United States
Department of
Agriculture

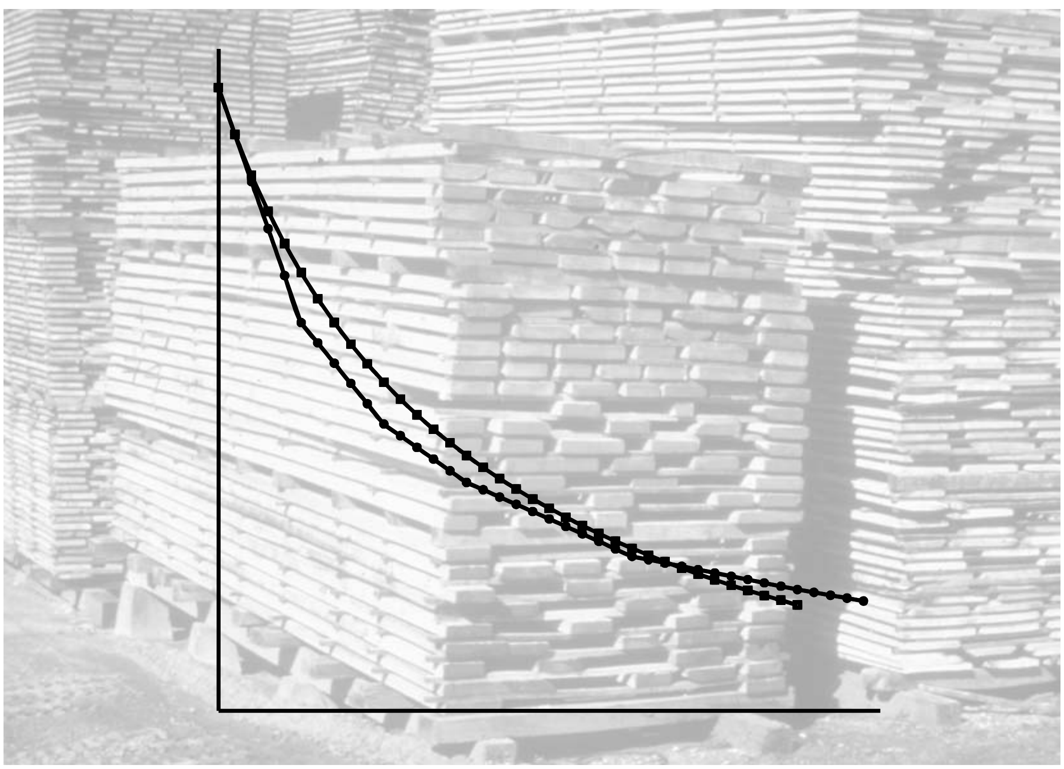
Forest Service

Forest
Products
Laboratory

Research
Note
FPL–RN–0293

Estimating Air Drying Times of Lumber With Multiple Regression

William T. Simpson



Abstract

In this study, the applicability of a multiple regression equation for estimating air drying times of red oak, sugar maple, and ponderosa pine lumber was evaluated. The equation allows prediction of estimated air drying times from historic weather records of temperature and relative humidity at any desired location.

Keywords: air drying, lumber drying, red oak, sugar maple, ponderosa pine

June 2004

Simpson, William T. 2004. Estimating air drying times of lumber with multiple regression. Res. Note FPL-RN-0293. Madison, WI: U.S. Department of Agriculture, Forest Service, Forest Products Laboratory. 6 p.

A limited number of free copies of this publication are available to the public from the Forest Products Laboratory, One Gifford Pinchot Drive, Madison, WI 53726–2398. This publication is also available online at www.fpl.fs.fed.us. Laboratory publications are sent to hundreds of libraries in the United States and elsewhere.

The Forest Products Laboratory is maintained in cooperation with the University of Wisconsin.

Estimating Air Drying Times of Lumber With Multiple Regression

William T. Simpson, Research Forest Products Technologist
Forest Products Laboratory, Madison, Wisconsin

Introduction

Several recent studies have been conducted to develop methodology for estimating the air drying times of lumber, logs, and square timbers based on species, size, geographic location (which determines average daily temperature and relative humidity), stacking date, and final moisture content. The initial study (Simpson and Hart 2000, 2001) utilized previously published air drying data for red oak, sugar maple, beech, yellow poplar, ponderosa pine, and Douglas-fir. That study applied a computer drying simulation developed by Hart (1982) and provided good estimates of air drying times for these species. However, it is difficult to develop the simulation parameters from the experimental data, and furthermore, the drying simulation computer program is not readily available to most potential users. Simpson and Wang (2003) developed estimated drying times for small-diameter (4 to 8 in. (102 to 203 mm)) ponderosa pine and Douglas-fir logs using multiple regression methods.

