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Wild Service Tree (*Sorbus torminalis* (L.) Crantz): A Review of Autecology, Silviculture, Dispersal Potential, and Response to Climate Change

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ABSTRACT

Climate change is expected to reduce the distribution range of major tree species in Europe. As a result, rare and underutilized tree species are gaining importance, despite limited research on their ecological characteristics. One such species is wild service tree (*Sorbus torminalis* (L.) Crantz), which has the potential to enhance the resistance, resilience, and adaptability of forest ecosystems to climate change. This paper provides an overview of previous research on its autecology, silvicultural characteristics, dispersal potential, and response to climate change. Wild service tree is native to Europe, northwestern Africa, and southwestern Asia. It exhibits broad ecological tolerance and thrives in various soil types, with a preference for deep, humus-rich soils while avoiding dry sandy and marshy conditions. In the Balkans, it grows at altitudes between 250 and 1400 meters above sea level, predominantly in thermofillic oak and beech forests, and less frequently in pine communities on sunny exposures. The species tolerates a wide range of climatic conditions, including low winter temperatures and summer droughts. Natural regeneration occurs primarily through root suckers, with seed-based regeneration being less frequent. For successful establishment, young plants should be planted in small groups within cleared patches of oak and beech forests. Post-planting protection against browsing and damage from rodents is essential. From the sapling stage onward, it requires high light availability for optimal growth. Due to limited seed production and strong competition from other tree species, the natural spread of wild service tree is relatively slow. Its expansion is more likely in cleared thermophilic habitats and can be accelerated through targeted afforestation efforts. Wild service tree exhibits high drought tolerance, making it a valuable species for areas affected by climate change. Its range is expected to expand in sessile oak and thermophilic beech forests. When combined with other drought-resistant tree species, it may contribute to stabilizing forest structures and mitigating the impacts of climate change.

Keywords: wild service tree; *Sorbus torminalis* L. Crantz; autecology; silviculture; potential dispersal; climate change

INTRODUCTION

Frequent and intensifying droughts are driving significant changes in forest ecosystems, altering tree species composition, competition dynamics, biodiversity, and stand stability. These changes also affect carbon sequestration and have long-term economic consequences (Kunz et al. 2018). One of the most pressing challenges in modern forestry is the widespread decline of commercially important and dominant tree species due to extreme climatic events (Hanewinkel et al. 2013).

European beech (*Fagus sylvatica* L.) and Norway spruce (*Picea abies* (L.) H. Karst.), two of the most important tree species in European forests, are particularly vulnerable to extreme climate conditions. Their distribution is expected to shrink significantly under future climate scenarios (Walentowski 2017, Buras and Menzel 2018). To mitigate these impacts, it is crucial to explore alternative native tree species that are better suited to the increasing intensity and frequency of droughts. Research on integrating drought-resistant and adaptive native species into forestry practices is gaining momentum across Europe (Koch et al. 2022). Such efforts support the development of stable, resilient forest ecosystems that align with principles of economically sustainable forestry (Lindner 2000, Bolte et al. 2009, Vitali et al. 2017).

One promising species is wild service tree (*Sorbus torminalis* (L.) Crantz), a deciduous tree species from the Rosaceae family known for its remarkable ecological tolerance and adaptability to various soil types. Although often associated with sub-Mediterranean climates, its natural range extends across Western, Central, and Southern Europe, as well as mountainous regions in Northwestern Africa and Southwestern Asia. In Bosnia and Herzegovina, it thrives in deep, moderately dry to fresh soils on diverse geological substrates, showing a preference for warm exposures and mild climatic conditions. It is commonly found in mixed oak and beech stands, highlighting its ecological plasticity and ability to adapt to different light and soil conditions.

Despite being a rare and underutilized native species, wild service tree holds significant potential in the face of climate change, particularly in areas where beech, spruce, fir, and valuable broadleaf species are retreating. Its resilience to drought, high-value timber, and potential for biodiversity enhancement and rural income diversification make it a valuable species for future forestry strategies. Promoting climate-smart forestry (CSF) through the inclusion of rare native species like wild service tree could shift traditional forest management perspectives, emphasizing ecosystem services and long-term sustainability over short-term economic gains (Koch et al. 2022).

This study explores the ecological characteristics of wild service tree and its contribution to building resilient forest ecosystems. It examines its distribution across various forest communities, seed production and propagation strategies, silvicultural traits, and interactions with other tree species. Additionally, they study assesses its potential range expansion in response to climate change and its suitability for restoring degraded forest ecosystems.

