wood; history; rural population

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Currently, the world's population exceeds 8.27 billion people (Worldometer 2026), with 55% living in urban areas (United Nations 2018), a figure projected to rise to 70% by 2050 (UNSD 2025). The most urbanised regions include North America (with 82% living in urban areas in 2018), Latin America and the Caribbean (81%), Europe (74%) and Oceania (68%). In Europe (47 countries), the rural population was 26.9% in 2023. Much higher percentages (over 40%) were found in countries such as Liechtenstein (85.38%), Faroe Island (57.01%), Moldova (56.63%), Bosnia and Herzegovina (49.73%), Slovakia (45.97%), Romania (45.33 %), Slovenia (43.91%), Serbia (42.89%), Croatia (41.42%), North Macedonia (40.52%), and Austria (40.47%) (The Global Economy 2025). In contrast, in 2023, countries such as Luxembourg (7.92%), the Netherlands (6.82%), Iceland (5.96%), Malta (5.06%), San Marino (2.16%), and Belgium (1.81%) had less than 10% rural populations (The Global Economy 2025).

Both urban and rural populations need energy for different purposes, from transport to heating and cooking. Globally, the total primary energy supply is met by fossil fuels (81%), nuclear energy (5%) and renewable energy sources (14%), of which about 70% is derived from biomass (Popp et al. 2021). 15 years ago, about 15% of global energy requirements would have been provided by biomass, of which about 13% was used in developing countries, the remaining 2% in developed countries (Baldini et al. 2007, as cited in Picchio et al. 2009). The total global biomass supply from agriculture and forestry is estimated at about 11.9 billion tons of dry matter annually, of which 61% is produced by agriculture and 39% by forestry. Wood biomass is primarily used as fuelwood for heating and cooking and power generation (23%), and as industrial roundwood converted to sawlogs for construction, paper and cardboard production (8%). Waste (primary residues) makes 8% (Popp et al. 2021).

In the European Union, biomass for energy (bioenergy) continues to be the main source of renewable energy, with a share of about 59% in 2021 (European Commission 2025). Forestry is the main source of this (logging residues, wood-processing residues, fuelwood, etc.) and accounts for more than 60% of all EU domestic biomass: in 2016, direct supply of woody biomass from forests and other wooded land contributed 32.5%, and indirect supply of wood contributed another 28.2%. Wood is the most important single source of renewable energy in many member states, for example, in Latvia (29%), Finland (24%), Sweden (20%), Lithuania (17%) and Denmark (15%), which have the largest proportion of wood and wood products consumption for energy (Eurostat 2025).

Globally, annual roundwood harvesting has amounted to about 4 billion m^3 in recent years, around half of which has been used for fuel, either directly (as fuelwood) or in the production of charcoal and pellets (FAO 2024). Coppice forests are a major source of this biomass for energy/fuel worldwide, as these regenerate from vegetative shoots, originating from the stump and/or the roots, depending on the species (Nicolescu et al. 2017). Coppice forests are characterised by short rotations (from 5–15 years up to 50–60 years), and are managed using various systems, of which simple (or low) coppice and coppice-with-standards are the most common. Simple (low) coppice is, without any doubt, the oldest silvicultural system known (Troup 1928; AFOCEL 1982; Auclair 1982), and the first evidence in Britain dates from the early Neolithic times (4000–3900 BC) (Peterken 2001; Starr 2008; Rackham 2015; Crowther, Evans 1984). Later, the Greeks and Romans preferred coppice to the detriment of high forest systems [Cato the Elder (234–149 BC), as cited in AFOCEL 1982]. They were aware of the resprouting potential of hardwoods and the coppice forests (so-called *sylvae caeduae* and *sylvae minutae*) were managed on a continuous basis to produce vine stakes or firewood (Huffel 1907; Arnould et al. 1997). Coppice-with-standards is also a very old silvicultural system, with the earliest evidence in Britain dating from Neolithic times when standard trees were occasionally retained over several rotations to produce construction wood (Rackham 1990, as cited in Rietbergen 2001).

Coppice forests have been widespread in the Mediterranean and in large parts of Europe since the Roman Empire (Johann 2021). From the Middle Ages onward, coppicing was widespread. The wood was harvested for charcoal production to fuel the melting of iron-ore, for glass and salt production, as well as firewood, with oak-rich stands providing tanbark for leather production (Buckley 2020). Coppice forests reached their peak in the 16th century, when an estimated 36% of all forested land in Europe was managed in this way. However, their economic importance has declined since the

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second half of the 19th century as firewood and charcoal have been replaced with alternative fuels such as gas, coal, kerosene (Savill 1993, 2004; Fabbio 2016; Mariotti et al. 2017; Cutini et al. 2021) and when the demand for high value construction timber increased (Buckley 1992; Johann 2021; Montagnoli et al. 2016). Consequently, conversion of low coppices and coppice-with-standards to high forests began in the second half of the 19th century, for example in French state forests (Auclair 1982). The decline of low coppices accelerated after World War I, as rural electrification spread (Crowther, Evans 1984), and again after World War II, when oil and gas became readily available (Matthews 1989; Rădulescu, Vlad 1955; Müllerova et al. 2015, as cited in Šimková et al. 2023). Interest in coppice fell further in the 20th century when demand for its main products – firewood and charcoal – sharply declined following the availability of fossil fuels (Bottero et al. 2022) and as tanbark was replaced by chemical tanning agents (Kamp 2022). The long-term decline of coppice forests was exacerbated by their low yield, low productivity, low vitality of stumps (the old ones show a high share of discolouration or rot – Figure 1A, B) and poor quality of wood and timber compared to high forest (Buckley, Mills 2015; Dodan, personal communication).

