



**Introduced tree species
in European forests:
*opportunities and challenges***

Frank Krumm and Lucie Vítková (eds.)





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5.2 Douglas fir in Freiburg City Forest: an introduced tree species in the light of multifunctional management objectives

Nicole Schmalfuss and Lucie Vítková

Freiburg City Forest is located in the southwestern part of Germany in the state of Baden-Württemberg covering forested area of 5 129 ha (Figure 88). The city forest serves the 220 000 inhabitants of Freiburg and its surrounding municipalities. The management of this forest has proven to be a successful approach fulfilling multiple aims under the label of Forest Stewardship Council certification (FSC).

The Municipal Forestry Office was established in 1835 in order to manage Freiburg City Forest. For more than 180 years the Municipal Forestry Office has continued its work irrespective of several administrative reforms in the forest sector in Baden-Württemberg. This work has been based on the successful identification of management objectives satisfying the multiple needs of Freiburg City Council as well as the city's citizens. The current management aims are to maintain ecological and social functions of the city forest and to create financial revenues.

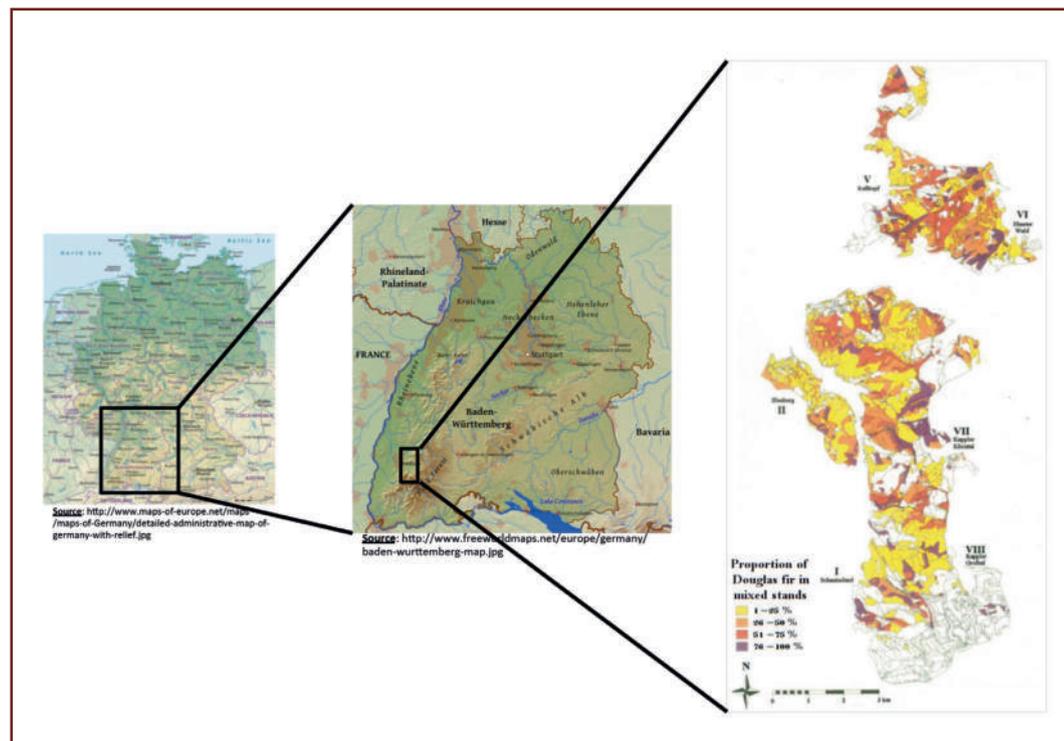


Figure 88. Location of Freiburg City Forest with a map showing the proportion of Douglas fir within the mixed stands in the mountain forest stands. The lowland forests are excluded due to absence of Douglas fir.

Freiburg City Forest is an example of a successful multifunctional forest management where the major management aim is to maintain ecological and social functions and to create financial revenues.

The city forest spreads around Freiburg and is located in the two contrasting climatic and geological areas of the Upper Rhine Valley and the Black Forest. The altitude range of the city forest spans from 200 to 1 284 m a.s.l. Such location also reflects city forest's different forest types; i.e. lowland alluvial forests found below 400 m a.s.l. and upland mountain forest located above 400 m a.s.l.

