

# Commercial Forestry as a Vector of Alien Tree Species – the Case of *Quercus rubra* L. Introduction in Poland

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## Abstract

The paper presents the history of *Quercus rubra* L. introduction and current distribution in the state forests of Poland. We followed the extent of *Q. rubra* planting on a spatial and temporal scale, based on data obtained from the Information System of the Polish State Forests (SILP) as of 2011. The current distribution of Northern Red oak, the characteristics of *Q. rubra* stands, the purposes of cultivation, the type of occupied forest habitat and differences of tree age were also analysed.

*Q. rubra* has been deliberately introduced to Poland as a commercially important tree since the beginning of the 19<sup>th</sup> century. During two hundred year period, the area of its intentional cultivation has been successively increased. In the second part of the 20<sup>th</sup> century, the scale and the rate of its planting have significantly accelerated. At present, *Q. rubra* occurs in the whole country and occupies 14.3 thousand ha of the state forests, including 10.5 thousand ha of timber plantations. Within the remaining area, *Q. rubra* was planted as an admixture woody species. Despite the relatively small proportion of area with planted *Q. rubra* in the total forest area (just 0.16%), red oak seems to occur commonly, mainly due to the very high number (over 80 thousand) localities through which it is spatially dispersed. It is planted in a wide range of forest soils: from dry and poor areas that are suitable for coniferous forest, to soils that are flooded and rich in nutrients and naturally overgrown by deciduous forests. The biggest area of its plantation, however, is located in mixed deciduous forests (with moisture and medium-rich soils). It is commonly used in forest restoration of post-industrial (e.g. post-mine) soils as well as in the afforestation of abandoned or poor post-agricultural lands. Currently, most of the stands are too young for logging, so the commercial significance of *Q. rubra* wood in the timber market is still low, but it is considered one of the most commercially important trees of alien origin in Poland.

The long lasting (200 years) and widespread cultivation of *Q. rubra* in European forests, however, in combination with the noted abundance of vital acorns, seedlings and saplings produced by numerous mature trees, may lead to a sustained propagule pressure and the expansion of this “sleeper weed”.

**Key words:** *Quercus rubra*; Northern red oak; introduction history; invasive species; sleeper weed

## Introduction

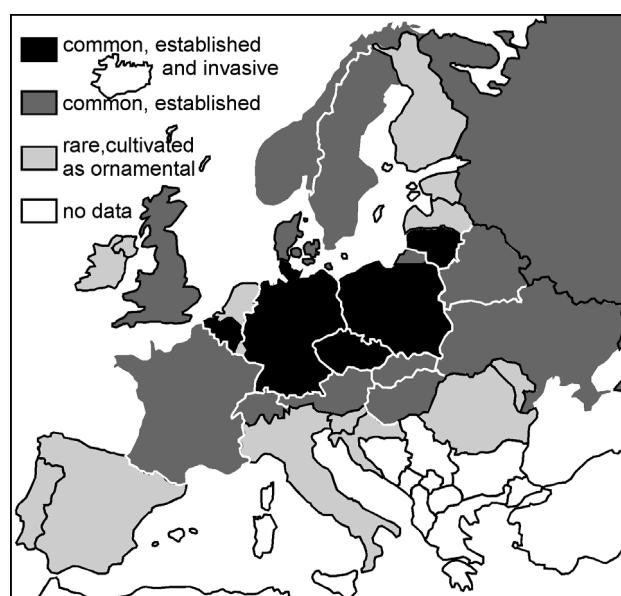
Contemporary commercial forestry is in substantial part based on cultivation of deliberately introduced non-native trees (Zobel et al. 1987, Sutton 1999, FAO 2001, FAO 2010). Many woody species have been in-

tentionally introduced for timber plantations or for restoration of degraded areas with success (Palmberg-Lerche et al. 2001). These introductions are justified by numerous positive silvicultural properties of planted trees: high capability of adapting to a wide variety of environments in new areas of introduction, easy

establishment, fast growth and high wood and fibre quality (Richardson 1998, Mead 2001, Sedjo 2001, Fenning and Geshernzon 2002). Some alien tree species used in commercial forestry, however, are negatively noted due to their real and/or potential invasiveness causing ecological, economical and/or social damage in new areas of introduction (Binggelli 1996, Peterken 2001, Rouget et al. 2002, van Wilgen et al. 2001, Kohli et al. 2009, Richardson and Rejmanek 2011, Pyšek et al. 2012a). The deliberately introduced alien species can host insects or pathogen fungi, which may also be a threat to native woody species (Mitchell et al. 2010, Mułenko et al. 2010, Vannini et al. 2012). As a result, the introduction of alien woody species for commercial reasons has led to controversy over whether the alien species are really economically necessary to forestry, and whether the further introduction should be limited or even stopped for environmental concerns (de Witt et al. 2001, Essl et al. 2010, Reinhardt et al. 2011, Dodet and Collet 2012, Low 2012, Yokimozo et al. 2012). One such species that gives rise to controversy is *Quercus rubra* L., native in eastern parts of the USA and Canada (Sander 1990), and intentionally introduced across large areas of Europe.