ECOLOGY AND DISTRIBUTION OF WILD SERVICE TREE

Wild service tree is considered by some authors to be a sub-Mediterranean species (Oberdorfer 1994), yet it is widely distributed across Western, Central, and Southern Europe, as well as in the mountainous regions of northwestern Africa and southwestern Asia (Welk et al. 2016).

It exhibits remarkable adaptability to various soil types, thriving in base-rich, slightly to moderately acidic, humus-rich soils that contain rocky, clayey, or loamy fractions (Roper 1993, Oberdorfer 1994). However, it avoids excessively dry sandy soils and wet or swampy areas (Welk et al. 2016). According to Kotar (1998), although it can tolerate shallow and dry soils, vigorous and high-quality growth and development can be expected on deep, fresh, and nutrient-rich soils. In Slovenia, it is more commonly found on limestone than on silicate substrates (Brus 2012). According to Idžojtić (2004), in the continental part of Croatia, it typically grows on rendzinas and other soils on limestone and dolomite, particularly in exposed and warm locations.

In Bosnia and Herzegovina, the species predominantly grows in deep, warm, and moderately dry to fresh soils, such as calcaric cambisols and eutric and dystric cambisols, which develop on a range of geological substrates, including limestone-carbonate, peridotite-serpentinite, gabbro,

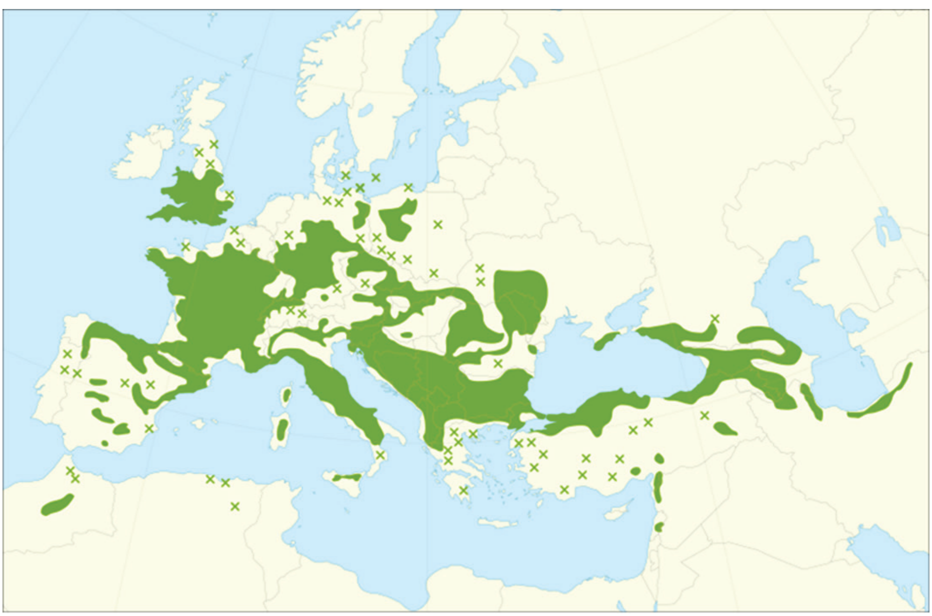

Figure 1. Distribution of wild service tree in Europe (Caudullo et al. 2017).

and silicate. Fukarek et al. (1974) report that it regularly occurs on peridotite-serpentinite substrates, while Beus (1979) documents its presence on deep soils, such as eutric cambisols (>40 cm), luvisols, and pseudogleys, but its absence on shallower soils like rankers and shallow eutric cambisols (<40 cm) over peridotite-serpentinite. Beus (1979) also records its occurrence on limestone soils, while Vojniković (2001, 2013) identifies it on deep eutric cambisols on gabbro in the Jablanica area and on dystric cambisols on cherts.

In Germany and Austria, wild service tree grows at elevations of up to 900 meters (Zeitlinger 1990, Oberdorfer 1997). Brus (2012) reports its occurrence in Central Europe at elevations around 900 m, reaching up to 1500 m on south-facing slopes. Kotar (1998) notes its presence in Slovenia at elevations of 650–700 m in the continental region, extending up to 900 m, in the sub-Mediterranean zone. According to Matić and Vukelić (2001) and Idžojtić (2004), in Croatia, it occurs between 150 and 400 m in the continental part of the country, while in the Mediterranean montane zone, it can be found up to 700 m. In Bosnia and Herzegovina, recorded elevations range from 250 to 800 m, with higher occurrences reported at up to 1,400 m (Šilić 2010) and between 300 and 1,300 m (Beus 1979). As a thermophilic species, it prefers horizontal terrains and sun-exposed slopes, particularly those facing south, southwest, and southeast. Its optimal average annual temperature range is 10 to 17°C (Montero et al. 2002), with a minimum precipitation requirement of around 600 mm and an optimal range between 800 and 1,500 mm (Oria De Rueda 2002). The species is highly resilient to climatic extremes, tolerating low winter temperatures, spring frosts, summer droughts lasting up to two months, and strong winds (Haralamb 1967, Montero et al. 2002).

