# Poplar Wood Density Assessed by X-Ray Densitometry: New Insights for Inferring Wood Quality

Fidel A. Roig[1,2], Alberto Calderón[2], Natalia Naves[2], Arturo Somoza[2],
Claudio S. Lisi[3] and Mario Tomazello Fo[4]
[1]Laboratorio de Dendrocronología, IANIGLA-CCT-CONICET, CC 330,
(5500) Mendoza, Argentina
[2]Catedra de Dasonomía, Facultad de Ciencias Agrarias, Universidad
Nacional de Cuyo, Mendoza, Argentina
[3]Instituto de Pesquisas Jardim Botânico do Rio de Janeiro, IP, JBRJ, Brasil
[4]Departamento de Ciências Florestais, ESALQ, Universidade de São Paulo,
CEP 13418-900, Piracicaba/SP, Brasil

**Abstract**

Cross-sectional disks from 12 to 19-year-old trees were obtained from 1.3 m stem height from 13 *Populus* clones in culture plantations in eastern Mendoza, Argentina. Wood samples were X-rayed and the resulted radiodensitometric data obtained from the radiographic images were evaluated. Results indicate that this radiometric technique is suitable for wood quality evaluations on poplar trees. The clones may differ in absolute ring width and density values, but for most of the variables the annual variation is similar. The X-ray density profiles show clear intra-annual and inter-annual fluctuations and reaches similar values of wood density as determined by the gravimetric/volumetric method. This makes the X-ray technique a valuable tool for density calculations in poplar woods.

KEY WORDS: poplar, wood density, X-ray densitometry, wood quality

## Introduction

Wood density is a variable influencing many of the technological and quality properties of wood. The X-ray techniques, traditionally applied to conifer woods to obtain information useful to detect those environmental factors influencing wood density in natural forests (eg. Schweingruber 1988), have also been successfully used to assess the wood quality properties of commercial tree plantations (eg. DeBell et al. 2002). Traditionally, conifer woods have been broadly studied with X-ray techniques due to its simple and relatively uniform wood structure observed in transversal sections. In broadleaf trees, the presence of large-diameter vessels would be, however, a serious limitation to produce reliable wood density data from the application of radiodensitometric techniques. This problem certainly decreases when pores become narrower and uniformly distributed in the growth ring. Since *Populus* woods show this particular type of anatomy, poplar clones cultivated in Mendoza, Argentina were selected to study wood density characteristics as determined by radiodensitometric techniques. Because of the increasing importance of poplar clonal plantations in Mendoza, Argentina, information on basic wood properties of these woods are essential to expand the commercial market utilities. In this way, the X-ray analysis merges as a valuable tool to assess the wood quality parameters in *Populus* plantations.

## Materials and Methods

Cross sections were collected from 12 to 19-year-old *Populus* stems grown in a silviculture research plantation from INTA-Rivadavia in eastern Mendoza (39° 09'S; 68° 28'W, 653 masl). This culture plantation was established in a multiple plot design planted at 4 m by 4 m. Soils are sandy loam and because annual rainfall (200 mm/year) is so far below the requirements of the tree plantation (800-1000 mm/year), it is necessary to supply water by artificial irrigation. This study included the following clones: Gélrica, Caroliniana grigio, Conti 12, I-78, I-488, Ge 14-57 Euroamericano Libre, Ge 21-57 Euroamericano Libre, Fogolino, Ge 9-56 Euroamericano Libre, Ge 7-56 Euramericano Libre, and Ge 2-56 Euroamericano Libre, hybrids of *Populus x canadensis*, and Harvard and Australia 106/60, hybrids of *Populus deltoides*.

Transversal sections of the poplar clone woods 2 mm thick were conditioned for 12 hours at 18ºC and 60% atmospheric relative humidity, and then radio graphed (Hewlett Packard, Faxitron 43805 N; 5 min, 16 kV, 3 mA). For densitometric calibration, a wedge of cellulose acetate with steps of known density was included in the radiography. After the development of the radiographic films, they were digitized with a scanner (Hewlett Packard ScanJet 6100C/T) to a resolution of 1000 dpi with a gray scale of 256 degrees. In the digitized image, comparisons were made between the gray scale of the wood samples and the calibration wedge. Density readings were obtained by using specific image analysis software (CRAD), producing a continuous reading of the optical density values and automatically transformed by the software into physical density values by comparison with the calibration wedge (see Figure 1). The following tree-ring parameters were obtained with CERD software: ring width, early- and late-wood width, mean ring density, early- and latewood density, and minimum (5% lower values) and maximum (5% higher values) density.

