

Article

The Influence of Scots Pine Log Type (*Pinus sylvestris* L.) on the Mechanical Properties of Lumber

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Received: 19 October 2020; Accepted: 23 November 2020; Published: 26 November 2020



Abstract: The paper presents an analysis of the influence of geographical origin and Scots pine log type on the mechanical properties of the timber sawn from them. The tested timber was sawn from logs obtained from three different forestry regions in Poland, located in the western part of the country. A batch of 150 timber pieces was obtained from each region. The cross-section had the dimensions of 40 mm × 138 mm. The timber was sawn from logs of three different types: butt, middle and top, from a fresh, mixed forest around 120 years old. The timber was dried in industrial conditions and planed four times. The values determined for the timber under research were the static modulus of elasticity in bending (MOE), and the bending strength (MOR). Moreover, timber density (DEN) was determined with the stereometric method. For all three sites, the highest average values of the tested timber properties were obtained for timber made of butt logs, and the lowest for timber made of top logs. It was concluded that the tested Scots pine properties depended on the type of log, and to limited extent, on its geographic origin. The statistical analysis revealed that the geographic origin of the logs that the tested timber was made of had a statistically significant impact on the variance of all the tested timber properties. The type of log also had a statistically significant influence on the variance of all the tested properties.

Keywords: scots pine timber; mechanical properties; MOE; MOR

1. Introduction

There has been a growing demand for round logs for industrial applications. In 2018, global sawnwood production totalled 493 million m³, which was 2.2 percent higher than in 2017 (482 million m³) and 13 percent higher than in 2014 (435 million m³) [1]. Wood, as a natural product, is characterised by a large variety of properties and qualities, even within the same species. At the same time, it has become highly challenging to provide wood with the proper quality, according to the specific requirements of customers, who expect particular quality parameters (i.e., stiffness and strength) from timber pieces with a given cross-section and length. Thorough knowledge of wood quality is crucial to rationalise wood usefulness processes, which is needed to assign timber to the end uses required by customers. The properties of wood can differ within the same species, depending on genetic factors, habitat conditions, and tree age, as well as the type of log (butt, middle, top) from which timber for a specific application will finally be sawn [2–5]. For this reason, it is of utmost practical importance to recognize the usage value of wood from different habitats, because sustainable forest and tree management is an essential factor of an effective economy and can contribute to attenuating climate change [6,7].

Numerous studies have aimed to verify whether the type of log determines its physico-mechanical properties which are important in view of specific construction applications. A study in Bavaria [8]

compared the efficiency of visual strength grading methods and machine grading methods for different log types of spruce timber (*Picea abies* (L.)) (butt, middle, top). The timber was strength graded with a visual method [9] and with a machine method. It can be concluded that the butt logs produced higher yields, both using visual and machine grading.

In Austria, within the framework of the XXL-Wood project [10] an extensive study of spruce was conducted, taking into account the geographical origin of wood, the conditions of growth, the quality class and the type of logs from which the tested timber was obtained. The timber obtained from the logs (butt, middle, top) was strength graded with the machine method, the dynamic modulus of elasticity was determined by measuring the frequency of its own vibrations, and afterwards, the modulus of elasticity in stretching, the average width of growth rings, density, and fibre twist were tested. As a result of the conducted tests, it was concluded that the type of log (butt, middle, top) does influence the tested properties to a large extent.

In Austria, a project called Gebirgsholz-Wald Ohne Grenzen [11] focused on testing the influence of height above sea level of the place of growth of spruce trees on the properties of timber produced from them. Timber from two regions was included in the research: Northern Tyrol (Navis valley—Navistal) and Southern Tyrol (Puster Valley—Pustertal), and samples were taken from 22 levels, between 810 m and 2060 m above sea level. Apart from height above sea level, the research also considered whether the trees grew on a southern or northern slope. The obtained timber was strength graded with the visual and machine methods. It was observed that trees growing on northern slopes produced more high-grade timber than trees growing on southern slopes. The strength grading efficiency of timber from northern slopes was higher than in the case of timber from southern slopes. The largest difference was observed for the combination of classes C18–C30 [12], where the efficiency of timber from southern slopes in grade C30 was 56.7%, while from northern slopes it was 70.6%.

