Influence of the origin on specific properties of European spruce and pine

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Abstract

Using timber for engineered wood products requires grading of the material. According to European standards producers are obliged to perform extensive testing for each country from which timber is used. Therefore, the project "Gradewood" was established to define reasoned source areas for timber independent of country borders.

More than 5 000 bending and tension test on spruce and pine specimens from different regions in Europe were tested. This paper compares the properties of Norway spruce and Scots pine of different origin based on the results of the destructive testing. It is shown that based on the properties alone the definition of growth regions is problematic. For spruce loaded in bending grading results are compared for countries and for smaller regions.

1 Introduction

In the ongoing European joint-project "Gradewood – Grading of timber for engineered wood products" more than 5 000 specimens of spruce and pine were tested in bending and in tension. While the specific properties of Central and Northern European timber are known, the information on Eastern European timber is limited. The lack of information from that area connected with a growing interest of industry in Eastern European timber requires additional tests from that area. Hence testing within the project was mainly focussed on timber from Eastern Europe.

For strength graded timber origin plays a major role in the standardization process. As it is possible, that differences within one country can be bigger than between countries information on sub regions were recorded additionally. This information can be used to compare grading results based on different zoom levels.

2 Material and Methods

Timber from ten different European countries with cross-sections of 40 x 100 mm², 50 x 150 mm² and 45 x 200 mm² was tested. The tests were performed according to EN 408 [1]. Factors given in EN 384 [2] were considered when calculating the test values. Specimens from Switzerland (CH), Slovenia (SI), Poland (PL), Ukraine (UA), Finland (FI), Russia (RU), Sweden (SE), Romania (RO), Slovakia (SK) and France (FR) were tested. In

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total, 3 548 spruce and 1 516 pine specimens were tested in bending or tension. For each country additional information narrowing the growth regions within one country is available.

Table 1 to Table 3 summarize mean values, standard deviations and characteristic values for strength, modulus of elasticity and density separated into different source countries, loading modes and species. Additionally knot values for tKAR describing the biggest knottiness over a length of 150 mm were recorded and are presented in Table 4. For visualization distribution curves are drawn based on mean values and standard deviations (Fig. 1 to Fig. 4).
These values are analysed based on countries and additionally for Slovenian regions. Slovenia was chosen as the territory is relatively small compared to other source countries while the available test data is substantial and results from four different regions. This makes it possible to compare variation between countries with the variation within sub regions of one country.

Spruce tested in bending is graded based on a linear regression model derived on an independent dataset including timber from Central and Northern Europe in an earlier step of the Gradewood project (Equation 1) [3]. Strength was used as the target value.

$$\mathrm{IP}(f_m) = 1.16 + 0.0318 * b + 0.0185 * h - 0.0189 * \rho - 25.5 * tKAR + 0.00413 * E_{dyn} \qquad \text{Equation 1}$$

The indicating property (IP) is calculated from b (width in mm), h (height in mm), ρ (density in kg/m³), tKAR (biggest knot related to the cross-section over the board on a length of 150 mm) and E_dyn (dynamic modulus of elasticity in N/mm²). The grading results are analysed for countries and the Slovenian regions (Table 6). Three artificial grades with fixed threshold values are used. The results can be used to judge whether differences in the basic population of countries and Slovenian regions can be recognized in the graded output.

3 Results

On the following pages the test results are summarized. While Fig. 1 to Fig. 4 and Table 1 to Table 4 give the values separated into source country, Fig. 5 and Table 5 combine the values from the four single regions in Slovenia. Even sources within one country can have bigger differences as sources compared on the level of countries. Nevertheless, comparing results from Slovenian regions to country wide results smaller differences are found within Slovenia. For example the mean strength varies from 42.2 N / mm² to 44.1 N / mm² for different Slovenian regions while it varies from 36.3 N / mm² for timber from Ukraine to 43.5 N / mm² for timber from Slovenia.

