

## Picea abies in Europe: distribution, habitat, usage and threats

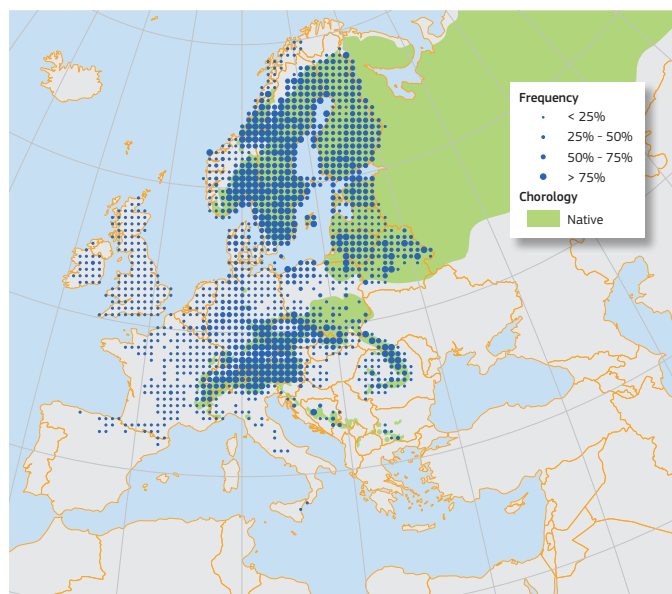
G. Caudullo, W. Tinner, D. de Rigo

Among the coniferous species, Norway spruce (*Picea abies* (L.) Karst.) is one of the most important trees in Europe both for economic and ecological aspects, with a long tradition of cultivation. It can be a big tree, reaching 50–60m in height with a straight and regular trunk, particularly used for timber constructions, pulpwood for paper and furniture. This widespread species dominates the Boreal forests in Northern Europe and the subalpine areas of the Alps and Carpathian Mountains. Thanks to its high performances in different site conditions, it can also be found outside its natural distribution on lower elevations in more temperate forests. Norway spruce has been massively planted up to its niche limits, where it is particularly susceptible to heat and drought, due to its shallow root system. For this reason it is expected to be severely affected under global warming conditions. Disturbed and weakened plants can be easily attacked by rot fungi such as *Heterobasidion annosum* and *Armillaria*, or by the bark beetles *Ips typographus*, one of the most destructive spruce forest pests.

Norway spruce (*Picea abies* (L.) Karst.) is a large coniferous tree, which can grow up to 50–60m and with a trunk of up to 150 cm in diameter, normally reaching an age of 200–300 years<sup>1–3</sup>. In the Swedish Scandes, fossil remains of dead Norway spruce underneath living individuals have been dated with radiocarbon to the early Holocene, about 9500 years ago, suggesting vegetative survival (by re-sprouting from the roots) over millennia<sup>4</sup>. The crown is regularly conic, columnar, with whorled, short and stout branches, the upper level ascending and the lower drooping. Buds are reddish brown, 5mm long with an acute apex. Needles are 1–2.5 cm long, 4-angled in cross section, rigid, light to dark green with fine white speckled lines. The species is **monoecious**, with **unisexual** flowers usually appearing at an age of 20–30 years, but up to 40 years in dense stands. Male flowers are located principally at the base of the preceding year's shoot, 1–2.5 cm long, globular, crimson then yellow when mature. Female flowers are located at the tip of the shoot, dark red, 5 cm long, erect before pollination, becoming pendent afterwards. Cones are cylindrical, 12–15 cm long, green before maturity, turning brown in autumn. When dry the cones open to disperse 4mm winged seeds. The bark is orange brown and the wood is creamy white and easy to work<sup>1, 5–8</sup>.

### Distribution

Norway spruce is the main species in the Boreal and subalpine conifer forests, from Central (in mountains) to Northern and Eastern Europe up to the Ural Mountains, where the species merges with Siberian spruce (*Picea obovata*), which is sometimes considered as a sub-species of *Picea abies*<sup>5, 9–13</sup>. Its elevation range goes from sea level in Northern Europe up to above 2400m in the Alps, where it grows in a stunted form<sup>14, 15</sup>. Due to its large



Map 1: Plot distribution and simplified chorology map for *Picea abies*.  
Caption: Frequency of *Picea abies* occurrences within the field observations as reported by the National Forest Inventories. The chorology of the native spatial range for *P. abies* is derived after EUFORGEN<sup>39</sup>.

distribution there are a great number of varieties and forms, which can be considered as normal patterns of variation within a widespread species. Historically cultivated since the 18th century, Norway spruce plantations, even outside natural ranges (e.g. in the temperate lowland areas), have changed natural forests into artificial ones<sup>2, 14</sup>. Now it is locally naturalised in many areas of Europe outside its native range, including Britain and the Pyrenees Mountains. It was also introduced in other countries outside Europe