The lowland forest accounts for about 40 % of the city forest area and is dominated by oaks (*Quercus* spp.), hornbeam (*Carpinus betulus* L.), ash (*Fraxinus excelsior* L.) and sycamore (*Acer pseudoplatanus* L.). The mean annual temperature in the lowland forest is 10.4°C with the mean annual precipitation being 880 mm.

The upland forest covers 60 % of the city forest and is mainly composed of European beech (*Fagus sylvatica* L.), Norway spruce (*Picea abies* (L.) H. Karst.), silver fir (*Abies alba* Mill.) and Douglas fir (*Pseudotsuga menziesii* (Mirb.) Franco) (Figure 89). The mean annual temperature is 9.4°C in the lower altitudes of the forest (400 m a.s.l.) and 5.1°C in the upper parts (1 250 m a.s.l.). The mean annual precipitation is between 950 mm and 1800 mm, which is also altitude dependent.

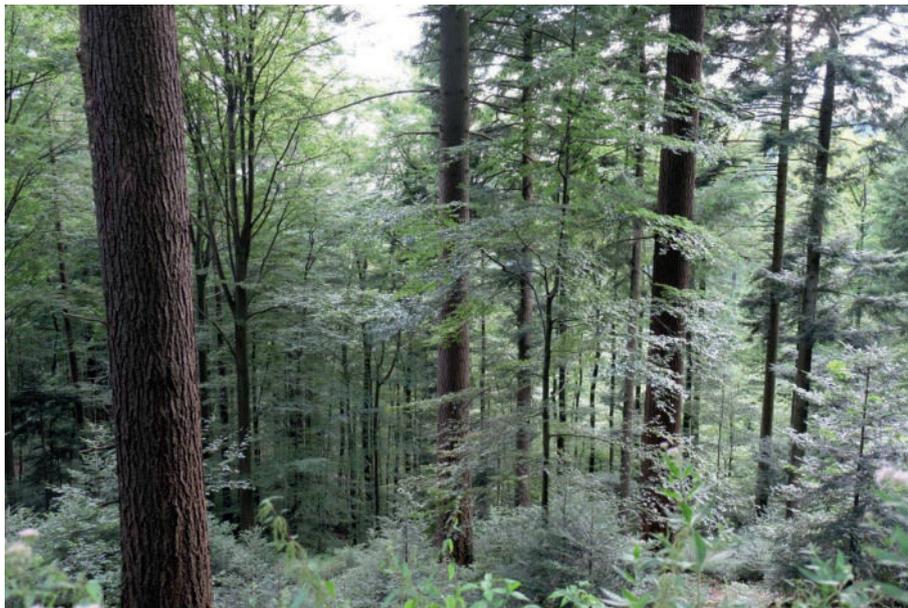


Figure 89. Douglas fir and European beech stand representing the altitudes middle ranges of Freiburg City Forest [photo: L. Vítková].

Although native tree species make up the majority of the area of the city forest, Douglas fir, a coniferous tree species of North American origin, fulfils a significant role in the city forest. Douglas fir was first planted in Freiburg City Forest in 1896 and became an impor-

tant tree species for timber production. This is mainly attributed to its fast growth rate and the possibility for multiple uses of its timber.

Although Douglas fir shows a comparable susceptibility to wind throw as Norway spruce, wind throw risk is not considered as a restricting issue in the city forest as the stands located in the upland areas are on rather well drained soils with tree roots penetrating to sufficient depths. Therefore, the wind throw is considered to be a risk only during extreme wind storms. Furthermore, the wind-thrown Douglas fir trees are subjected to much less economic loss than wind-thrown Norway spruce. Up to now, even after extreme wind events, Douglas fir timber can still be sold without major losses as it tends to retain its value following the wind event and does not require quick management action as is the case of Norway spruce, which is affected by bark beetle following severe wind events (Albrecht et al. 2015).