Oberdorfer (1994) classifies wild service tree as part of the syntaxonomic categories *Quercetalia pubescentis, Cephalantero-Fagenion,* and *Quercion roboris-petraea*. In Serbia, it has been recorded in oak alliances, including *Quercion pubescentis-petraeae, Quercion frainetto, Quercion petraeae-cerridis,* and *Fraxino orni-Quercion dalechampi* (Jovanović 1997, Tomić 2004, Cvjetićanin et al. 2007, Tomić and Rakonjac 2017). It is also present in beech forest communities such as *Helleboro odori-Fagenion moesiacae*, *Fago-Corylenion colurnae*, and *Ostryo-Fagenion moesicae*, as well as in black pine forests within the *Pinenion illyricum calcicolum* suballiance (Tomić 2004, Tatić and Tomić 2006, Tomić and Rakonjac 2017).

In Croatia, wild service tree is rare in the Mediterranean zone (Idžojtić 2004). According to Matić and Vukelić (2001), it is more common at higher elevations of the Mediterranean-montane belt, particularly in the *Ostryo-Quercetum pubescentis* (Ht. 1938) association, which consists of downy oak (*Quercus pubescens*) and hop-hornbeam (*Ostrya carpinifolia*). In the continental regions of Croatia, it occurs within the *Epimedio-Carpinetum* (Ht. 1938, Borh. 1963) association, which includes sessile oak (*Quercus petraea*) and common hornbeam (*Carpinus betulus*). More rarely, wild service tree is also found in the *Carpino betuli-Quercetum roboris* association (Anić 1959, Rauš 1969), an assemblage of pedunculate oak (*Quercus robur*) and common hornbeam that occurs in drier areas of Slavonia.

In Slovenia, according to Kotar (1998), wild service tree is widely distributed. Brus (2012) specifically mentions its presence in Dolenjska, Styria (Štajerska), Prekmurje, and Bela Krajina, with exceptionally well-formed trees also recorded in the Gorenjska region near Kranj. According to the same author, wild service tree in Slovenia is found within several forest communities, including *Querco-Luzulo-*

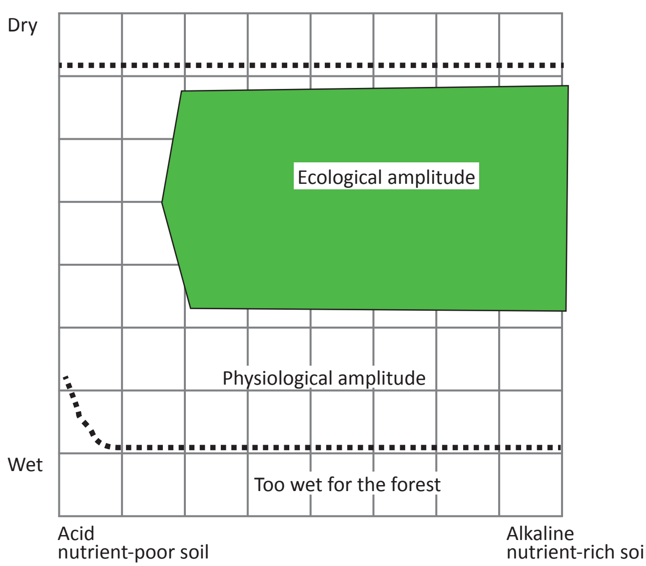

Figure 2. Soil ecogram for wild service tree (Kotar et al. 1995, after Zeitlinger 1990).

Fagetum, Querco-Carpinetum, Querco-Fagetum, Hacqueto-Fagetum, Ostryo-Quercetum pubescentis, and *Bromo erecti-Quercetum pubescentis*.

