



Seeding to establish Ravni Srem oak forests, Northern Serbia

Vladan Ivetić¹✉, Marko Marinković²

¹University of Belgrade – Faculty of Forestry, Kneza Višeslava 1, 11030 Belgrade, Serbia

²PE “Vojvodinašume”, Preradovićevo 2, Petrovaradin 21132, Novi Sad, Serbia

✉ vladan.ivetice@sfb.bg.ac.rs

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Abstract

Broadleaf species dominate Serbia's diverse forests including the Srem Forest District, where oak regeneration is focused on the Ravni Srem portion of the district. Pedunculate oak (*Quercus robur* L.) is the dominant species, making up about 50% of standing volume. The most important supporting species in mixed stands are narrow-leaved ash (*Fraxinus angustifolia* Vahl) and common hornbeam (*Carpinus betulus* L.). Seeding is used when acorn crops are poor or absent. In good mast years, acorns are incorporated into the soil or sown mechanically (about 450 kg ha⁻¹), 2 to 5 cm deep in rows 0.7 m apart with acorns spaced 15 to 20 cm in a row. Seeds are manually collected from registered stands and orchards, and subject to quality testing, thermotherapy, and fungicide treatment before storage. Herbicides and arboricides are used to control competition. Fencing protects seeds and seedlings from animals; rodenticides, fungicides, and insecticides are applied as required. Regeneration areas are limited to 56.25 ha, with seed trees left for shelter. Sowing is done in autumn–winter using machines, with acorns spaced in rows. Early competition is controlled by herbicides. Mechanical weeding and fencing continue during the sapling phase. Fire lanes are established and maintained for up to 15 years. Success is measured by seedling establishment and survival after the first growing season. Impacts of invasive plants and animal damage are mitigated by site management and maintaining fencing. Failure is mainly due to unfavorable climatic factors. The moderate-continental climate is expected to experience increased temperature and precipitation by 2040.

Keywords

Quercus robur; Seed treatments; Thermotherapy; Arboricides; Wildlife damage; Rodenticide

Contents

1	The forest	200
2	Impacts of deforestation or degradation to restoration sites	202
3	Mitigating impacts for seeding	202
4	Seed procurement and preparation	203
5	Plantation establishment	204
6	Post-sowing practices and maintenance	205
7	Successful seeding	205
8	Acknowledgements	206
9	References	206

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1 The forest

The Republic of Serbia has a large biome diversity from north to south—steppe, broad deciduous forests, boreal forests, and high mountain tundra (Republic of Serbia 2010). Forests in Serbia cover 2.8 million ha (36.8% of the total area of the country), of which 91% are semi-natural forests and 6.5% are planted forests (NFI 2023). Broadleaf species are dominant with 45% of all stands being primarily single species and 42% being mixed broadleaf stands; about 7% are pure conifer stands and the remaining 6% are mixed conifer and broadleaf or mixed conifer stands (NFI 2023). Of the 49 tree species recorded in Serbia by the National Forest Inventory (NFI), 40 are broadleaf species and 9 are conifer species, with European beech (*Fagus sylvatica* L.) being the most dominant species, followed by Turkey oak (*Quercus cerris* L.), sessile oak (*Q. petraea* (Matt.) Liebl.), and Hungarian oak (*Q. frainetto* Ten.) (Banković et al. 2009). Within the Northern Forest area, the Srem Forest District extends between 44° 37' 53" and 45° 11' 37" N latitude, and 18° 59' 45" and 20° 21' 30" E longitude (Figure 1). It is situated in the northwestern part of Serbia where it covers an area of 42,319 ha and is framed by Fruška gora Mountain in the north, the Sava River in the south, the Danube River in the east, and the Republic of Croatia in the west.