The proportion of Douglas fir throughout the city forest varies from being absent in the lowland alluvial forest to being rather abundant at an altitude of around 800 m a.s.l. and then again decreasing in abundance towards yet higher altitudes. The proportion of Douglas fir in the tree species mixture of the upland city forest continuously increased from 1912 to 1980 and peaked in the 1990s at 21 % (Figure 90) more or less stagnating since then. The management aims to keep the area dominated by Douglas fir at 20 % in the upland forest as Douglas fir timber harvested from these areas significantly contributes towards city forest's timber income (Douglas fir forms 13 % from the whole city forest's area). However, it is important to note that the FSC certification standard does not allow for more than 20 % of a forest to be composed of introduced species (more information on certification can be found in Text Box III).

Box 24. Proportion of Douglas fir in German forests

According to the latest German National Forest Inventory (2012), Douglas fir forms 2 % of German forests with the largest proportion found in Rhineland-Palatine (51 718 ha; i.e. 6.4 % of the local forest cover) and the lowest in Hamburg and Bremen (117 ha; i.e. 0.9 % of the local forest cover). As for the state of Baden-Württemberg, the state with second largest representation of Douglas fir, and where Freiburg City Forest is located, Douglas fir covers 43 928 ha, which equates to 3.3 % of the local forest cover. It is also important to note that the proportion of Douglas fir in individual federal states increase in comparison to the National Forest Inventory in 2002.



Figure 90. Douglas fir forming an important proportion of Staufen Municipal Forest in southwestern Germany (photo: L. Vítková).

The forest stands where the proportion of Douglas fir exceeds 50 % were established between 1930 and the end of the 1980s when pure Douglas fir was initially planted after clearcutting. This management practice was abandoned at the beginning of the 1990s when the principles of continuous cover forest management were first put to practice in Freiburg City Forest. Since then, the forest management preferences were given to promoting small scale openings (i.e. single tree or small patches) where natural regeneration of mixed species has been favoured.

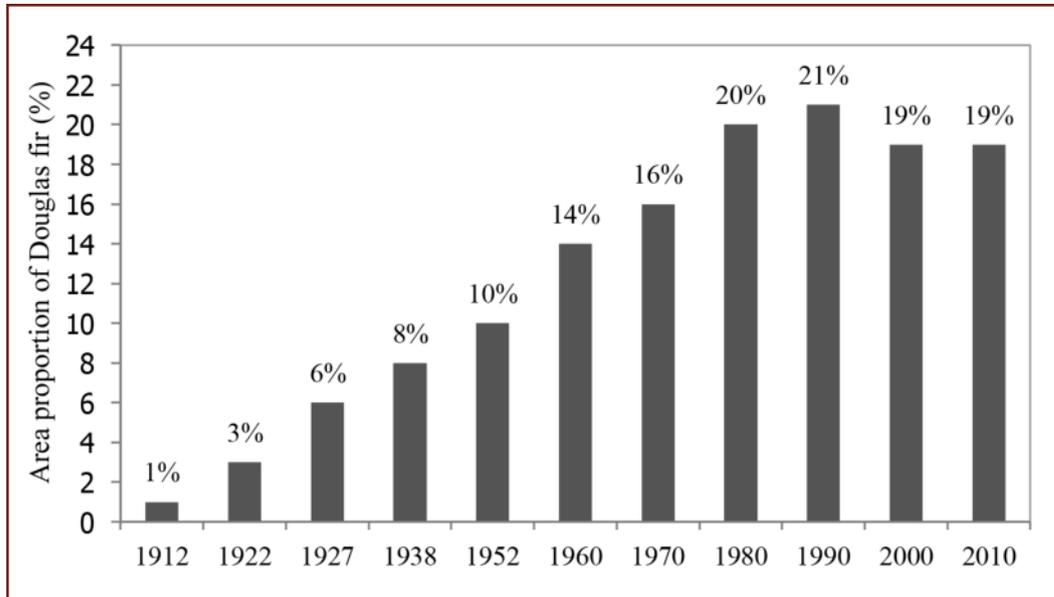


Figure 91. Proportions of Freiburg City Forest area (mountain part) dominated by Douglas fir.

The major management objective in Freiburg City Forest with regards to Douglas fir is to produce high quality timber of large size that brings substantial financial revenue.