Coppicing has now been abandoned due to the lack of management in many places across Europe (Van Calster et al. 2007, as cited in Baaten et al. 2009; Zeneli, Kola 2017; Müllerova et al. 2015, as cited in Notarangelo, La Marca 2021). The reasons are abandonment of the countryside, migration from the mountains to the plains and from south to north, harvesting costs due to the high labour costs and lack of mechanisation, changes in socio-economic conditions, technical and political restrictions (Ciancio et al. 2006; Picchio et al. 2009; Chianucci et al. 2016; Mariotti et al. 2017; Notarangelo et al. 2018; Camponi et al. 2022). Abandonment results in so-called 'aged coppices' or 'stored coppices' (stands left growing beyond the customary coppice rotation – Picchio et al. 2009), which occupy important areas in different European countries (e.g. in Italy 89% of the whole coppice area – Chianucci et al. 2016). Abandoned coppice quickly resembles high forests (UK – Kirby et al. 2017) or will probably evolve towards a transitional high forest through thinning (Harmer 2004; Italy – Picchio et al. 2009; Mariotti et al. 2017; Spain – Núñez et al. 2012; Piqué, personal communication); however, the nature and time frame of succession processes tend to be unpredictable (Notarangelo et al. 2018).

Although – 'in many areas of the world, including Europe, existing coppice woodlands are considered relics by a bygone age' (Harmer 2004), this management system is still applied across large areas in different parts of Europe. Since the 16th century, 15 million ha of European coppice has been abandoned (McGrath et al. 2015, as cited in Kamp 2022), but there is still over 29 million ha (about 14 per cent of total European forest area) managed in this way. The countries where coppice forests are still important are listed in Table 1.

(A)

(B)

Figure 1. Hollow trunk of a sessile oak tree treated as coppice (second generation) (Photo V.N. Nicolescu)

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Table 1. The most important European countries in terms of area covered by coppice forests (taken partially from Unrau 2018)

Country	Area	
	ha	% of total forest area
France	6 372 000	38
Turkey	4 874 712	41
Spain	4 000 000	22
Italy	3 666 310	39
Greece	1 930 000	49
Ukraine	1 531 824	16
Serbia	1 456 400	54
Bosnia and Herzegovina	1 252 200	59
Portugal	863 000	27
Hungary	581 420	28
North Macedonia	564 000	57
Croatia	533 828	28
Bulgaria	481 747	13

Coppicing is almost forgotten as a management method in some European regions (Poleno et al. 2009, as cited in Šimková et al. 2023), with the lowest areas in the Netherlands (1 500 ha = 0.4%) and the UK (2 000 ha = 0.1%) (Unrau 2018).

What happens currently to the coppice forests in Europe? Obviously, they are not all treated the same: (*i*) they may have been abandoned without any practice of silviculture for different reasons for decades, (*ii*) they may continue to be managed under the traditional coppice regime as a major source of firewood, or (*iii*) they may have been converted to high forests (Fabbio, Cutini 2017, as cited in Cutini et al. 2021).

Due to this situation, the objective of the paper is to present and analyse these three options in-depth, and to draw some relevant conclusions on the future of coppices in Europe. Such an approach is, to best of our knowledge, the first attempt of this kind at a pan-European level and it is necessary to consider this for two reasons: (*i*) the ecological, economic and social importance of coppices in various areas of our continent, and (*ii*) the fact that this significant management method is not acknowledged as important in program documents such as the EU Biodiversity Strategy for 2030 (European Commission 2020) and the New EU Forest Strategy with the same time horizon (European Commission 2021).

METHOD

Our analysis, which is a narrative review, was conducted using Web of Science (WoS) Core Collection. Literature searches, which had no restrictions in terms of language or year of publication, were conducted using combinations of keywords related to coppice systems, including, but not limited to: coppice forests, coppice management, coppice conversion, coppice restoration, all of them at the European level. As a result, WoS database included an abundance of existing literature: 230 results for coppice management in Europe, 41 results for coppice conversion in Europe and 32 results for coppice restoration in Europe. We also took into account other scientific publications belonging to Journal Citation Report (JCR) indexed journals, as well as the available grey literature from different European countries and published in different national languages, as recommended by experts in coppice-related issues. Expert knowledge and personal communications were also used to complement the peer-reviewed literature, especially for regions, forest species and management systems that are underrepresented in international journals. The expert inputs were applied primarily for contextual interpretation and regional comparison, and not as a substitute for published scientific evidence. Last but not least, relevant institutional and policy documents such as FAO reports, European Commission strategies or COST Action FP1301 outputs, as well as national silvicultural guidelines, were consulted.

