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PREDICTION OF HEAT-TREATED CEDAR WOOD SWELLING AND SHRINKAGE WITH ARTIFICIAL NEURAL NETWORKS AND RANDOM FOREST ALGORITHM

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Keywords
Heat Treatment,
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Abstract
Wood material is a natural, sustainable, renewable and environmentally friendly material that can be used in both structural and non-structural applications. However, one of the most important negative features of wood material is that it is a hygroscopic material. Heat treatment application increase dimensional stability of the wood material and becomes more hydrophobic. In this study, firstly, the contact angle values of Cedar wood have been determined in the tangential and radial direction by dropping them on the surface of the wood material. Then the swelling and shrinkage amounts of the same samples were determined. TS 4084 standard was used to determine the swelling and shrinkage amounts. As a result, shrinkage and swelling amounts of the samples were estimated by using artificial neural network (ANN) and Random Forest (RF) algorithm. In the estimation made by RF and ANN methods, contact angle values were used as input. It has been determined that the predictions made with RF Algorithm give the most accurate results (tangential direction, R^2= 0.91, radial direction, R^2= 0.97). As a result, it has been determined by RF Algorithm that shrinkage and swelling values of a wood material whose con-tact angle values are known can be better predicted.

ISIL İŞLEM GÖRMÜŞ SEDİR ODUNU DARALMA VE GENİŞLEME DEĞERLERININ YAPAY SİNİR AĞLARI VE RASTGELE ORMAN ALGORİTMASI İLE TAHMİNİ

Anahtar kelimeler
Isıl işlem,
Sedir,
Tahmin,
Yapay Sinir Ağları,
Rastgele Orman Algoritması.

Öz
Ahşap malzeme, hem yapısal hem de yapısal olmayan uygulamalarda kullanılabilen doğal, sürdürülebilir, yenilenebilir ve çevre dostu bir malzemedir. Ancak ahşap malzemenin en önemli olumsuz özelliklerinden biri higroskopik bir malzeme olmasıdır. Isıl işlem uygulaması ahşap malzemenin boyutsal stabilitesini arttırmakta ve daha hidrofobik hale getirmektedir. Bu çalışmada öncelikle, Sedir odununun temas açısı değerleri, ahşap malzeme yüzeyine damlatma ile teğet ve radyal yönde belirlenmiştir. Daha sonra aynı numunelerin genişleme ve daralma miktarları belirlenmiştir. Genişleme ve daralma miktarlarının belirlenmesinde TS 4084 standardı kullanılmıştır. Deneysel çalışma sonucunda, yapay sinir ağı (ANN) ve rastgele orman algoritması kullanılarak örneklerin daralma ve genişleme miktarları tahmin edilmiştir. Rastgele orman ve ANN yöntemleri ile yapılan tahminlerde temas açısı değerleri girdi olarak kullanılmıştır. Rastgele Orman Algoritması ile yapılan tahminlerin en doğru sonuçları verdiği tespit edilmiştir (teğet yön, R^2= 0.91, radyal yön, R^2= 0.97). Sonuç olarak, temas açısı değerleri bilinen bir ahşap malzemenin Rastgele Orman Algoritması ile daralma ve genişleme değerlerinin daha iyi tahmin edilebileceği belirlenmiştir.

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1. Introduction

Wood has one of the first materials to serve as a source for construction and energy for the early nomadic cultures. However, its wide range of versatility and ability to easy of workability takes people back to the many applications (Sahin and Onay, 2020). Thanks in part to its natural origin with aesthetic features, wood is also well suited to apply in many implementations (Sahin and Onay, 2020; Sahin et al., 2020). Moreover, wood is a natural biological material whose properties vary not only from one species to another but within the same species. Some variations can even be expected in wood cut from the same tree. For that reason, the properties of wood are important influences on end uses.