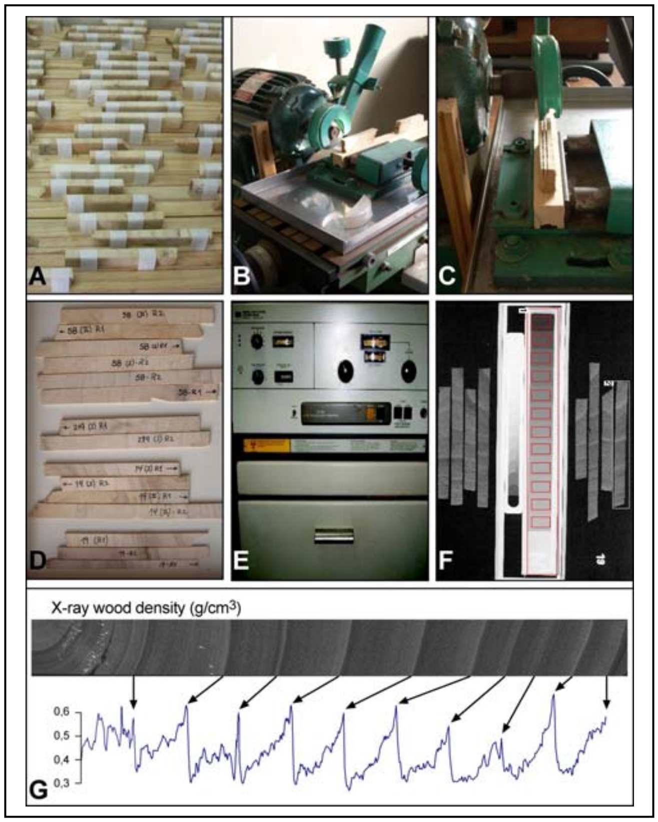


**Figure 1**: *The wood sample processing for X-ray analysis. A, poplar wood samples are first mounted onto wooden supports. B and C, a double saw device is used to obtain uniform thin laths. D, the resulted 2 mm thick laths are acclimatized prior to radiography. E, the control panel and the power source of X-rays used in this study. F, the resulted radiography showing the wood samples and the wedge of cellulose acetate placed at the center of the film. G, a typical X-ray density profile obtained in this study.*

## Results

The results of the radiodensitometric analysis of poplar woods exhibit a promising potential in the evaluation of the wood physical properties. The poplar wood images on the X-ray film reproduces well the anatomical boundary of the annual growth rings composed by a thin zone of latewood fibers with thicker and radially flattened cell walls. The small vessel size of the *Populus* wood and its diffuse arrangement in the growth ring facilitate, however, the reading and construction of the X-ray density profiles. The anatomy of the poplar growth rings produce a sustained increase of the intra-ring densities, clearly reproducing a gradual transition from early- to latewood density zones. Thus, the profile reach its maximum value at the end of the latewood zone of a ring, dropping suddenly to a minimum density values in the early stages of the early wood zone of a contiguous ring (see Figure 2). This sharp delimitation of consecutive rings resembles the density profiles obtained from conifer woods, so far considered the best type of woods for X-ray studies. For this reason, the wood anatomical characteristics of the *Populus* woods mark the first outstanding character for studies by application of radiodensitometric methods.