The output of this selection work, based on individual relevance to the topics – coppice management, coppice conversion, and coppice restoration – pursued in our review paper, is 116 references (109 books and articles and 9 web references) included in the reference list at the end. However, due to differences in the use of terminology, there may be additional sources in the literature that we remain unaware of, and therefore have not been considered in this analysis.

CURRENT AND FUTURE MANAGEMENT OF COPPICE FORESTS IN EUROPE

Coppice forests with native tree species. As previously stated, coppice is 'the oldest form of systematic and sustainable use of forests' (Fabbio et al. 2017, as cited in Šimková et al. 2023),

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'one of the oldest forms of systematic utilisation of forests carried out by human beings' (Corcuera et al. 2006, as cited in Notarangelo, La Marca 2021), and considered 'the best form of management for small forest owners' (Dengler 1935), or 'a rational model of forest management, especially for small private owners' (Gil 2018). Coppicing is still important in the more southerly, Mediterranean parts of Europe (Italy, Spain, Greece, Portugal – Gil 2018), the Balkans (Serbia, Bosnia and Herzegovina, North Macedonia, Croatia, Albania, Bulgaria) and France. Forests in these countries are dominated by native broadleaved coppice species such as oaks (e.g. *Quercus robur*, *Q. petraea*, *Q. pubescens*, *Q. cerris*, *Q. frainetto*, *Q. pyrenaica*, *Q. ilex*, *Q. faginea*, *Q. canarensis*, in Austria, Bosnia and Herzegovina, Bulgaria, Croatia, Greece, Italy, Portugal, Slovakia, Spain, Turkey, etc. (Ciancio et al. 2006; Durkaya et al. 2009; Núñez et al. 2012; Salomón et al. 2017; Trajkov et al. 2019; Manetti et al. 2020; Cutini et al. 2021; Johann 2021; Ganatsas et al. 2022; Carvalho 2023; Šimková et al. 2023; Dodan, personal communication; Piqué, personal communication; Višnjić, personal communication), European beech *Fagus sylvatica* (Nocentini 2009; Coppini, Hermanin 2007; Ciancio et al. 2006; Chianucci et al. 2016; Mariotti et al. 2017; Dodan, personal communication; Piqué, personal communication), and sweet chestnut *Castanea sativa* (Italy, Spain – Ciancio et al. 2006; Piqué, personal communication). In coppice-with-standards, less important forest species such as *Fraxinus excelsior*, *Acer pseudoplatanus*, *A. platanoides*, *Sorbus torminalis*, *S. domestica*, and *Prunus avium* are grown in the overstory with *Carpinus betulus*, *Acer campestre*, *Ulmus nimor*, and *Tilia cordata* in the understory (Johann 2021).

There are many reasons for the current management of native broadleaved species as coppice and continuing to do so; the most relevant are as follows:

– Coppices (low) are the main source of firewood for local communities in rural areas (Diku et al. 2017, as cited in Lazdina, Celma 2017), so the production of bioenergy from coppice forests could play a role in reducing emissions from fossil fuels (Bottero et al. 2022).
– Coppice-with-standards provide both firewood and larger timber for building and furniture, simultaneously increasing biodiversity value by providing additional habitat for old-growth and deadwood dwelling species (Dolek et al. 2018, Mölder et al. 2019, Weiss et al. 2021, all cited in Kamp 2022).
– The management is simple to apply, needing little expertise (Zeneli, Kola 2017).
– The rotation periods are shorter than those of high forests (Cutini et al. 2021; Bottero et al. 2022).
– Regeneration is usually reliable and cheaper than natural or artificial regeneration by seed (Zeneli, Kola 2017).
– Coppice regeneration is less damaged by wildlife than artificial planting, an important consideration with the increasing number of ungulates in Europe (Valente et al. 2020, Carpio et al. 2021, both cited in Šimková et al. 2023). In addition, coppice forests are resilient to browsing in the medium term and capable of recovery after a few years (Bottero et al. 2022).
– Coppices show higher drought tolerance due to the established root system, a benefit in the context of the risks associated with climate change (rainfall reduction, higher temperature, prolonged droughts, water stress, fire risks) (Cutini et al. 2021).
– Carbon sequestration combined with the use of wood products rather than fossil derivatives from active coppicing could support climate change mitigation (Bottero et al. 2022).
– The small size and fragmentation of private forests make coppice forest biomass production a viable additional income stream in rural areas (Zeneli, Kola 2017).
– Coppice (low) and coppice-with-standards show an increased species richness compared to high forests, which have more closed canopies (Ciancio et al. 2006).
– Coppices have high overall biodiversity value, as they provide habitat for many open ground species that are threatened and in decline in such as butterflies and moths, as well as supporting woodland birds, some of which are long-distance migrants, which are declining in Europe and are therefore of high conservation interest (Vollmuth 2022; Vacik et al. 2009; Kamp 2022).

