



# Improving the accuracy of wood moisture content estimation in four European softwoods from Spain

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## Abstract

**Aim of study:** To obtain improved models to predict, with an error of less than  $\pm 2.0\%$ , the gravimetric moisture content in four different softwoods commonly present in the Spanish and European markets, based on electrical resistance measurements. This improved moisture content estimation is useful not only for assessing the quality of wood products, especially in the case of laminated products, during the transformation and delivery process, but also for accurately monitoring the evolution of moisture in wood present in bridges and buildings, which is of great importance for its maintenance and service life improvement.

**Area of study:** The study was carried out on samples of Scots, laricio, radiata and maritime pines of Spanish provenances.

**Material and methods:** On 50x50x20 mm<sup>3</sup> solid wood samples (36 per species, 9 per condition), conditioned at 20°C ( $\pm 0.5^\circ\text{C}$ ) and 40 $\pm 5\%$ , 65 $\pm 5\%$ , 80 $\pm 5\%$  or 90 $\pm 5\%$  Relative Humidity (RH), electrical resistance and oven-dry moisture content was measured. The Samuelsson's model was fitted to data to explain the relationship between the two variables. The accuracy of the model was evaluated by the use of an external sample.

**Main results:** With the proposed mathematical functions the wood moisture content can be estimated with an error of  $\pm 0.9\%$  in the four species, confirming the effectiveness of this nondestructive methodology for accurate estimation and monitoring of moisture content.

**Research highlights:** our results allow the improvement of the moisture content estimation technique by resistance-type methodologies.

**Keywords:** Resistance-type moisture meter; species correction.

**Abbreviations used:** MC: Moisture content; RH: relative Humidity; R: electrical resistance; R<sub>p</sub>: wood electrical resistance measured parallel to the grain; R<sub>T</sub>: electrical resistance measured perpendicular (transversally) to the grain; GM-MC: gravimetrically measured moisture content.

**Authors' contributions:** All the authors conceived the idea, structured the article and revised and criticized the manuscript. María CG: performed the acquisition of data. Marta CG analyzed the data with the advice from JIFG and Maria CG. JIFG, supervised the work and coordinated the research project.

**Citation:** Conde-García, M.; Conde-García, M.; Fernández-Golfín, J.I. (2020). Improving the accuracy of wood moisture content estimation in four European softwoods from Spain. Forest Systems, Volume 30, Issue 1, e002. <https://doi.org/10.5424/fs/2021301-17798>.

**Received:** 20 Nov 2020. **Accepted:** 25 Feb 2021.

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Funding agencies/institutions	Project / Grant
Laboratories of Wood Technology of CIFOR-INIA and University of Cordoba	BIA2013-42434-R
Operational Group "Wood Sustainable Construction"	

**Competing interests:** The authors have declared that no competing interests exist.

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## Introduction

The moisture content (MC) influences most of the physical, mechanical and technological properties of wood, and also affects its quality and service life, especially in constructions. The MC in service can vary widely depending on the surrounding climatic conditions and its hygroscopic history.

The time to initiation and subsequent rate of wood decay is affected by a series of concomitant factors which make up the so-called "material climate" (the temperature and moisture content of the wood), which in turn has a direct impact on the service life of the wood products and constructions (Brischke *et al.*, 2007). For this reason, it is vitally important to have moisture and temperature measurement devices which are reliable, safe and precise

in order to control building decay, especially where these are highly valued historical buildings.

Different studies have been carried out (Brischke *et al.*, 2008; Dyken & Kepp, 2010; Tannert *et al.*, 2010 and 2011; Dietsch *et al.*, 2015b; Li *et al.*, 2018; Niklewski *et al.*, 2018) in which both environmental and wood temperature as well as moisture content are monitored, mainly on in-service wood structures (bridges, buildings, etc.) exposed to different climatic conditions and with different design details.

Moreover, the introduction of the Building Products Regulation has made compulsory for European manufacturers of solid wood structural products to measure the moisture content with an accuracy of at least  $\pm 3\%$  (for at least 95% of the measurements) and to ensure the maintenance of this accuracy over time by checking it (at least annually) with a set of at least three resistances from 1 MOhm to 100 GOhm in the case of resistance-type moisture meters (EN 14081-1:2016+A1:2020).

Accuracy of moisture content measurement is also important to reduce the percentage of wood declassified due to excessive or reduced moisture content. The presence of a high declassification percentage is a factor that seriously affects the profitability of the transformation process.