A broad research project concerning the habitat characteristics and genetic variance of spruce was conducted for five full-sub families of spruce from Norway. The parameters tested were: the modulus of elasticity (MOE), bending strength (MOR), and other characteristics important for wood quality such as: the share of latewood, wood density (DEN), growth rings, microfibrillar angle, and lignin content [13]. MOE varied between 7.9–14.1 GPa among the trees and 9.4–11.0 GPa when comparing families. MOR ranged between 47–87 MPa for trees and 61–71 MPa for families. The families differed between one another significantly, concerning the correlations MOE/DEN and MOR/DEN. Therefore, an analysis of wood density as the only quality parameter would be inadequate. Wood density is the most important trait controlling wood stiffness and strength [14]. It has a strong and positive correlation with both tensile and compression strength [15], although wood density is only moderately correlated with wood stiffness.

The environmental variance related to the geographical origin from post-agricultural lands and post-forest lands was analysed for Scots pine (*Pinus sylvestris* L.), Douglas fir (*Pseudotsuga menziesii* (Mirb.)) and Norway spruce wood [16,17]. Higher technical quality (by means of the mechanical properties of wood) was identified in the case of wood from forest lands, compared to post-agricultural lands. For example, in the case of wood from forests lands, compressive strength of pine samples that grew in a fresh coniferous forest was 67.8 MPa, whereas in fresh mixed forest the compressive strength was 65.3 MPa. However, wood samples taken from trees that grew in a fresh coniferous forest on post-agricultural lands had a compressive strength of 66.9 MPa. The compressive strength of Scots pine trees that grew in a mixed fresh forest on post-agricultural lands was much lower (50.7 MPa).

Stöd [18] conducted research related to the determination of MOE and MOR of Scots pine wood from different regions of Finland. The wood under research had quite a diverse density (from 474 kg/m³ to 546 kg/m³) and mechanical properties: MOR (42.7 MPa–65.8 MPa), MOE (11.4 GPa–14.9 GPa).

In another study of Stöd [19] the number of thinning procedures was also taken into account (first, second and final logging), as was the type of log (butt, middle, top), to check their influence on the properties of timber obtained from them. Test results revealed that most timber pieces classified as C30 and C35 came from the second thinning. In the case of construction wood obtained from the last

cutting of trees, there was no statistically significant difference between the density of timber from the middle and top logs. The density of wood obtained from the butt, middle and top logs was 514 kg/m³, 466 kg/m³ and 460 kg/m³, respectively. The corresponding MOR values were the following: 56.1 MPa, 39.7 MPa and 36.4 MPa; and the MOE values were: 13.5 GPa, 11.7 GPa and 10.2 GPa.

A similar relationship—a lower MOR, MOE and density of Scots pine wood from butt towards the top—were confirmed by other studies [20,21].

Johansson and Kliger [22] noticed that Norwegian spruce wood produced timber with a much higher bending strength and modulus of elasticity from the first (butt) and second (middle) logs, than timber from top parts of the trees. Moreover, according to [23], in higher parts of spruce trees, the values of MOE and MOR diminish.

The Combigrade project that was carried out in Finland consisted of studying the influence of the geographical origin of Scots pine and spruce wood on the mechanical properties of timber used in construction applications. The wood under research was obtained in south-east Finland and north-west Russia. The relationship between the parameters of round logs and the properties of timber produced from them was studied. Both non-destructive and destructive tests were carried out [24]. The examinations clearly indicated that Scots pine timber from Russia had a lower density, modulus of elasticity in bending, and static bending strength than timber from Finland. The density of wood from Finland was, on average, 12% higher than the density of Russian wood. Similarly, the modulus of elasticity of Finnish wood was 18% higher, while static bending strength was by 35% higher than in the case of Russian wood.