*Q. rubra* was first brought to Europe, primarily for ornamental purposes and for botanical curiosities, in the 17<sup>th</sup> century (Magni Diaz 2004). Planted in numerous botanical and residential gardens, and as a roadside tree, it has become very common. The successful acclimatisation, large ecological amplitude, fast growth and suitable wood properties of this species were recognised by European foresters towards the end of 18<sup>th</sup> century, which initiated its widespread introduction into timber forests (Król 1967). The intensification of the wood market due to the growing demand for wood products by developing industry in Western Europe, together with the shrinking amounts of wood acquired from impoverished or degraded native forests, favoured and justified the introduction of this fast growing exotic species for timber production (Magni Diaz 2004). At present, *Q. rubra* is a commercially important tree (Vansteenkiste et al. 2005, Redei et al. 2010) and one of the most frequent deciduous species of foreign origin noted in European forests (Figure 1).

For the wood industry, *Q. rubra* is an important source of hardwood timber (Vansteekieste et al. 2005). It produces a close-grained, heavy and hard wood that can be used in a broad range of applications (Gilman and Watson 1994, AHEC 2005). The high fuel value of *Q. rubra* wood makes it excellent firewood as well (USDA 2002). Due to these characteristics it is called an “*American Beauty*” in the timber market (AHEC 2005). It is also noted as a valuable species that pos-



**Figure 1.** The distribution of *Q. rubra* in Europe (based on NOBANIS data and additionally on Magni Diaz 2004, Verloove 2006 and Redei et al. 2010)

itively impacts on degraded or poor habitats and is also decorative and ornamental (Gilman and Watson 1994, Redei et al. 2010). It is also considered to be a threat to native biodiversity (Riepšas and Straigytė 2008), which generates warnings against its further cultivation (Reinhardt et al. 2003, Straigytė and Žalcauskas 2012). Accurate data are required on areas of planting and on the scale of invasion events, before the species will be classified as “invasive”, and the appropriate management proceedings will be applied (Haysom and Murphy 2003).

The aim of this study is: i) concerned with the reconstruction of the course of *Q. rubra* introduction in the state forests in Poland on a temporal and spatial scale; ii) the recognition of the current distribution of *Q. rubra* within different types of forest; iii) the analysis of the age and structure of stands; and, iv) the assessment of the impact of contemporary *Q. rubra* on forest management.

## Materials and Methods

Data on *Q. rubra* occurrence in Polish state forests were obtained from the Information System of the National Forest Holding State Forest (SILP). The study concerns only the Northern red oak stands that were planted intentionally. The current data on the State Forests of Central Statistical Office (CSO 2011) were also used. The year of plantation was calculated based on the SILP data on the current age of *Q. rubra* tree stands. It was carried out for all cultivations that cur-

rently exist in the State Forests, which allowed us to follow the history of *Q. rubra* spread on a temporal and spatial scale. The process of this alien tree cultivation and its current distribution were analysed in 16 administrative provinces (binding administrative divisions of Poland) and presented on the map set using the ArcGIS 10.0 Geographic Information System software.

Two types of cultivated *Q. rubra* stands were distinguished in accordance with its role in forest management and to the proportion of introduced trees in tree-stand composition. The timber forests include those forests where *Q. rubra* dominates or co-dominates and where the trees were planted for commercial purposes. The second type of introduced *Q. rubra* stand includes those forest patches where it was planted as a biocenotic admixture, usually in small clusters (10 x 10 m in area) with other broadleaved species (e.g. *Fagus sylvatica*, *Acer pseudoplatanus*) or as single individuals dispersed between native trees. In such cases, the area occupied by Northern Red oak stands was calculated at a level of 1.5% of the total area of the division where it was planted as an admixture. The range of forest types where *Q. rubra* currently occurs was analysed. The current age structure of stands and the participation of *Q. rubra* in different layers of forest communities (understory and/or overstory) were also studied.