As an example, in 2014, the average price for Douglas fir logs (stem wood) was 121 €/m³ with the average price for all Douglas fir assortments, including pulpwood, being 103 €/m³. However, the top quality Douglas fir logs yielded prices of around 300 €/m³ at sale auctions that year. In order to promote timber quality from an early age, specific management focus is on young and medium-aged Douglas fir stands. In such cases, careful pre-commercial thinning is usually carried out once the top height reaches 6 m. Trees of the poorest quality are removed and, if present in the stand, broadleaved species are favoured in order to increase species richness. A high number of stems in the stand is retained in order to suppress formation of large branches. Once the top height in such stands reaches 18 m, 50 final crop trees/ha (Z1 trees) and an additional 50 final reserve crop trees/ha (Z2 trees) are selected and retained. The choice is based on stem quality, growth vitality, light branching as well as convenient spatial distribution of trees. The selected trees are pruned up to 10 m of height in order to increase the future volume of

quality timber. The target diameter of the final crop trees is 100 cm. The final crop trees are promoted by a continuous and careful removal of their competitors in order to achieve consistent diameter increment. In addition, careful harvesting is applied to prevent damage to the final crop trees.

Not only do top quality Douglas fir assortments attract high prices, the mean timber price for this species over time are also higher than for Norway spruce, silver fir and European beech (Figure 92). It is also important to note that the annual net profits generated by Douglas fir-dominated stands provide a considerable revenue of 500–700 €/ha/year that is subsequently used for various purposes throughout the forest.

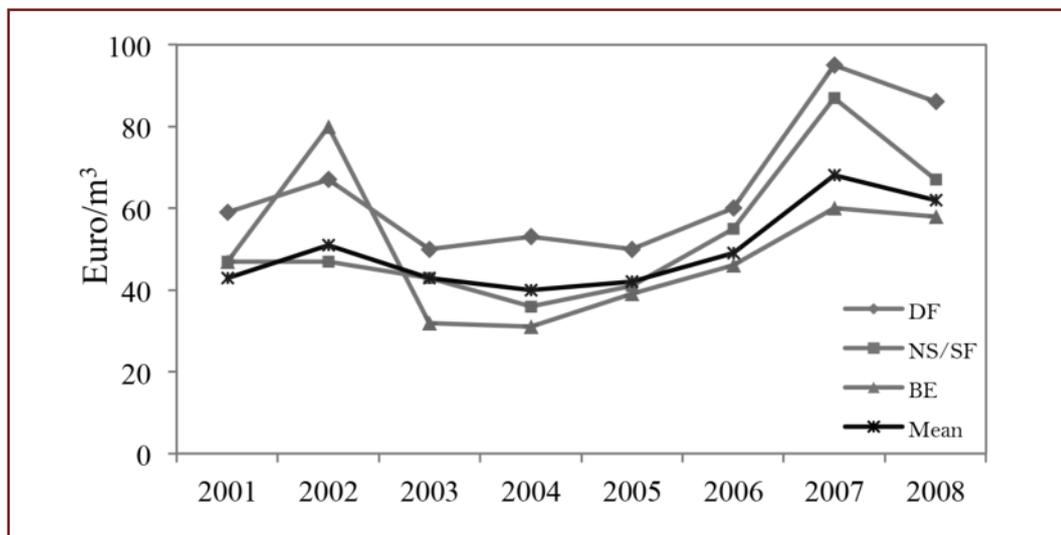


Figure 92. The development of the mean timber prices (€/m³) between the years 2001 and 2008 for major commercial species in Freiburg City Forest. DF=Douglas fir, NS =Norway spruce, SF=silver fir, BE=European beech and Mean=average values.

Douglas fir plays an important role in Freiburg City Forest as it accounts for 28 % of the total income covering only 13 % of the total forest area.

Although Douglas fir covers only 13 % of the entire area of Freiburg City Forest, it accounts for 28 % of city forest's total income from timber sale, which makes this species of North American origin a substantial contributor to the city forest's income. Douglas fir also has a higher mean annual increment (18 m³/ha/year) in comparison to other species such as silver fir and Norway spruce (15 m³/ha/year), European beech and larch (9 m³/ha/year) or sycamore and ash (8 m³/ha/year).

