

Increase of natural regeneration area of Norway spruce (*Picea abies* L. Karst.) in the Kaszuby Lake District during the decade 2002–2012

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Abstract. The Kaszuby Lake District is located beyond the natural range of Norway spruce, however its share in local forest stands is considerable (14.8%) and its vitality and growth are here not less than within the natural range. The study presents the results of stock-taking of natural regeneration of Norway spruce in this region in year 2002 and 2012 and the relevant silvicultural recommendations.

The stock of spruce natural regeneration was taken using the electronic database of the Regional Headquarters of State Forests in Gdańsk. The regeneration was put into following categories: seedlings (height below 0.5 m), lower advanced growth (height above 0.5 m and DBH below 7 cm), higher advanced growth (height above 3 m and DBH above 7 cm) and undergrowth (with dominating self sown spruce). In total 20 834 ha of Norway spruce natural regenerations were listed in year 2002 and 26 016 ha in year 2012 (increase by 24.9%). Most of them occur in fresh sites suited for mixed deciduous forests (LMśw) – in years 2002 and 2012 respectively 52.5% and 50.1%, and fresh sites suited for mixed coniferous forests (BMśw) – in years 2002 and 2012 respectively 30.4% and 32%.

The increase of natural regeneration of Norway spruce in this period was connected with the 23.6% decrease in volume of spruce stands in age of above 40 years.

Majority of spontaneously arriving spruce regenerations turn to the undergrowth, because of unfavorable light conditions under canopy and much to high density of seedlings and advanced growth. Good quality advanced growth on suited forest sites should be uncovered by thinning cuttings and consequently included into the future multispecies stands, with Norway spruce share up to 30%.

Keywords: *Picea abies*, natural regeneration stock-taking, natural range, silviculture, northern Poland

1. Introduction

The Kaszuby Lakeland lies outside the natural range of Norway spruce (*Picea abies* (L.) Karst.) in Poland (Boratyńska 1998); however, the share of this species in local forest stands amounts to 14.8%, which is important for forest management in this region. The Kaszuby Lakeland Norway spruce shows high vitality and large increments comparable to those in its natural range. However, due to some doubts regarding the range of its natural occurrence, spruce planting in the territory of some forest districts is discontinued,

and the spontaneous regeneration of this species is used to a limited extent.

Indications about the high dynamics of the natural regeneration of Norway spruce can be found in the forest management plans of local forest districts, as well as in some publications (Karpinski 1971, Nowosielski 1973, Borusewicz 1998); however, the issue of natural regeneration of this species in the Kaszuby Lakeland has so far not been fully explored. For this reason, the authors decided to undertake systematic studies (part of them are presented in this study) whose principal purpose was to analyse the results of

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the inventory of spruce natural regeneration in the Kaszuby Lakeland, and make recommendations for silviculture.

2. Materials and methods

Study Site

The Kaszuby Lakeland is located at the highest elevation of all Pomeranian Lakelands, reaching a height of 329 m above sea level (Wieżycza Mt.) on Szymbarskie Hills (Kondracki 2001). The soils of the region are characterised by a mosaic structure, with a clear dominance of brown and podzolic soils (Augustowski and Sylwestrzak 1979). The specificity of the climate in this region of Poland results from a relatively short distance from the sea and a significant elevation above sea level. The mean annual temperature is 6.4°C, which is almost 2°C lower than in the neighbouring mesoregions. The mean annual precipitation is 715 mm (Kwiecień 1979). There is a significant share of mountain and foothill species in the flora of the region (Herbich 1982).

Forests (mostly mixed and deciduous) occupy about 32% of the area. The fresh mixed deciduous forest (LMśw) covering 50.7% of the forest area administered by the 'State Forests' National Forest Holding is the dominant forest habitat type in the study area. Fresh mixed coniferous (BMśw), fresh deciduous (Lśw) and fresh coniferous (Bśw) forest account for 22.5%, 13.6% and 8.0% of the forest area, respectively. Other forest habitat types account for 5.2% (BULiGL 2002). The Kaszuby Lakeland comprises the Kartuzy, Cewice, Strzebielino, Kolbudy and Gdańsk Forest Districts and part of the Lębork, Kościerzyna, Lipusz and Starogard Gdański Forest Districts – all of them located within the confines of the Regional Directorate of State Forests (RDSF) in Gdańsk (Kondracki 2001; BULiGL 2002).