One of the biggest research projects in this scope was the International Gradewood Project. It included tests of Scots pine and spruce timber from Poland, Slovakia, Slovenia, Romania, Ukraine, France, Sweden, Switzerland, Finland and Russia [25]. The tests revealed that timber from Finland had the highest quality out of the sources of wood under research (MOR 44.9 MPa). The bending strength of Finnish timber was almost 15% higher than the bending strength of Polish timber (39.2 MPa). As far as the modulus of elasticity in bending was concerned, Polish timber had the highest value (12,500 MPa), which equalled 105% of the modulus of the Finnish timber (11,900 MPa) and 111% of the modulus of the Swedish timber (11,300 MPa). The density values of the timber batches under research ranged from 481 kg/m³ (Swedish timber), to 493 kg/m³ (Finnish timber), and 516 kg/m³ (Polish timber). The Gradewood project showed a noticeable influence of the geographical origin of wood on its technical parameters, including physical and mechanical characteristics.

The tests of Scots pine timber that were performed by the authors of this paper accounted for its geographical origin from three different forestry regions in Poland, as well as the kind of log that the timber was sawn from: butt, middle and top. The aim of this study was to verify the influence of geographical origin and the type of logs that the timber was obtained from on wood quality expressed by density, modulus of elasticity in bending, and static bending strength.

Due to the fact that Scots pine is the dominant species throughout the country, it is important to know about the regional diversity of the physical and mechanical properties of wood (especially when used as a construction material). Knowing the properties of sawnwood depending on the type of log may contribute to a more rational use of this scarce raw material.

2. Experimental Details

2.1. Material

The material for this study consisted of Scots pine timber from logs obtained from three different forestry regions in Poland (Figure 1): Silesia (Site 1), Greater Poland–Pomerania (Site 2) and the Baltic forestry region (Site 3). Timber from each region was acquired from raw wood that was ca. 120 years old, from butt, middle and top logs. In the case of each of the regions, timber was sawn from logs obtained from mixed, fresh forests. Specific locations of the sample collection sites were as follows: Silesian forestry region—area under the Regional Directorate of State Forests in Katowice

(Forest Inspectorate Olesno, Forest District Sternalice, Division 14d, coordinates: 50.898629, 18.423915); Greater Poland–Pomerania forestry region—area under the Regional Directorate of State Forests in Zielona Góra (Forest Inspectorate Wymiarki, Forest District Lutynka, divisions 23c and 23d, geographic coordinates: 51.553569, 15.060495); and Baltic forestry region—area under the Regional Directorate of State Forests in Piła (Forest Inspectorate Kalisz Pomorski, Forest District Cybowo, division 526k, geographic coordinates: 53.297281, 15.841192). Habitat and geographical origin characteristics from which the material was obtained is presented in Table 1. The timber was dried in industrial conditions in a chamber drier, up to the humidity of ca. 12%, and planed. The nominal cross-section dimensions of the tested timber batch after drying and planing were 40 × 138 mm. Each batch contained 150 pieces, with 50 pieces from each kind of logs (butt, middle, top) within each of the forestry regions for a total of 450 pieces.

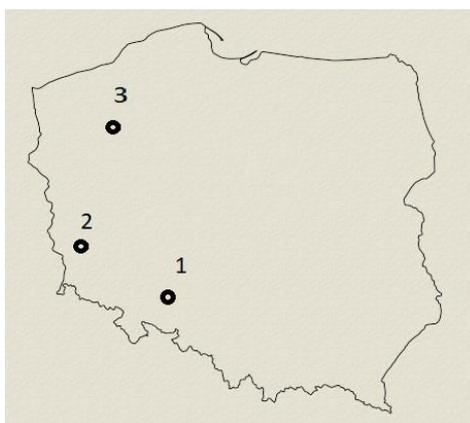


Figure 1. Location of research material collection sites: Site 1—Silesian Forestry Region; Site 2—Greater Poland–Pomerania Forestry Region; Site 3—Baltic Forestry Region.

Table 1. Habitat and geographical origin characteristics.