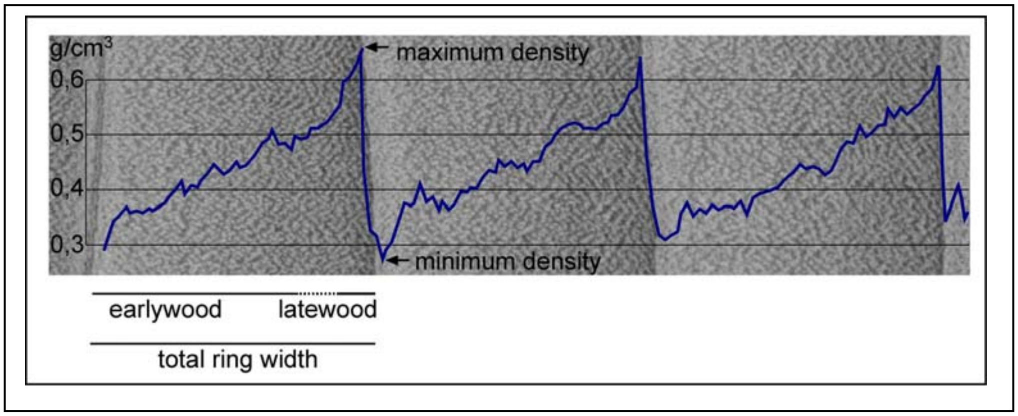


**Figure 2**: *Intra-annual and inter-annual density profiles from a Conti 12 clone wood sample. Note the abrupt passage from latewood to earlywood areas between two adjacent rings. The density amplitude values observed between these areas agree with the expected values published for poplar woods (mean density of 450 kg/m$^3$, and minimum and maximum density values of 300 kg/m$^3$ and 650 kg/m$^3$, respectively).*

The year-to-year density cyclic fluctuation is also well reproduced when considering complete and longer records from pith to bark (Figure 3). The figure also shows the parallel agreement of density fluctuations when two radii originated from the same tree are compared. This agreement suggests that there is a synchronous and similar density variations around the stems of the same tree and measured at the same level of the stem. This characteristic certainly facilitates the analysis and comparison of the wood density variations of the tree wherever the cardinal origin of the radii is chosen.

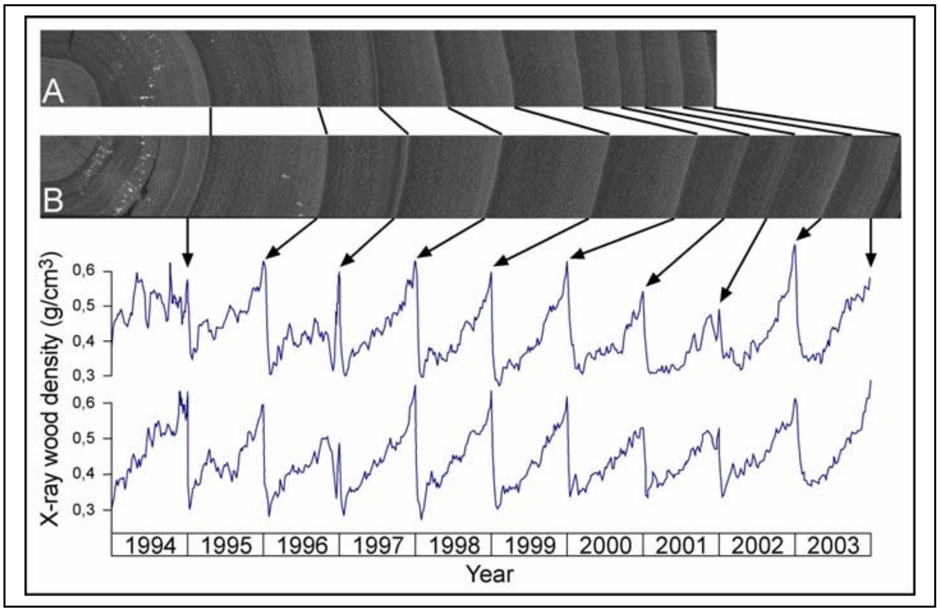


**Figure 3**: *A two opposite (north to south) radii density profiles from an Australia 106/60 clone wood sample. Note the similarity in the density patterns between the two records and the annual variations on both the minimum and maximum density values.*

After a precise control of the year-to-year ring variations synchrony (cross dating) and the cross-correlation quality between samples (not shown here), we were able to construct the tree-ring records included in Figure 4. For each width and density parameters we construct a composite plot to show the year-by-year variability between the different studied clones. The agreement between the records is unequal according to the parameter considered. The tree ring width variables seem to be more correlated between them than when considering some of the density records. This is evident from the Figure 4 by a higher common variation in, e.g., the ring width, early and latewood widths, minimum density and in a lower extent, in the mean ring density, and maximum and latewood density. Another interest aspect of the data is that the amplitude decreases from pith to bark for almost all the variables. This is particularly evident for the ring width parameters and for the minimum and maximum density records, and probably is related to adaptations of the plant during the first stages of the tree plantation. The analysis of the density behavior through time may facilitate the evaluation of many technological and quality properties from trees under intensive cultures.