To determine the MC, two general approaches can be distinguished: a) In-laboratory measurements, the MC is determined by oven-drying according to international standards (EN 13183-1) or water extraction, and b) In-service measurements, the MC is usually estimated by means of indirect measurement methods that use physical properties of wood which are correlated to the MC. Indirect and non-destructive measurement methods include the capacitive, electrical resistance, microwave, radiometric, spectrometric, sorption and color reaction methods (Dietsch *et al.*, 2015). A complete review of methods for measuring MC can be read in Dietsch *et al.* (2015) and Englund Thybring *et al.* (2018).

The resistance-type method is widely used in the monitoring the MC in practice, forming an integrated part of the control and regulation equipment of the sawmill wood-drying process, and for assessing the conformity of the final MC of sawn timber and other kinds of wood products. Dielectric, radiometric and spectrometric-type moisture meters are mainly used in production lines to provide on-line and non-contact measurements.

In order to monitor the MC of in-service timber structures and to assess the conformity of MC in the reception process and/or in the inspection procedures for wood products, the most used and reliable method is the resistance-type. Among the reasons for arriving at this conclusion are: its acceptable accuracy, the possibility of localized measuring (at exactly the worst point of the wood element), the durability and fast response of moisture-pin sensors under changing environmental conditions, the ease of connection of the measuring devices to data-logging systems and the limited damage to the structure, al-

though it is necessary to deal with the problem of maintaining close contact over time between the pin-sensors and the wood in certain places where the dimensional changes in the wood are extreme.

Since Stamm (1927) is known that the resistance of wood decreases with increasing moisture content. The main matter of concern about this technology is its accuracy. One of the main factors affecting its accuracy is the in-built calibration curves that relate the non-destructive measurements (electrical resistance) to real MC. The effect of other factors related to the methodology of measurements can be easily overcome by following the recommendations included in the EN 13183-2 standard.

Forsén & Tarvainen (2000) carried out an extensive study on the accuracy of the hand-held wood moisture content meters working not only according to the resistance-type method but also to the capacitance-type method. They concluded that most of the resistance meters showed a systematic deviation from the oven-dry determined MC because of incorrect MC-resistance curves. According to these authors, the accuracy of the resistance-type meters (95% confidence interval) for in-field measurements is about  $\pm 2.0$  to  $\pm 5.0$  MC percentage degrees (%) and about  $\pm 3.0\%$  to  $\pm 5.0$  MC percentage degrees (%) for the capacitance-type meters. In this sense, the most important source of quantitative error in resistance-type meters is associated with the different effect of wood species followed by the effect of material temperature. In accordance with this, resistance-type MC measurements must be compensated for variation caused by wood species and wood temperature. These authors provided clear evidenced of the fact that only meters that can offer sufficient accuracy (which they considered to be over 55% of readings within 1% of oven-dry measurements) should be used for contractual quality control purposes. For this reason, the wood sector industry as a whole, as well as its users, demand improved measurement accuracy of these devices.

All the resistance-type meters have their own built-in resistance curves for different species, although these curves differ for different species depending on the electrical properties of the wood. Due to the different built-in resistance curves and the fact that many commercial devices use a single internal calibration curve, along with the multiplicity of methods for correcting the effect of species, instruments produced by different manufacturers also show different readings when used on the same wood material (Forsén & Tarvainen, 2000).

Vermaas (1982) reported that most of the moisture meters did not provide the required accuracy when used on Monterrey (*Pinus radiata*) and maritime pines (*P. pinaster*) grown in South Africa due to inadequate correction of the effect of wood species. Only by using the specific calibration functions, or by means of appropriate species correction systems, can the accuracy of the MC

estimation attain values better than the  $\pm 3\%$  demanded by the EN 14081-1 standard.

The literature contains different expressions describing the relationship between the electrical resistance and MC (see Vermaas, 1982) but most of them are on non-European species. One of the last and most extensive studies carried out on native European species (softwoods, hardwoods and modified woods) is that of Brischke & Lampen (2014), who proposed a functional relation between measured electrical resistance and gravimetric MC in a limited range between 15% and 50 % MC. By using the proposed specific calibration functions, the precision of MC estimation of the measurements was in the range between  $\pm 2.5\%$  and  $\pm 5\%$ , far from the objective of  $\pm 1\%$  established by Forsén & Tarvainen (2000) and that of better than  $\pm 3\%$  considered by the EN 14081-1:2020 standard.