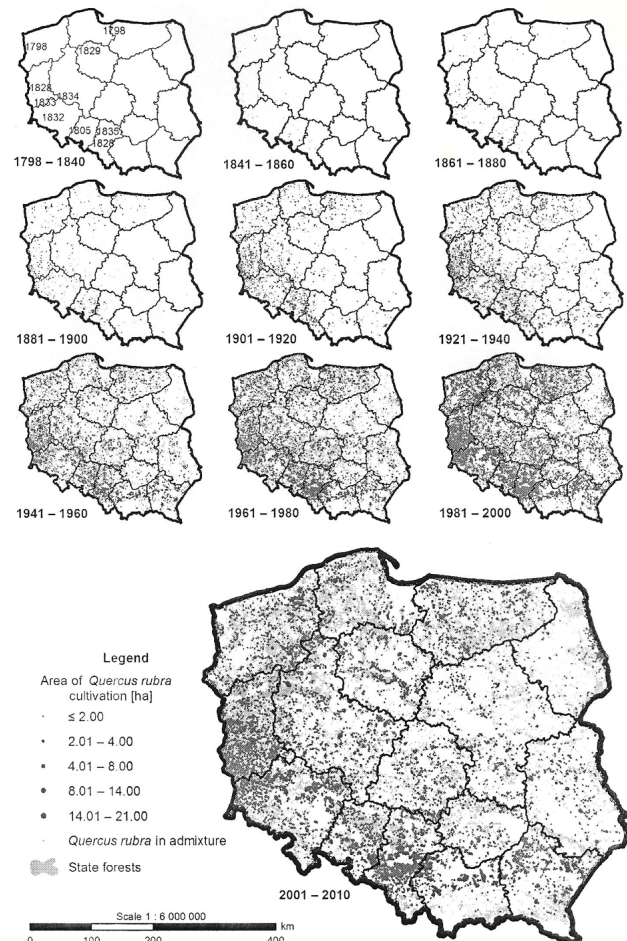
## Results

### *History of Q. rubra introduction and extent of its new range*

The first *Q. rubra* introduction in the forests of Poland took place at the turn of the 18<sup>th</sup> and 19<sup>th</sup> centuries. The oldest stands occur in the northern part of the country (currently in the Elbląg Forest District) and in north-western Poland (Gryfino Forest District) where *Q. rubra* was planted as an admixture species in 1798 (Figure 2). In 1805 it was also introduced in the south of the country (in Tułowice Forest District). The first commercial plantation of *Q. rubra* was established in 1835 in Zawadzkie Forest District (southern Poland). Only ten experimental cultivations of this alien tree species were established in dispersed localities until 1840 (Figure 2). The number of stands with planted *Q. rubra* then increased gradually up to the end of 19<sup>th</sup> century (Figure 2). The forests located in the western and north-western parts of contemporary Poland were managed at that time by Prussian foresters, and the south-western and southern forests by Austrian foresters.

The whole of the 20<sup>th</sup> century was a period of common plantation of *Q. rubra* in Polish forests, with

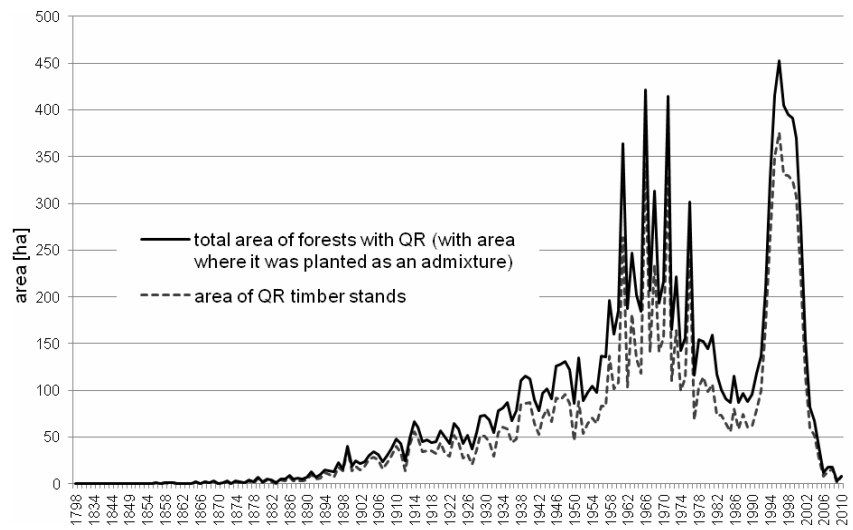
a significant increase in the number of spatially dispersed oak cultivations. Simultaneously, the border range of area with planted *Q. rubra* was moved successively to the east (Figure 2). This process was especially intensive in the second part of the last century when *Q. rubra* was commonly cultivated in over 10 thousand hectares.



**Figure 2.** The location of *Q. rubra* stands over the course of its intentional planting in Polish State Forests. The presence of the *Q. rubra* during a given time period is based on its present age, which was derived from the SILP data

The scale and rate of introduction decreased temporarily between 1972 and 1993, but then increased markedly again until 2001 (Figure 3). The *Q. rubra* introduction reached its peak in 1996 when this tree was planted in more than 450 ha of state forests. The establishment of new cultivations has reduced significantly in the last decade and is now at the same level as the 1890s (Figure 3).