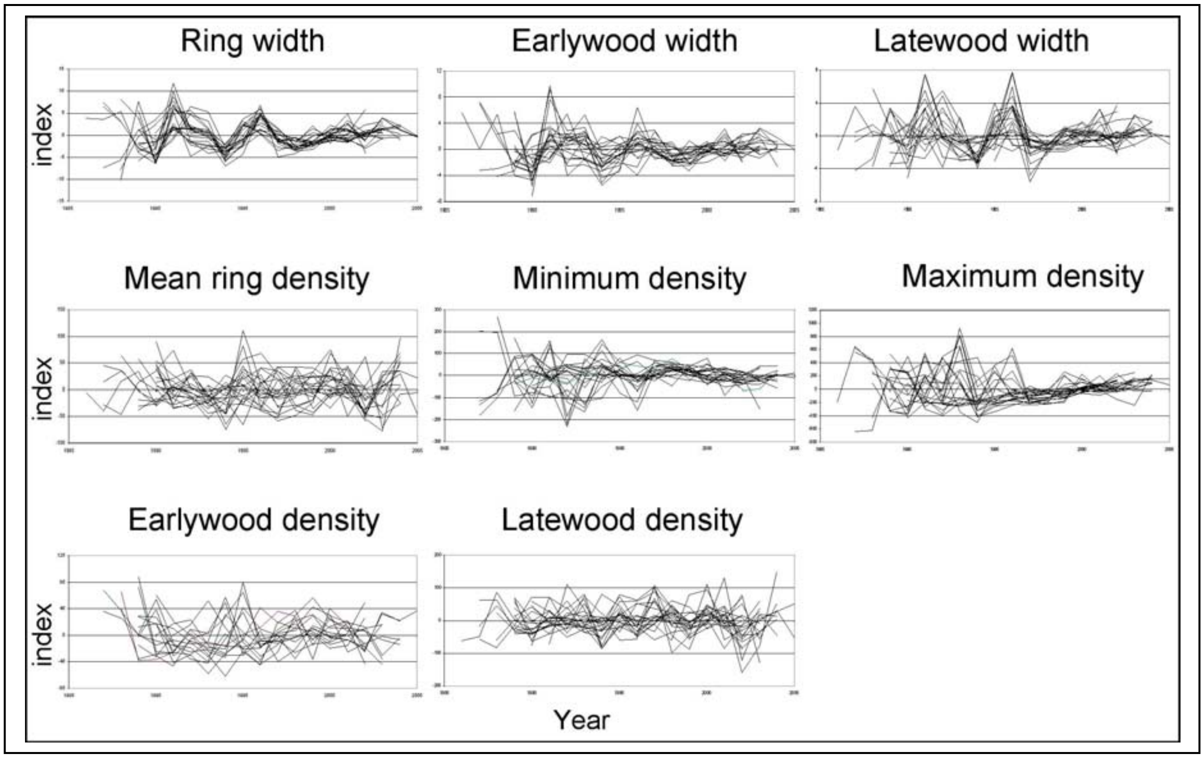


**Figure 4**: *Ring width and density parameters recorded from the 13 clones analyzed.*

Since technical and biological sources are factors causing differences between gravimetric/volumetric and X-ray density values (Lenz et al. 1976) it is necessary to analyze the magnitude of these differences in poplar woods. This is not only important to calculate a correction factor to convert optical to physical densities but also to estimate absolute differences in density resulted from both methods. We compared for one radius of the clone Conti 12 the density values reached by traditional (gravimetric/volumetric) and X-ray methods, through comparisons from five different wood blocks. Results indicate a similar density values obtained from the applications of the two methods. The differences observed in block N° 2N could be attached to the presence of high-density components at the innermost rings (the white areas in the X-ray film) that could severely increase the density, falsifying the radiodensitometric density values. For the other blocks (3N, 4N, 5N, and 6N), the density values are quite similar indicating a good performance when the wood density is obtained for any of the mentioned methods. Although a larger number of samples and clones should be analyzed, the results indicate that wood density values are comparable for any of the methods used here.