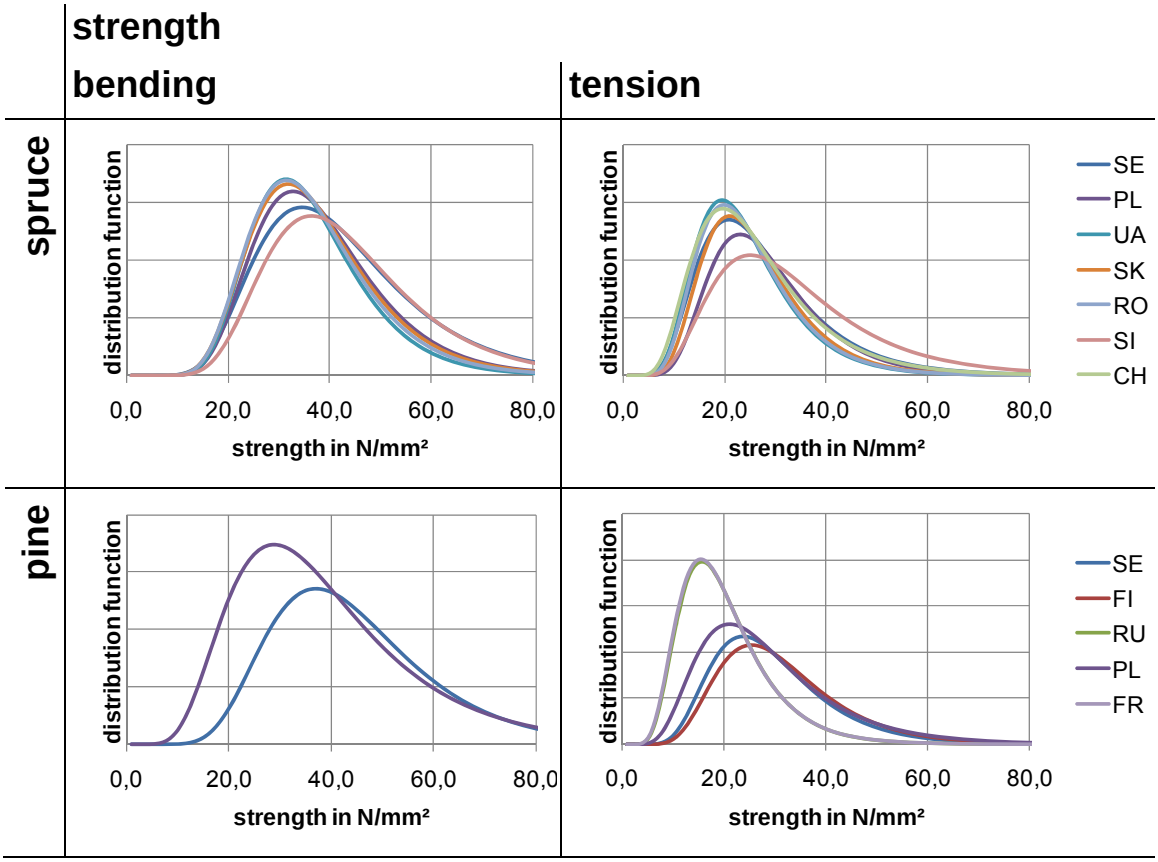

Fig. 1: Strength distribution separated into country, species and loading mode, n = 5066 specimens.

Table 1: Strength values in N/mm² separated into country, species and loading mode, n = 5066 specimens.

	bending	n	mean	std. dev.	5th perc.	**tension**	n	mean	std. dev.	5th perc.
spruce	SE	210	42.5	15.0	19.5	SE	214	27.3	10.4	10.6
	PL	433	38.5	12.1	20.9	PL	219	28.5	10.7	14.4
	UA	204	36.2	10.6	19.4	UA	203	24.4	9.8	11.9
	SK	100	37.5	11.8	20.6	SK	99	25.9	9.4	13.4
	RO	203	36.8	11.1	19.8	RO	201	24.9	10.4	12.4
	SI	1126	43.4	13.3	22.5	SI	104	34.0	15.0	13.2
						CH	233	26.4	11.7	11.3
pine	SE	209	44.7	15.0	23.0	SE	207	29.7	11.6	14.7
	PL	221	39.3	16.8	14.9	FI	253	31.7	12.4	16.4
						RU	171	20.4	8.8	8.6
						PL	217	28.9	12.9	12.4
						FR	239	20.3	8.4	8.8
Σ		2706					2360			