Although the conditions favouring the natural regeneration of Douglas fir vary throughout the city forest, the highest densities of Douglas fir natural regeneration can be found on drier south facing slopes as observed by the local managers. The natural regeneration of Douglas fir is usually accompanied by natural regeneration of silver fir and/or European

beech. Douglas fir requires at least medium light levels and it does not regenerate well under dense, closed canopies. Natural regeneration of more shade tolerant species such as silver fir and European beech is usually observed in more shaded parts of the stands (Figure 93). Steinmetz (2014) focused on the occurrence of natural regeneration of Douglas fir in the city forest and did not report any major increases in the Douglas fir natural regeneration between the forest enterprise inventories conducted in 1999 and 2009. The proportion of Douglas fir natural regeneration decreased between the two inventories with the exception of the early stages of natural regeneration (below a height of 20 cm) where it slightly increased.

The topic of invasive potential of Douglas fir has been the subject of intense debate in Germany (for further details, please see chapter 3.3). The fact that Douglas fir has been planted at such considerable rates in Freiburg City Forest has also created debate; in simple terms, foresters consider Douglas fir as suitable addition to the mixed-species mountain forests regardless of its non-native origin, while nature conservationists see it as a tree species that should not be present in local forests. Nonetheless, unless heavier cut allowing higher light level reaching the forest floor is applied in order to provide conditions for Douglas fir to regenerate, natural regeneration of shade bearing species such as silver fir is generally observed. Competing vegetation is also considered as a hindrance to the natural regeneration of Douglas fir (Steinmetz 2014).

Another important point to note is that Douglas fir is considered as a possible alternative to the native conifer species (e.g. Norway spruce and silver fir) whose native range is likely to shift and substantially reduce due to the climate change. The issue of climate change means that management objectives must be reassessed and include species that create positive revenue streams.

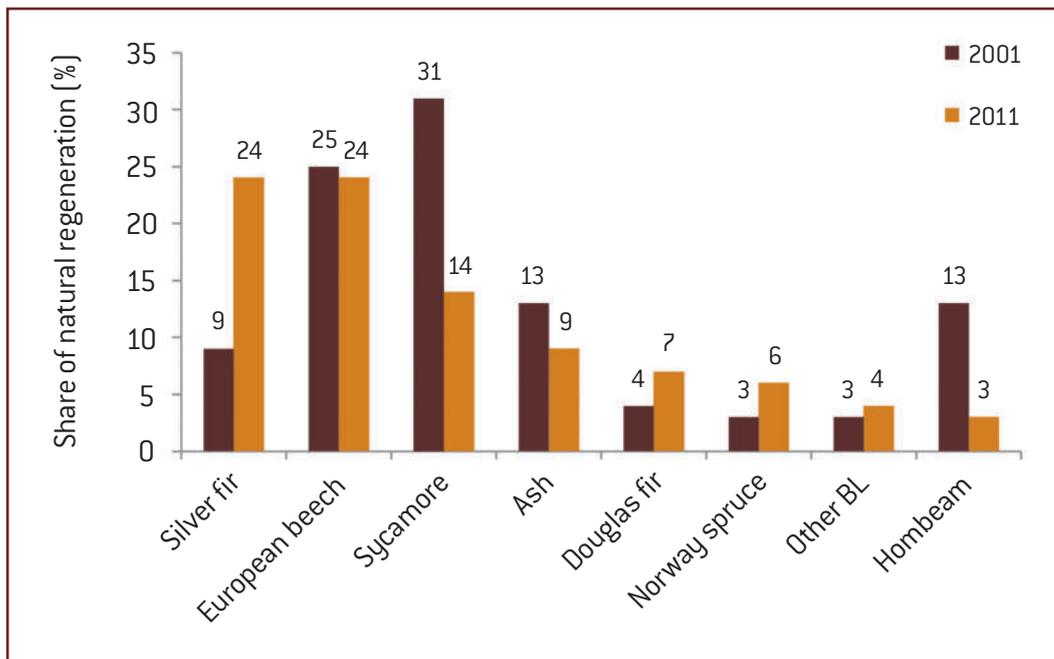


Figure 93. The share of natural regeneration of major tree species found in Freiburg City Forest under shelter in mature stands in the upland parts of the forest (proportions of natural regeneration that are $\geq 3\%$ are shown).