Not only is multiple regression easier than computer simulation for establishing the relationship between air drying times and the parameters that affect it, but once the regression parameters are developed from experimental data, the results are readily usable in simple user-built computer programs or spreadsheets. The purpose of this study is to determine if multiple regression analysis can be successfully applied to predict air drying times of lumber from historic daily average temperature and relative humidity data. The test will be applied to the air drying data previously analyzed by Simpson and Hart (2000, 2001).

Methods

The multiple regression relationship applied in this study was

$$\Delta M = M^{a} T^{b} H^{c} \qquad (1)$$

where ΔM is daily loss of moisture content (%); M, moisture content at the start of any day during air drying (%); T, average daily temperature (°F); H, average daily relative humidity (%); and a, b, and c are regression coefficients determined by fitting experimental drying data to Equation (1) using nonlinear regression analysis. In the log drying study (Simpson and Wang 2003), diameter was also a variable and was included as diameter raised to a power to be determined by regression analysis. However, the lumber data being reanalyzed did not include thickness as a variable.

Analyzing air drying data with Equation (1) requires moisture content data throughout drying—not just the drying time to some final moisture content. Some of the data analyzed by Simpson and Hart (2000, 2001) were in the form of moisture content time curves, and some were in the form of only a time to some final moisture content with no intermediate moisture content time data. Therefore, not all the data from Simpson and Hart could be reanalyzed and was limited to 1-in.-thick northern red oak air dried in Madison, Wisconsin; 1-in.-thick sugar maple in upper Michigan; and 1- and 1.5-in.-thick ponderosa pine in Flagstaff, Arizona. In each case, the data were in the form of moisture content time curves for four stacking dates—in January, May, July, and October. The data of all four stacking dates for each species were used in the regression analysis with Equation (1). Daily average temperature and relative humidity were also available in each case.

Results and Discussion

The regression coefficients a, b, and c, and the coefficient of determination R^2 for each species–thickness are shown in Table 1. The R^2 values ranged from 0.808 to 0.920, indicating that Equation (1) works well in correlating the decrease in moisture content each day based on the moisture content at the start of the day and the average daily temperature and relative humidity. Equation (1) allows us to develop moisture content time curves by subtracting each daily loss in

Table 1—Regression coefficients *a*, *b*, and *c* and coefficients of determination R^2 for the moisture content time relationships of red oak, sugar maple, and ponderosa pine according to Equation (1) ($\Delta M = M^{a} T^{b} H^{c}$)

Species, thickness	*a*	*b*	*c*	R^2
Red oak, 1 in.	2.38	0.759	–2.91	0.808
Sugar maple, 1 in.	2.18	1.89	–3.57	0.812
Ponderosa pine, 1 in.	1.64	1.22	–2.39	0.878
Ponderosa pine, 1.5 in.	1.27	1.84	–2.86	0.920

moisture content from the moisture content at the start of that day. Moisture content time curves for each species–thickness and each of the four stacking dates are shown in Figures 1–4, and each graph includes both the experimental curves and those calculated by Equation (1). The agreement between the experimental and calculated curves was reasonably good in many cases, but in some cases, it was not good. Overall, Equation (1) seems to have good potential in predicting the progress of moisture content loss during air drying. One problem in this analysis is working with old data taken from the literature. The data had to be manually extracted from graphs of drying curves, which resulted in less than exact data. And, with all due respect to the original researchers, not all of the details or possible pitfalls and errors in their experiments are known. However, the results of this analysis suggest that Equation (1) has good potential as a means of estimating air drying times and that future research projects could be designed specifically to develop that potential, including thickness as a variable.

Conclusions

This study has shown that the nonlinear multiple regression equation that relates the daily moisture content loss in air drying lumber to the moisture content at the start of any day during drying and the average daily temperature and relative humidity can be applied successfully to estimate air drying times.