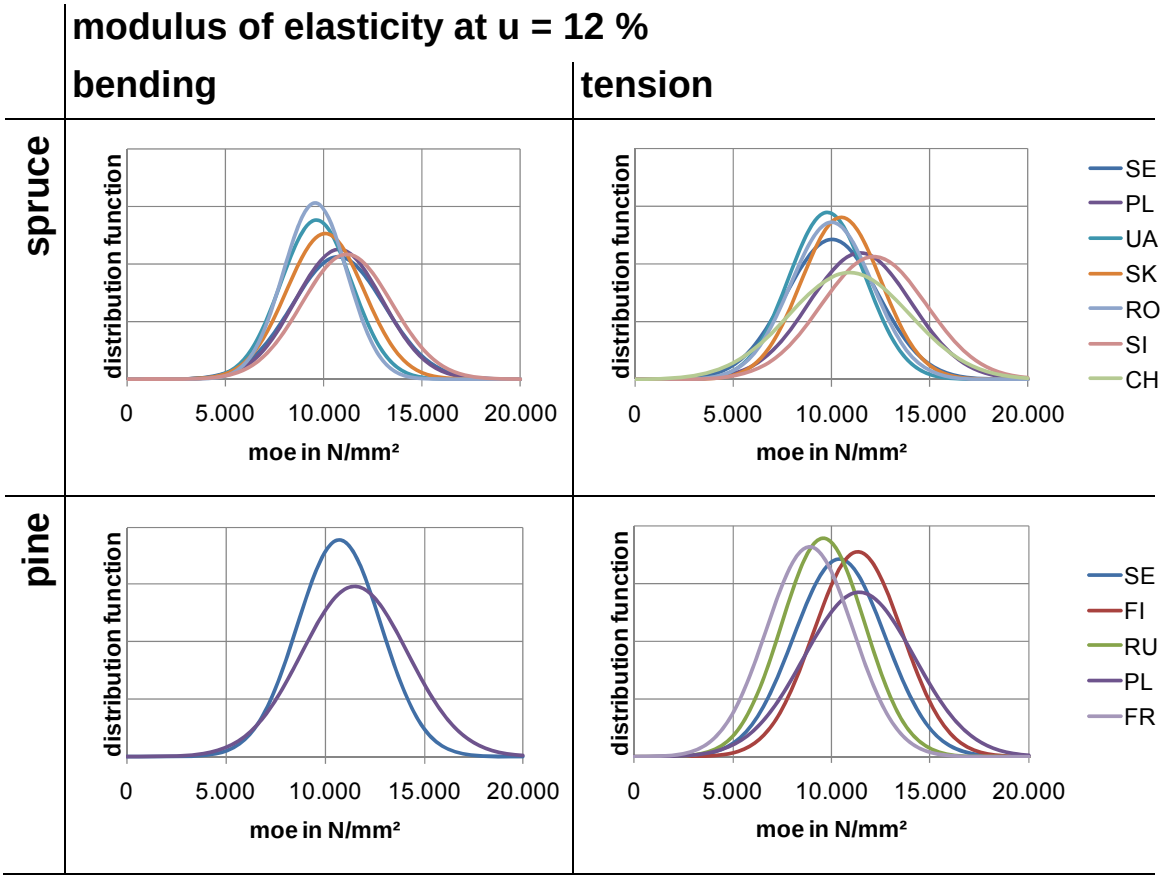

Fig. 2: MOE distribution separated into country, species and loading mode, n = 5066 specimens.