In the present work, the function initially proposed by Samuelsson (1990) has been used not only because of its demonstrated viability in predicting the value of the oven-dry determined moisture content but also for the purpose of comparing our results with those of the study conducted by Forsén & Tarvainen (2000) in which common species were sampled (Scots pine and maritime pine), albeit of different origin. The use of the same fitting function and measurement methodology as the ones used in the studies carried out by Forsén & Tarvainen (2000) and Fernández-Golfín *et al.* (2012, 2014) has the advantage of being able to increase the number of species and origins for which the Samuelsson fitting coefficients (a and b) are known. Another added advantage is to be able to compare our fitting coefficients with those obtained by Forsén & Tarvainen (2000) in those species also sampled by us (Scots pine and maritime pine), increasing the number of origins, as well as to build up comparable databases.

The aim of the present work was to improve the estimation accuracy of the oven-dry determined MC for the most important softwood species available on Spanish markets (and also present on European markets), below the lower threshold of 2% revealed in the study by Forsén & Tarvainen (2000).

It is not within the scope of this work to compare the accuracy of the different mathematical models dealt with in the literature, although the database created is likely to be used for this purpose in future studies.

## Materials and Methods

### Test material: selection and conditioning

Twelve 50 mm-thick flat sawn timber planks were selected from each of the following species: radiata pine-PR (*Pinus radiata* D. Don), Scots pine-PS (*Pinus sylvestris* L.), lario pine-PL (*Pinus nigra* Arn. Subsp. *salzmannii*)

and maritime pine-PP (*Pinus pinaster* Aiton). Radiata-pine came from the Vasque Country (northern Spain), Scots-Pine from Valsain (central Spain), Lario-Pine from Cuenca (central-eastern Spain) and Maritime-pine from Galicia (northwestern Spain) provenances. These planks of each species were sampled in three different sawmills in order to include as much variability as possible in the sample, thus being as representative as possible of the material present on the market.

The sawn timber planks were cut into test specimens approximately 50 mm long, 50 mm wide and 20 mm thick. At least 50 cm were discarded from each end of the planks before the specimens were cut. 36 specimens for each species, 12 per sawmill, free of visible defects such as knots, decay, resin pockets, juvenile and compression wood, checks and high deviation in fiber orientation, were randomly selected (Fig. 1).

All the specimens were conditioned at  $20 \pm 0.5^\circ\text{C}$  and  $65 \pm 5\%$  RH for three weeks. After the initial conditioning, 36 samples of each species were randomly divided into groups of nine, each group being conditioned at  $20^\circ\text{C}$  and  $40\pm 5\%$ ,  $65\pm 5\%$ ,  $80\pm 5\%$  or  $90\pm 5\%$  RH.

Prior to placing the samples into each climatic chamber they were weighed on a METTLER TOLEDO (Delta Range PB 303) balance with a resolution of 1 mg. Once in the climatic chamber the masses of each sample were monitored daily, recording the mass gain or loss. To avoid the effect of internal moisture gradients on the electrical resistance measurements, the test materials were kept in the chambers until the daily mass variation was  $\leq 0.1\%$ . Both the chambers and the balance were subjected to periodic calibration and maintenance procedures included in the ISO/IEC 17025:2017 Manual of Quality adopted by our laboratory (externally accredited).

To evaluate the accuracy of the models, a second sample was used. For operational reasons only three climatic conditions were used ( $20\pm 0.5^\circ\text{C}$  and  $40\pm 5\%/65\pm 5\%/90\pm 5\%$  RH), since these were the only ones possible and they coincide with the extreme and average validation values of the models. Equilibrium in MC was reached (daily variations  $\leq 0.1\%$ ), on average, after fourteen days, which is when the electrical resistance measurement was performed. 10 additional specimens of  $50\times 50\times 20\text{ mm}^3$  per species and chamber climatic conditions were selected and used to calculate the measurement uncertainty and the mean error corresponding to each of the three study points considered.

### Measurement of electrical resistance and gravimetric moisture content

Once the testing material had reached equilibrium, the electrical resistance of each sample was measured using an AGILENT 4339B resistance meter (range 103-1015  $\Omega$ ,



**Figure 1.** The four groups of specimens used in the study: above from the left 20/65 and 20/40 *P. pinaster*, *P. radiata*, *P. laricio* and *P. sylvestris* specimens, below from the left 20/80 and 20/90 specimens of the same species

accuracy 0.5%, display resolution 5 digits). On each occasion that the electrical resistance of the wood was measured, the ability of the equipment to measure correctly was verified using a TINSLEY 4721 decade box (with an external ISO/IEC 17025:2017 calibration certificate). The verification was performed at 100 Gohms.