Literature Cited

Hart, C.A. 1982. SIMSOR: A computer simulation of water sorption in wood. Wood and Fiber. 13(1): 46–71.

Simpson, W.T.; Hart, C.A. 2000. Estimates of air drying times for several hardwoods and softwoods. Gen. Tech. Rep. FPL–GTR–121. Madison, WI: U.S. Department of Agriculture, Forest Service, Forest Products Laboratory. 70 p.

Simpson, W.T.; Hart, C.A. 2001. Method for estimating air-drying times of lumber. Forest Products Journal. 51(11/12): 56–63.

Simpson, W.T.; Wang, X. 2003. Estimating air drying times of small-diameter ponderosa pine and Douglas-fir logs. Res. Pap. FPL–RP–613. Madison, WI: U.S. Department of Agriculture, Forest Service, Forest Products Laboratory. 14 p.

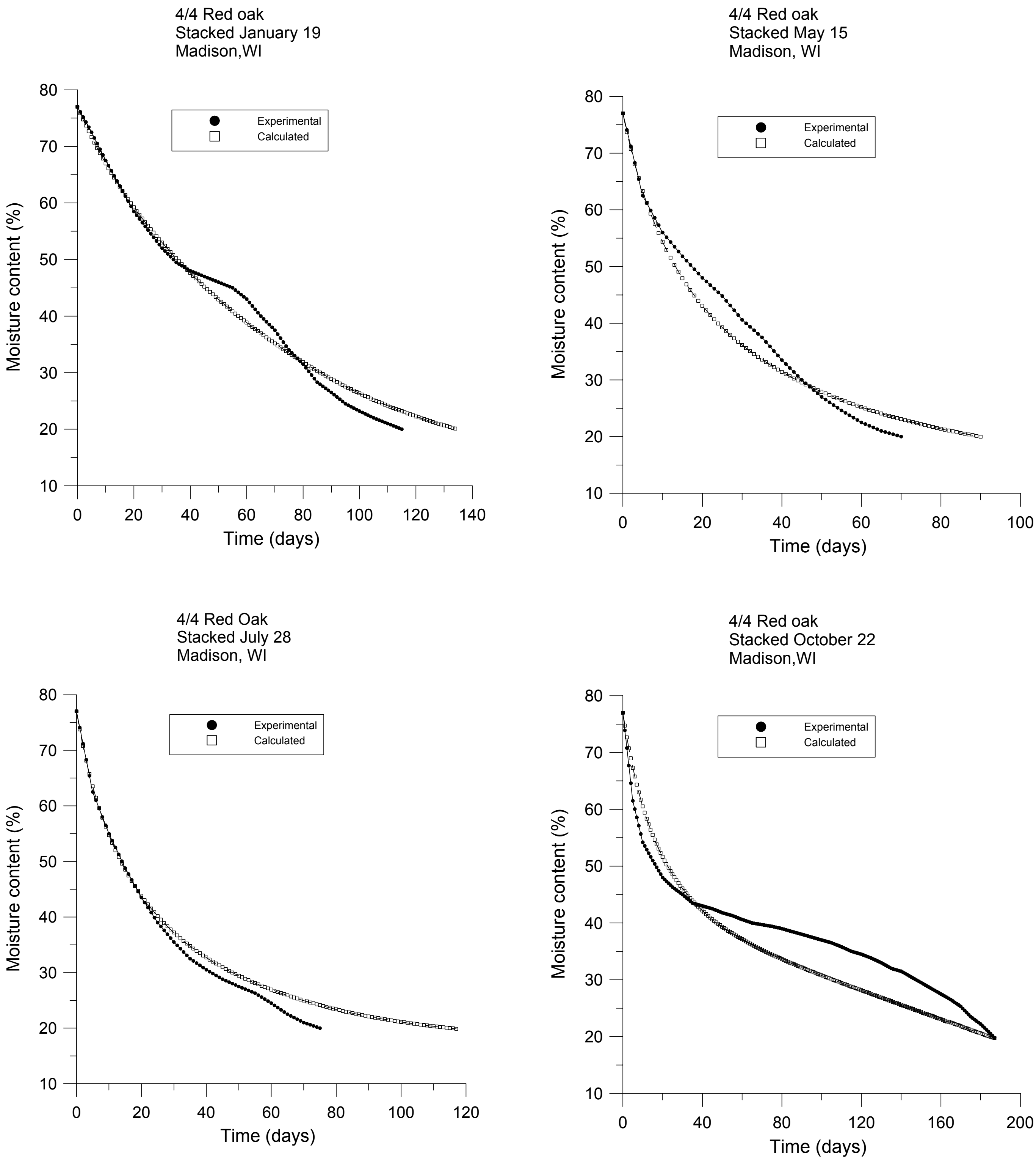


Figure 1—Moisture content time graphs for air drying 1-in.-thick red oak in Madison, Wisconsin, with stacking started in (a) January, (b) May, (c) July, and (d) October.