Coppice forests are 'traditional landscapes', 'cultural landscapes', 'organically evolved landscapes' or 'continuing landscapes'. They have cultural values, and are an important component of cultural heritage, due to their centuries-long establishment of rules, customs and specific tools (Johann 2021; Slach et al. 2021, as cited in Kamp 2022), but

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their effective conservation should not be based on transforming them into ''museums of rural civilisation' (Santoro 2024).

Financial support to private owners can, with professional input, result in sustainable management of coppice forest resources and so contribute significantly to the ecological stability and economic development of the region (e.g. in the Western Balkans – Zeneli, Kola 2017). On this basis, coppicing can be recommended in different parts of Europe, as it may address a wide array of sustainability issues. As emphasised by Cutini et al. (2021), 'it may represent a sound Climate Smart Forestry option in mitigating the risk associated with climate change and providing complementary ecosystem benefits'.

Coppice management of non-native and fast-growing species. In Europe, in addition to native species, low coppices also include important non-native and fast-growing species, such as black locust (*Robinia pseudoacacia* L.) and eucalypts (*Eucalyptus* spp.), as well as fast-growing species such as poplars (*Populus* spp.) and willows (*Salix* spp.). Black locust, which has excellent sprouting ability, relative plasticity in the face of unfavourable growing conditions, and versatile usability of its wood (Nicolescu et al. 2020; Keserű et al. 2025), regenerates from stump shoots or, frequently, root suckers (Honfy et al. 2021; Keserű et al. 2025) and occupies over 2.3 million ha in Europe (Nicolescu et al. 2020). The species is treated in traditional coppice, with a rotation age up to 25 (30) years and yield 200 $m^3 \cdot ha^{-1}$ at 20 years and 290 $m^3 \cdot ha^{-1}$ at 30 years (Nicolescu et al. 2020). Black locust can also be treated as very short rotation coppice (SRC) (3–5 years) and short rotation coppice(5–7, even 10 years), for the production of biomass/bioenergy (Marosvölgyi, Vityi 2019; Honfy et al. 2021; CNPF Île-de-France Centre-Val-de-Loire 2023), and can produce up to 14 dry matter $t \cdot ha^{-1} \cdot yr^{-1}$ (Starker et al. 2015, as cited in Nicolescu et al. 2020). Despite not being the topic of our paper, the use of the above species in very SRC and SRC are included as their use for biomass production reduces the pressure on natural forests. Black locust has many *positive* socio-economic effects (e.g. a nitrogen-fixing species for waste land and surface-mine reclamation, for erosion prevention and control, for carbon sequestration, as windbreaks and shelterbelts, as an ornamental tree in parks, gardens, alleys, and as a street tree as it is tolerant of air pollution and salinity and thrives in the urban environment – all in Nicolescu et al. 2020), but can also have *negative* environmental effects on native vegetation as a light-demanding pioneer species that can substantially, and rather quickly, change the specific habitats which it invades (Vítková et al. 2016, 2017).

Eucalypt species, mainly *Eucalyptus globulus* (the main forest species in Portugal, covering 26.2% of the total forest area of the country – Malico, Gonçalves 2021), together with *E. maidenii*, *E. gunnii*, *E. viminalis* and *E. camaldulensis*, are fast-growing, have good stem characteristics and exceptional pulping quality (Miranda, Pereira 2015) so have a particular importance for pulp and paper production, especially in southern Europe (Portugal and Spain, along with France and Italy). These eucalypts occupy over 1.3 million ha, four times more than in 1970 (Deus et al. 2018, as cited in López-Sánchez et al. 2021), with over 80% found in the Iberian Peninsula. These are managed with rotations of (8) 10–12 years for three harvest cycles, with high forest in the first and coppice in the latter two (Malico, Gonçalves 2021; Kardell et al. 1986; Ferraz Filho et al. 2014; Carvalho et al. 2015; Cerasoli et al. 2016). Eucalypts are also used for very SRC, with rotations of 3 to 5 years (Carvalho et al. 2015). Poplars (both species and clones) show rapid growth rates, have a high capacity for vegetative reproduction, and are the most effective short- to medium-term carbon sequestration tool (Oliveira et al. 2020; Fuertes et al. 2023). They are used in traditional coppices (Fornes, Ricodeau 2023), very SRC (rotations 2–3 years), as well as SRC (7–8 years cycle) for energy purposes and yield up to 20 dry matter $t \cdot ha^{-1} \cdot yr^{-1}$ (Carvalho et al. 2015; Desair et al. 2022; Fuertes et al. 2023; Eubia 2026; Forestiers d'Alsace 2026). In the Mediterranen conditions, poplar very SRC (12-year plantation length, with 4 rotations each of 3 years) with irrigation play an active role in mitigating climate change from the third year from planting and can be profitable due to fast growth and so are an attractive proposition for the bioeconomy, and a profitable option for farmers, contributing to a robust and diversified energy mix (Fuertes et al. 2021, 2023). Last but not least, the majority of SRC and very SRC (rotations of 2–3 years) for biomass production across Europe consist of willows which produce up to 12 dry matter $t \cdot ha^{-1} \cdot yr^{-1}$ (Nguyen 2010; Dimitriou, Rutz 2015; Dimitriou et al. 2011; Lindegaard et al. 2016; De-

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sair et al. 2022; Forestiers d'Alsace 2026; Forest Research 2026). SRC and very SRC, 'forest crops specifically designed for the production of woody biomass' (Oliveira et al. 2020), have been important since the early 1970's, in the context of bioeconomic development based on the potential of natural resources, including biomass (Oliveira et al. 2020) and the need to reduce pressure on natural forests by providing a raw material for bioenergy and/or bioproducts demanded by society and industry (Fuertes et al. 2021). They currently cover only about 56 000 ha in the EU countries such as Sweden, Italy, Poland, the UK, Germany, and are not likely to have a future without specific subsidies and political support (Schiberna et al. 2021).