Table 2: MOE values in kN/mm² separated into country, species and loading mode, n = 5066 specimens.

	bending	n	mean	std. dev.	5th perc.	**tension**	n	mean	std. dev.	5th perc.
spruce	SE	210	10.7	2.3	7.2	SE	214	10.0	2.4	6.5
	PL	433	10.8	2.2	7.5	PL	219	11.5	2.6	7.8
	UA	204	9.6	1.8	7.1	UA	203	9.8	2.0	6.9
	SK	100	10.1	2.0	7.4	SK	99	10.5	2.0	7.2
	RO	203	9.6	1.6	6.8	RO	201	10.0	2.1	6.9
	SI	1126	11.2	2.3	7.7	SI	104	12.2	2.7	7.4
						CH	233	10.9	3.1	6.6
pine	SE	209	10.7	2.1	7.5	SE	207	10.4	2.3	7.1
	PL	221	11.5	2.7	7.1	FI	253	11.3	2.2	7.9
						RU	171	9.6	2.1	6.6
						PL	217	11.4	2.8	7.1
						FR	239	8.9	2.2	5.5
Σ		2706					2360			

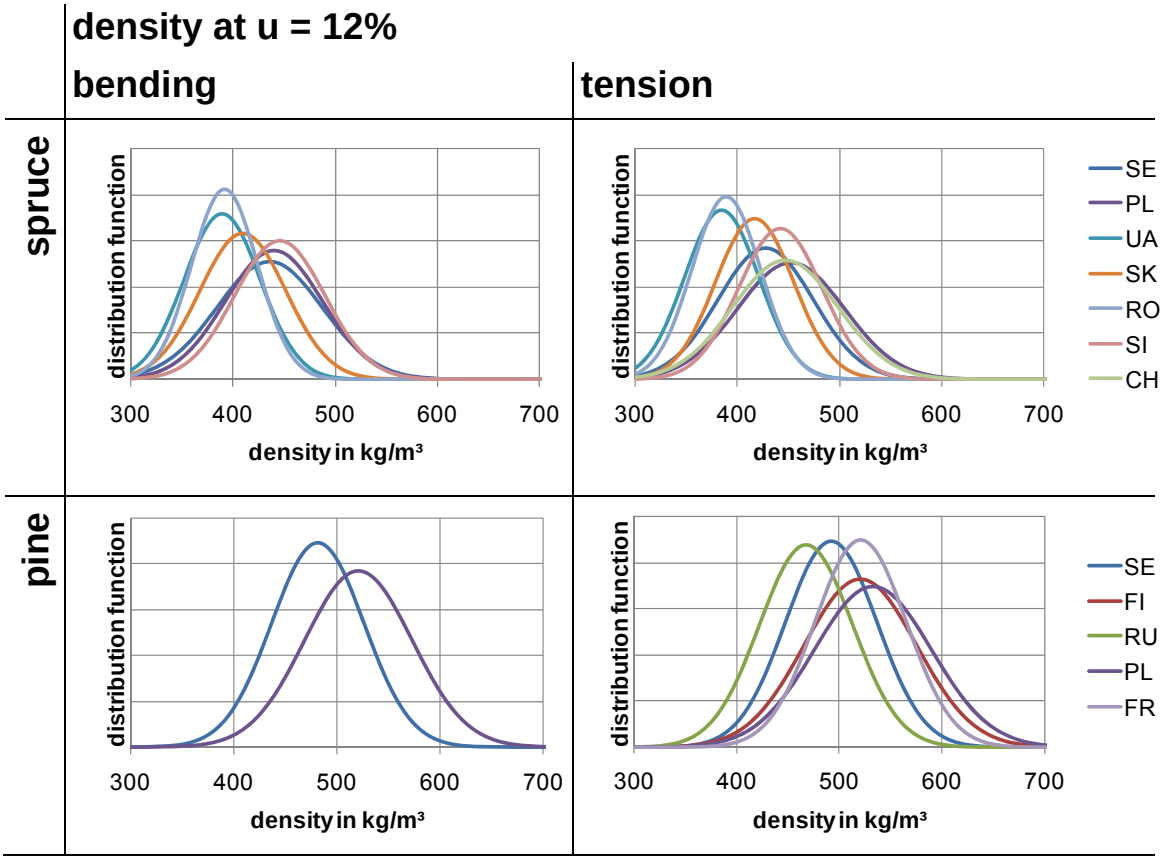

Fig. 3: Density distribution separated into country, species and loading mode, n = 5065 specimens.