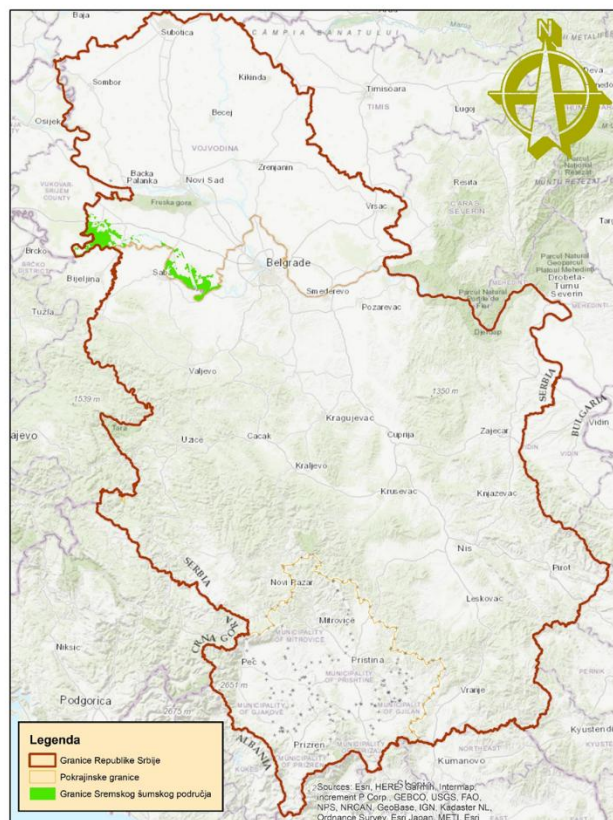


Figure 1. Location of Srem forest areas in Serbia (in green). The north-western area corresponds to Brdoviti Srem forests, and the southeastern area corresponds to Ravni Srem forests.

The Srem Forest District has held a history of forest management by various management systems since 1755 (Bobinac 2008) and currently is managed by Public

Enterprise¹ (PE) "Vojvodinašume". The forest district is not a single, continuous area. Brdoviti Srem is the smaller part in the north that encompasses the southern and eastern slopes of Fruška gora Mountain. Ravni Srem is the larger, southeastern part that encompasses the alluvial terrace along the Sava River, with its individual ponds and canals. The Ravni Srem has undulating terrain with pronounced depressions (canals and ponds) at an elevation of 75–80 m above sea level which experiences high groundwater levels that emerge in spring and autumn filling canals, depressions, and ponds, and drying-up during July and August.

This area experiences a Pannonian steppe, moderate-continental climate. The mean annual temperature is 11 °C. The mean temperature of the coldest month is -0.1 °C, mean temperature of the warmest month is 21.1 °C, and mean temperature during the growing season is 17.6 °C (Babić 2008). The mean annual precipitation is 579 mm, with an average of 344 mm during the growing season (Babić 2008). Based on the "RCP 8.5" climate change scenario of business-as-usual emissions growth (Riahi et al. 2007), the daily average temperature in the Srem area is expected to rise 1.5 to 2 °C, and precipitation is expected to rise about 0 to 10 mm by 2040 (Serbia NAP 2024).

The typical soils of floodplains belong to the FAO systematic units: Fluvisols, Humic Fluvisols, Humic Gleysols (rhyolitic chert), and Gleysols (swamp-gley soil). Soils in the protected areas of floodplains are predominantly heavy and clayey heath loam and meadow loam with unfavorable water and air capacity and a gleyic layer in the lower horizons with the occasional appearance of slatina (waterlogged ground with saline soils) in different stages of development. High groundwater and surface water levels limit the use of seeding across the landscape.

There currently is no significant deforestation in the Srem forest area, other than deforestation for construction of road infrastructure. The more common degradation factors are natural, caused mainly by abiotic factors, i.e., windstorms, drought, or flooding. For example, the windstorm of July 2023 caused damage to 100,000 m³ of high-quality wood and destroyed 1,300 ha of poplar (*Populus* spp. L.) plantations. Abiotic factors related to moisture availability have a negative impact on existing vegetation in terms of physiological weakening, less frequent fruiting, slower growth, and increased moisture stress. Biotic factors also create disturbance or degrade forests. Oak powdery mildew (*Erysiphe alphitoides* (Griffon & Maubl.) U. Braun & S. Takam.), the oak lace bug (*Corythucha arcuata* Say), and ash dieback (*Hymenoscyphus fraxineus* (T. Kowalski) Baral, Queloz, Hosoya) are currently the most common biotic factors causing natural disturbance in Srem forests. In general, abiotic factors are more significant than biotic factors, in both frequency and intensity.