At present, the total area of *Q. rubra* stands is 14.3 thousand ha. The occurrence of the species is

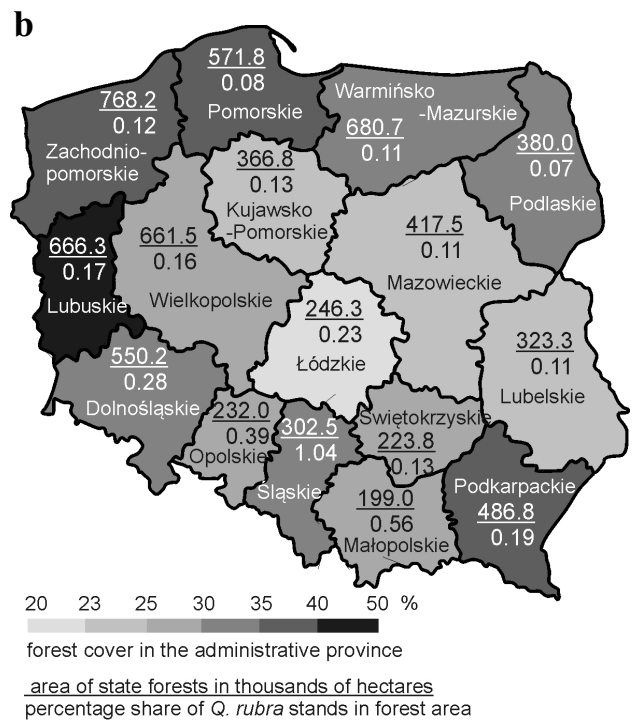
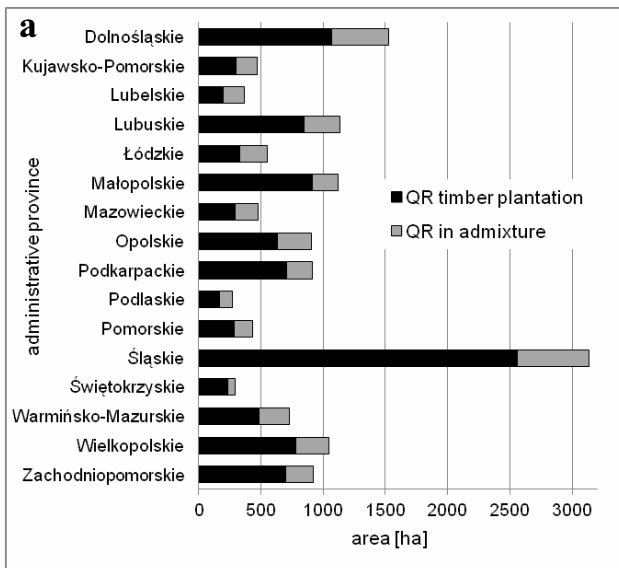


**Figure 3.** The rate and scale of *Q. rubra* planting in Polish State Forests since 1798 (own calculations based on SILP data)

widespread in Polish state forests in almost all of the country (Figure 2), with the exception of the mountain belt in the south. The concentration of its plantation is notable in southern provinces (Figure 4a) where it often makes compact plantations in areas over 5 ha. In general, it is much more common in the western part of Poland, and, so far, this alien tree species is less popular in eastern provinces (Figure 4a). Individual *Q. rubra* also occurs, however, in numerous dispersed localities within the middle and eastern parts of the country (Figure 2), due to its common planting as an admixture tree.

It is noteworthy that the percentage share of *Q. rubra* stands in the total forest area is slight in all provinces (Figure 4b). These cultivations constitute only 0.16% of the total forest area managed by the State Forests Holding.

During the early periods of cultivation, *Q. rubra* was planted exclusively as an undergrowth component or as an admixture species (Table 1). Since 1800, most of the new plantations of *Q. rubra* were established initially as experimental cultivations, and then as commercial cultivations. In the subsequent twenty-year period, timber plantations constituted over 60% of the



**Figure 4.** The area of introduced *Q. rubra* (QR) stands in administrative provinces (a) and its proportion to the total area of state forests (b) occurring in the province (own calculations based on CSO 2011 and SILP data)

introduction area. The significant advantage in the areas of *Q. rubra* stands planted for production purposes, over areas where it was applied as an admixture in tree stands, was noted in the last decade of 20<sup>th</sup> century, when the commercial stands covered almost 80% of the area with *Q. rubra* share. The area of planting increased significantly – the biggest changes (period to period) were up to 1920, but the biggest increase was in 1960-2000. The rate and scale of *Q. rubra* plantation, however, decreased in the last decade (Table 1).