Wood has been used in various fields for many years because of positive properties (Kılınçarslan and Şimşek Türker, 2020a). It is a common industrial problem that the wood materials are subjected to dimensional changes due to environmental effects and deformed by the effects of various tree pests (insects and fungi) (Suat and Ciritçioğlu, 2012 , Kılınçarslan and Şimşek Türker, 2019, Kılınçarslan et al., 2020). Although chemical methods used in wood material modification have positive aspects such as being easy to apply, giving wood material resistance against deterioration and rotting, it also has negative aspects such as it contains toxic substance, high cost and the need to repeat over time. Heat treatment; it is an alternative modification method to the use of chemicals to increase the dimensional stabilization of the wood material and to protect it against tree pests.

The hygroscopic feature of the heat-treated wood is reduced, and its dimensional stability and the resistance to biological pests are improved. As the wood is being heat-treated, followed in an attempt to enhance some of the wood drawbacks. Thermal modification may alter the chemical constituents as well s color and aesthetic appearance of wood substrates (Sahin et al., 2011). However, the effectiveness of the heat treatment application; Depending on wood types, wood properties, chemical and anatomical properties, initial moisture content and process parameters (temperature and time) and tree material direction (Brunetti et al.,2009, Esteves et al., 2007, Garcia et al., 2008, Kamdem et al., 2002, Unsal et al., 2005). Two important surface properties that determine whether a liquid (water, paint, glue) adheres to the surface are wettability and surface energy. Wetting quality is affected by many factors including wood macroscopic properties (porosity, surface roughness, moisture content, etc.). There are various techniques for measuring the wettability of wood material (Walinder and Johansson, 2001, Walinder and Strom, 2001, Shi et al., 1997). The most widely known and widely used method is the drop technique (Neumann and Spelt, 1996). The contact angle can be determined directly from the drop image recorded during the wetting test using the drop technique (Cengiz, 2010). The contact angle is defined as the angle formed between the drop of liquid and the solid surface and is a measure of the wetting property of the liquid. As the contact angle of the liquid dropped on a material surface decreases, its wettability property increases (Kocaefe et al., 2008, Kılınçarslan and Şimşek Türker, 2019).

In this study, it is aimed to estimate the tangential and radial swelling and shrinkage amounts of Cedar (*Cedrus Libani*) wood with heat-treated artificial neural networks and random forest algorithm. In the study, contact angle values determined by a method that does not require any effort in a short time were used to estimate these data. The focus is on the development of artificial neural networks model and random forest algorithm, which has the ability to estimate the swelling and shrinkage amounts that provide information about the dimensional stability of the wood material.

2. Material and Method

2.1. Supply of Material and Conducting Experiments

In this study, Cedar (*Cedrus Libani*) wood was used as material. The heat-treated timber used in the study was obtained dealership of Naswood Ltd Şti. from Antalya. Timber was heat-treated at the time and temperature that the factory deems suitable for the tree species. In this study, timber without fiber defects, cracks, caries and knots were preferred. For the dynamic wetting test of the cedar samples, the dimensions were cut with a motorized saw in 20x20x30 mm dimensions. After the samples were dimensioned, the surfaces of the samples were sanded with sand paper. Samples whose surfaces have been smoothed are taken into the air conditioning cabinet at 20 ± 2 ° C and 65 ± 5% relative humidity until they were unchanged. Drops of 5 µl of pure water drawn into a syringe were dropped onto the surfaces of the samples and after the dropping process, the image of the drop on the surface was taken at the end of the 30th second (Kocaefe et al., 2008, Kılınçarslan and Şimşek

Türker, 2019, Kılınçarslan and Şimşek Türker, 2020b). In order to determine the contact angles over the drop images, the '' Image J '' image analysis program was used.

Experiments for determining the shrinkage amounts were carried out based on the TS 4083 standard. Until the weights of the test samples have remained unchanged, the samples have been kept in pure water at 20 ± 5 ° C and the unchanged samples have been measured and recorded. The test pieces were dried to approximately 12-15% humidity under normal room conditions. The test pieces were then dried in the drying cabinet at 103 ± 2 ° C until they reached a constant weight. Measurements in full dry condition were taken. TS 4084 standard was used to determine the amount of swelling. The test pieces were dried in the drying cabinet at 103 ± 2 ° C until they reached invariable dimensions, without cracks that could distort their size and shape. Then, the sizes of the test pieces were immersed in distilled water at a temperature of 20 ± 5 ° C in a container until they were unchanged. Then, the final measurements in full wet state were taken.