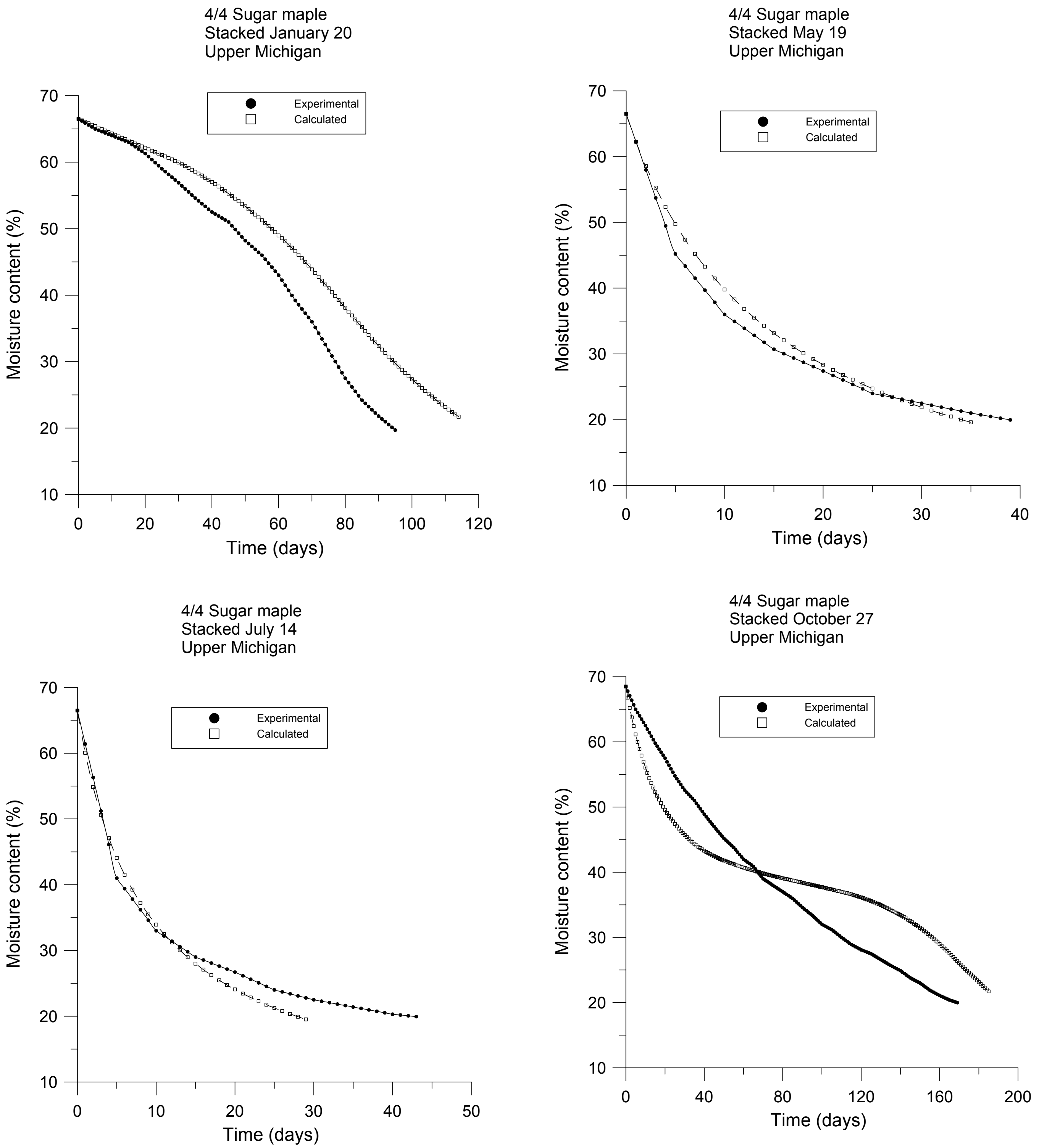


Figure 2—Moisture content time graphs for air drying 1-in.-thick sugar maple in upper Michigan, with stacking started in (a) January, (b) May, (c) July, and (d) October.