**Table 1.** The area of *Q. rubra* (QR) intentional planting in Polish State Forests since 1798 (own calculations based on SILP data)

<i>Q. rubra</i> planted in years	as dominant tree species [ha]	as an admixture [ha]	in total [ha]	Increase of QR area with each successive period [ha]	Changes of QR area in relation to the in last period
1798–1820	0.00	0.20	0.20	0.20	
1821–1840	0.14	0.09	0.23	0.43	2.15
1841–1860	3.35	2.42	5.77	6.20	14.42
1861–1880	24.62	11.21	35.83	42.03	6.78
1881–1900	165.13	54.89	220.02	262.05	6.23
1901–1920	616.76	174.27	791.03	1 053.08	4.02
1921–1940	976.37	428.43	1 404.80	2 457.88	2.33
1941–1960	1 599.46	788.20	2 387.66	4 845.54	1.97
1961–1980	3 258.90	1 247.60	4 506.50	9 352.04	1.93
1981–2000	3 340.20	918.17	4 258.37	13 610.41	1.46
2001–2010	521.06	157.05	678.11	14 288.52	1.05
total	10 505.99	3 782.53	14 288.52		

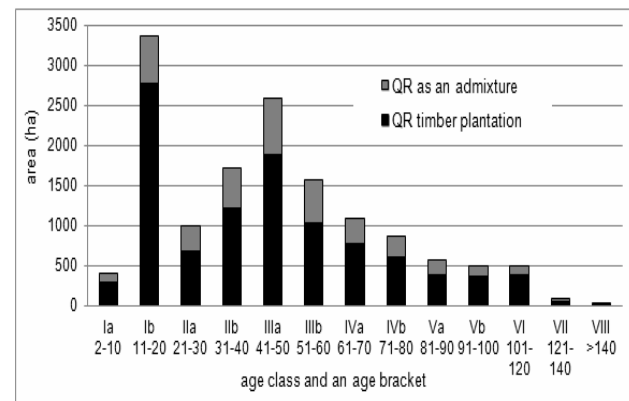
At present, there are 10.5 thousand ha of stands where *Q. rubra* dominates or co-dominates and where it was planted for wood production (Table 1). The smallest plantations, however, (in areas below 1 ha) predominate numerically (Table 2). The number of monocultures in areas bigger than 4 ha amount to only 153, and they cover just less than one thousand hectares in total. As a tree-stand admixture, *Q. rubra* occurs within 3.8 thousand ha of state forests, but it is dispersed in more than 63.5 thousand localities (Table 2).

**Table 2.** The number of *Q. rubra* localities and the area of *Q. rubra* stands in Polish State Forests (based on SILP data)

Area of plantation [ha]	Number of localities	Area in total [ha]
≤1.0	17 335	5 549.6
1.01–2.0	1 681	2 354.6
2.01–4.0	620	1 667.3
4.01–8.0	131	693.0
8.01–14.0	18	175.9
14.01–21.0	4	65.6
in admixture	63 553	3 782.5
in total	83 342	14 288.5

**Current *Q. rubra* age structure**

The age of *Q. rubra* stands is diversified. At present, the youngest tree stands (Ia and Ib age classes) and single trees under 20 years of age constitute almost 27% of all stands (Figure 5). The area of tree stands over 100 years of age (VI class and higher) and suitable for logging, amounts to just 4.5% of all stands established for commercial purposes. Such old *Q. rubra* also grows as dispersed single trees or small clumps in 146 ha of forests.



**Figure 5.** The current age structure of *Q. rubra* (QR) stands (based on SILP data)

The oaks from the first age classes (Ia and Ib) are the components of the understory within 3.8 thousand ha of forest communities, one-fifth of which have patches where this species was planted as a biocenotic admixture. The trees over 20 years of age and below 60 years of age (II<sup>nd</sup> and III<sup>rd</sup> classes) compounds the lower layer of the tree stand. These forests constitute around 50% of the total *Q. rubra* area. The trees over 60 years of age constitute almost a quarter of all stands and usually build the upper tree-stand layer (the forest overstory). The forest area with trees in the reproductive phase (over 25–30 years of age) and able to form new self-sown generations amounts to almost 9.5 thousand ha and constitutes 67% of all *Q. rubra* cultivations.