The wood resistance measuring specifications were as follows:

- Measuring voltage: 10 V
- Measuring temperature (laboratory): 20±2°C
- Measuring time delay: 5 s

These measurement specifications were those used by Forsén & Tarvainen (2000) in their research as well as in previous research work conducted by the team responsible for the present study (Fernandez-Golfin *et al.*, 2012, 2014), thus allowing comparison of results. All the electrical measurements were performed once all the samples, under each of the conditions, had reached moisture content equilibrium (daily variations ≤0.1%).

Two stainless steel pin-type electrodes 10 mm long, 2.6 mm in diameter and with 28.5 mm spacing were used as sensors. The pins were inserted radially (*i.e.*, perpendicularly to the growth rings and presented from the tangential face) as far as the center of the samples. Electrical resistance of the wood was measured in both directions: parallel to the grain ( $R_p$ ) (as required by standard EN 13183-2:2002) and perpendicular (transversally) to the grain ( $R_t$ ).

To prevent any changes in moisture content or temperature during the measurement process, all electrical readings were taken with samples still in the climate chambers.

After completing all the electrical readings under each climatic condition, all the specimens were removed from

each of the chambers and weighed (wet weight [ $w_h$ ]) with a delay of no more than 1 min. Once wet-weighed, all specimens were oven-dried to a constant mass at 103±2°C and the dry weight ( $w_d$ ) recorded. The gravimetric moisture content ( $h$ ) of each specimen was then calculated according to the following expression (Equation 1):

$$h = [(w_h - w_d) / w_d] \cdot 100 \quad [1]$$

where:

$w_h$  is the wet weight, in g, and  
 $w_d$  is the dry weight, in g.

## Statistical analysis

The calibration function used in the present study was that proposed by Samuelsson (1990, 1992) but under the format of (Equation 2):

$$\text{Log}[\text{Log}(R)+1] = a \cdot h + b \quad [2]$$

where  $R$ , the electrical resistance (in  $M\Omega$ ), is the dependent variable and  $h$  (Equation 1), the oven-dry determined MC (%), is the independent one.

This model was fitted to existing data and ANOVA tests were performed using the Statgraphics Centurion XVII software. The independence of the results of wood resistance tests was considered ensured since the correct operation of the measuring device was verified prior to each measurement, according to the methodology previously explained and the samples were randomly selected. The assumptions of normality (Shapiro-Wilk's test)

and of the homogeneity of variance (Levene's test) of data in the populations of the different groups under study was verified prior to carry out the ANOVA test. The method used to discriminate between means was the Fisher's least significant difference (LSD) procedure.

## Results

Table 1 shows the regression coefficients for the selected model [2] where  $R$ , the electrical resistance (in  $M\Omega$ ), is the dependent variable and  $h$ , the oven-dry determined moisture content (%), is the independent one.

In order to assess the influence of the species variable, an ANOVA test was carried out for each of the chamber climatic conditions. Table 2 shows the results of the multiple range test (arranging the samples into homogeneous groups per species and measurement direction) carried out to determine which means are significantly different. In Table 2, P and T indicates the measurement direction of the electrical resistance, being P parallel and T perpendicular to the grain.

Three homogeneous groups have been identified according to the alignment of the Xs in columns in Table 2. There are no statistically significant differences (significance level of 95%) between those levels that share the same column of Xs.

Similarly, in Table 3 the results of the ANOVA test are arranged to show the estimated statistical differences between each pair of means (per species), climatic condition and measurement direction (significance level of 95%).

Table 4 includes a comparison of the estimated moisture content for each species by means of both parallel (P) and perpendicular (T) measurement of the electrical resistance.

Considering only the data included in the second sample, Table 5 shows the maximum, minimum and average error values as well as the measurement uncertainty for the difference between gravimetrically measured (GMC) and estimated MC values, according to the models included in Table 1 for both measuring directions, Parallel (P) and Transversal (T).

## Discussion

According to the data included in Tables 1, 2 and 3, the species seems to have a significant influence on behaviour under the different chamber climatic conditions and thus on the model coefficients. The results of the multiple range tests (Tables 2 and 3) also show that it is not possible to group any of the considered species.