COPPICE CONVERSION – CURRENT AND FUTURE APPROACHES

Conversion is the transition of a forest from one specific regeneration method to another regeneration method, by change in the management objectives, such as targeted yield or products – industrial wood vs. firewood (Constantinescu 1973; Nicolescu et al. 2017; Caglayan et al. 2018). Obviously, this will also require the transition from one silvicultural system to another (Ionescu 1932, Stinghe 1952, both cited in Constantinescu 1973; Matthews 1989).

Over time three regeneration methods, high forest (with most trees regenerated by seed), coppice and coppice-with-standards, have been differentiated, so conversion can be carried out in six possible directions (Boppe 1889; Popovici 1922; Perrin 1954; Lorentz, Parade 1883; Rădulescu 1956; Rucăreanu 1962; Constantinescu 1973; Giurgiu 1988; Bastien 2001; Rădulescu, Vlad 1955; Rucăreanu, Leahu 1982; Ningre, Dussot 1993), these are: (*i*) from high forest to simple coppice or to coppice-with-standards, (*ii*) from simple coppice to coppice-with-standards or high forest, and (*iii*) from coppice-with-standards to simple coppice or to high forest.

However, in stands from various European countries where conversion techniques have been applied (from Portugal and Spain to France and Germany, from Slovakia and the Czech Republic to the Balkan countries such as Serbia, Croatia, Bosnia and Herzegovina, North Macedonia to Romania), this has mainly been from simple coppice or coppice-with-standards to high forest. The target is the transformation of less productive coppices, producing mostly small-sized firewood into more productive high forests, resulting in more large diameter logs with various industrial uses (especially for carpentry and furniture) (Rucăreanu 1962; Zeneli, Kola 2017; Manetti et al. 2020; Carvalho, personal communication) (Table 2).

Conversion results in the disappearance of the difference between the low-growing stock of coppice forests and that much bigger of high forest (4–6 times more – Stinghe 1939; 5–10 times more – Rucăreanu 1962). Coppice conversion targets may be (*i*) to increase forest owner's revenue, (*ii*) to improve the beneficial functions of the forests, (*iii*) to improve the structure, stability and resistance of forests to climate change and, in the long term, (*iv*) to increase the economic value of former coppice forests, (*v*) to increase the use of renewable energy sources in rural areas as well as (*vi*) to increase carbon sequestration and help climate change mitigation (Dodan, personal communication; Piqué, personal communication; Spyroglou, personal communication). Regarding the latter rationale it must be remembered that coppicing contributes to a quicker release of CO_2 back in the atmosphere so reducing the function of forest ecosystems as natural carbon sinks due to (*i*) shorter rotation periods than in case of high forests and (*ii*) management of coppice forests mainly for low-quality fuelwood production resulting in an immediately release of CO_2 back in the atmosphere (Ganatsas et al. 2022).

There are some specific situations where conversion is appropriate, for example:

Table 2. Different wood products derived from forests (per cent of total production) (based on Lanier 1986)

Regeneration method	Waste and small-sized wood	Fuelwood	Pulpwood	Sawlogs and veneer logs
High forest (broadleaves)	18	34	17	**31**
High forest (conifers)	13	14	25	**48**
Coppice (simple)	15	**65**	20	0
Coppice-with-standards	16	**58**	20	6

Bold – highlights differences between different forest types

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(*i*) The existing crop yield does not match the capability of the site for timber production and the owner seeks a higher income from the forest.
(*ii*) The soils are liable to damage under the present silvicultural system or, in degraded forests, conversion into high forest is necessary to protect the site.
(*iii*) Markets and communications have improved and national policy favours conversion.
(*iv*) There is a need to provide employment in the forest and wood-using industries.
(*v*) The aesthetic quality of the forest must be improved.
(*vi*) Advances in silvicultural techniques make conversion practicable (all in Matthews 1989).

On the contrary, coppice conversion is not appropriate when:
(*i*) The growing stock provides sufficient quantities of produce, such as fuelwood, to satisfy the needs of the owner or right holder so there is no incentive to change.
(*ii*) The existing forest occupies a particularly fragile site or one of low capability.
(*iii*) It has conservation value as a refuge for wild plants and animals.
(*iv*) It is suitable for field sports and recreational use.
(*v*) The aesthetic quality or historical significance is high (all in Matthews 1989).