**General characteristics of forests with planted *Q. rubra***

The vast majority of *Q. rubra* stands (90.5%) are located in lowland forests. This 12.9 thousand ha constitute just 0.17% of the total area of state forests growing in lowlands (SILP and CSO data). The next 1.2 thousand ha (8.7%) occur in uplands and in the sub-mountain zone, which constitute only 0.24% of the total forest area managed by the State Forests. The proportion of *Q. rubra* patches located in the mountains amounts to less than 1% and 0.01% of the total

area of mountain forests. The majority of *Q. rubra* stands were established in deciduous and mixed deciduous forests (Tables 3 and 4). Currently they cover in total around 9 thousand ha, of which two-thirds are timber plantations (they constitute 66% of all *Q. rubra* timber plantations in Polish State Forests). The next 47% of forest patches with this alien tree species is located on soils suitable for mixed coniferous and coniferous forests (Tables 3 and 4). This species was also commonly planted in mixed deciduous forests, as well as in mixed coniferous forests, for the enrichment of tree-stand composition (Table 3). The proportion of forests patches, however, with *Q. rubra* in the total areas of determined types of forest is sparse (Table 3). Deciduous and mixed deciduous forests were preferred for its plantation, however, the permanent and significant increase of coniferous and mixed coniferous forests included into *Q. rubra* plantation areas is notable since the 1940s (SILP data).

**Table 3.** The *Q. rubra* occurrence in different forest types (based on SILP data)

Type of forest	<i>Q. rubra</i> planted as						% of the total area of forest type in Poland
	timber plantation		an admixture		in total		
	area in ha	%	area in ha	%	area in ha	%	
mixed deciduous	3 972.5	37.8	1 309.3	34.6	5 281.8	36.4	0.22
deciduous	2 912.6	27.7	824.9	21.8	3 737.5	25.7	0.18
mixed coniferous	2 719.1	25.9	1 205.5	31.9	3 924.6	27.5	0.14
coniferous	901.8	8.6	442.8	11.7	1 344.6	9.4	0.07

*Q. rubra* trees were planted in a wide range of forests in accordance with soil fertility and moisture: from poor (oligotrophic) to rich in nutrients (eutrophic), and from dry to wet, or even boggy or flooded (Table 4). The biggest area with *Q. rubra*, however, occupy moisture and mezo-eutrophic soils suitable for mixed deciduous forests.

Most of the sites where *Q. rubra* was planted are classified as natural or close-to-natural (SILP data). The area of distorted or transformed forest habitats constitutes more than one-fifth of the total area of *Q. rubra* plantation (it amounts to around 3.2 thousand

**Table 4.** The general characteristic of soil fertility and moisture within forest sites with planted *Q. rubra* (based on SILP data)

Soil fertility (type of forest)		Soil humidity				
		dry	moisture	wet	swampy flooded	
oligotrophic (coniferous)	area [ha]	10.38	1312.30	21.55	0.38	–
	%	0.07	9.18	0.15	–	–
oligo-mezotrophic (mixed coniferous)	area [ha]	–	3425.85	492.43	6.30	–
	%	–	23.98	3.45	0.04	–
mezo-eutrophic (mixed deciduous)	area [ha]	–	<b>4331.37</b>	942.70	7.74	–
	%	–	<b>30.31</b>	6.60	0.05	–
eutrophic (deciduous)	area [ha]	–	3201.02	393.43	15.60	127.47
	%	–	22.40	2.75	0.11	0.89
in total	area [ha]	10.38	12270.54	1850.11	30.02	127.47
	%	0.07	85.88	12.95	0.21	0.89

ha). The further 1.8 thousand ha is classified as degraded.

Due to the broad tolerance of *Q. rubra* to habitat conditions (broader than oaks native to Poland), it has been readily used in wasteland afforestation programmes. So far, 3.3 thousand ha of these alien tree stands have been established within recent forests growing on abandoned lands and on the poorest post-agricultural soils. The area of tree stands planted on reclaimed lands, however, amounts to only 87 ha (0.6% of the total *Q. rubra* area).

The adaptive capacity of *Q. rubra* to grow in heavily polluted areas allow this tree to be successfully planted within industrial zones. There are around 950 ha of forests, however, (in which there are 216 ha of forest with dominant or co-dominant *Q. rubra*), where this tree also experiences damage by industrial emissions (SILP data). There are 448 ha of forests with *Q. rubra* which are threatened by pathogenic fungi.

**Other *Q. rubra* applications in forestry**

*Q. rubra* is commonly planted to create suitable habitats for wild and game animals (Burzyński 1999). Such places are attractive to deer, boar, mice and other herbivores browsing broadleaved trees or eating oak acorns. In this way the animals are “drawn away” from agricultural fields or from younger forest cultivations where they readily feed. Where the density of herbivores is too high within forest complexes it may, however, result in the intensive browsing pressure that could have a detrimental impact on tree growth (Stange and Shea 1998). It might cause economic losses, mainly due to planted seedling destruction and the limitation of natural spontaneous regeneration of trees. The damage caused by herbivores was reported at 6.9% of the *Q. rubra* tree stands (SILP data).