Pedunculate oak (*Quercus robur* L.) is the dominant species in the Ravni Srem forest, it accounts for about 50% of the standing volume. The most important supporting species in mixed stands are narrow-leaved ash (*Fraxinus angustifolia* Vahl) and common hornbeam (*Carpinus betulus* L.). Even-aged stands 100 to 140 years old dominate the forest, with the number of oak trees ranging between 50 to 120 ha⁻¹ and tree heights ranging between 28 to 36 m, depending on stand condition.

Pedunculate oak is a shade intolerant species with a seed crop periodicity of 3 to 5 years in this region. Narrow-leaved ash is somewhat tolerant of low light with a small and easily dispersed seed. In the past, narrow-leaved ash fruited often and

¹ State owned enterprises such as public forests were transformed into joint-stock or limited liability companies in response to a reform policy agreed to with the International Monetary Fund (IMF). PE Vojvodinašume was formed in 2002.

abundantly, but in recent years, due to ash dieback, the seed crop has been gradually reduced and now is completely absent. Common hornbeam, a shade tolerant species, is characterized by abundant seed crops. The most viable and ecologically stable mixed stands of these species are designed with the most rational use of available moisture in the soil, considering that narrow-leaved ash is least plastic, pedunculate oak is moderately plastic, and common hornbeam is most plastic to available soil moisture. Silvicultural practices are applied with regard to the developmental stages of stands, e.g., competition control occurs during stand regeneration and selective high thinning once individuals of dominant tree species attain a height over 17 m and DBH over 25 cm (\approx 25 years old).

In years of a poor or absent acorn crop, seeding is practiced on all areas planned for regeneration. In good mast years, fallen acorns are incorporated into the soil for overwintering by cultivating with a disc implement, or collected and sown mechanically. In the case of mechanical sowing, around 450 kg ha⁻¹ of acorns are used, depending on seed viability.

2 Impacts of deforestation or degradation to restoration sites

After deforestation of large areas, especially near settlements, that took place from the late 1880s until the 1950s (Rađević et al. 2020), there has been no significant impact of deforestation or degradation in the Srem forest area. During the 10-year forest regeneration period, there are short-term changes in the hydrological regime of soils and colonization by invasive plants such as *Solidago spp.* L., *Ambrosia artemisiifolia* L., and *Amorpha fruticosa* Thunb. Roe deer (*Capreolus capreolus*) clip terminal buds and red deer (*Cervus elaphus*) peel bark, but this damage is reduced to a minimum by fencing the reforestation areas. Additional causes of damage are abiotic such as early frosts and occasional site flooding and soil waterlogging.

3 Mitigating impacts for seeding

Land leveling, plowing, or ripping are rarely performed, then only if the condition of the soil prevents use of mechanization for seeding. Woody and herbaceous species that can be obstacles to seeding and later oak development are removed. On sites with herbaceous vegetation and woody species of small dimension, competition is removed by mulching and then sites are maintained relatively clear of vegetation using glyphosate-based herbicides. Woody weeds with a DBH over 8 cm are cut with chainsaws. Their stumps are treated with a triclopyr-based arboricide. Seed depredation or damage is caused by feral pigs (*Sus spp.*), wild boar (*Sus scrofa*), rodents (Order Rodentia), pathogenic fungi, and seed insects. Protection is provided by fencing, rodenticides, insecticides, and fungicides. Woven wire fences are built around regeneration areas. Fence height varies between 1.5 to 2.5 m, depending on site conditions. The fence is usually removed after 20 years. Rodenticides are based on zinc phosphide, and the most commonly used fungicides are Falcon (Spiroxamine, Tebuconazole, Triadimenol; Bayer CropScience), Tenor (Propiconazole; Jiangsu Flag), Impact (Flutriafol; FMC), Stroby (Kresoxim-methyl; BASF), and Anvil (Hexaconazole; Syngenta); and insecticides Actara (Thiamethoxam; Syngenta), Laser (Spinosad, Dow Agro Sciences) and Decaguard (Deltamethrin, Gharda Chemicals Limited). Pesticides are applied in line with the Law on Plant Protection Products ("Sl. glasnik RS", br. 41/2009 and 17/2019) and according to labeled instructions from producers.