Many methods of simple coppice conversion to high forests have been developed since the first half of 19th century, these can be grouped into direct conversions: (*i*) conversion by ageing – conversion by full cessation of simple coppice cuttings, (*ii*) mixed conversion –conversion by partial cessation of simple coppice cuttings, and (*iii*) conversion by replacement/restoration; and indirect conversions (through the use of coppice-with-standards). The most frequently used of these is conversion by ageing, considered a passive procedure, when the low coppice stand is no longer cut with a waiting period until it reaches maturity and so able to regenerate naturally by seed (Negulescu 1959; Rucăreanu 1962). During the waiting period, repeated selective thinning (from below – Ciancio et al. 2006; Piqué, personal communication – as well as thinning from above as part of a crop tree silviculture – Mariotti et al. 2017; Ganatsas et al. 2022; Piqué, personal communication) are applied. These cease when the stand reaches the regeneration rotation age, after which high forest silvicultural systems (e.g. uniform shelterwood cutting, group shelterwood cutting, irregular shelterwood cutting) are applied to encourage natural regeneration by seed (MFE 1966; Giurgiu 1988; Mariotti et al. 2017). Thinning improves the species composition, growth, and quality of the growing stock (Matthews 1989; Nocentini 2009; Ciancio et al. 2006) and accelerates the transition of coppice to high forest (Chianucci et al. 2016). However, as stressed by Motta et al. (2015, as cited in Notarangelo, La Marca 2021), conversion to high forest with repeated thinning requires more intensive management, and single interventions may not always be economically viable for the owner. Conversion by ageing, which increases the stand's carbon storage until the end of the high forest rotation age, for example 120 years in Greek oak stands (Vlachou, Zagas 2023), is applicable to healthy, vigorous, productive simple coppice stands, with full canopy cover, with a high proportion of the target species and soil conditions favourable to natural regeneration by seed (MFE 1966). This is the case of different European countries (Vacik et al. 2009) such as Bulgaria (Markoff 2017, as cited in Lazdina, Celma 2017; Velichkov et al. 2009; Kostov et al. 2019), Croatia (Dodan, personal communication), France (Matthews 1989), Italy (Montagnoli et al. 2016; Notarangelo et al. 2018; Manetti et al. 2020; Pelleri et al. 2021), Greece (Vlachou, Zagas 2023; Spyroglou, personal communication), Portugal (Carvalho 2023). The main tree species for conversion by this method are some species of *Quercus*, *Fagus* and *Castanea* (Table 3).

Coppice replacement/substitution is the second most commonly used conversion method in Europe. It is usually applied in degraded or low-productivity simple coppice stands that have a low proportion of valuable tree species, low canopy cover, old stumps with little potential for natural regeneration by seed, on compacted and fallow soils, etc. (MFE 1966). In such stands, substitution is usually done by clear-cutting, followed by planting, typically conifer species (*Picea abies*, *Pinus* spp.) (Bastien 2001), or following the clear cut with manual/mechanical seeding of species such as *Quercus* (Rădulescu, Vlad 1955). Replacement/substitution of degraded simple coppice, followed by planting, has been used at different scales in European countries (Vacik et al. 2009), such as Bosnia and Herzegovina (Višnjić, personal communication), Bulgaria (Velichkov et al. 2009), Croatia

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Table 3. Major and minor forest species to use in coppice stands under conversion to high forest in different European countries

Species	Country	Source
Fagus sylvatica L.	Italy	Coppini, Hermanin 2004; Ciancio et al. 2006; Chianucci et al. 2016; Mariotti et al. 2017; Scolastri et al. 2017; Pelleri et al. 2021
	Bulgaria	Markoff 2017, as cited in Lazdina, Celma 2017
	Croatia	Dodan, personal communication
	Romania	Negulescu 1959, 2018
Fagus × moesiaca (Maly) Czeczott	North Macedonia	Trajkov 2017, as cited in Lazdina, Celma 2017
Fagus orientalis Lipsky	Turkey	Bariş Özel, Ertekin 2017, as cited in Lazdina, Celma 2017
Quercus robur L.	France and Belgium	Bary-Lenger, Nebout 1993
	Slovakia	Feher 2017, as cited in Lazdina, Celma 2017
	Romania	Negulescu 1959; Nicolescu 2018
Quercus petraea (Matt.) Liebl.	North Macedonia	Trajkov 2017, as cited in Lazdina, Celma 2017
	France and Belgium	Bary-Lenger, Nebout 1993
	Belgium	Vandekerkhove 2017, as cited in Lazdina, Celma 2017
	Bulgaria	Markoff 2017, as cited in Lazdina, Celma 2017
	Slovakia	Feher 2017, as cited in Lazdina, Celma 2017
	Turkey	Bariş Özel, Ertekin 2017, as cited in Lazdina, Celma 2017; Bariş Özel, personal communication
	Romania	Negulescu 1959; Nicolescu 2018
Quercus cerris L.	North Macedonia	Trajkov 2017, as cited in Lazdina, Celma 2017
	Italy	Notarangelo et al. 2018; Manetti et al. 2020; Camponi et al. 2022
	Turkey	Bariş Özel, personal communication
	Grecia	Ganatsas et al. 2022
	Romania	Negulescu 1959; Nicolescu 2018
Quercus frainetto Ten.	North Macedonia	Trajkov 2017, as cited in Lazdina, Celma 2017
	Turkey	Bariş Özel, personal communication
	Romania	Negulescu 1959; Nicolescu 2018
Quercus trojana Webb	North Macedonia	Trajkov 2017, as cited in Lazdina, Celma 2017
Quercus pubescens Willd.	North Macedonia	Trajkov 2017, as cited in Lazdina, Celma 2017
	Turkey	Bariş Özel, Ertekin 2017, as cited in Lazdina, Celma 2017
	Croatia	Dodan, personal communication
Quercus coccifera L.	North Macedonia	Trajkov 2017, as cited in Lazdina, Celma 2017
Quercus pyrenaica Willd.	Portugal	Carvalho 2023; Carvalho, personal communication
	Spain	Núñez et al. 2012; Salomón et al. 2017
Quercus faginea Lam.	Portugal	Carvalho, personal communication
Quercus ilex L.	Portugal	Carvalho, personal communication
Castanea sativa Mill.	Portugal	Carvalho, personal communication