Due to the very decorative red autumn leaves, this tree is planted near forester’s lodges and forest settlements (Danielewicz and Wiatrowska 2012), along forest roads, and in the past, even near the information boards located in entrances to nature reserves or nature parks. It is also universally cultivated in cottage gardens and in urban residential areas, located in the neighbourhood or even within forest complexes.

**Discussion**

The results show that *Q. rubra* is a widespread alien broadleaf woody species in Polish state forests (Figure 2). It was intentionally introduced both for commercial purposes and for the increased structural complexity of forest communities (Tables 1 and 2). It has been planted in a wide range of forest sites (Tables 3 and 4) and used in the restoration of degraded

or abandoned lands due to its high capability of adapting to a wide variety of environmental conditions. The majority of *Q. rubra* stands were established in semi-fertile and moist soils suitable for deciduous and mixed deciduous forests (Table 4), which is in accordance with the ecological preferences of this tree, both in its native range (Crow 1988) and in the introduction area in Europe (Rameau et al. 1989 in Magni Diaz 2004).

The common and deliberate *Q. rubra* plantation is justified by numerous positive silvicultural and growth characteristics of this species. It grows faster and produces more wood than native oaks *Q. robur* and *Q. sessilis* (Vanstekeeste et al. 2005, Redei et al. 2010). The high survival rate and good growth of *Q. rubra* in unproductive sites, where our native oaks perform poorly (Bellon et al. 1977, Danusevičius et al. 2002), also justify its further use in afforestation of the permanently increasing area of abandoned agricultural land (CSO 2011) and in forest restoration of post-industrial land (Zieliński and Nowak 2011).

The thousands of hectares of stands, where *Q. rubra* dominates or co-dominates and where it was planted as timber plantation (Table 2), will bring satisfying economic profits (Kuc et al. 2012). The best increase of stand volume is obtained, however, when *Q. rubra* is planted as an admixture species in mosaic with other coniferous or deciduous trees (Jaworski 1995, Murat 2002), i.e. the high proportion of areas where it occupies small patches (Table 2). At present, the majority of *Q. rubra* stands are very young (Figure 5) and the increase of profits from wood sale can be expected in only 50-70 years, when trees achieve harvestable size. The significant increase of interest in *Q. rubra* wood, noted in European and Asian timber markets (AHEC 2005, Vansteenkiste et al. 2005) is a positive indication for its commercial value.

So far, however, the total area of *Q. rubra* stands constitute just 0.16% of the total forest area managed by the State Forest Holding State Forests and only 2.2% of the total area (649 thousand ha) of tree stands of all oak species (SILP data) in Poland. Moreover, in the last decade, the tendency towards a decrease in *Q. rubra* plantation rate and scale is noted (Figure 3). This slowdown is the response of the State Forests to international awareness on the negative effects of the aliens' introduction (Moore 2005, COM 2011, Roberts et al. 2011, Simberloff 2011, Vilá et al. 2011), but there is no clear assessment of the negative and positive effects of this woody species introduction. The thick net of over 80 thousand patches with intentionally planted alien trees located in a wide range of forests (Figure 2, Table 2), however, already constitute the real source for spontaneous spread of self-sown *Q. rubra* seedlings. The combination of such strong-

ly dispersed localities with observed abundance of vital corns and seedlings and saplings (Bodył 2011) produced by numerous mature trees (in age over 25-30 years, Table 5) may potentially lead to the expansion of *Q. rubra* in new areas. Long-lasting and widespread alien cultivation leads to a sustained propagule pressure in the new range, which dramatically increases the chances of finding suitable sites for colonisation (Pyšek et al. 2009, Richardson 2011, McGregor et al. 2012, Proches et al. 2012). According to Křivánek et al. (2006) and Bucharowa and van Kleunen (2009), the long introduction history and, particularly, the high planting frequency, determine the naturalisation success and invasiveness of North American woody species in Europe. The problem of uncontrolled *Q. rubra* spread can be imperceptible due to its live trait: like other persistent woody species (Schrader and Starfinger 2009, Aikio et al. 2010, Webster and Wangen 2009, Pyšek et al. 2012a), *Q. rubra* has likely a long-lasting lag-phase between introduction and naturalisation and expansion. Admittedly it is unable to establish beneath its own canopy within even aged monocultures, but (in the native range) it regenerates effectively through gap-phase replacement (Crow 1988). In new areas it germinates and self-reproduces successfully in different forests and it is possible for it to establish new self-sown and self-sustaining stands in proper conditions. It is already reported in Poland as a naturalised species (Chmura 2004, Otręba and Ferchmin 2007) as well as an invasive species (Tokarska-Guzik 2005), likewise in adjacent countries (Riepišas and Straigytė 2008, Pyšek et al. 2012b), which generates warnings against further *Q. rubra* cultivation in European forests (Reinhardt et al. 2003, Straigytė and Žalkauskas 2012). *Q. rubra* is probably one of the "sleepers weeds" (*sensu* Groves 2006), which is why its spontaneous spreading outside areas of cultivation calls for more focused research concerning the risk of uncontrolled invasiveness. The inappropriate decisions, both on further *Q. rubra* plantation as well as on introduction cessation, may also bring long-lasting negative effects. The full recognition of positive and negative ecological, economic and social effects of *Q. rubra* introduction in forest ecosystems is essential for proper management and requires further studies (Otręba and Ferchmin 2007, Woziwoda et al. 2012).