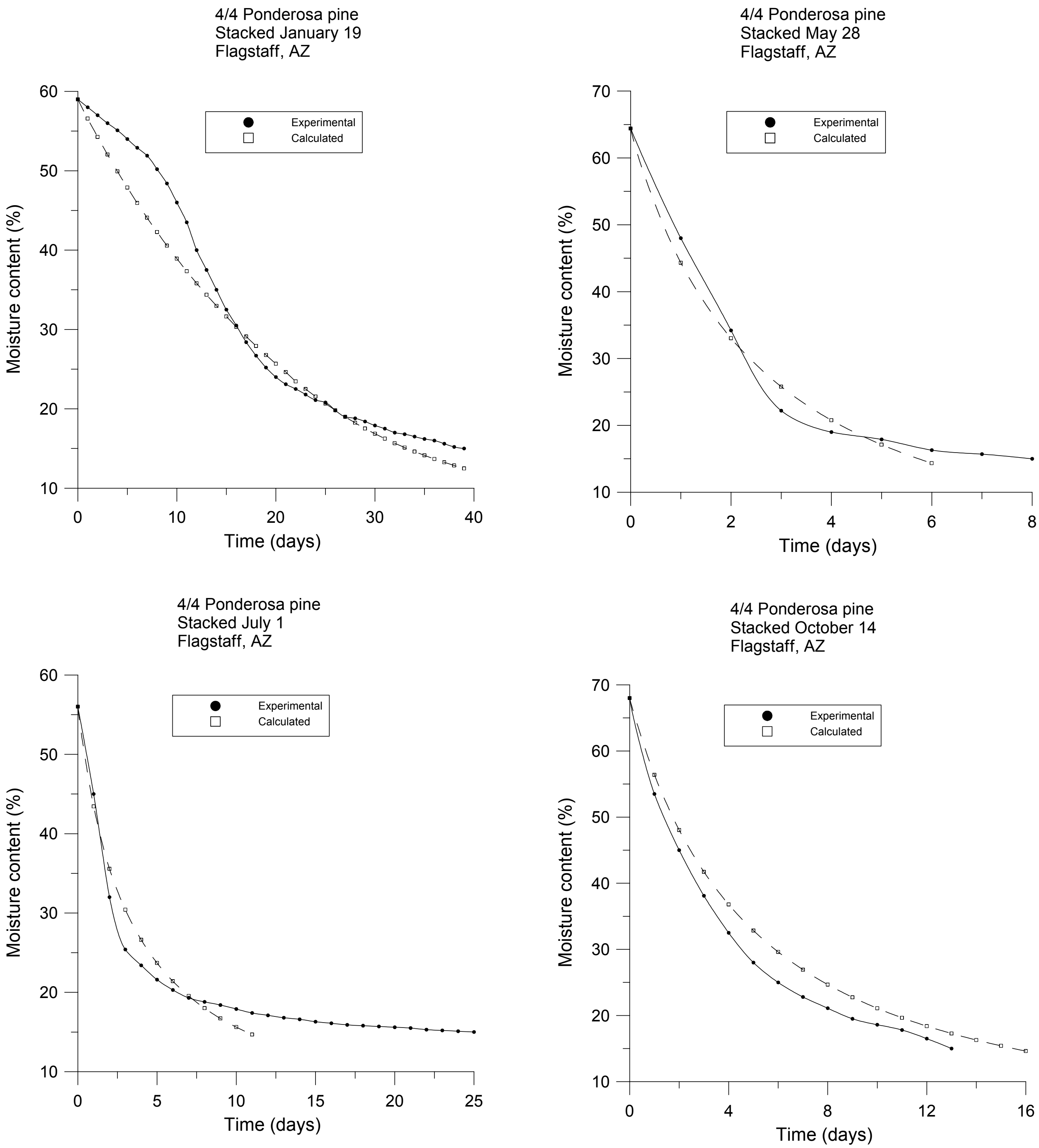


Figure 3—Moisture content time graphs for air drying 1-in.-thick ponderosa pine in Flagstaff, Arizona, with stacking started in (a) January, (b) May, (c) July, and (d) October.