Inventory method of spruce natural regeneration

Using the electronic database of the Gdańsk RDSF, the natural regeneration of Norway spruce in the forest stands of the Kaszuby Lakeland was inventoried and classified into the following categories: renewals types, forest habitat types and forest districts (BULiGL 2002, 2012). The database included the descriptions of single- and multi-species stands, with a share of spruce exceeding 10%, where the natural regeneration of this species was recorded (as of 01.01.2002 and 01.01.2012).

The following regeneration categories were taken into account: seedlings (not exceeding 0.5 m in height), lower advance growth (spruce trees higher than 0.5 m, DBH less than 7 cm under bark), higher advance growth (spruce trees

higher than 3 m, DBH more than 7 cm under bark, not yet included in the understorey of the stand) and underbrush (with the predominant share of spruce trees established by natural means, not included in the seedlings and advance growth). However, the underbrush also comprised the seedlings and advance growth that showed the lowest silvicultural quality when the share of spruce regeneration in the composition of the future stand was higher than that foreseen for the production forest type. The area with the natural regeneration of Norway spruce was recalculated into so-called reduced area. Parallel to the inventory of spruce natural renewals, the inventory of forest stands with the share of spruce exceeding 10% and aged over 40 years was carried out.

In 2002, the assessment of the quality of the regeneration was carried out on randomly selected sample plots (three plots for each of the habitats: Lśw, LMśw, LMb, BMśw and BMb; five 3-m radius regeneration circles on each plot) using the following scale:

- quality class 1 – unsatisfactory (trees with a deformed crown structure, top shoots significantly shorter than the radius of the last whorl, occurrences of damage and symptoms of tree dieback),
- quality class 2 – satisfactory (trees with a well-developed crown and normal stem, top shoots approximately equal to the radius of the last whorl, without damage and symptoms of tree dieback),
- quality class 3 – good quality (trees with well-developed crown and stem, live green top shoots clearly longer than the radius of the last whorl, increments increasing with age).

3. Results

The results of the inventory of spruce natural regeneration in 2002 and 2012, by habitat type, are summarised in Tables 1 and 2.

In 2002, the share of spruce natural regeneration in each category was as follows: seedlings – 0.1% of the total regeneration area (26.0 ha), lower advance growth – 1.5% (317.0 ha), higher advance growth having the characteristics of the understorey – 2.8% (593.0 ha) and underbrush with dominant spruce – 95.6% (19,898.0 ha). The year 2012 saw significant differences compared to the state from before 10 years when the share of each regeneration category was as follows: seedlings – 0.2% of the total regeneration area (50.0 ha), lower advance growth – 1.0% (270.5 ha), higher advance growth with the characteristics of understorey – 3.9% (1010.5 ha) and underbrush with dominant spruce – 94.9% (24,685.0 ha).

Most areas of spruce natural regeneration were found in the fresh mixed deciduous (LMśw) and fresh mixed coniferous (BMśw) forest habitats, with the total share of the

Table 1. Area of the natural regeneration categories in the Kaszuby Lake District, according to forest site types, in year 2002

Site type	Seedlings	Lower advanced growth	Higher advanced growth	Seedlings and advanced growth	Undergrowth	All regeneration categories
	ha	ha	ha	ha	ha	ha
Bśw	-	6.5	17.0	23.5	1148.0	1171.5
Bw	-	-	-1.5	-	2.0	2.0
Bb	-	0.5		2.0	68.0	70.0
BMśw	-	18.0	256.5	274.5	6064.0	6338.5
BMw	-	0.5	2.5	3.0	55.0	58.0
BMb	10.0	28.5	29.5	68.0	619.5	687.5
LMśw	14.0	230.0	250.0	494.0	10443.5	10937.5
LMw	-	2.0	-	2.0	37.5	39.5
LMb	1.0	1.0	5.0	7.0	62.5	69.5
Lśw	1.0	30.0	30.5	61.5	1321.0	1382.5
Lw	-	-	0.5	0.5	17.0	17.5
Lł	-	-	-	-	3.0	3.0
Oł	-	-	-	-	45.5	45.5
OLJ	-	-	-	-	11.5	11.5
Total	26.0	317.0	593.0	936.0	19898.0	20834.0
Share [%]	0.1	1.5	2.8	4.5	95.5	100.0