Majestic isolated spruce in a mountain field in Leskova Dolina (Snežnik, South Slovenia).  
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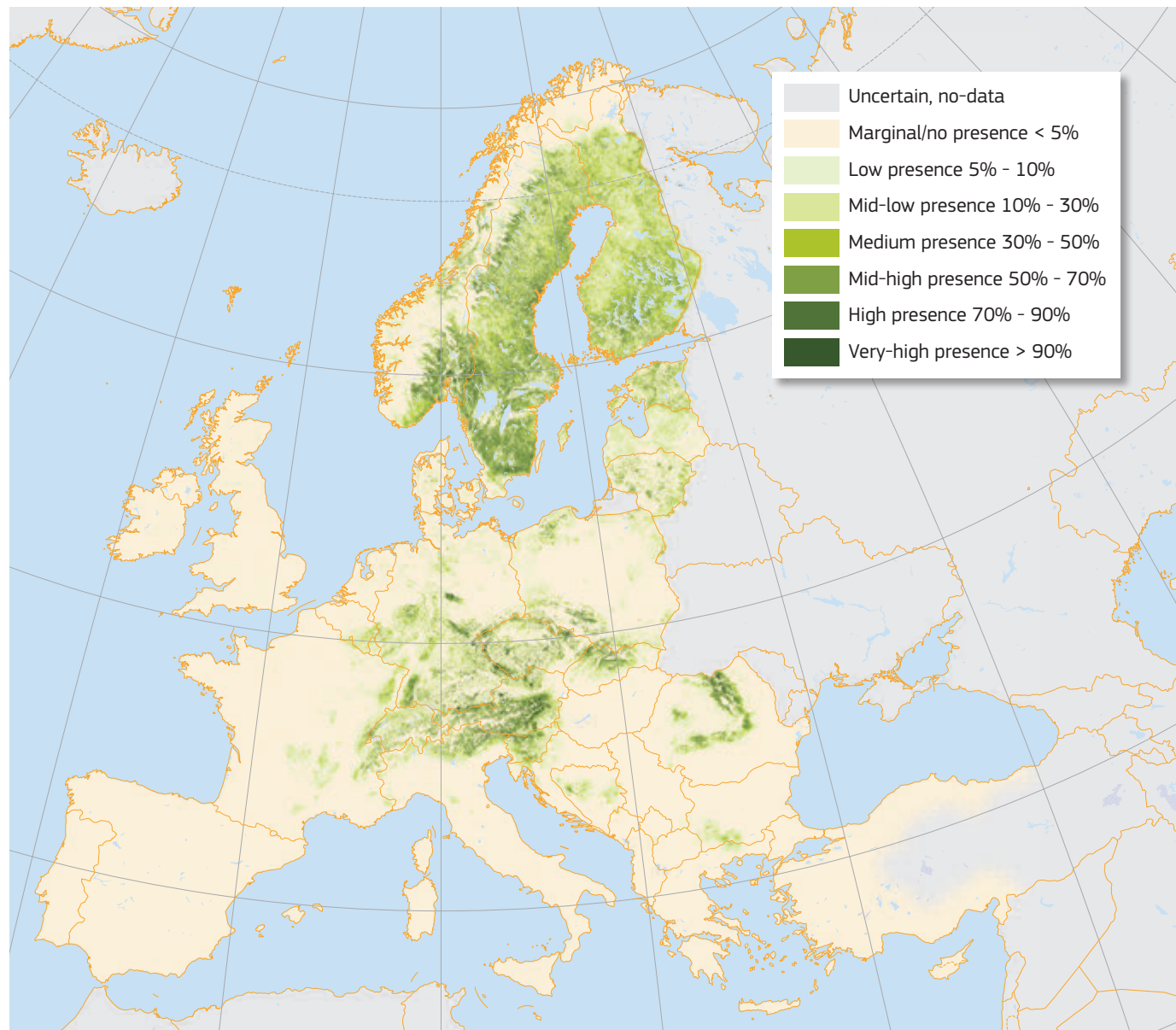
(United States, Canada and Japan) and in the southern hemisphere (South Africa, Tasmania and New Zealand)<sup>6, 16</sup>.