Table 3: Density values in kg/m³ separated into country, species and loading mode, n = 5065 specimens.

	bending	n	mean	std. dev.	5th perc.	**tension**	n	mean	std. dev.	5th perc.
spruce	SE	210	435	52	350	SE	213	427	47	353
	PL	433	440	48	370	PL	219	452	52	374
	UA	204	389	37	336	UA	203	384	36	327
	SK	100	409	42	351	SK	99	416	38	353
	RO	203	391	32	337	RO	201	389	33	335
	SI	1126	445	44	376	SI	104	442	41	384
						CH	233	447	52	358
pine	SE	209	481	45	414	SE	207	492	45	427
	PL	221	520	52	443	FI	253	521	55	450
						RU	171	467	45	409
						PL	217	533	57	447
						FR	239	521	45	452
Σ		2706					2359			

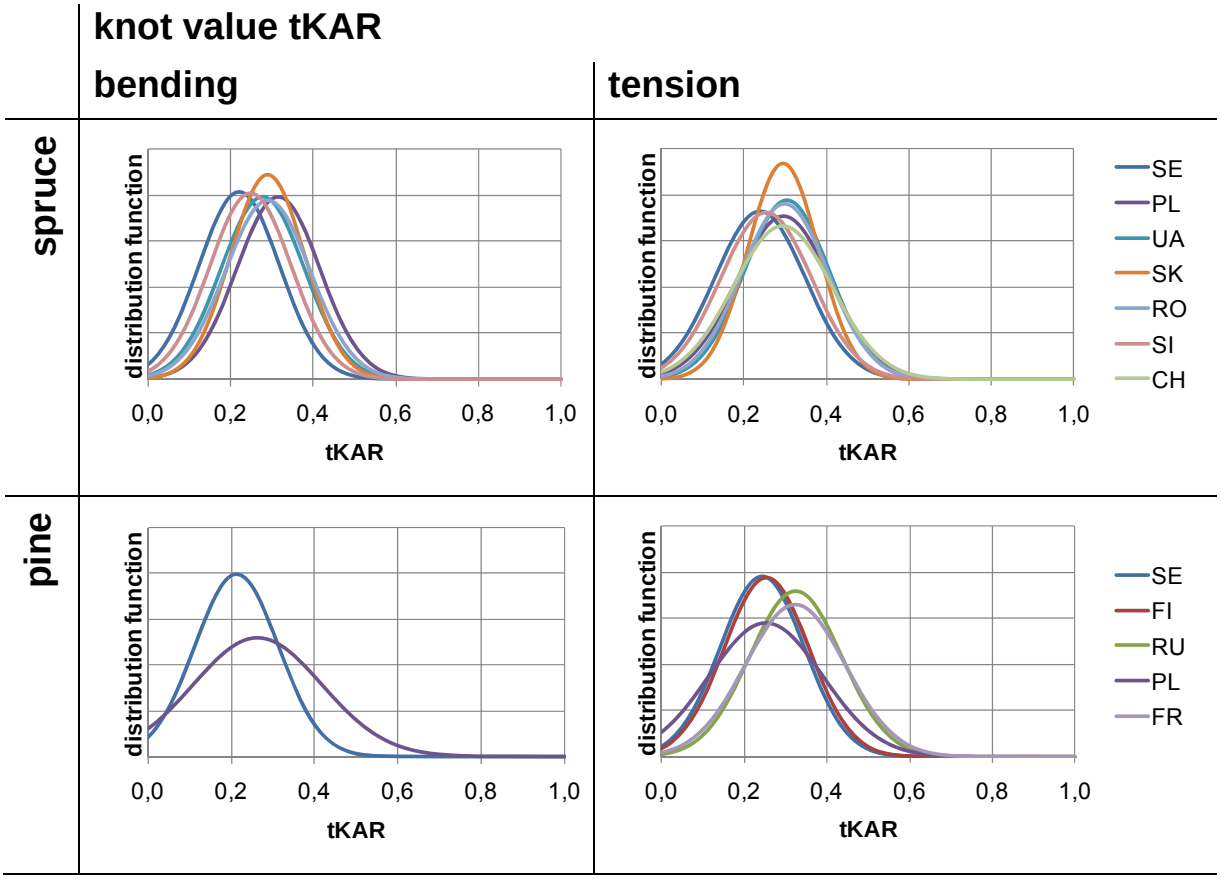

Fig. 4: tKAR distribution separated into country, species and loading mode, n = 5064 specimens.