Explanations: Bśw – fresh coniferous forest, Bw – moist coniferous forest, Bb – boggy pine forest, BMśw – fresh mixed coniferous forest, BMw – moist mixed coniferous forest, BMb – boggy mixed coniferous forest, LMśw – fresh mixed broadleaved forest, LMw – moist mixed broadleaved forest, LMb – boggy mixed broadleaved forest, Lśw – fresh hardwood forest, Lw – moist hardwood forest, Lł – flood plain forest, Oł – alder swamp forest, OLJ – ash-alder swamp forest

Table 2. Area of the natural regeneration categories in the Kaszuby Lake District, according to forest site types, in year 2012

Site type	Seedlings	Lower advanced growth	Higher advanced growth	Seedlings and advanced growth	Undergrowth	All regeneration categories
	ha	ha	ha	ha	ha	ha
Bśw	-	-	67.0	67.0	1735.0	1802.0
Bw	-	-	-	-	0.5	0.5
Bb	-	-	2.5	2.5	76.5	79.0
BMśw	1.0	20.0	475.5	496.5	7837.0	8333.5
BMw	-	0.5	1.5	2.0	73.5	75.5
BMb	24.0	30.0	44.0	98.0	741.5	839.5
LMśw	21.0	204.5	378.5	604.0	12428.5	13032.5
LMw	-	-	1.5	1.5	73.5	75.0
LMb	2.5	2.0	4.0	8.5	87.5	96.0
Lśw	1.5	13.0	35.5	50.0	1517.5	1567.5
Lw	-	-	0.5	0.5	25.0	25.5
Lł	-	-	-	-	7.5	7.5
Oł	-	0.5	-	0.5	64.5	65.0
OLJ	-	-	-	-	17.0	17.0
Total:	50.0	270.5	1010.5	1331.0	24685.0	26016.0
Share [%]	0.2	1.0	3.9	5.1	94.9	100.0

Explanations as in Table 1.

renewals in these two habitats in 2002 being 83% (17,276 ha), and in 2012 – 82% (21,365 ha).

The evaluation of the quality of spruce regeneration in individual study plots showed that there was at least one plot with regeneration in quality class 3.0 (the highest silvicultural quality) in each forest habitat. Spruce at the age of 10–20 years exhibited the highest quality of: 2.0 (BMb, LMb), 2.3 (BMśw), 2.4 (LMśw) and 2.6 (Lśw). At the age of over 20 years, the quality of the regeneration under comparable conditions was much lower.

The average quality of the regeneration on various types of soil was similar – the best quality had spruce on podzolic and rusty soils (2.4), medium – on brown soils (2.2), and the worst – on gley soils and peats (2.0).

The average quality of the regeneration in the adopted three-point scale ranged from 1.95 in the LMb to 2.60 in the Lśw forest habitats. In other habitats, it had intermediate values, with 2.0 in the BMb habitat, 2.10 in the BMśw habitat and 2.35 in the LMśw habitat. In conclusion, the quality of the regeneration was considered to be satisfactory, with a tendency towards good.

Most renewals were found in single-storey forest stands. The area of the regeneration largely correlates with the area ($r = 0.76$) and volume ($r = 0.84$) of spruce stands (and stands with spruce) older than 40 years.

The decade 2002–2012 saw major changes in the volume of spruce stands (and stands with spruce) older than 40 years in the Kaszuby Lakeland (Figure 2). In this period, the volume of spruce in these stands decreased from 3.095 million m³ to 2.365 million m³, an increase of 23.6%. Stand volume in each forest habitat in 2002 and 2012 was respectively: LMśw – 2.206 and 1.609 million m³ (down by 27.1%), Lśw – 0.430 and 0.277 million m³ (down by 35.6%). There was a slight increase in spruce volume in the BMśw habitat – from 0.282 million m³ in 2002 to 0.302 million m³ in 2012 (up by 7.1%), while in the BMb and other forest habitats, the total volume remained almost the same (0.136 and 0.135 million m³ and 0.041, and 0.042 million m³, respectively).