4 Seed procurement and preparation

Abundant mast crops of oak generally occur every 3 to 5 years. Acorns are collected manually (by hand) by PE employees, local people, and volunteers, in registered seed stands and plantations in autumn (October–November). There are 8 registered seed stands (≈ 645 ha) and 2 seed orchards (≈ 16 ha) for collecting selected Forest Reproductive Material (FRM, as defined in European Union 1999). However, in years with abundant seed crops, the FRM category “source-identified” (as defined in European Union 1999) is also used for seeding. Seed quality is checked by the float method during seed purchase, and it is followed by seed quality testing at a certified institution. After collection, acorns are temporarily stored in a shed before seed processing. Seed processing is conducted with additional float separation, thermotherapy, and fungicide application (Ivetić 2023; Figure 2). Thermotherapy is applied prior to oak seed storage to limit *Ciboria batschiana* (Zopf) N.F.Buchw., one of the major fungal pathogens on stored acorns. Following seed processing, acorns are stored in plastic bags in a refrigerated chamber at 3–5°C for up to one year before sowing.

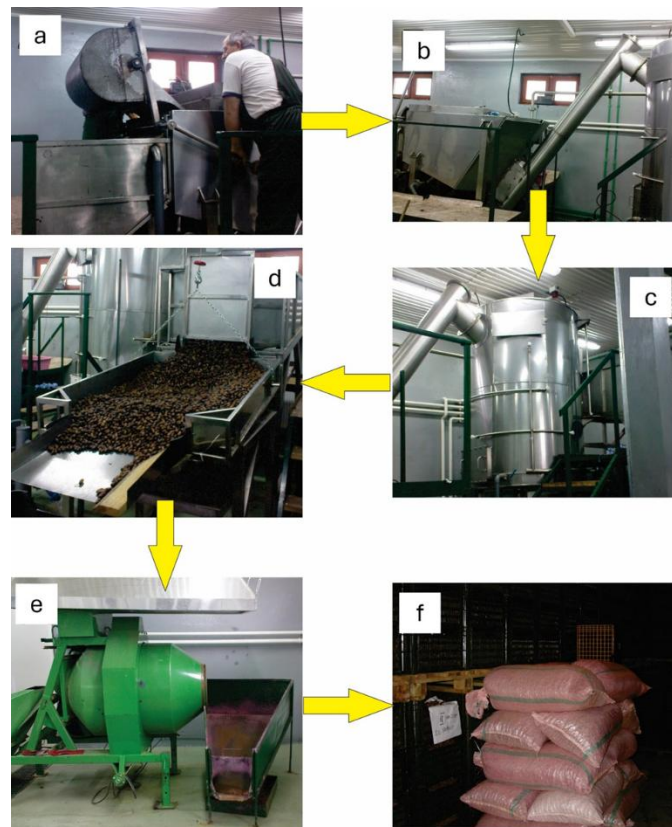


Figure 2. Processing acorns using thermotherapy at the Seed Center in Sremska Mitrovica, Serbia. (a) The acorns are first immersed in water in a perforated drum for separation by floating. (b) The acorns are transferred to the preparation chamber where they are pre-conditioned with water at a 30 to 35 °C. (c) Acorns are transferred by a screw conveyor to the heat treatment chamber, which is filled with hot water from the flow-type boiler room. In this process, the acorns are continuously dosed into the chamber. (d) After 2.5 hours at 41 to 41.5 °C, acorns are spread on a table for drying. (e) After the final heat treatment, the acorns are protected with a fungicide in the drum of an adapted concrete mixer. (f) Treated acorns are stored in a refrigerator facility at 3–5 °C (Photo credits: Vladan Ivetić).