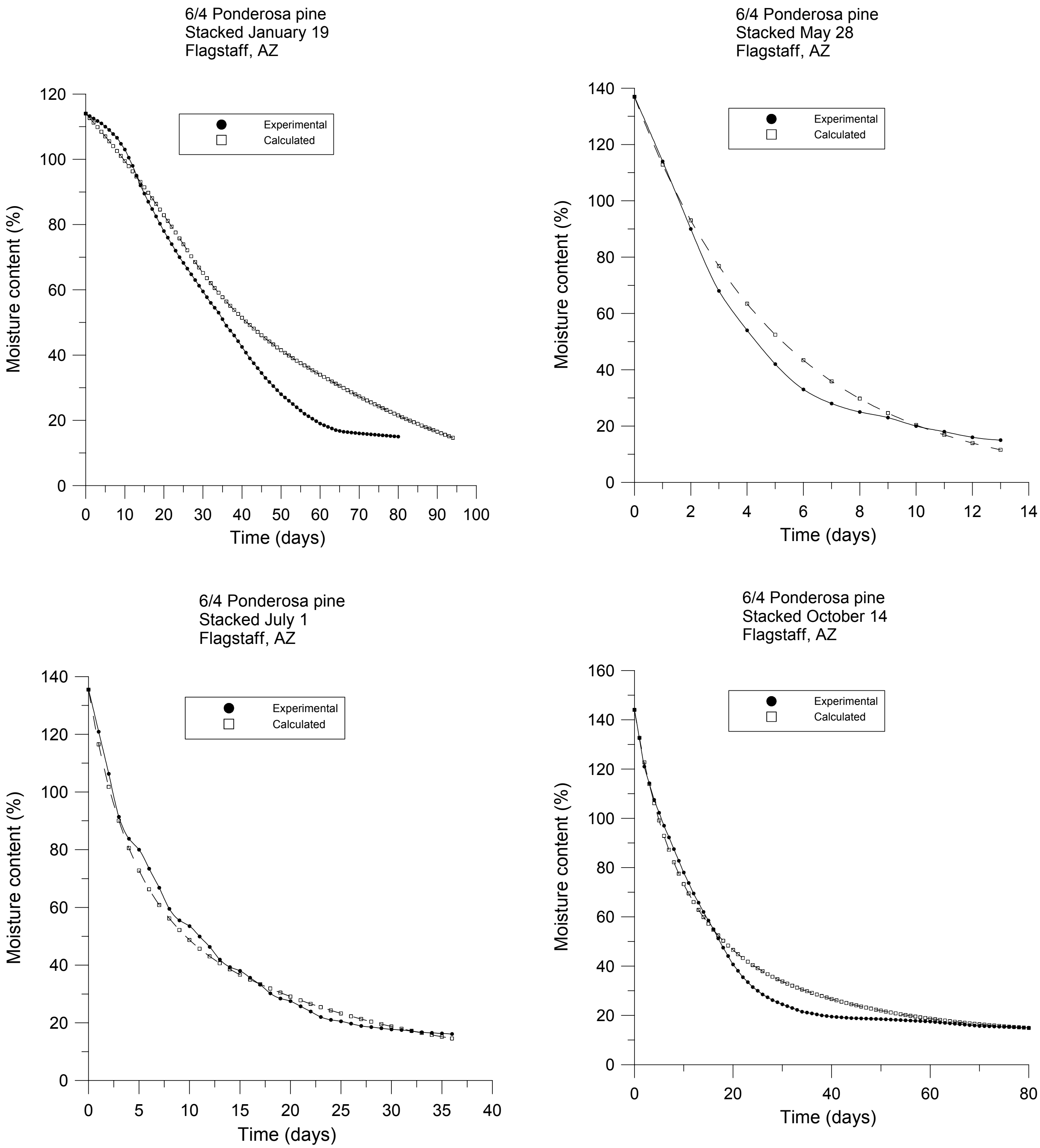


Figure 4—Moisture content time graphs for air drying 1.5-in.-thick ponderosa pine in Flagstaff, Arizona, with stacking started in (a) January, (b) May, (c) July, and (d) October.