Forestry Region (Inspectorate)	Climate	Soil	Share of Pine (%)	Growing Stock (m ³ /ha)	Other Species	Technical Quality
Silesian (Olesno)	Submontane lowlands and structural basins	Sands, peat soils, clays and silts, rendzina and loess soils	94	156	Spruce Beech	2 *
Greater Poland–Pomerania (Wymiarki)	Large valleys, quite moderate and warm	Post-glacial, mostly sands and clays	87	136	Oak Alder	2 *
Baltic (Kalisz Pomorski)	Pomeranian Lakeland	Haplic Podzols originating from weak loamy sands and loamy sands.	69	159	Beech Spruce	3 **

* Technical quality 2—corresponds to stands that are usually well adjusted to the habitat, with good development dynamics, and healthy, straight, and well cleaned tree-length trunks expected to provide good quality sawn timber;

** Technical quality 3—corresponds to generally healthy stands adjusted to the habitat, with poor development dynamics, tree-length trunks and tree crowns that are partially defective, not fully straight, slightly tapered and contain knots, and usually not well cleaned, expected to provide sawn timber of worse quality.

2.2. Methods

Destructive Tests of Timber

The destructive tests of research material included:

- determination of the global modulus of elasticity for timber in static bending (MOE),
- determination of static bending strength (MOR),

Tests were conducted according to EN 408 [26], with the use of the 10-tonnes universal testing machine TIRA Test 2300 (TIRA GmbH, Schalkau, Germany). The static diagram of the test has been

presented in Figure 2. The tests were performed with control of movement. The speed of the crosshead was 3 mm/min. During the test, we registered the value of the load and the bend. Bending was determined using additional equipment in the form of movement sensors by Novotechnik, type TRS 75, with a precision of 0.01 mm. The tested element was placed in the worst position (typically the largest knot was placed in the middle). The orientation of tested boards in the test machine was at random. The density was determined according to the EN 408 standard.

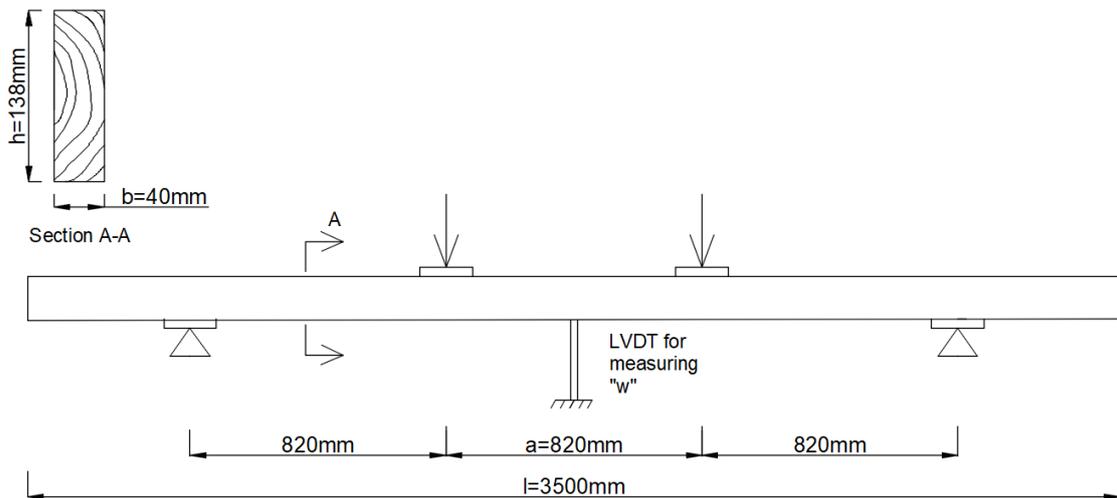


Figure 2. Static diagram of a four-point structural timber bending test to determine MOE and MOR in line with EN 408 [26]; w —deflection.

2.3. Statistical Analysis

The statistical analysis of test results was carried out in the Statistica v.13.3 software (StatSoft, Inc., Tulsa, OK, USA). The data was analysed and provided as the mean \pm standard deviation. Then, the two-factor variance analysis ANOVA was performed for the physico-mechanical properties of Scots pine (density, MOE, MOR) depending on the log geographical origin (Site 1, Site 2, Site 3) and log type (butt, middle, top). The analysis was carried out with a confidence level of 95%. In order to find out exactly which parameter (density, MOE, MOR) was influenced by the individual factor (log geographical origin or log type) a post-hoc test was conducted. Firstly, Levene's test was used to verify the assumption of homogeneous variance. Then, the normal distribution of results was verified with the Kolmogorov–Smirnov test, with a minimum level of significance of $p = 0.05$. After verifying the basic assumptions for performing a post-hoc test, Tukey's test was carried out.