In accordance with the data presented in Table 4, the direction of measurement seems to have an almost negligible (<0.2%) influence on the moisture content reading, especially at moisture content <16%. This result not only agrees in part with that of Forsén & Tarvainen (2000), who noted that this factor has no significant influence over the entire moisture content range, but also, in particular, with the information provided by standard AS/NZS 1080.1 (1988 version). This standard notes that, in practical terms, at moisture contents of <15% the effect of the direction of

**Table 1.** Regression coefficients of Equation [2] ( $\text{Log} [\text{Log}(R)+1]=a.h+b$  for studied species)

Species	Number of samples	R measured parallel to the grain ( $R_p$ )			R measured perpendicular to the grain ( $R_T$ )		
		b	a	$R^2$	b	a	$R^2$
Maritime pine-PP	36	1.0873	-0.0405	99.6	1.0751	-0.0391	99.6
Radiata pPine-PR	36	1.09641	-0.0387	99.5	1.0891	-0.0377	99.8
Laricio pPine-PL	36	1.07005	-0.0374	99.2	1.0771	-0.0374	99.4
Scots pine-PS	36	1.1008	-0.0394	99.69	1.0930	-0.0381	99.6

**Table 2.** Multiple range tests (homogeneous groups)

Species	Climatic Condition climatic conditions and measurement direction							
	20°C/40%RH		20°C/65%RH		20°C/80%RH		20°C/90%RH	
	P	T	P	T	P	T	P	T
Maritime pine-PP	a	a	a	a	a	a	a	a
Radiata pine-PR	b	b	b	b	b	b	b	b
Laricio pine-PL	c	bc	b	b	c	b	c	b
Scots pine-PS	c	c	c	c	d	c	d	c

**Table 3.** Multiple range tests (differences among species)

Species	Climatic conditions and measurement direction							
	20°C/40%RH20/40		20°C/65%RH20/65		20°C/80%RH20/80		20°C/90%RH20/90	
	P	T	P	T	P	T	P	T
Laricio-MaritimePinaster	*	*	*	*	*	*	*	*
Laricio-Radiata	*				*	*	*	*
Laricio-Scots			*	*	*		*	
PinasterMaritime-Radiata	*	*	*	*	*	*	*	*
PinasterMaritime-Scots	*	*	*	*	*	*	*	*
Radiata-Scots	*	*	*	*	*	*	*	*

**Table 4.** Comparison of estimated moisture content (%) for Parallel (P) and Transversal (T) measurements and different resistance values R

R (Mohms)	Radiata P.		Radiata P.		Laricio P.		Scots P.	
	P	T	P	T	P	T	P	T
150000	7.3	7.3	7.9	7.9	7.5	7.7	7.9	7.9
<b>100000</b>	7.6	7.6	8.2	8.2	7.8	8.0	8.2	8.3
<b>10000</b>	9.6	9.6	10.3	10.3	9.9	10.1	10.2	10.4
1000	12.0	12.1	12.8	12.9	12.5	12.7	12.7	12.9
300	13.5	13.7	14.3	14.5	14.2	14.3	14.2	14.5
<b>100</b>	15.1	15.3	16.0	16.2	15.9	16.0	15.8	16.2
50	16.2	16.5	17.2	17.4	17.1	17.3	17.0	17.4
25	17.5	17.8	18.5	18.8	18.5	18.6	18.3	18.7
<b>10</b>	19.4	19.8	20.6	20.9	20.6	20.8	20.3	20.8
5	21.2	21.6	22.4	22.8	22.5	22.7	22.1	22.7

(\*) in bold the four resistance values and the estimated MC values proposed for verifying the accuracy of the moisture meters.

measurement on meter readings is negligible. However, the present results show that above a moisture content of 16%, the difference between parallel and transversal measurements increases by up to 0.5%, with the exception of Laricio pine, which showed a difference of only 0.2-0.3% across the entire moisture content range, again proving the fact that the species factor is highly important.

Table 4 also provides useful data for the calibration/verification of handheld and industrial resistance-type moisture meters when estimating wood moisture content below the fibre saturation point. Table 4 shows in bold the four resistance values and the estimated MC values, which are proposed to verify the accuracy of the moisture meters and thus fulfil the requirements of the EN 14081-1 (2020) standard. Although the European Standard EN 13183-2:2002 establishes that the direction of measurement of electrical resistance should be longitudinal, the present work provides functions for both parallel ( $R_p$ ) and transversal ( $R_T$ ) measurement, thus allowing calibration/verification in both directions. At present this information by direction of measurement may be relevant, since

there are currently moisture meters on the market whose manufacturers recommend carrying out the measurement transversally.