### Habitat and Ecology

Spruce forests dominates in the Boreal zone of N and N-E Europe; in central Europe spruce forests cover wide areas of the montane (mostly planted) and the sub-alpine zones, in lowlands it is more mixed with other species<sup>2</sup>. The natural distribution shows continental tendencies but thanks to its climatic tolerance it grows even in extreme oceanic climates<sup>9, 17</sup>. Norway spruce is a secondary coloniser, but can be both a pioneer and a climax species. It shows good yield and quality performance under very different site conditions, and has been favoured over long periods by silviculture, especially in the lowlands, but also in mountain areas<sup>18</sup>. Shade-tolerant, it can survive for decades under a closed canopy, fast growing after 5–10 years. It does not grow close to coasts when exposed to salt winds, nor does it like summer drought or waterlogged conditions<sup>2, 7</sup>. Although it can occur on most substrates, it is most common and widespread on acidic soils, preferring nutritious deep soils with enough fresh moisture<sup>8, 9</sup>. Spruce shows a noticeable soil-acidifying ability<sup>19</sup>. In the Boreal forests it grows with birch (*Betula* spp.) and European aspen (*Populus tremula*), with willow (*Salix* spp.) alongside streams and lakes. In the Alps, when it is not in pure stands, it occurs with European larch (*Larix decidua*) and Swiss stone pine (*Pinus cembra*) on higher elevations (ca. 1800–2100m), with European beech (*Fagus sylvatica*) and European silver fir (*Abies alba*) under fresh conditions at intermediate altitudes (800–1800m), and with Scots pine (*Pinus sylvestris*) in drier conditions<sup>9, 15</sup>. Stages and reproductive processes are regulated by climatic conditions, in particular by temperature, which become more important in higher



Droplets of resin are common over the bark of the trunk and branches.  
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Map 2: High resolution distribution map estimating the relative probability of presence.

latitude regions. Seeds are dispersed mainly by wind, but also by birds and other animals. The symbiotic relationship between roots and mycorrhizal fungi (hundreds of species described) is important for spruce forest ecosystems, especially in non-optimal growing conditions such as in dry and marginal habitats<sup>2, 5</sup>.



••• Mature Norway spruce plantation in Dalbeattie Forest (Dumfries and Galloway, South Scotland).  
(Forestry Commission, www.forestry.gov.uk © Crown Copyright)

## Importance and Usage

Norway spruce is one of the most important coniferous species in Europe both from an economic and ecological point of view. It has a long history of cultivation, having expanded its range considerably<sup>9, 14</sup>. Especially in northern European countries the main products of economic interest are the solid wood for timber constructions and pulpwood for paper<sup>9, 14</sup>. The wood is also used for a wide range of commodities, such as joinery timber, furniture, veneer and as tone-wood (sound boards of pianos and the bodies of guitars and violins)<sup>2, 7, 14</sup>. However, spruce wood is not durable, so not suitable when decay-resistance and toughness are required<sup>20</sup>. Stradivari and other eminent Italian violinmakers of the 17<sup>th</sup> and early 18<sup>th</sup> centuries used Norway spruce wood from the forests of the southern parts of the Italian Alps for the tops of their violins, in particular from the "Forest of the Violins" in the Parco Naturale di Paneveggio (Trentino, N-E Italy), known among violinmakers for its trees of resonance<sup>21, 22</sup>. This species is also the most popular Christmas tree, a tradition that actually started in Germany, with the extensive afforestation beginning in the 18<sup>th</sup>



••• Open and opening cylindrical brown cones in autumn.  
(Forestry Commission, www.forestry.gov.uk © Crown Copyright)

century<sup>9</sup>. Spruce stands are also planted for protection forests and erosion control, and can provide considerable recreational value<sup>20</sup>. Since the 1940s the importance of this species has led some European countries to develop long-term breeding programmes to create base material for seed procurement with the objective of improving wood quality<sup>14</sup>. The Norway spruce genome was sequenced in 2013, the first available for any gymnosperm. Its genome contains approximately 20 billion base pairs (about six times the size of the human genome, despite a similar number of genes). The large genome size seems to result from the slow and steady accumulation of a diverse set of long-terminal repeat transposable elements, possibly owing to the lack of an efficient elimination mechanism<sup>23</sup>.

## Threats and Diseases

The most important natural disturbance factors affecting Norway spruce are fires, drought, storms and pathogens such as bark beetles. The fire tolerance is very poor. Spruce has a shallow root system, so that storms easily blow them down, especially in pure and dense stands, and access to deep soil water is impossible during dry periods<sup>2, 7</sup>. The root system makes spruce less resistant to windthrow and rockfall<sup>24, 25</sup>. Its rockfall mortality rate is higher than that of thicker-barked species such as larch<sup>24</sup>. The bark beetles *Ips typographus* is one of the most destructive forest pests causing damage to spruce forest ecosystems in Europe<sup>26</sup>. This bark beetle is often associated to damaging assemblages of fungal pathogens<sup>27-30</sup>. It is a secondary agent, affecting trees