Figure 3 presents the comparison of the percentage share of different forest habitats in the spruce stand volume, the area of spruce stands, and the area of spruce natural regeneration in the Kaszuby Lakeland in 2012. The percentage share of the

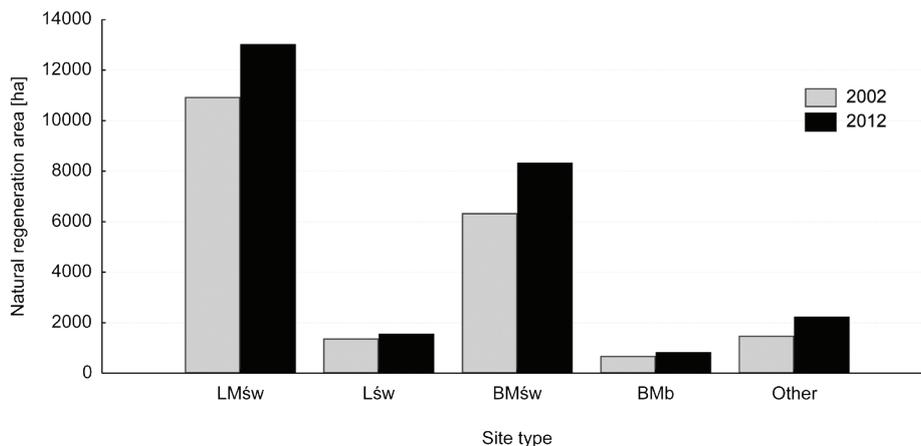


Figure 1. Area of natural spruce regeneration in different forest site types of the Kaszuby Lake District in 2002 and 2012

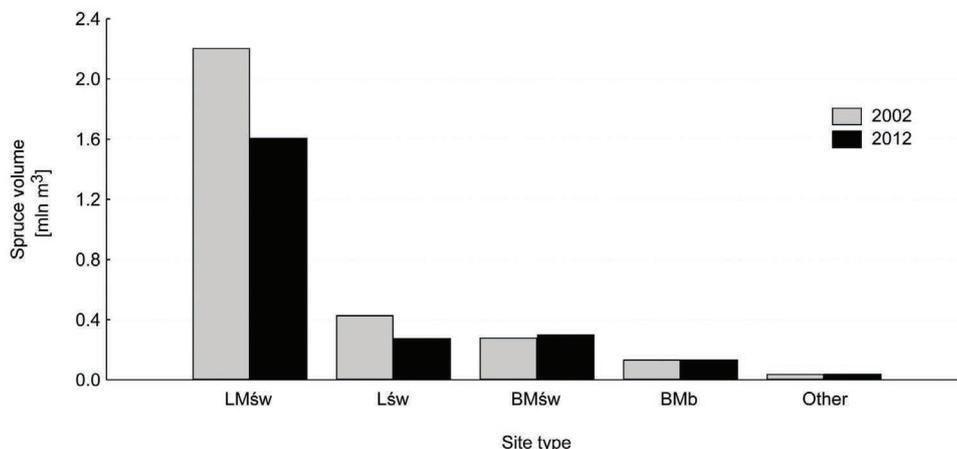


Figure 2. Spruce volume in the Kaszuby Lake District in 2002 and 2012

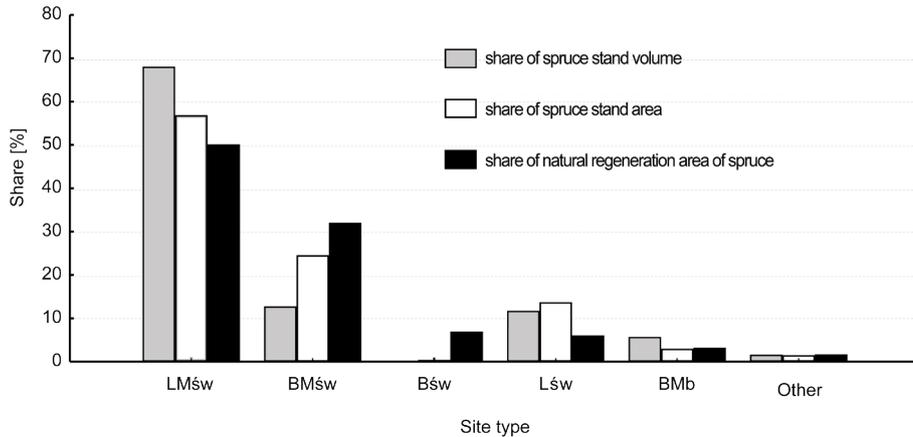


Figure 3. Comparison of the share of particular sites in the spruce stand volume (gray), spruce stand area (white) and area of spruce natural regeneration (black), in year 2012 in the Kaszuby Lake District