In Bosnia and Herzegovina, studies have recorded *wild service tree* in numerous oak and beech (with fir) forest associations, typically as individual trees or, less frequently, in small groups. These include *Lathyro-Fagetum, Quercetum montanum illyricum, Quercetum frainetto-cerris, Quercetum petraeae-cerris, Seslerio autumnalis-Quercetum petraeae, Lathyro-Quercetum petraeae, Querco-Castanetum illyricum, Erico-Quercetum petraeae serpentinicum, Querco-Carpinetum illyricum, Ostryo-Fagetum, Aceri obtusati-Fagetum, Seslerio autumnalis-Fagetum, Blechno-Abietetum*, and *Abieti-Fagetum serpentinicum* (Pavlović et al. 1978, Stefanović et al. 1978, 1986, Beus 1979, Redžić et al. 1985, 1987, Grgić 1986, Stefanović et al. 1986, Šilić et al. 1986, Vojniković 2001, 2013). Additionally, Stefanović (1986) reports its presence in Scots pine forests on serpentinite (*Erico-Pinetum silvestris serpentinicum*).

In the central Balkans, *wild service tree* occurs in various oak, beech, and pine communities, which are predominantly meso-xerothermic. Sofletea and Curtu (2001, 2007) similarly describe it as a submesothermic species. As previously noted, wild service tree demonstrates broad ecological adaptability to different soil types. Its tolerance to light varies depending on forest conditions. In Slovakia (Paganova 2007, 2008) and the UK (Roper 1993), wild service tree is classified as heliophilous, often found as solitary trees in meadows, hedgerows, or as subspontaneous individuals in orchards. However, within its core distribution range in the Balkans, it demonstrates remarkable adaptability to varying light conditions within forest stands. For example, in Bosnia and Herzegovina, Redžić (1985) recorded wild service tree in beech and fir stands with *Blechnum spicant* (*Blechno-Abietetum*), characterized by a dense canopy. Similarly, Tomić and Rakonjac (2017) describe beech forests of the *Helleboro-Fagenion* suballiance as having a dense tree layer dominated by beech, with wild service tree and silver linden (*Tilia tomentosa* Moench) also present. Additionally, the species has been documented in beech and fir forests on serpentinite (*Abieti-Fagetum serpentinicum*) (Beus 1979), which are predominantly sciophilous.

In summary, within the analyzed Balkan region, wild service tree is predominantly found in warm, open to fully closed oak and beech stands, with occasional occurrences in pine forests. It thrives on deep soils across diverse substrates at elevations ranging from 250 to 1,400 m, favoring warm, sun-exposed slopes. Overall, wild service tree exhibits a remarkably broad ecological niche, displaying a high tolerance to a wide range of environmental conditions.

SILVICULTURAL CHARACTERISTICS

Seed and Nursery Production

Wild service tree begins flowering early, typically around 10 years of age, with abundant and frequent seed production starting between 15 and 20 years (Thomas 2017). Flowering occurs after leaf emergence, from May to early June (Faust and Fussi 2011, Thomas 2017). Its fruits