5 Plantation establishment

Regeneration areas are limited to 56.25 ha (the traditionally sized management unit in the Srem Forest Area), with a minimal distance between two regeneration areas of 400 m (PE Vojvodinašume 2023). Before regeneration, all unwanted vegetation is removed, including herbaceous and woody weeds, supporting species, and most oak trees. Typically, 80–100 oak trees ha⁻¹ are left in the regeneration area as seed trees, but more for a sheltering role rather than as a source of seed. These trees are removed once 70-80% of regeneration area is regenerated (naturally, by direct seeding or by their combination) with 2-5 well developed seedlings per square meter, usually after 3-5 years, but depending on specific conditions, this period can be extended up to 10 years. Pedunculate oak is the primary species seeded, while the supporting species naturally occupy the site. Sowing is done in the autumn–winter with mechanical seeding machines (Figure 3). About 450 kg ha⁻¹ of acorns are sown at 2 to 5 cm deep in rows 0.7 m apart and acorns spaced 15 to 20 cm in a row (Figure 4). When acorns are sown immediately following collection, they are not treated in any way. Acorns stored following thermotherapy are treated with the fungicide VITAVAX-200 ff (Carboxin+Thiram; Chemtura), prior to storage. In any case, there is no need for additional stratification or pre-sowing treatment of acorns.



Figure 3. A tractor-drawn sowing machine being loaded with acorns (Photo credits: PE “Vojvodinašume”).



Figure 4. Pedunculate oak (*Quercus robur* L.) seedlings on a regeneration area after the first growing season (Photo credits: PE “Vojvodinašume”).

6 Post-sowing practices and maintenance

Early competition control is accomplished with herbicides. If competing vegetation establishes before oak germination, directed spraying of glyphosate is used for control. If oak germination has occurred, selective herbicides are used to control competition, e.g., Nikogan (Nicosulfuron; Syngenta); Pulsar (Imazamox; BASF); and Lontrel (Clopyralid; Corteva). The tending of oaks is performed during the sapling phase of development, with mechanical weed control using hand tools (Figure 5). Regeneration sites are fenced to protect acorns, seedlings, and saplings from animal damage, and they are protected from fire with established fire lanes or strips. The fire lanes are maintained by tilling for up to 15 years after initiation of regeneration.



Figure 5. Manual weeding in regenerated pedunculate oak (*Quercus robur* L.) in an early stage (Photo credits: PE "Vojvodinašume").

7 Successful seeding

There are three pillars of reforestation success through seeding in the Ravni Srem forest area. 1) Application of established and proven reforestation technology, based on knowledge of the biology of pedunculate oak and supporting species, and developed from experience from previous trials. 2) Implementation of reforestation efforts are timely and supported by technical and financial resources. 3) The Forest District receives the support and understanding of the community. This is achieved through education and outreach by forestry professionals participating in media opportunities.

Regeneration success is assessed by mapping establishment and survival after the first growing season. The regenerated area is divided into working plots (60 x 150 m) and in each working plot, sample plots are established; 2–4, 10 m² plots in homogenous conditions or 6–8 sample plots in heterogenous germination conditions. Inside sample plots, seedlings meeting a 15 to 30 cm height criterion are counted, and there should be at least 1 established seedling per 1 m² (the usual number is 2 to 5). In the establishment phase, reforestation is considered successful if oak seedlings originating from seeding show good survival and are well developed, and supporting species are present in the stand as well. The primary reasons for failure are unfavorable climatic factors, including high groundwater and surface water levels.

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This paper may include research involving pesticides. It does not contain recommendations for their use, nor does it imply that the uses discussed here have been registered. All use of pesticides must be registered by appropriate agencies before they can be recommended.

CAUTION

Pesticides can be injurious to humans, domestic animals, desirable plants, and fish or wildlife if they are not handled or applied properly. Use all herbicides selectively and carefully. Follow recommended practices for the disposal of surplus pesticides and their containers.

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