3. Results and Discussion

Table 2 presents the test results of the timber: density, modulus of elasticity and bending strength, divided into geographic regions, and taking into account the log types from which timber was obtained. Table 3 presents the values of correlation coefficients between the given physico-mechanical characteristics of timber from different log types, divided into geographic regions.

Table 2. Average values of density, modulus of elasticity and bending strength for the Scots pine timber under research (standard deviation is given in parentheses), DEN—density, MOE—modulus of elasticity, MOR—bending strength.

		Total	Site 1	Site 2	Site 3
DEN (kg/m ³)	Total	524 (66)	537 (64)	533 (71)	503 (57)
	Butt	574 (65)	581 (58)	604 (58)	537 (63)
	Middle	514 (55)	533 (61)	518 (46)	495 (50)
	Top	484 (39)	496 (41)	476 (35)	481 (38)
MOE (MPa)	Total	11,800 (2400)	11,900 (2500)	12,400 (2500)	11,000 (2000)
	Butt	13,200 (2400)	13,700 (2300)	14,000 (2800)	11,800 (2400)
	Middle	11,800 (1900)	11,700 (2100)	12,700 (1700)	11,000 (1600)
	Top	10,300 (1600)	10,400 (1800)	10,600 (1300)	10,100 (1600)
MOR (MPa)	Total	46.1 (17.3)	51.5 (18.8)	47.3 (15.6)	39.4 (15.1)
	Butt	53.5 (19.0)	60.1 (19.9)	59.8 (13.1)	40.6 (16.8)
	Middle	46.4 (16.1)	52.5 (18.5)	46.4 (13.5)	39.8 (13.5)
	Top	38.3 (12.8)	41.9 (12.9)	35.7 (9.8)	37.4 (14.7)

Table 3. Correlation coefficient between the given physico-mechanical properties.

		Property	Total	Butt	Middle	Top
1	DEN/MOE		0.77	0.68	0.72	0.62
	DEN/MOR		0.41	0.46	0.15	0.10
	MOR/MOE		0.45	0.74	−0.02	0.02
2	DEN/MOE		0.69	0.38	0.80	0.57
	DEN/MOR		0.65	0.20	0.52	0.38
	MOR/MOE		0.58	0.08	0.68	0.59
3	DEN/MOE		0.65	0.66	0.53	0.60
	DEN/MOR		0.40	0.56	0.29	0.32
	MOR/MOE		0.71	0.81	0.51	0.78
All	DEN/MOE		0.72	0.68	0.67	0.57
	DEN/MOR		0.52	0.24	0.33	0.30
	MOR/MOE		0.58	0.74	0.42	0.32

By analysing the values of correlation coefficients between the properties under research, taking into account only the geographic differences and not the log type differences, it can be concluded (Table 3) that the coefficient of correlation density/MOE fell in the range from 0.77 (Site 1) to 0.65 (Site 3); the coefficient of correlation density/MOR fell in the range from 0.65 (Site 2) to 0.40 (Site 3); and the coefficient of correlation MOR/MOE fell in the range from 0.71 (Site 3) to 0.45 (Site 1). On the basis of the presented values, it can be concluded that the region of origin has a strong influence on correlation coefficient values. Differences between the coefficients of correlation have been also observed, taking into account the type of log from which the timber was obtained. The biggest differences between correlation coefficients were observed for the correlation between MOR/MOE in Site 1: 0.74 (for timber made of butt logs) and −0.02 (for timber made of middle logs). In the case of the same correlation for timber from Site 2, the values ranged between 0.68 (for timber made of middle logs) and 0.08 (for timber made of butt logs). In the case of the correlation density/MOR for Site 1, the values obtained were from 0.46 (for timber made of butt logs) to 0.10 (for timber made of top logs).