The error for the bulk of the data (Table 5) is clearly within  $\pm 0.9\%$  (MC percentage degrees), which confirms the validity of the models proposed in Table 1. This error is in line with that reported by Forsén & Tarvainen (2000) for maritime pine ( $\pm 1.1\%$ ) and Scots pine ( $\pm 1.2\%$ ). The calculated error of estimation can only be used when the wood to be inspected has been well-conditioned in terms of environment, its temperature has been accurately determined, and the model used to calculate the predicted value of the moisture content from the measured resistance,  $R_p$  or  $R_T$ , is taken from Table 1. Greater values are to be expected if these conditions are not adhered to.

## Conclusions

The Samuelsson model,  $\text{Log}[\text{Log}(R_x)+1]=a.h+b$ , was successfully fitted to experimental data to accurately

**Table 5.** Error and other statistics of estimation (in MC percentage degrees)

T/RH	Variable	Radiata P.		Pinaster P.		Scots P.		Laricio P.	
		P	T	P	T	P	T	P	T
20/40	Average GMC (%)	9.4				9.6			
	Mode GMC (%)	9.1				9.4			
	Max error (%)	0.4	0.5	0.2	0.1	0.4	0.4	-0.0	0.1
	Min error (%)	-0.6	-0.6	-0.8	-0.8	-0.0	-0.0	-0.5	-0.4
	Desvest error (%)	0.5	0.4	0.4	0.3	0.1	0.1	0.1	0.2
	Average error (%)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Uncertainty (%)	-0.1	-0.1	-0.3	-0.2	0.2	0.1	-0.3	-0.1
20/65	Average GMC (%)	12.8				12.8			
	Mode GMC (%)	12.8				12.8			
	Max error (%)	0.7	0.5	0.1	0.2	0.7	0.8	0.2	0.3
	Min error (%)	-0.0	-0.2	-0.8	-0.6	-0.7	-0.7	-0.1	-0.2
	Desvest error (%)	0.2	0.2	0.3	0.3	0.4	0.4	0.1	0.2
	Average error (%)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Uncertainty (%)	0.4	0.2	-0.1	-0.0	-0.1	-0.1	0.1	0.1
20/90	Average GMC (%)	20.8				22.5			
	Mode GMC (%)	21.2				22.7			
	Max error (%)	0.8	0.8	0.4	0.1	0.5	0.3	0.8	0.3
	Min error (%)	-0.1	-0.1	-0.8	-0.9	-0.7	-0.5	-0.6	-0.7
	Desvest error (%)	0.3	0.3	0.4	0.3	0.4	0.3	0.4	0.5
	Average error (%)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Uncertainty (%)	0.4	0.4	-0.2	-0.3	-0.1	-0.1	-0.0	-0.2

predict the gravimetric moisture content of wood from the four conifers (pines) most frequently used by the building sector in Spain. The expected maximum estimation error is of  $\pm 0.9\%$  (MC percentage degrees). This maximum error is well below the limit of  $\pm 3\%$ , required in Annex C of the harmonized standard EN14081-1: 2020 and even below of that considered as optimal (1%) in the extensive study by Forsen & Tarvainen.

The Samuelsson model with the proposed regression coefficients (Table 1) will be of interest for constructing more reliable MC monitoring devices and for improving the calibration/verification processes of the hand-held moisture meters commonly used by the wood industry and building sectors. The proposed mathematical functions are valid only for a temperature of 20°C and thus a correction will be necessary for all other measurement temperatures.

To increase the accuracy of the estimation of the MC value, it is recommended to use the mathematical model of each species instead of using generalized models.

The direction of measurement seems to have an almost negligible ( $<0.2\%$ ) influence on the moisture content reading, especially at moisture content  $<16\%$ . For moisture contents above a value of 16%, the difference between parallel and transversal measurements can increase by up

to 0.5%, being the species factor important in this regard. Attention should be paid to the instructions provided by meter manufacturers when the wood moisture content is estimated to be over 16%.

## Acknowledgements

We gratefully acknowledge Juan Carlos Cabrero (INIA) for his support in the calculation of the measurement uncertainty.

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