Table 4: tKAR values separated into country, species and loading mode, n = 5064 specimens.

	bending	n	mean	std. dev.	**tension**	n	mean	std. dev.
spruce	SE	210	0.22	0.10	SE	213	0.24	0.11
	PL	433	0.32	0.10	PL	219	0.30	0.11
	UA	204	0.28	0.10	UA	203	0.30	0.10
	SK	100	0.29	0.09	SK	99	0.30	0.09
	RO	203	0.29	0.10	RO	201	0.30	0.11
	SI	1126	0.25	0.10	SI	104	0.25	0.11
					CH	233	0.29	0.12
pine	SE	209	0.21	0.10	SE	207	0.24	0.10
	PL	220	0.26	0.15	FI	253	0.25	0.10
					RU	171	0.33	0.11
					PL	217	0.25	0.14
					FR	239	0.32	0.12
Σ		2705				2359		

property variability within Slovenia

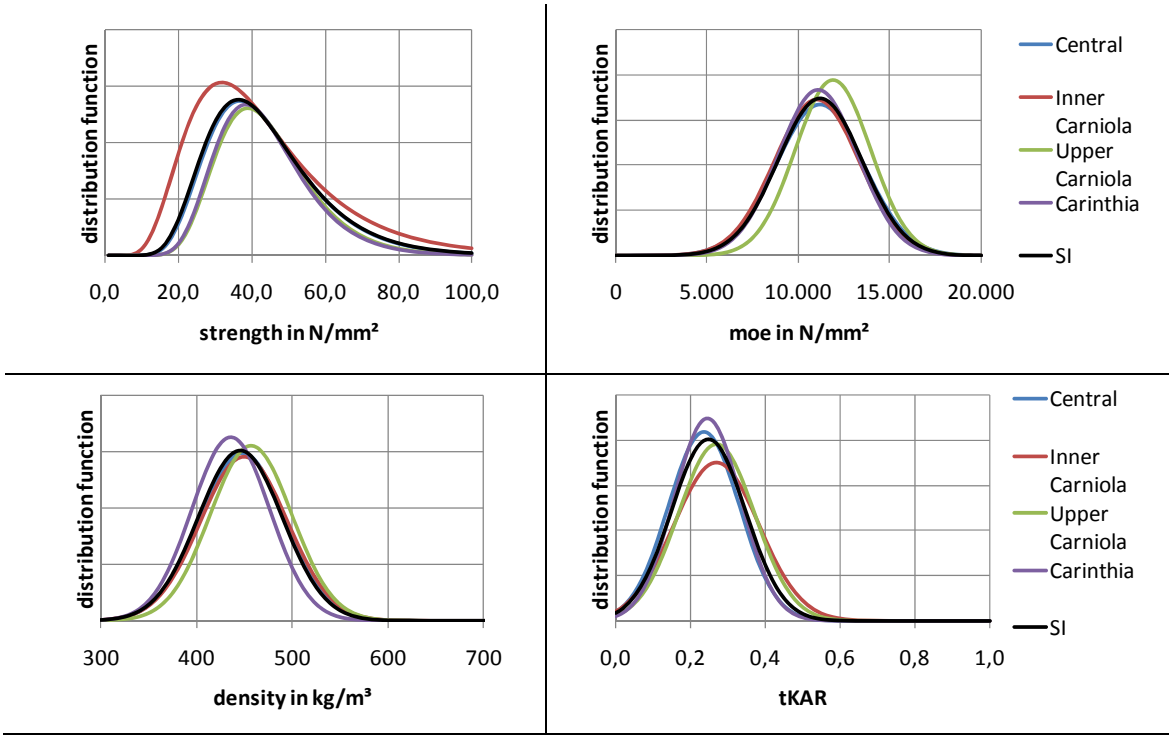

Fig. 5: Comparison of variability within country Slovenia
distribution for strength, MOE, density and tKAR; n = 1126 specimens.