Research of Finnish Scots pine timber [24] resulted in a coefficient of correlation MOR/MOE of 0.83, while for German Scots pine timber the obtained correlation coefficients MOR/MOE were 0.71 [27] and 0.81 [28]. The coefficient of correlation between density/MOR was 0.76 in the case of Finnish timber [24]; and the coefficient of correlation density/MOR for German Scots pine timber was 0.47 [27]. The coefficient of correlation for density/MOE in the case of Finnish Scots pine timber was 0.85 [24]. On the basis of the presented values, it can be concluded that the geographical origin has an influence on correlation coefficient values. There was, however, no clear relationship between those characteristics, which may be caused by the habitat conditions (different growing conditions of trees, different soil). An analysis of the results in view of the kind of log from which the timber was obtained (butt, middle, top) for all the three sites revealed that the highest average values of the tested properties of timber (density, MOR and MOE) were observed for timber from butt logs; lower values were found for middle logs, and the lowest was for timber from the top logs.

Similar dependencies for full-size pine timber obtained from three types of logs (butt, middle, top) sourced from the Forest Division Olesno were obtained by Mirski et al. [29]. The highest average density value was obtained for the timber made of butt logs (610 kg/m^3), and the lowest for the timber made of top logs (548 kg/m^3). A similar dependency was found by Jelonek et al. [30] when examining the density of pine wood in laboratory scale. The highest value of density was obtained for wood harvested from diameter at breast height (which corresponds to butt logs) and the lowest for wood obtained from the height of the crown (which corresponds to top logs). Similar relationships were obtained for Scots pine from Estonia [31].

Taking into account the regional differences concerning wood origin (Table 2) and its influence on the tested wood properties, it has been concluded that the highest average density was characterised by timber from Site 1 (537 kg/m^3). For Site 2, a comparable average density (533 kg/m^3) was obtained. The lowest wood density was obtained for the sawn timber originating from Site 3 (503 kg/m^3).

Based on the ANOVA analysis (Tables 4 and 5), it was found that there was an influence of the stand technical quality class on the obtained density values. For Site 1 and Site 2 (the same technical quality, class 2), there were no statistically significant differences in the mean density values. Pine timber obtained from logs originating from Site 3 (technical quality class 3), had a significantly lower density (Tukey's test, $p < 0.05$).

Table 4. Values of ANOVA (probability level for the significance test) for DEN, MOE and MOR, depending on the type of the log and its geographical origin.

	Factor		
	b m t	Site	b m t \times Site
DEN	0.000000	0.000000	0.000022
MOE	0.000000	0.000000	0.007224
MOR	0.000000	0.000000	0.000038

b—butt, m—middle, t—top.

Table 5. Probability of post-hoc tests for log geographical origin as the differentiating factor.

Property	Place of Origin	Site 1	Site 2	Site 3
DEN	Site 1		0.597144	0.000020
	Site 2	0.597144		0.000077
	Site 3	0.000020	0.000077	
MOE	Site 1		0.059792	0.000403
	Site 2	0.059792		0.000011
	Site 3	0.000403	0.000011	
MOR	Site 1		0.027728	0.000011
	Site 2	0.027728		0.000047
	Site 3	0.000011	0.000047	

Roszyk [32] studied the density of Scots pine from stands of technical quality class 2, the average density obtained by him (526 kg/m^3) was similar to the density obtained in the reported research for Site 1 and 2 (the same technical quality class). A regional variance of density of Polish-grown Scots pine timber was also suggested in studies performed by Krzosek [33]. The author tested timber from five selected forestry regions in Poland. The average density of this timber determined for the individual forestry regions was between 443 kg/m^3 for timber from the Carpathian forestry region, and 524 kg/m^3 for timber from the Baltic forestry region. The regional differences in the properties of Polish timber were also confirmed by research conducted within the framework of the Gradewood Project. It included Polish timber from two forestry regions: Silesia (Murów locality) and Masuria–Podlachia (Świątajno locality). The average density of timber from Murów was 558 kg/m^3 , and from Świątajno it was 515 kg/m^3 . Density of Swedish timber was found to have the following average values: 458 kg/m^3 (Lapland region) and 522 kg/m^3 (Västerbotten region) [24].

Analysis of the results showed that the average MOE of timber obtained from butt logs was the highest, while the lowest was for timber obtained from the top logs. This dependence applied to all three sites. Similar relationships were obtained by Mirski et al. when examining full-size pine timber [29]. The highest value of MOE obtained by the author for sawn timber made of butt logs was 12,400 MPa, and the lowest value of MOE corresponded to the top logs (9100 MPa). Similar dependencies were obtained by Antony et al. [34].