The dimensional stability of wood materials is an important feature for the sustainability and durability of the material. With the heat treatment application, the dimensional stability of the wood material increases, so the wettability feature decreases. Radial-tangential swelling and shrinkage amounts were estimated instead of swelling and shrinkage experiments, which were long and laborious in laboratory studies. In the study, the amount of radial-tangential swelling and shrinkage according to the contact angle values of Cedar (*Cedrus Libani*) type samples were estimated. In the study, 30 contact angle data were used. Of these data, 22 were used as training data and 8 as test data. These data are; tested on the same computer with artificial neural networks and random forest algorithm using the same configuration and optimization methods.

2.2. Machine Learning Methods Used for Predictive Purposes

Machine learning try to find mathematical relationships for existing data to predict new data (Shrestha and Solomatine, 2006). Supervised, Unsupervised and Reinforcement Learning (Sasakawa et al., 2008) are machine learning types that are used for artificial intelligence problems. Supervised learning is used for finding relations between labeled input data and output data which is called training phase. In testing phase, it is used to generate output data for unknown corresponding input data for the system (Ghosh-Dastidar and Adeli, 2009). Classification and curve fitting-regression problems are basic usage areas of this algorithm. Unsupervised learning tries to find structures from input data without any supervising process (Sanger, 1989). Clustering is the fundamental usage are of unsupervised learning. Reinforced learning includes goal-reward-action stages that is inspired by behavioral psychology. Some application area of this learning type are robot navigation, real-time decision making (Singh et al., 2000). There are many artificial intelligence methods such as artificial neural networks, random forest algorithm, decision trees and support vector machine for machine learning problems (Rodriquez-Galiano et al., 2015). In this study, artificial neural networks and random forest algorithm are used as supervised learning method. Artificial neural networks inspire the human nervous system (Van Geryen and Bohte, 2017) and consists of input, output and hidden layers. ANN tries to predict the result of new data that are not shown to them by the help of training process (Zhang et al., 1998). For this purpose, it uses the neurons and activation function in the layers. In this study, radial-tangential swelling and shrinkage amounts of cedar tree was tried to be predicted by radial and tangential contact angle. Therefore, radial and tangential contact angles are used as input data; radial-tangential swelling and shrinkage amounts are used as output data for the ANN. For this purpose, different layer and neuron count are tried in training phase to obtain best results. Parameters which give best result are chosen for ANN parameters. Thus, two hidden layered artificial neural networks with 2 inputs, 4 outputs and 10 neurons were used (Figure1). Training rate was taken as 0.5 and sigmoid was used as activation function.

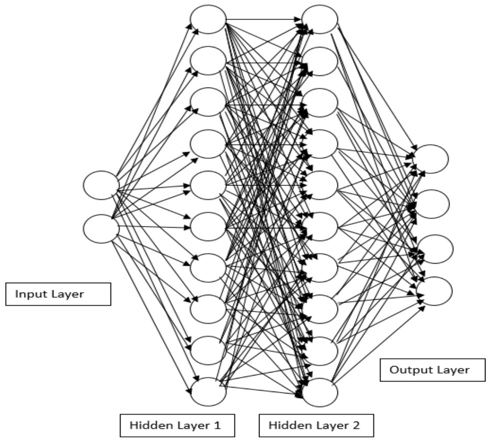

Figure 1. Artifical neural network model used.