area with natural regeneration in the LMśw, Lśw and BMb habitats taken together is lower (59.3%) than the percentage share of the area with spruce stands (73.5%) and the percentage share of volume in these habitats (85.5%). Different relationships were found in the BMśw, Bśw and other habitats taken together, where the percentage share of the area of spruce natural regeneration was higher (40.7%) than the percentage share of the area of spruce stands (26.5%) and the percentage share of spruce stand volume (14.5%).

In 2002, the largest number of natural regenerations of spruce was found in the territory of the forest districts located in the central and northern regions of the Kaszuby Lakeland at an elevation of 160–200 m above sea level, with a diversified topography and relatively fertile soils. A total of 13,124 ha of spruce regeneration, representing 63% of the total area of spruce natural regeneration was inventoried in the adjoining Kartuzy, Cewice, Strzebielino and Gdańsk Forest Districts located in this part of the Lakeland. In 2012, 15,543 ha was inventoried in the same forest districts, representing 60% of the total area of spruce natural regeneration inventoried in the Kaszuby Lakeland.

4. Discussion

The natural regeneration of spruce in the Kaszuby Lakeland occurs in all types of forest habitat, except for dry coniferous forest (Bs). The largest area of spruce natural regeneration in 2002 and 2012 was found in the LMśw and BMśw forest habitats, which is largely consistent with the results of the research conducted by other authors in the region (Czerw 1969, Karpiński 1971, Szydlarski 1999). Spruce naturally regenerates across the Polish lowland usually in the LMśw and Lśw habitats (Zajączkowski 1998, Głaz, Zajączkowski 2002).

The inventory of spruce natural regeneration in the Kaszuby Lakeland showed its occurrence mainly in single-sto-

rey stands. Also, Żybura (1983) and Zajączkowski (1998) demonstrated that the one-storey structure of the stand creates the best conditions favouring the appearance and growth of the natural regeneration of this species.

The analysis of the dynamics of spruce natural regeneration showed a significant relationship between the declining volume of spruce stands and the increasing area of natural regeneration. Conducting large-scale sanitation cuts (secondary pests and fungal diseases) consequently led to the creation of favourable conditions for spruce natural regeneration and its further expansion in the thinned stands.

These processes being commonplace in the Kaszuby Lakeland, have not so far been a subject of systematic research. It seems that this issue deserves more attention, more so because the rapid expansion of spruce natural regeneration is observed also in pine stands and stands with the dominant share of pine in the Bśw and BMśw forest habitats in which the share of spruce is insignificant or even scarce. In 2012, the inventory of the natural regeneration of spruce in pine stands covered an area larger by 2600 ha or 35.0% more than in 2002.

The inventory showed a surprisingly high proportion of underbrush in the whole area of natural regeneration. In most cases, however, it was not underbrush in the strict sense of the word. It was often the good quality advance growth which, in the forest management plans, was described as underbrush in the situation when spruce had not been foreseen in the target composition of the forest stand in a given habitat or when its share was larger than that foreseen for the production forest type (Magnuski et al. 1997; BULiGL 2002, 2012). Nowosielski (1973) believes that the natural regeneration of Norway spruce in the Kaszuby Lakeland appears usually during 1–3 seed years and, at the age of ca 15 years, forms the advance growth with a density of 200,000 plants/ha. According to our observations, the number of spruce trees of good and very good quality, despite

their high density, was enough large to successfully establish valuable young-growth spruce stands.

The inventory of spruce natural regeneration in the Kaszuby Lakeland covered an area of more than 20,000 ha (while in 2012 – more than 26,000 ha) of seedlings, advance growth and underbrush of which at least 20% were of the highest quality. This area with spruce natural regeneration potentially useful for forest economy, is contrasted with the area of only 12.26 ha identified in the territory of the Gdansk RDSF in 1988–1998 (Tomczyk 1999).