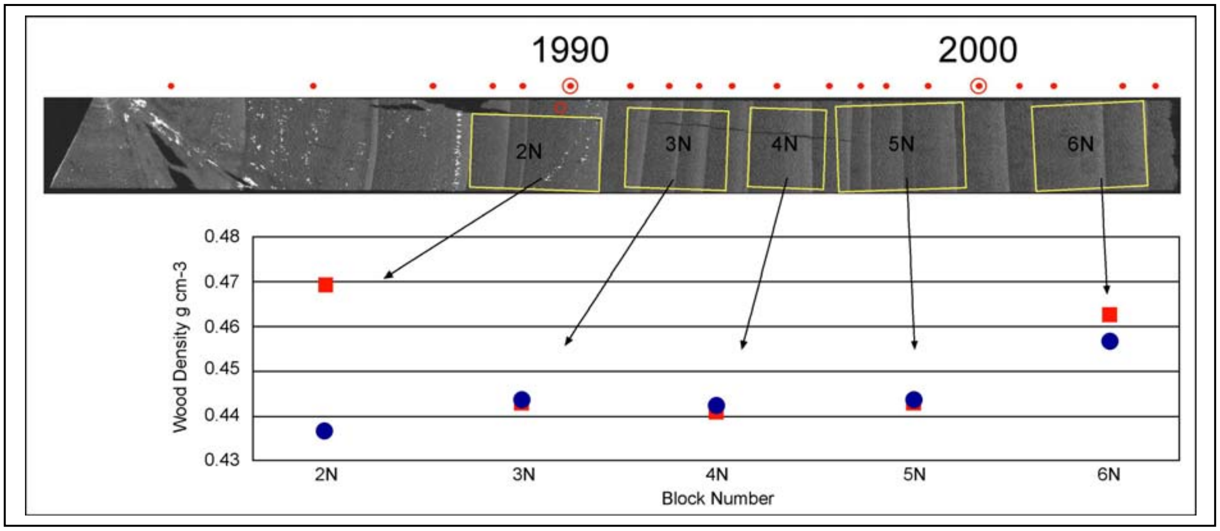


**Figure 5**: *Comparison between gravimetric/volumetric density data and X-ray density data from the same wood blocks obtained from the tree of the clone Conti 12.*

## Conclusions

The X-rays applied to poplar wood gave promising results as a technique to infer wood quality properties: a) the densitometric profile clearly identifies the passage from maximum to minimum density zones between adjacent rings, b) the intra-ring density profile follows a similar incremental progression to those observed in conifer woods, c) the X-ray density values successfully reproduce the gravimetric/volumetric mean density data values usually found in poplar woods, d) the X-ray method allows the analysis of density values throughout the complete life-span of the tree, giving a continuous densitometric profile from pith to bark, and e) the method allows densitometric comparisons between radii of the same tree, between trees on the same site and mean density values between sites. The only limitation of the X-ray method is its relatively high cost and the time it takes. However, we strongly suggest the use of X-ray techniques in density calculations related to poplar wood quality.

## References

DeBell, D.S., R. Singleton, C.A. Harrington, and B.L. Gartner. 2002. Wood density and fiber length in young *Populus* stems: Relation to clone, age, growth rate, and pruning. Wood and Fiber Science, 34(4): 529-539.

Lenz, O., E. Schär, and F.H. Schweingruber. 1976. Methodische Probleme bei der radiographish-densitometrischen Bestimmung der Dichte und der Jahrringbreiten von Holz. Holzforschung 30: 114-123.

Schweingruber, F.H. 1988. Tree Rings. Basics and Applications of Dendrochronology. Reidel, Holand.

## Acknowledgements

This research was supported by funding from the Secretaría de Ciencia, Técnica y Posgrado, Universidad Nacional de Cuyo, Grants 06/A279 and 06/A351.