About 18 % (938 ha) of the city forest are designated as special forest habitats, with the most common habitat being the rare near-natural forest communities occupying 67 % of the entire designated area. The special forest habitats are managed in order to preserve and enhance their valuable structures and species biodiversity. Detailed information on the role and occurrence of introduced Douglas fir in the designated habitats can be found in chapter 5.3.

The principles of continuous cover forest management are incorporated into the management of Freiburg City Forest.

The forest management principles of 'continuous cover forestry' have been adopted in Freiburg City Forest for the past 25 years. One of the aims has been to transform even-aged and even-sized stands of Douglas fir (but not only) towards an uneven-sized forest structure (Figure 94). About 11 % (549 ha) of Freiburg City Forest have been categorised as 'Dauerwald', which is considered as a mixture of trees of all sizes and species. Such type of management in the city forest usually results in the use of a single-tree selection system where only a few trees from the upper diameter classes (>100 cm) are cut. A relatively short harvesting cycle is applied (i.e. once every five years) as the management decisions and the harvesting depends on the volume increment and quality of individual trees. Harvesting of individual trees is spread uniformly across the stand resulting in rather closed canopy. In the case small gaps occur, the canopy closes rapidly leading to low light conditions at ground level. The presence of European beech in the middle storey tends to enhance this effect. As Douglas fir has an intermediate light demanding character, this led to a decrease of natural regeneration of Douglas fir between 1999 and 2009 (Steinmetz 2014).

According to the objective of keeping the proportion of Douglas fir in the upland forest at 20 %, slight changes in silvicultural management have been adopted in the last five years in older stands of Douglas fir. Where natural regeneration of Douglas fir is desired, the single tree harvesting of trees of larger diameters is complemented by thinning of poor quality trees (e.g. those with heavy branching, poorly developed crowns, etc.) in order to establish suitable light conditions facilitating successful natural regeneration of Douglas fir, which is otherwise outcompeted by other, more shade bearing species.



Figure 94. Douglas fir stands of varying forest stand structure (photos: L. Vítková).

Recreation in Freiburg City Forest plays an important role as 4–5 million people visit the forest each year.

One of the management objectives of the city forest is to make the forest not only freely accessible to everyone, but also to enhance the recreation potential of the forest. This may be demonstrated by the number of visitors to Freiburg City Forest, which is estimated by the Municipal Forestry Office to be between 4 and 5 million each year. Visitors say that they appreciate the presence of the older Douglas firs that can reach large proportions (diameters exceeding 100 cm at 100 years of age) and consider Douglas fir an integrated component of the pleasing aesthetical value of the forest. Due to the high visitor pressure in the city forest, extra money is spent on maintenance and creation of infrastructure in order to satisfy visitor needs. The income from the sale of Douglas fir timber substantially contributes towards the social function of the forest. Freiburg City Council spends €1 million each year to be used for activities related to recreation, environmental education and increase of public awareness regarding forest ecosystems. Some 437 km of marked footpaths, 126 km of mountain bike paths and 78 km of sign-posted bridle (horse riding) paths have been created in the city forest. There are also 68 km of jogging and fitness parkour paths. Barbeque sites and huts have also been installed in the city forest to increase the forest use.

As a proof of how the Freiburg City Forest serves multiple forest management, and how the administration provides necessary information for public, around 150 events are organised by specially trained foresters each year, especially for school and kindergarten children. In line with educational objectives, the children spend some time in the forest learning to understand forests as complex natural ecosystems.

Freiburg City Forest has been managed in a way that it accommodates for various recreational demands of the 4–5 million visitors every year and at the same time gains revenue from timber harvesting. The management applied has been in accordance with FSC certification standards where traditional forest practices have been combined with the principles of continuous cover forest management. Although there has been much debate regarding the presence of introduced Douglas fir, this species of North American origin plays an important role contributing to the aesthetic and economic value of the city forest.

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