The random forest algorithm uses a lot of randomly generated decision trees. Both regression and classification tasks can be solved by this algorithm. The multiple decision trees are called as bagging in this algorithm (Lahouar and Slama, 2015). Each decision tree on a different data sample that is made by changing the sampling are trained (Vitorino et al., 2014). The bagging process uses multiple decision trees instead of the individual decision trees to vote samples. By having majority vote of decision trees, output is selected as output of the random forest algorithm (Belgiu and Dragut, 2016). Thus, over fitting problem is eliminated in this algorithm (Li et al., 2016). Moreover, the random forest algorithm does not require a normalization like ANN and can use real numerical values. Therefore, it can be seen as fast, simple and flexible algorithm. In this study, different random forest algorithm parameters are tried in training phase which gives the best result are chosen as parameters. Defined parameters for Python programming language which is used in this study, are as follows; n_estimators is 100, min_samples_split is 2, min_samples_leaf is 1 and random_state is 0.

2.3. Performance Measurement Metrics

Root Mean Square Error (RMSE) is the standard deviation of the prediction errors and used in regression problems to analyze the success of the prediction. It tries to find regression line that how far it away from data points and how far it spreads (Nevitt and Honcock, 2000). R-Square (R^2) shows how close the regression line is to real data values (Recchia, 2010) and its value should be between 0 (worst value) and 1 (best value). Another metrics is Mean Absolute Error (MAE) and it represents the average of absolute differences between target values and prediction (Willmott and Matsuura, 2005). Individual differences are on average equal weight in this metric and it is desired to be approximate to small value.

3. Experimental Results

In this study, the swelling and shrinkage amounts of the materials were estimated according to the contact angle data of the heat-treated wood material. Heat-treated Cedar (*Cedrus Libani*) wood contact angle, swelling and shrinkage amount data are given in Table 1.

Table 1. Dynamic wetting, swelling and shrinkage test results

	Contact angle (^{O})	Swelling (%)	Shrinkage (%)
Tangential	45.27	5.06	4.43
Radial	43.53	3.42	3.50

In this study, artificial neural networks and random forest algorithm were used to estimate swelling and shrinkage values from contact angle values. In Table 2, statistical analysis results of the tangential and radial prediction data of heat-treated samples are given.

Table 2. Statistical analysis of forecast data of heat-treated Cedar samples

Artificial Neural Network				
	Swelling		Shrinkage	
	Tangential	Radial	Tangential	Radial
RMSE	0.14031369	0.06685541	0.17335465	0.14111078
R^2	0.71997769	0.9457028	0.59419264	0.64938219
MAE	0.13273111	0.05998216	0.15184809	0.1286789
Random Forest Algorithm				
	Swelling		Shrinkage	
	Tangential	Radial	Tangential	Radial
RMSE	0.1304054	0.08070237	0.1479741	0.12552907
R^2	0.9285589	0.97835781	0.9190347	0.92512433
MAE	0.1099763	0.06807625	0.12271	0.1149325

In the estimations made by two different methods on heat-treated cedar samples, the most accurate estimate was made by random forest algorithm. R square values gave higher values in random forest algorithm, while RMSE and MAE values were similar in both methods, giving results very close to 0.

4. Result and Discussion

In this study, shrinkage and swelling amounts are predicted with contact angles of cedar wood by using ANN and random forest algorithm. Training data is not enough so ANN shows low performance. However, random forest algorithm shows better performance than ANN because it can be worked little data by the help of having bagging system on various decision trees. In heat-treated cedar samples, the estimates made by the artificial neural networks method yield the lowest estimate in the tangential direction shrinkage amount (R^2 = 0.59), while the highest estimated swelling amount is in the radial direction (R^2 = 0.94). In the estimations made with random forest algorithm, it was determined that the lowest estimated shrinkage amount gives tangential direction (R^2 = 0.91) while the best estimated swelling amount is radial direction (R^2 = 0.97). It was determined that the best estimates were made by random forest algorithm. Depending on the contact angle method, which is an easy method of wood material, it will be simple, practical and economical to estimate the swelling and shrinkage amounts by random forest algorithm. Thus, it will be easy to estimate the swelling and shrinkage amounts of the wood material with dropping method which is an easy method.

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Conflict of Interest

No conflict of interest was declared by the authors.