## Conclusions

*Quercus rubra*, a woody species native to North America, has been deliberately introduced to Polish forests since the beginning of 19<sup>th</sup> century. During this two-hundred-year period, the rate of its intentional cultivation increased, and the area with *Q. rubra* suc-

cessively spread from western to eastern parts of the country. Currently, this tree species is widespread throughout the whole country, and it can be considered as one of the most commercially important trees of alien origin. Despite the relatively small proportion of area with *Q. rubra* compared to the total forest area, *Q. rubra* seems to occur commonly, mainly due to the very high number of localities. It is planted in a wide range of forest sites, suitable for coniferous, mixed coniferous, mixed deciduous and deciduous forests. It is successfully used in forest restoration of post-industrial lands as well as in the afforestation of abandoned or poor post-agricultural lands. The majority of *Q. rubra* stands are too young for logging, so the commercial implications of its wood in the timber market are currently low. The long-lasting and widespread cultivation of *Q. rubra*, however, in combination with abundant self-reproduction, may potentially lead to a sustained propagule pressure which suggests the possible spread of this alien tree species both in Polish and in other European forests.

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## КОММЕРЧЕСКОЕ ЛЕСНОЕ ХОЗЯЙСТВО В КАЧЕСТВЕ ВЕКТОРА ЧУЖЕРОДНЫХ ВИДОВ ДЕРЕВЬЕВ – СЛУЧАЙ ИНТРОДУКЦИИ ДУБА КРАСНОГО В ПОЛЬШЕ

Б. Возивода, М. Потоцки, Я. Саган, М. Засада, Р. Томусяк и С. Вильчински

### Резюме

В статье представлена история интродукции и распределения североамериканского красного дуба *Quercus rubra* L. в государственных лесах Польши. Нами были проанализированы пространственные и временные масштабы об истории интродукции на основе полученных данных информационной системы Польских Государственных Лесов с 2011 года. Проанализированы были распределение красного дуба и характеристика древостоев в соответствии с целью их внедрения, а также место расположения леса и различия возрастных структур деревьев.

В начале 19-го века красный дуб был введен в Польше в качестве важной коммерческой древесины. В течение двести лет площадь выращивания лесных насаждений была увеличена. Во второй половине 20-го века, масштабы и скорость введения лесных насаждений значительно ускорился. В настоящее время *Q. rubra* занимает 14 300 га государственных лесов в стране, в том числе из них - 10 500 га монокультур. На остальных площадях был посажен в качестве смешанной лесной породы. Несмотря на относительно небольшую долю об общей площади лесов (всего 0,16%), красный дуб распространен во многих (более 80 тысяч) пунктов страны. Они растут в широком диапазоне лесных местообитаний: от сухих и до бедных среды обитания, которые подходят для хвойных лесов, к затопленным средом обитания, богатым питательными веществами и естественно заросшими лиственными лесами. Однако самая большая площадь дуба находится в среде обитания смешанных лиственных лесов (с влажностью и средних почвах, богатых). Они широко используется в восстановлении лесных постиндустриальных районов, а также в облесении заброшенных или бедных сельскохозяйственных земель. В настоящее время для лесозаготовки интродуцированных лесных насаждений считается молодым и поэтому коммерческое значение красного дуба в лесном рынке по-прежнему остается низким. Но они могут рассматриваться как один из самых коммерчески важных дерево чужеродного происхождения в Польше.

Тем не менее, длительное (200 лет) и широкое внедрение *Q. rubra* в польских и европейских лесах с сочетанием изобилия семян, сеянцев и саженцев, произведенных многочисленными зрелыми насаждениями может привести к постоянному спонтанному распространению данного вида.

**Ключевые слова:** дуб красный; *Quercus rubra* L.; государственные леса; интродукция; инвазивность