Table 5: Comparison of variability within country Slovenia:
values for strength, MOE, density and tKAR; n = 1126 specimens.

			n	mean	std.dev.	5th perc.
strength in N/mm²	region	Central	489	43.8	14.2	22.9
		Inner Carniola	219	42.2	14.4	19.8
		Upper Carniola	104	44.1	11.8	24.1
		Carinthia	314	43.5	11.6	24.3
	country	SI	1126	43.4	13.3	22.5
modulus of elasticity u = 12% in kN/mm²	region	Central	489	11.2	2.4	7.6
		Inner Carniola	219	11.0	2.3	7.9
		Upper Carniola	104	11.9	2.1	8.4
		Carinthia	314	11.1	2.2	7.6
	country	SI	1126	11.2	2.3	7.7
density, u = 12% in kg/m³	region	Central	489	448	45	379
		Inner Carniola	219	449	46	383
		Upper Carniola	104	457	43	374
		Carinthia	314	435	41	371
	country	SI	1126	445	44	376
tKAR	region	Central	489	0.24	0.10	
		Inner Carniola	219	0.27	0.11	
		Upper Carniola	104	0.27	0.10	
		Carinthia	314	0.25	0.09	
	country	SI	1126	0.25	0.10	

In a next step the grading results of timber from different sources are compared. The regression model based on the independent dataset seems to work well for the new dataset. Fig. 6 shows the relation between the model value and the strength separated into countries and for Slovenian regions. The model fits well for different countries: the R^2-value varies from 56 % for Ukraine to 64 % for Poland. The strength of the Slovenian timber is also well described by that model. For the SI region the accuracy of prediction is lower with an R^2-value of only 47 %.

As expected the difference between the countries are lower in the single grades. Table 6 shows that after the grading differences in strength within one country can be as big as between countries. Mean strength values of the low grade within Slovenia vary from 30.2 to 34.7 N / mm², while the values between countries in that grade vary from 32.6 to 34.4 N / mm² only.

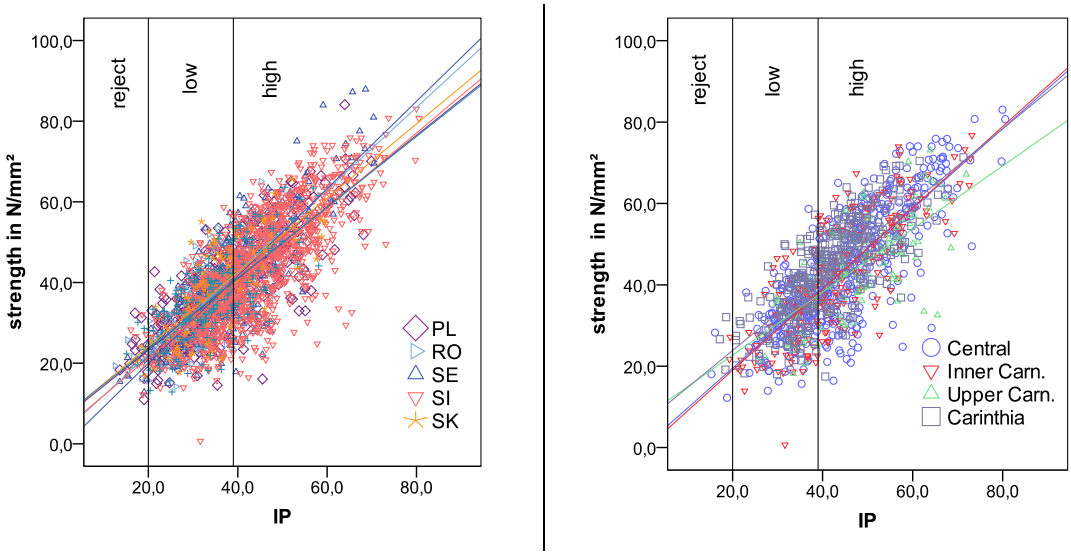

Fig. 6: Comparison of model results and strength for spruce in bending within Europe (n = 2276) and Slovenia (n = 1273).