References

Belgiu, M., Drăguţ, L., 2016. Random Forest in Remote Sensing: A Review of Applications and Future Directions. ISPRS Journal of Photogrammetry and Remote Sensing, 114: 24-31.

Brunetti M., Cremonini C., Crivellaro A., Feci E., Palanti S., Pizzo B., Santoni I., Zanuttini R., 2007. Thermal Treatment of Hardwood Species from Italian Plantations: Preliminary Studies on Some Effects on Technological Properties of Wood. alin: International Scientific Conference on Hardwood Processing, Que´bec City, 24–26 Sep. Available at http://www.ischp.ca/FR/pdf/ISCHP_proceedings.pdf. Accessed 26 Feb 2009.

Cengiz, O., 2010. Design Of Contact Angle Meter. University of İstanbul Technical, Mechanical Engineering Department, Master Thesis: 83s.

Esteves, B., Marques A.V., Domingos I. and Pereira, H., 2007. Influence of Steam Heating on the Properties of Pine (Pinus pinaster) and Eucalypt (*Eucalyptus globulus*) Wood. Wood Sci Technol 41(3): 193–207.

Garcia, R.A., Riedl, B. and Cloutier, A., 2008. Chemical Modification and Wetting of Medium Density Fibreboard Produced from Heat-Treated Fibres. J Mater Sci 43: 5037–5044.

Ghosh-Dastidar, S. and Adeli, H., 2009. A New Supervised Learning Algorithm for Multiple Spiking Neural Networks with Application in Epilepsy and Seizure Detection. Neural networks, 22(10): 1419-1431.

Kamdem, D.P., Pizzi, A. and Jermannaud, A., 2002. Durability of Heat-Treated Wood. Holz Roh Werkst 60: 1–6.

Kilincarslan, S. and Simşek Türker, Y., 2019. ''The Effect of Strengthening With Fiber Reinforced Polymers on Strength Properties of Wood Beams'', 2nd International Turkish World Engineering and Science Congress, November 7-10, Turkey.

Kilincarslan, S. and Simsek Türker, Y., 2019. Determination of Contact Angle Values of Heat-treated Spruce (*Picea abies*) Wood with Image Analysis Program. Biomedical Journal of Scientific & Technical Research, 18(4), 13750-13751 (2019).

Kilincarslan, S. and Simşek Türker, Y., 2020a. Physical-Mechanical Properties Variation with Strengthening Polymers, Acta Physica Polonica A, 137(4): 566-568.

Kilincarslan, S. and Simşek Türker, Y., 2020b. The Effect Of Heat Treatment Application on Wettability Properties of Wood Materials, Journal of Engineering Sciences and Design, 8(2): 460 – 466.

Kilincarslan, S. and Simşek Türker, Y., İnce, M. 2020. Prediction Using Different Classification Methods of Tree Species Depending on Contact Angle Values, Journal of Bartin Faculty of Forestry, 22 (3): 861-870.

Kocaefe, Poncsak, Dor´e, Younsi., 2008. Effect of Heat Treatment on The Wettability Of white Ash and Softmaple By Water. Holz Roh Werkst, 66: 355–361.

Lahouar, A. and Slama, J. B. H., 2015. Day-Ahead Load Forecast Using Random Forest and Expert Input Selection. Energy Conversion and Management, 103: 1040-1051.

Li, C., Sanchez, R. V., Zurita, G., Cerrada, M., Cabrera, D. and Vásquez, R. E., 2016. Gearbox Fault Diagnosis Based on Deep Random Forest Fusion of Acoustic and Vibratory Signals. Mechanical Systems and Signal Processing, 76: 283-293.

Neumann, A.W. and Spelt, J.K., (eds) 1996. Applied Surface Thermodynamics (Surfactant series v. 63). Marcel Dekker Inc, New York

Nevitt, J. and Hancock, G. R., 2000. Improving The Root Mean Square Error of Approximation for Nonnormal Conditions in Structural Equation Modeling. The Journal of Experimental Education, 68(3): 251-268.