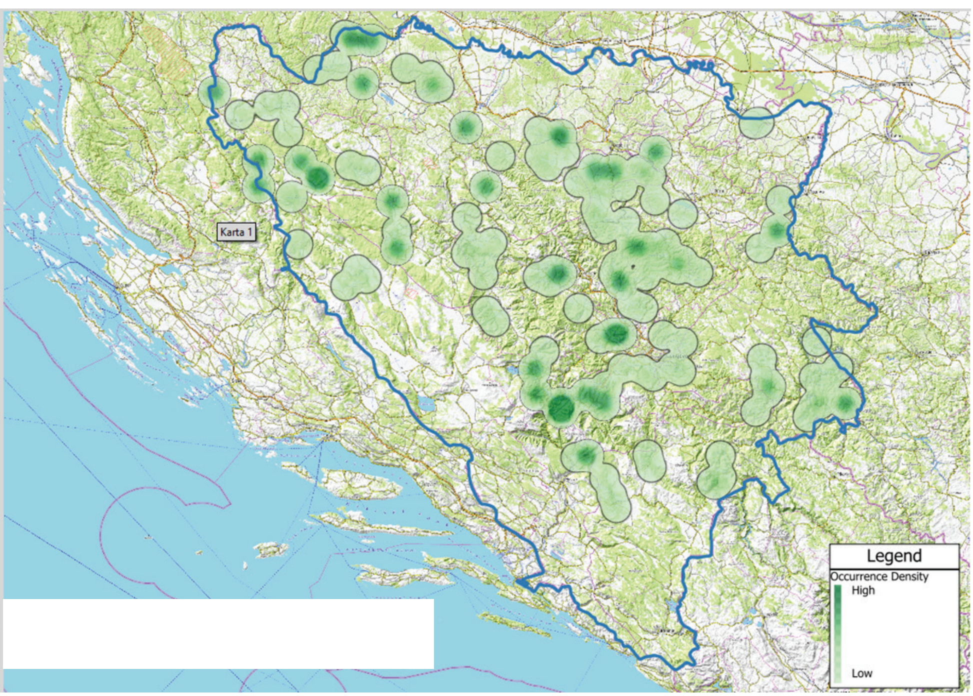

Figure 3. Spatial distribution of wild service tree in Bosnia and Herzegovina based on inventory data, literature sources (Pavlović et al. 1978, Stefanović et al. 1978, 1986, Beus 1979, Redžić et al. 1985, 1987, Grgić 1986, Stefanović et al. 1986, Šilić et al. 1986), and unpublished maps by Pavle Fukarek. Darker green shades indicate areas with higher occurrence of the species.

ripen between September and November (Rich et al. 2010, Drvodelić 2021). Good seed years generally occur every 2–3 years (Oršanić et al. 2009, Thomas 2017), at the edge of its range, it fruits even less frequently (Roper 1993). The fruits are small, round to oval, with average length from 12.67 to 15.85 mm, and average width of 10.63-12.10 mm (Bednorz 2007, Espahbodi et al. 2007, Oršanić et al. 2009, Memišević Hodžić et al. 2016). Initially, fruits are reddish-yellow colored, with light lenticels. Later they become leathery and brown (Faust and Fussi 2011). Fruits appear in clusters of 5–10 fruits (Oršanić et al. 2009, Welk et al. 2016). The seeds are light brown, oval, and range in size from 2 to 6 mm, with each fruit containing 2–4 seeds (Bednorz 2007, Oršanić et al. 2009). A kilogram of fruit contains approximately 1,300–1,500 seeds (Kausch-Blecken von Schmeling 1994), with an absolute weight of 1,000 seeds ranging from 18 to 24 grams.

Fruit collection takes place in September and October, either by handpicking directly from the tree or, less commonly, gathering fallen fruits from the ground (Faust and Fussi 2011). Seeds should be extracted immediately after harvesting, as decayed fruits can induce secondary dormancy, preventing germination in the following spring. Large-scale extraction is carried out using centrifugal pulp separators, while smaller quantities are processed manually (Kausch-Blecken von Schmeling 2000). After extraction, seeds are thoroughly washed and dried to a moisture content of 10%. When properly stored, they remain viable for 4–6 years at -5°C and up to 10 years in freezers at -21°C (Kausch-Blecken von Schmeling 2000, Faust and Fussi 2011, Drvodelić 2021).

Wild service tree seeds exhibit double dormancy, caused by chemical inhibitors in the seed coat and deep embryo dormancy (Thomas 2017). To overcome dormancy and ensure successful germination within the year of sowing, stratification is essential. The standard protocol involves cold moist stratification in sterile sand at +3°C for 120 days (ISTA 1996, Var et al. 2010). However, extended stratification can lead to pre-germination during storage, which may decrease seedling emergence. Some studies recommend a shorter stratification period of 105 days (Gültekin et al. 2007, Oršanić et al. 2009), while others suggest removing seeds after 14 weeks since the germination begins (Kausch-Blecken von Schmeling 2000). Ebinger (2010) proposed a two-stage process: an initial warm stratification at +20°C for 2–4 weeks, followed by cold stratification at +3 to +5°C for 16 weeks before sowing. Seeds from higher elevations require longer stratification (Oršanić et al. 2009), while larger seeds with greater absolute mass stratify more quickly. Germination rates after stratification vary from 40.1% (Drvodelić 2010) to 75% (Faust and Fussi 2011). A kilogram of seeds can yield between 13,000 and 20,000 seedlings (Peev 1969, Faust and Fussi 2011).

For direct sowing, non-stratified seeds can be planted in July, allowing natural stratification to occur in the soil throughout autumn and winter. With proper protection from birds and other pests, germination will take place the following spring with a good success rate (Buechner and Boehner 2010). Stratified seeds, on the other hand, are sown in spring, either in open-air seedbeds or earlier in heated greenhouses. Sowing can also be conducted in biodegradable or plastic containers. Germination is more successful in darkness (Winkler 1999), so seeds should be covered with 1.5–3 mm of substrate (Espahbodi et al. 2002). In open nurseries, 4 grams of seeds per meter of seedbed are sown and covered with a 2 cm layer of aged sawdust, with row spacing of 10–15 cm. Depending on seed quality, approximately 40 seeds are sown per meter of row (Faust and Fussi 2011). Stratified seeds germinate within 10–15 days, with peak germination occurring by day 30.