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(Dodan, personal communication), North Macedonia (Trajkov, personal communication), Romania (Rucăreanu 1962; Giurgiu 1988; Rucăreanu, Leahu 1982; MWFEP 2000), etc.

The drivers for coppice conversion are very diverse in the European context. In some former Communist countries, where the forests are broadleaved-dominated and were fully nationalised after the Second World War, this approach has been legally required (forest laws, national policies, technical norms). This is the case in the former Yugoslavian countries (e.g. Serbia, Croatia, North Macedonia, Montenegro, etc.), in Bulgaria and Romania (Krstic, personal communication; Trajkov, personal communication; Višnjić, personal communication). This is also the case in Turkey and Greece, where state-owned or public-owned forests dominate (99% in Turkey, 75% in Greece) and the state-imposed coppice conversion in all its own forests (Caglayan et al. 2018; Spyroglou, personal communication). A similar situation occurred in Central European former Communist countries such as Slovakia or Czech Republic, where this policy resulted in the area covered by coppice forests decreasing dramatically due to conversion: in Slovakia, from 208 438 ha in 1920 to 34 463 ha recently (Feher 2017, as cited in Lazdina, Celma 2017), and in the Czech Republic from 1 457 400 ha in 1845 to 109 900 ha in 2013 (Maděra et al. 2017, as cited in Šimková et al. 2023). In the UK, the area under coppice has reduced from 140 000 ha in 1947 (Kirby et al. 2017) to 2 000 ha in 2018 (Unrau et al. 2018). In Germany, the area of low coppice is currently ca 6 400 ha, compared to 678 500 ha in 1827 (Müller-Wille 1938, as cited in Kamp 2022), while coppice-with-standards cover just ca 5 000 ha, compared to 790 000 ha in 1883 (Vollmuth 2021, as cited in Kamp 2022), both changes the result of coppice conversion.

Conversion to high forest is mandatory for simple coppices of *Fagus sylvatica* and *Quercus* spp. older than 50 years in Tuscany (Italy) (Marchi, Travaglini 2017, as cited in Lazdina, Celma 2017). The same threshold age is used in Turkey, where coppice forests older than 50 years must be converted to high forests (Bariș Özel, Ertekin 2017, as cited in Lazdina, Celma 2017). In other countries, such as Croatia, coppice conversion has been driven by EU subsidies for public and private forest owners (Dodan, personal communication). Finally, in more liberal countries such as France, Italy and Portugal, all dominated by private broadleaved forests, there have been no legal requirements or obligations for coppice conversion (Carvalho, personal communication).

Even though many European countries have adopted plans and developed strategies for the conversion of existing coppice into high forest (Ganatsas et al. 2022), legal requirements or subsidies do not always achieve the desired results; coppice conversion requires suitable sites, species and market conditions, and should not be generalised (Carvalho et al. 2018). As emphasised by Fabbio (2016), coppice conversion is appropriate on fertile sites with dense stands, where the valuable tree species, even if sporadic, are an added value. The option of conversion has special significance in the public domain, particularly in (*i*) mountain areas, where the coppice system has been suspended due to low profitability and where high environmental sensitivity should be of primary importance, as well as (*ii*) areas which are valuable because of tree-specific composition and of scenic value, or are priorities for conservation. In countries like those of Western Balkans (Albania, Bosnia and Herzegovina, Kosovo, Montenegro, North Macedonia, Serbia), where conversion to high forest was believed to be achievable in several decades (Stajic et al. 2009, as cited in Zeneli, Kola 2017), this turned out to be unfeasible in practice mainly due to the social and economic conditions of the region: energy poverty is a significant problem, the use of firewood is widespread so the coppice forests producing this remain as a basic commodity for the present and future (Zeneli, Kola 2017). A similar situation is encountered in Bulgaria: two million households depended on firewood as energy in 2002 (Kostov 2002, as cited in Velichkov et al. 2009); firewood has been one of the most important and cheapest heat energy sources in the country since 1990, and between 1997 and 2005, firewood consumption tripled (Velichkov et al. 2009). In Romania, ca. 3.5 million households use firewood for heat; about 2.7 million of these are in rural areas. Last but not least, a warning should be given regarding converting coppice forests in different parts of Europe, especially in the southern and south-eastern areas: 'The overall conversion of coppice forests to high forests could lead in the long run to (*i*) less income to forest villagers, (*ii*) increase of forest crimes such as unauthorised logging and (*iii*) unauthorised grazing (Bekiroğlu et al. 2013). The lower income for communal or private forest