Spruce in the Kaszuby Lakeland regenerates successfully both by side and top seeding. The natural regeneration also appears when spruce occasionally occurs in the composition of the mother stand. The macro-habitat of this region (as well as in the entire West Pomerania) can be compared to that of the lower montane zone of the Sudeten and Carpathian Mountains, where the growth conditions for spruce are close to its physiological optimum (Modrzyński 1998, 1999).

Pawłowski (1969), Szydłarski (1998), Szymański (1998) and Zajączkowski (2002) drew attention to the dynamic renewal of spruce stands in this area. Karpinski (1971) reports dense spruce regeneration by natural seeding in this region even in small gaps in beech stands. Brakowski and Świącieński (1969) proposed to introduce a shelterwood strip system developed by Wagner, especially for spruce stands to ensure optimal possibilities of its natural regeneration in this region. Gunia et al. (1982), however, believes that in the Kaszuby Lakeland, spruce regenerates naturally regardless of the applied cutting system.

5. Summary and conclusions

1. The decade 2002–2012 saw an increase in the area of spruce natural regeneration in spruce stands and stands with spruce older than 40 years in the Kaszuby Lakeland by 24.9% (from 20,834 ha to more than 26,000 ha of reduced area).

This increase is associated with a 23.6% decrease, both in the volume of spruce stands (and stands with the admixture of spruce) aged over 40 years, as well as with the expansion of spruce natural regeneration in pine stands (especially in Bśw and BMśw forest habitats) with a small admixture of spruce.

2. The presence of spruce natural regeneration on ca 58% of the area of spruce stands (and stands with the admixture of spruce) aged over 40 years indicates a widespread occurrence of spruce natural regeneration in the Kaszuby Lakeland. Almost 100% of stands older than 60 years with dominant spruce regenerate there in a natural way.

3. Most spruce natural regeneration in the Kaszuby Lakeland was found in the forest habitats of LMśw (52.5% of the total area of renewals in 2002 and 50.1% in 2012) and BMśw (30.4% in 2002 and 32.0 % in 2012). Noteworthy is

also the share of the natural regeneration in the forest habitats of Lśw (6.6% and 6.0%), Bśw (5.6% and 6.9%) and BMb (3.3% and 3.2%). A total of 98.4% of all renewals in 2002 and 98.2% in 2012 occurred in these habitats.

4. The highest quality of the natural regeneration of spruce in the Kaszuby Lakeland was found in the Lśw, LMśw and BMśw, while the lowest in the LMb and BMb forest habitats.

5. Most spruce renewals (63%) were inventoried in the central and northern part of the Kaszuby Lakeland characterised by the highest elevation above sea level, the highest share of fertile soils and wet habitats. The nature of the habitats in this part of the region resembles the mountain habitats in southern Poland and clearly favours the natural regeneration of spruce.

6. Most of the spruce natural regeneration in the Kaszuby Lakeland turned to underbrush, which was mainly due to the unfavourable light conditions below the canopy and excessive density of the regeneration. In spite of this, about 20% of the seedlings and advance growth inventoried in the region exhibited a very high silvicultural quality, allowing obtaining valuable forest stands. The good quality advance growth in the LMśw, BMśw and Lśw forest habitats should be exposed through late thinning and sanitation cuts. Improvement treatments should also be applied in advance to establish multi-species forest stands with the share of Norway spruce up to 30% in the future.

7. The lack of interference in the spontaneous regeneration of spruce, which today is a common case, leads, on the one hand, to the appearance of underbrush over large areas, and, on the other hand, to an excessive share of this species in the composition of some forest stands. In order to prevent the establishment of spruce monocultures by natural regeneration and obtain a more complex vertical structure of the stand, it is desirable to use other admixture species, mainly beech and pine. In the partial cutting systems used primarily for the sake of the process of beech natural regeneration, the natural regeneration of spruce and other species should be applied and promoted to a larger extent.

Conflict of interest

The authors declare that they are free of potential conflicts of interest.

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Authors' contribution

M. S. – literature review, methods, data collection and processing, manuscript preparation. J. M. – concept and supervision of the research project, participation in the interpretation of results, manuscript preparation.