Seedling growth during the first year is slow (5–7 cm) as the plant prioritizes the development of a strong taproot, which should be pruned after the first growing season (Harlamb 1967, Faust and Fussi 2011). One-year-old seedlings are then transferred to nursery beds, where they typically grow for an additional one to two years until reaching a height of 40–50 cm (Favre D'Anne 1990). Proper nursery cultivation is essential for developing a compact, well-structured root system (Kausch-Blecken von Schmeling 1994, Büchner and Böhner 2010).

For field planting, both container-grown and bare-root seedlings can be used. Container-grown seedlings, initially raised in heated greenhouses, reach 40–80 cm. Bare-root nursery seedlings (1+1 or 1+2) are also commonly used (Faust and Fussi 2011). Seedling quality can vary within the same nursery; therefore, only those reaching 30–50 cm in height, with a well-developed terminal bud and a compact, symmetrical root system rich in fine root hairs, should be selected for planting (Skovsgaard and Graversgaard 2013). For better establishment in overgrown or degraded sites, using multi-year containerized seedlings is recommended.

Regeneration

Under natural conditions, wild service tree primarily regenerates through root suckers, although seed-origin trees can also be found (Müller-Kroehling and Franz 1999, Schrötter 2001). In the northern part of its range, such as Denmark, 94–100% of recorded trees originate vegetatively (Rasmussen and Kollmann 2008). In contrast, studies in Germany report a lower proportion, with root-sprouted trees accounting for 43% of the total tree population at three sites in southwestern Germany (Pyttel et al. 2013). Root suckers exhibit greater shade tolerance than seedlings and demonstrate faster height growth during the first 10–15 years (Crave 1985, Savill 1991). Although their growth rate declines significantly after this period, vegetatively regenerated trees are better adapted to the shaded conditions beneath tree canopies (Nicolescu et al. 2009). This higher prevalence of vegetatively regenerated wild service trees in oak forests can be attributed to their superior shade tolerance compared to seed-origin trees. Establishing wild service tree in mixed stands presents a challenge, particularly when competing with beech and valuable hardwoods. As a result, it should be regenerated as a secondary species by planting small groups of several individuals in small gaps created by selective cutting of low-quality beech or oak coppice trees (Bednorz 2007). Additionally, it can be introduced in larger clear-cut areas for the conversion of coppice forests into high forests, as well as in clear cuttings of high forests at the end of their rotations cycle (Demesure et al. 2000). To encourage natural regeneration, Bednorz (2007) recommends creating small gaps, clusters, or larger openings where seedlings can receive sufficient light for development (Demesure et al. 2000). Establishing pure plantations of wild service tree is not recommended (Severin 1992). For afforestation, one- and multi-year containerized seedlings or three-year-old nursery-grown seedlings (1+2) with bare-roots are used (Müller-Kroehling and Franz 1999). If the root has not been pruned in the nursery, it should be done before planting. Young plants, particularly their green shoots, are susceptible to damage from roe deer and rodents and should be protected using fencing or tree tube shelters (Bednorz 2007). Beyond protecting against wildlife, tube shelters also help maintain moisture around the stem and prevent the development of lateral branches.

Tending

Wild service tree seedlings require full overhead light for optimal development, necessitating intensive post-planting or post-regeneration care. They must be free from the competition of weeds. Natural regeneration of pioneer tree species tolerate moderate shade in its early development but becomes increasingly light-demanding from the pole stage onward, especially in the colder northern part of its range (Oria De Rueda et al. 2006). During the seedling and sapling stages, they can survive under oak canopies, where enough light penetrates to support growth (Wilhelm 1993). However, their growth rate in these conditions remains lower than in more open canopies.