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owners was a key reason for the success of coppice conversion applied long term and on a large scale only in public forests (in the case of France or Belgium – Bary-Lenger, Nebout 1993). Consequently, in countries such as Greece, private forest owners have no incentives to convert their coppice forests because they will lose revenue. They lobby the state for subsidies for converting the 25% of coppice forested area as they are required by law (Spyroglou, personal communication).

RESTORATION OF COPPICE FORESTS

In many parts of Europe, restoration of different forms of coppice is considered as legitimate and there have been attempts at its reintroduction since the second half of the 20th century for example in the UK from 1964 (Rackham 1976), Germany (since 1966 – Strubelt et al. 2019), and the Czech Republic (after 1999 – Utinek 2004; Vild et al. 2013) (all cited in Kozdasová et al. 2024). It can contribute to landscape diversity (Rackham 1976, as cited in Coppini, Hermanin 2007; Kozdasová et al. 2024) and help maintain biodiversity by providing habitats for plants and animals typical of more open coppice stands which would not survive in high forest stands. This is one reason for the increase in the area of so-called 'open forests' favoured by biologists (Buckley 1992, Harmer, Howe 2003, both cited in Kadavý et al. 2015). The main argument for this change is the decline of biodiversity in high forests and the need to enhance biodiversity for the future (Kadavý et al. 2015). Consequently, the restoration of coppice is 'an improvement in the context of environmental-biological stability' (Andreatta 2006, Niemela et al. 1996, Joys et al. 2004, all cited in Coppini, Hermanin 2007). It produces a useful diversification in wood production, forest work, and related skills (Coppini, Hermanin 2007).

Since the beginning of this century, there has been renewed interest in coppice because of (*i*) its higher biodiversity (Valbuena-Carabana et al. 2008, Van Calster et al. 2008, both cited in Kneifl et al. 2011); (*ii*) its higher production of firewood in short rotations (Proe et al. 1999, as cited in Kneifl et al. 2011); (*iii*) the global economic crisis; and (*iv*) constantly increasing prices of fossil energy sources. Other reasons for coppice restoration are (*v*) educational (it is a tool to inform and educate foresters, students and the wider public); (*vi*) as coppices are resistant to heat and drought (they are thought to be the best solution to preserve forest ecosystems against the effects of climate change-related drought, e.g. in the Mediterranean regions); and (*vii*) as a source of firewood for small forest owners living in the countryside (Kozdasová et al. 2024). Unfortunately, there are challenges to restoration/reintroduction of coppices in Europe such as legal frameworks that limit the use of coppices through the forest laws, negative public opinion of coppice cuts, lack of workforce to carry out coppicing, biotic factors (such as invasive species, as well as high ungulate populations), and abiotic factors, most significantly drought (Kozdasová et al. 2024).

The restoration or reintroduction of coppice has received support from the EU on the basis of energy production from renewable resources (Jansen, Kuiper 2004, as cited in Kneifl et al. 2011). Surprisingly, as mentioned before, neither the EU Biodiversity Strategy for 2030 (European Commission 2020) nor the New Forest Strategy for 2030 (European Commission 2021) mention coppices as a conservation and/or restoration target despite including primary and old-growth forests, closer-to-nature forestry and continuous cover forestry. This is surprising in the context of EU countries where broadleaved coppice forests cover millions of hectares (e.g. France, Italy, Spain) and are owned by millions of small-scale forest owners.

CONCLUSION

Coppice, 'a very ancient but modern system as well' (Fabbio 2016), currently faces three options:

(*i*) It can be managed continuously using traditional rotational silvicultural systems, as they are a valuable and sustainable source of various wood products (Buckley, Mills 2015), have important ecological functions, contribute to biodiversity conservation and represent traditional landscapes, integral to cultural heritage, and are still crucial for the future wellbeing of rural communities and the environment in many parts of Europe (Santoro 2024). Coppice forests have a silvopastoral use and have proved to be stable, resilient and adaptable to climate change (Buckley, Mills 2015).

(*ii*) It can be converted to high forest, a process driven by political measures at country level, by national or European subsidies, and/or by the need to produce large wood products for specific important industrial uses.

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(*iii*) It can be restored in recognition of the multiple functions that coppice forests play, especially in rural areas, from the provision of fuelwood to plant, animal and landscape diversity.

In this wide and complex context, we strongly believe, along with Antrop (2005, as cited in Santoro 2024), that 'Traditional landscapes ... should not be preserved as museums; they can be maintained and valorised making them the multifunctional and sustainable basis of the rural society and economy'. Despite the trend for conversion, coppice is likely to remain a good option for woodland management into the future and can gain more ground if it is accepted as a viable alternative to high forest, particularly for small woodland owners (Kozdasová et al. 2024).

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