Recchia, A., 2010. R-Squared Measures for Two-Level Hierarchical Linear Models Using SAS. Journal of Statistical Software, 32(2): 1-9.

Rodriguez-Galiano, V., Sanchez-Castillo, M., Chica-Olmo, M. and Chica-Rivas, M. J. O. G. R., 2015. Machine Learning Predictive Models for Mineral Prospectivity: An Evaluation of Neural Networks, Random Forest, Regression Trees and Support Vector Machines. Ore Geology Reviews, 71: 804-818.

Sahin, H.T., Arslan, M.B., Korkut, S., Sahin C., 2011. Colour Changes of Heat-Treated Woods of Red-Bud Maple, European Hophornbeam And Oak. Color Research & Application, 36(6):462-466.

Sahin, C. K., Onay, B., 2020. Alternatıve Wood Species For Playgrounds Wood From Fruit Trees. Wood Research, 65(1), 149-160.

Sahin, C., Topay, M., Var, A.A., 2020. A Study on Some Wood Species For Landscape Applications: Surface Color, Hardness And Roughness Changes at Outdoor Conditions. Wood Research, 65(3): 395-404.

Sanger, T. D., 1989. Optimal Unsupervised Learning in a Single-Layer Linear Feedforward Neural Network. Neural networks, 2(6): 459-473.

Sasakawa, T., Hu, J. and Hirasawa, K. 2008. A Brainlike Learning System with Supervised, Unsupervised, and Reinforcement Learning. Electrical Engineering in Japan, 162(1): 32-39.

Shi, Q., Gardner, D.J. and Wang, J.Z., 1997. Surface Properties of Polymeric Automobile Fluff Particles Characterized by Inverse Gas Chromatography and Contact Angle Analysis. In: Int. Conf. of Woodfiber-Plast. Compos. 4th Forest Product Society, Madison, USA, pp: 245–256.

Shrestha, D. L. and Solomatine, D. P., 2006. Machine Learning Approaches for Estimation of Prediction Interval for the Model Output. Neural Networks, 19(2): 225-235.

Singh, S., Jaakkola, T., Littman, M. L. and Szepesvári, C., 2000. Convergence Results for Single-Step on-Policy Reinforcement-Learning Algorithms. Machine learning, 38(3): 287-308.

Suat, A. Y. A. N. and Ciritcioğlu, H. H., 2012. Determination of Heat Treatment Effect on Some Mechanical Properties and Screw Withdrawal Strength of Laminated Wood Panels, Journal of Advanced Technology Sciences, 1(1): 35-46.

Unsal, O. and Ayrilmis, N., 2005. Variations in Compression Strength and Surface Roughness of Heat-Treated Turkish River Red Gum (Eucalyptus camaldulensis) Wood. J Wood Sci 51: 405–409.

Van Gerven, M. and Bohte, S., 2017. Artificial Neural Networks as Models of Neural Information Processing. Frontiers in Computational Neuroscience, 11: 114.

Vitorino, D., Coelho, S. T., Santos, P., Sheets, S., Jurkovac, B. and Amado, C., 2014. A Random Forest Algorithm Applied to Condition-Based Wastewater Deterioration Modeling and Forecasting. Procedia Engineering, 89: 401-410.

Walinder, M.E.P. and Johansson, I., 2001. Measurement of Wood Wettability by the Wilhelmy Method. Holzforschung 1(55): 21–32.

Walinder, M.E.P. and Strom, G., 2001. Measurement of Wood Wettability by the Wilhelmy Method. Holzforschung 2(55): 33–41.

Willmott, C. J. and Matsuura, K., 2005. Advantages of The Mean Absolute Error (MAE) Over The Root Mean Square Error (RMSE) in Assessing Average Model Performance. Climate Research, 30(1): 79-82.

Zhang, G., Patuwo, B. E. and Hu, M. Y., 1998. Forecasting with Artificial Neural Networks: The State of the art. International Journal of Forecasting, 14(1): 35-62.