Table 6: Grading results for spruce in bending within Europe (n = 2276) and Slovenia (n = 1273).

			strength in N/mm²			moe in kN/mm²			density in kg/m³		
grade	origin	%	mean	std.dev.	5th p.	mean	std.dev.	5th p.	mean	std.dev.	5th p.
reject	PL	3.5	22.2	5.5	11.0	7.0	6.4	6.0	375	29	311
	RO	3.4	21.6	4.0	16.2	6.8	3.6	6.3	364	22	334
	SE	3.3	17.7	4.0	12.8	6.7	4.6	5.9	341	25	306
	SI	0.7	23.1	6.5	12.2	6.6	12.6	4.1	382	43	336
	SK	5.0	20.5	2.6	16.8	7.2	3.3	6.7	371	36	345
	UA	2.9	24.1	4.3	19.6	7.0	4.9	6.1	362	15	339
low	PL	57.3	32.6	8.1	20.0	9.6	12.3	7.5	417	33	368
	RO	68.0	33.4	9.6	19.8	9.0	12.1	6.8	384	30	336
	SE	38.6	34.6	9.7	19.2	9.0	10.7	7.1	404	37	340
	SI	35.1	32.8	8.3	19.2	9.1	12.9	7.0	416	33	363
	SK	70.0	34.4	9.7	21.2	9.3	11.1	7.5	397	34	349
	UA	68.6	32.6	8.1	18.3	8.9	11.7	7.0	379	33	332

			strength in N/mm²			moe in kN/mm²			density in kg/m³		
grade	origin	%	mean	std.dev.	5th p.	mean	std.dev.	5th p.	mean	std.dev.	5th p.
high	PL	39.3	48.5	10.1	32.0	12.9	1.6	10.5	478	40	418
	RO	28.6	46.7	8.0	32.6	11.3	1.0	9.5	413	27	362
	SE	58.1	49.2	14.2	28.0	12.1	1.9	9.9	462	43	393
	SI	64.2	49.5	11.7	29.9	12.4	1.8	9.8	462	40	405
	SK	25.0	49.6	7.6	34.9	12.8	1.3	10.5	450	35	387
	UA	28.4	46.3	9.5	30.1	11.8	1.2	9.9	417	33	353
reject	Cen.	0.6	19.5	8.1	12.2	5.7	1.7	4.1	359	27	336
	I. C.	0.9	24.4	3.9	21.7	7.6	0.1	7.5	394	27	374
	U. C.	0.0	-	-	-	-	-	-	-	-	-
	Cari.	1.0	25.9	6.5	19.1	6.8	0.7	6.3	398	64	352
low	Cen.	33.3	32.7	7.6	19.2	9.1	1.2	6.8	417	33	363
	I. C.	36.1	30.2	9.3	18.6	8.9	1.4	7.0	418	30	364
	U. C.	24.0	31.7	8.6	18.9	9.5	1.2	6.6	423	45	364
	Cari.	40.8	34.7	8.2	21.5	9.3	1.3	7.0	410	32	361
high	Cen.	66.1	49.6	13.2	27.8	12.3	2.0	9.6	464	41	405
	I. C.	63.0	49.3	11.8	28.4	12.2	1.8	9.8	468	42	407
	U. C.	76.0	48.1	9.9	30.7	12.7	1.6	10.1	467	36	400
	Cari.	58.3	49.9	9.2	34.0	12.4	1.6	10.0	454	36	404

4 Conclusions

Timber properties vary considerable across Europe. Between Slovenian regions the differences in the raw material are considerably lower than between countries. However the graded material can show as much variability if regions from one country or countries all over Europe are graded. The definition of an area for which the same grading machine settings can be used should not be based on the characteristic values only.

Acknowledgement

This project is supported by the industry via CEI-Bois. The Gradewood-project belongs to the Wood Wisdom.Net-programme and is funded by national technology development bodies, e.g. Federal Ministry of Education and Research. The contributions from funding organisations and other support are gratefully acknowledged.

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