••• Top side of a violin made with spruce wood.  
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••• Dead spruces killed by the bark beetle *Ips typographus* near Boží Dar inside the protected area Krušnohorské plató (Ostrov, North-West Czech Republic).  
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that are already weakened (by storms, drought or other causes). It is currently expanding its range with mass outbreaks mainly on spruce stands outside their natural range<sup>2, 31</sup>. The large pine weevil (*Hylobius abietis* L.) is among the most serious pests affecting young coniferous forests in Europe<sup>32</sup>. In northern and central Europe, Norway spruce coexists with the natural niche of the large pine weevil<sup>32, 33</sup>. The fungus *Heterobasidion annosum* causes root and butt rot throughout the northern hemisphere, which leads to important economic losses both in growth and wood quality<sup>14, 17, 34</sup>. Another important root rot disease is caused by the fungi of the genus *Armillaria*. *Armillaria* affects a wide range of tree and shrub species: larch, spruce and pine trees mainly, resulting in serious economic losses, reducing timber volumes and wood quality. As primary pathogens, both of these fungi can weaken plants, cause mortality and growth reduction in natural and planted forests over Europe, principally in the Boreal forest of Fennoscandia. Severe damage can be caused by deer and wild boar with bark peeling, which affects seedlings and young trees, allowing them to be more easily infected by fungi<sup>31, 35, 36</sup>. Starting from the 1980s, spruce forests have shown symptoms of decline in mountainous areas of central Europe including yellowing, loss of needles, die-back of branches and reduced growth. Air pollution has often been used to explain this<sup>14</sup>. Health problems in central European forests have reduced its popularity for reforestation, particularly outside its natural



••• Pale green new needles sprouting from reddish buds. (Copyright Michael Wunderli, www.flickr.com: CC-BY)

range<sup>2, 8</sup>. Due to its preferences for cool and moist climatic conditions this economically very valuable species may become severely affected under global warming conditions<sup>37</sup>. European alternatives to Norway spruce are mostly fir species such as *Abies alba* (e.g. Mediterranean or dry inner Alpine provenances) which can tolerate significantly warmer and drier conditions<sup>37, 38</sup>.



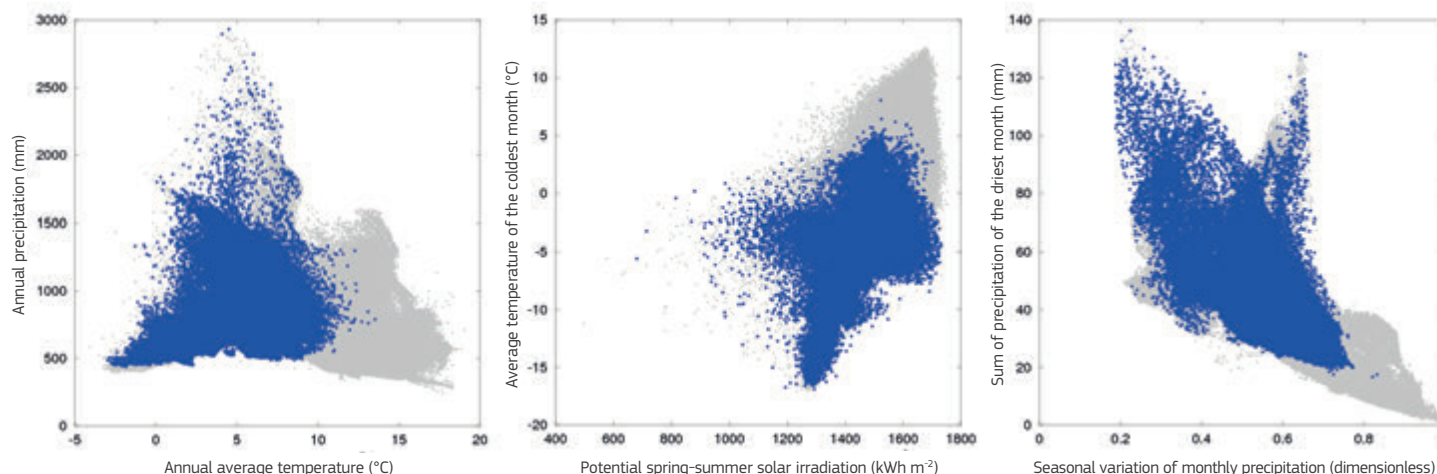
••• Old Tjikko, claimed to be the oldest tree in the world, a 9 550-year-old spruce possibly surviving by root re-sprouting in Fulufjället Mountain (Dalarna, Sweden). (Copyright Karl Brodowsky, commons.wikimedia.org: CC-BY)



••• Pure Norway spruce forest by Lake Carezza in the western Dolomites (Bolzano, North-East Italy). (Copyright Son of Groucho, www.flickr.com: CC-BY)

Field data in Europe (including absences) ● Observed presences in Europe ●

••• Autoecology diagrams based on harmonised field observations from forest plots.



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