In the presented research, the average MOE depended on the geographical origin. The highest value of MOE was obtained for sawn timber originating from Site 2 (12,400 MPa). A slightly lower value of MOE (11,900 MPa) was obtained for timber from Site 1. The lowest value was obtained for sawn timber from Site 3 (11,000 MPa). Based on the ANOVA analysis (Tables 4 and 5), it is possible to notice the influence of the technical quality class of the stand on the obtained MOE values. For Site 1 and 2, with the same technical quality class, there were no statistically significant differences in the mean MOE values. Timber obtained from Site 3 logs, technical quality class 3, had a significantly lower MOE (Tukey's test, $p < 0.05$).

The variability of MOE depending on the geographical origin of wood was found also in the research performed by Krzosek [33]. The average values for timber from individual forestry regions were between 7800 MPa for the Carpathian forestry region and 11,100 MPa for timber from the Greater Poland–Pomerania Forestry Region. According to the framework of the Gradewood Project the average MOE value for timber from Murów was 12400 MPa, and from Świątajno: 10,900 MPa, MOE of Swedish timber was found to have the following average values: 9100 MPa (Lapland region) and 11,800 MPa (Västerbotten region) [25].

In the studies of Roszyk et al. [32], despite the comparable average density of wood from the technical class of stand 2, the average MOE values were significantly lower than those obtained in the reported studies (in the range of 7000–7800 MPa). The values of MOE were also lower than in other studies for Scots pine [24,35]. This phenomenon may be explained by the age of trees from which the logs were obtained (i.e., younger thinning) and type of the log (upper logs) in referenced and reported

studies. Auty also showed a relationship between the geographical origin of Scots pine laboratory samples and average MOE [36].

In the presented research, similarly to density and MOE, MOR was also influenced by the geographical origin of timber. Depending on the site, mean MOR values ranged from 51.5 MPa (Site 1) to 39.4 MPa (Site 3). The lowest mean MOR value was obtained for timber from the stand of the lowest technical quality (Site 3). Based on ANOVA analysis, it can be found that the type of habitat has a significant impact ($p < 0.05$) on the MOR value (Tables 4 and 5). The average values of MOR for individual forestry regions spanned between 25 MPa for the Carpathian forestry region, up to 45 MPa for timber from the Greater Poland–Pomerania forestry region [33]. The regional differences in the properties of Polish timber were also confirmed by research conducted within the framework of the Gradewood Project. It included Polish timber from two forestry regions: Silesia (42 MPa—Murów locality) and Masuria–Podlachia (36 MPa—Świątajno locality). MOR of Swedish timber was found to have the following average values: 38 MPa (Lapland region) and 56 MPa (Västerbotten region) [25].

Hautamaki [37] also showed the geographic variability of the MOR value—MOR for sawn timber obtained from Finnish habitats was significantly higher than for sawn timber obtained from Russian habitats.

4. Conclusions

A statistically significant variance of the tested Scots pine wood properties depending on the type of log was observed.

A statistically significant variance of the tested pine wood properties depending on its geographic origin was observed to a limited extent. Post-hoc analysis showed full dependence between geographical origin and wood property only for MOR.

Independently of the geographic region, the highest average values of the properties under research (DEN, MOE, MOR) were observed for timber made of butt logs, and the lowest values were for top logs.

Author Contributions: Conceptualization: I.B.-K., S.K. and P.M.; methodology, I.B.-K., S.K. and P.M.; investigation, I.B.-K., S.K. and P.M.; data curation, I.B.-K. and P.M.; writing—original draft preparation, I.B.-K., S.K. and P.M.; writing—review and editing, I.B.-K., S.K. and P.M.; supervision, S.K.; project administration, I.B.-K. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by the National Centre for Research and Development, Poland, under “Environment, agriculture and forestry”—BIOSTRATEG strategic R&D programme, agreement No BIOSTRATEG3/344303/14/NCBR/2018.

Conflicts of Interest: The authors declare no conflict of interest.

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