If planted during the conversion of beech coppice forests, more frequent and intensive silvicultural measures are required, as wild service tree struggles to compete with the fast-growing beech suckers from stumps after logging. It can be effectively mixed with hornbeam and field maple, which facilitates self-pruning of lateral branches (Wilhelm 1993). In contrast, beech, sycamore maple, common ash, and fast-growing pioneer species like birch and aspen, should be removed from its immediate growing space (Wilhelm 1993, Wilhelm and Ducos, 1996). Forked stems should be corrected early by pruning one of the competing branches to maintain apical dominance. From the thicket stage, when trees reach a height of 2–3 meters, selective corrective pruning should be performed on individual trees to remove competing branches that encourage broad crown formation and redirect growth upwards (Crave 1985, Severin 1992, Drapier 1993, Wilhelm 1993, Kausch-Blecken von Schmeling 2000). In young stands, wild service tree frequently develops low branches and leans toward the light source. If not freed from shading in time, it becomes deformed and rapidly deteriorates (Wilhelm 1993, Rasmussen 2007). During the pole-stage, when trees reach a diameter of 10 cm, branch pruning should commence. Lower branches should be removed to create a clear trunk of at least 2–3 m, ideally 6–7 m (Hochbichler 2003). High thinning should be introduced at this stage, selecting future crop trees while removing their strongest competitors to ensure direct sunlight exposure to the crown (Müller et al. 2000). Greater light availability promotes increased diameter growth, making thinning essential to free the crowns from overhead and lateral shading. Studies confirm that even delayed high thinning influences diameter increment, showing that suppressed older wild service trees can still respond by immediately increasing their diameter growth (Elflein et al. 2008). The width of annual rings in closed-canopy stands is typically small, ranging from 1 to 2 mm, whereas in open canopies, it increases to 2.5–4.0 mm (Hochbichler 2003, Kahle 2004, Sjöman et al. 2012).

Harvesting

A rotation period for wild service tree typically ranges from 100 to 120 years. However, on more productive sites, the rotation age is significantly shorter, ranging from 50 to 70 years, by which time the trees attain a diameter at breast height of approximately 60 cm (Montero et al. 2002). The main goal of managing wild service tree is to obtain high-quality trees with a BHD of 50 cm or more, a crown width of 9 to 11 meters, and an optimal number of trees per hectare between 80 and 100 (LKÖ 2015).

Selective harvesting occurs when trees reach maturity, without any consideration to the rotation age of main species such as oaks or beech (Nicolescu, et. al. 2009). Harvesting is conducted during the dormant season, and immediately after felling, the bark should be stripped and logs removed from the stand. If left exposed, the wood oxidizes and develops an undesirable coloration (Lanier et al. 1990, Severin 1992).

POTENTIAL DISPERSAL OF WILD SERVICE TREE

Wild service tree has a limited natural dispersal potential due to the low availability of viable seeds. A portion of its seeds is sterile (Rasmussen and Kollmann 2004), while a significant fraction is consumed by rodents (Lloyd 1977, Rich et al. 2010). Additionally, it is a weak competitor and struggles to establish itself in mixed forests alongside beech, valuable hardwoods, and oak (Bednorz 2007). Various animal species contribute to seed dispersal by feeding on its fruits, including foxes, badgers, martens, wild boars, and domestic livestock such as pigs, sheep, and cattle (Herrera 1989, Roper 1993, Demesure-Musch and Oddou-Muratorio 2003). However, research studies on the role of birds in seed dispersal are contradictory. Some studies suggest that only a small portion of fruits is consumed by birds (Herrera 1984, Rasmussen and Kollmann 2004), possibly because the brown coloration of ripe fruits is less visually appealing to them (Thomas 2017). Additionally, many frugivorous birds migrate before the fruits fully ripen (Rasmussen and Kollmann 2004). In contrast, Welk et al. (2016) highlight birds as important seed dispersal agents. Despite seed dispersal via animals and birds (endozoochory), natural regeneration is limited due to the species weak competitive ability and its high light requirements, which are crucial for the survival of generative-origin seedlings (Savill 1991, Bednorz 2007). Furthermore, wild service tree seeds exhibit dormancy and often remain in the soil for a year, where they are exposed to unfavorable abiotic and biotic factors. Seedlings that do emerge from seeds or root suckers lack defense mechanisms against large herbivores that feed on young shoots and buds (Bednorz 2007, Borchard et al. 2011), as their tissues contain few digestion inhibitors (Ellenberg et al. 1991). The dispersal range of seeds from mother trees is generally short. Most generative-origin seedlings are found within an average distance of 174 meters from the mother tree, with those within a 150–300 m radius often sharing the same genetic origin. Only 17% of seedlings originate from seeds dispersed beyond this range (Oddou-Muratorio et al. 2004). Vegetative regeneration through root suckers is typically confined to a 5–15 m radius around mother trees (Rasmussen and Kollmann 2004), though in some cases, suckers have been recorded at distances of 25–30 meters

(Germain 1993, Hoebee et al. 2006) and, in rare instances, up to 110 meters (Lloyd 1977). Root suckers are more shade-tolerant and can survive under the canopy of mature trees. The human-supported expansion of wild service tree through afforestation has been minimal. The production of planting material has been neglected due to limited demand and the complexity of seedling propagation. Large-scale afforestation efforts have been discouraged by the high costs of tending (Kausch-Blecken von Schmeling 1994, Espahbodi et al. 2007). Given its naturally low occurrence in forests, the species presence is unlikely to increase without targeted afforestation efforts. Dynamic climate models predict a moderate natural expansion of wild service tree toward northern and northeastern regions (Harrison et al. 2006, Thuiller et al. 2006). However, this expansion is expected to be slow and limited in scope due to weak sexual reproduction, inefficient seed dispersal, and low competitiveness against other tree species (Bednorz 2007). In southern regions, the species is likely to shift toward higher elevations. Localized expansion is possible in areas where drought-sensitive tree species decline, potentially leading to a higher presence of wild service trees (Hemery et al. 2011). It may also spread within degraded beech and oak coppice forests, which have resulted from decades of high forest degradation where it tends to appear as scattered individuals rather than in groups, which is the most typical form of its occurrence in these forest types (Višnjić et al. 2025).

RESPONSE TO CLIMATE CHANGE

Wild service tree is a rare native species with broad ecological adaptability to variations in temperature, light availability, and soil conditions. It demonstrates greater drought tolerance than major temperate tree species such as beech, silver fir, Norway spruce, and valuable hardwoods (sycamore, common ash, and wych elm). Although primarily a light-demanding species, it can persist for extended periods under the canopy of dominant trees. While not particularly soil-selective, it thrives best in deep, base-rich soils (Hemery et al. 2009). As a species adapted to warm and dry habitats across Europe, wild service tree exhibits superior drought resistance compared to most temperate forest species (Kausch-Blecken von Schmeling 1994, Rasmussen and Kollmann 2004). Future climate projections indicate that such conditions will become more prevalent at higher elevations, on northern exposures, and in mesophilic northern areas currently occupied by beech and beech-fir forests in Europe (Walentowski et al. 2014, Schmucker et al. 2023). Given the expected changes in climate, wild service tree could replace more drought-sensitive species within beech and beech-fir communities, particularly thermophilic beech forests, which are among the most vulnerable to extreme climatic events (Paganova 2007). Climate models consistently predict an expansion of its range (Kölling and Müller-Kroehling 2011). The species is highly tolerant of low winter temperatures (Schute 2000, Rasmussen 2007); however, late spring and early autumn frosts can damage young terminal buds, leading to forking into two or more co-dominant shoots (Pietzarka et al. 2009). Optimal growth occurs in areas with an average annual temperature above 7.5°C and on base-rich soils (Kölling and Müller-Kroehling 2011). Its ability to endure summer drought and recover quickly from drought-induced stress (Kunz et al. 2016, Kunz et al. 2018) makes it well-suited for regions where climate change is expected to raise mean annual temperatures above 11°C. Climate change impact predictions suggest that the ranges of beech, fir, and spruce will decline, while rare native species such as field elm, field maple, hornbeam, and wild service tree will expand. This shift will play a key role in enhancing the climate resilience of European forests (Kunz et al. 2018, Koch et al. 2022, Schmucker et al. 2023). The species' strong drought tolerance and relatively stable diameter growth under drought-induced stress make it a valuable option for managing mixed forests in xerothermic habitats (Schute 2001 Walentowski et al. 2014, Kunz et al. 2018, Schmucker et al. 2023, Višnjić et al. 2025). Alongside service tree (*Sorbus domestica* L. Crantz) and wild cherry (*Prunus avium L.*), wild service tree is expected to play a crucial role in restoring degraded beech and oak forests in Bosnia and Herzegovina (Višnjić et al. 2025). Increasing the proportion of rare native tree species will enhance forest drought resilience, biodiversity, and ecosystem services, making their integration into beech and oak forests a strategic priority (Schmucker et al. 2023).

CONCLUSIONS

Wild service tree is an important species for sustainable forest management in the face of climate change. It has the potential to contribute significantly to the restoration of degraded forests and the development of climate-smart forests (CSF). Its integration into forest ecosystems can enhance biodiversity, increase resilience, and provide valuable ecosystem services, particularly in rural landscapes. Given its resilience and ability to recover from environmental stress, it is a key alternative species for adapting forests to climate change. Future efforts should focus on establishing seed sources (seed trees, stands, and plantations) to facilitate seed collection and seedling production. Dynamic modeling should be employed to identify suitable planting sites under changing climatic conditions. Additionally, further research should optimize planting techniques, light management, seedling protection from herbivores and rodents, and assess young plant responses to stand and site conditions.

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ĆV, BB and SV conceived and structured the paper, SV wrote the ecological part, ĆV and MČ wrote the silviculture part, all authors wrote the climate change part.

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The authors declare no conflict of interest.

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