Analysis of Wood Density to Improve Understanding of Wood Buoyancy in Rivers

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V. Ruiz-Villanueva, H. Piegay, M. Stoffel, V. Gaertner, and F. Perret

Abstract

Drift wood (or in-stream large wood, LW) plays an important role in river ecosystems by influencing hydrodynamics and morphology. The final goal of this work is to improve our understanding of wood buoyancy in rivers through the assessment of wood density. We analyse wood pieces retained in the Genissiat dam, French Rhone, and a set of freshly cut riparian trees from the Ain River. Different protocols were set to measure density and buoyancy of these two series of wood samples and to test the effects of drying and wetting, species and wood decay stages. *Living* and *dead* trees show average wood density ranging from 590 to 1,080 kg m^{-3} and from 350 to 910 kg m^{-3} respectively. Differences in water content clearly affect buoyancy, which ranges from 0.36 (36 % emerged; *Abies*) to 0.18 (*Acer* and *Fraxinus*) as initial values, and increases up to 0.48 (*Abies*) for dry samples and decreases up to 0 (100 % submerged; *Acer*) for wet wood. We observed a significant negative linear correlation between wood density and buoyancy. The results from this work will help to understand the evolution of buoyancy through time and estimate local conditions of entrainment and transport.

Keywords

Large wood • Buoyancy • Wood density • Wood dynamics • Drift wood

33.1 Introduction

Large wood (LW) plays an important role in river ecosystems by influencing hydrology, hydraulics, sedimentology, and morphology (Montgomery 2003). An extensive literature now exists describing the influence of wood on stream ecology (Gregory et al. 2003; Kasprak et al. 2011), and more recently on stream geomorphology (Gumell 2012; Wohl 2013). Recent research has focused on the mobilization of woody material during floods (Comiti et al. 2012), as transported woody material can cause a substantial increase in the destructive power of floods (Ruiz-Villanueva et al. 2012). The first works by Braudrick et al. (1997) provided the basic framework to approach wood mobility. Following this, other studies were carried out to explore wood dynamics in rivers (Haga 2002), monitoring and calculate wood budget (Benda and Sias 2003; MacVicar and Piegay 2012) and numerical modeling (Ruiz-Villanueva et al. 2013).

Various characteristics of a piece of wood affect its likelihood of movement (e.g., wood density, buoyancy, orientation, size, and form related to flow depth, velocity, and roughness; Le Lay et al. 2013). In this study, we analyze

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wood buoyancy as this is the main factor for wood dynamics in rivers. Buoyancy typically varies with tree species, moisture content and decay rates. So, the most important property affecting river wood mobility and particularly the capacity of LW to float in freshwater is wood density. Wood density varies greatly among tree species, but it also varies for each of the species according to moisture (water) content and degree of decay. Therefore, the time during which wood pieces are wetting or drying can affect their dynamics when they enter the river. The final goal of this work is the assessment wood density to improve our understanding of wood buoyancy.

33.2 Study Site and Methodology

33.2.1 Sampling

Wood characteristics are assessed using two series of wood pieces, one extracted from a reservoir (decayed floating wood) and another from living trees used as a reference (green or fresh wood). The decayed wood analyzed was collected from wood pieces retained in the Genissiat reservoir, French Rhone (watershed area of 10,910 km^2 at Genissiat). This gravity dam is 105 m high, 100 m wide at its base and 140 m long at its top, forming a reservoir of 23 km in length stretching up to the French-Swiss border. Genissiat dam has no overflow pathway so that all wood coming from two main tributaries, the Arve and Valserine Rivers, is blocked by the dam, even during floods, and must be extracted mechanically. The green wood was obtained from trees cut from the riparian forest of the Ain River. We collected 150 samples of green wood from 5 different trees, one per species (*Fraxinus*, *Acer*, *Populus*, *Alnus* and *Abies*), and 120 samples from Genissiat dam (identified as *Populus*, *Abies*, *Alnus*, *Fraxinus* and *Quercus*).

33.2.2 Experimental Set up

Wood sample size (length and diameter) and weight were measured immediately after they were cut using a balance with an accuracy of 10 g. An estimate of the average wood density was obtained by measuring the size, calculating the volume and weighting the mass (Table 33.1).

Table 33.1 Experiment aspects: factors (inputs) to the process; settings of each factor in the study, and response (outcomes) of the experiment

Factors	Settings	Outcomes
Wood density	Different species	Buoyant force (C), density (C)
Water content	Dry/wet wood	weight (M), emerged height (M)
Wood decay	Green/dead wood	

Samples were then divided into different groups to analyze drying and wetting processes. A total of 220 samples were stored outside protected from rainfall and where air temperature was recorded, and 50 samples were placed in plastic boxes in water. Weight and buoyancy of the wood samples belonging to both categories were measured twice every month.

To measure wood buoyancy, we put samples in sinks filled with water, and used a point gauge to measure the emerged height at both ends of the wood sample, thereby obtaining buoyancy as a ratio between emerged height (h) and log diameter (D). In case that the log was not perfectly straight, several stable floating positions could be observed. In this case, we measure the emerged height in all stable positions.

33.3 Preliminary Results

Preliminary results after 3 months of experiments show different behaviors in buoyancy depending on species and decay stage.

As expected, *Abies* samples show the lowest average wood density just after cutting, ranging from 590 to 890 kg m^{-3}; whereas *Acer*, *Alnus, Fraxinus*, and *Populus* showed densities between 720 and 1,080 kg m^{-3}. The dead wood samples extracted from Genissiat dam exhibit a much larger difference in wood density ranging from 350 to 910 kg m^{-3}. After 2 months of wetting, the 50 samples placed in the containers increased their water content by 12 %; whereas the samples that were stored in dry conditions reduced their water content by 24 %.

Large variability was observed in *Abies* and *Acer* samples, indicating significant differences in water content as compared to initial conditions in both the wetting and drying experiments; results of *Alnus*, *Fraxinus* and *Populus* samples were similar (Fig. 33.1).

Differences in water content clearly affect buoyancy, which is ranging from 0.36 (*Abies*) to 0.18 (*Acer* and *Fraxinus*) as initial values, and increased up to 0.48 (*Abies*), 0.33 (Acer) and 0.22 (*Fraxinus*) for dry samples; for wet samples wood buoyancy decrease between 0 (Acer) to 0.19 (Abies). From the wetted samples, all *Acer* specimens sank within 2 months, as did 33 % of the *Alnus*, but only 10 % of the Genissiat (decayed wood) samples. *Abies* specimens did not sink either and exhibit a buoyancy of about 0.19 (Fig. 33.2).

We can classify all the green wood samples according to the average wood density (wet and dry samples included) in light wood, medium, dense and very dense wood, and

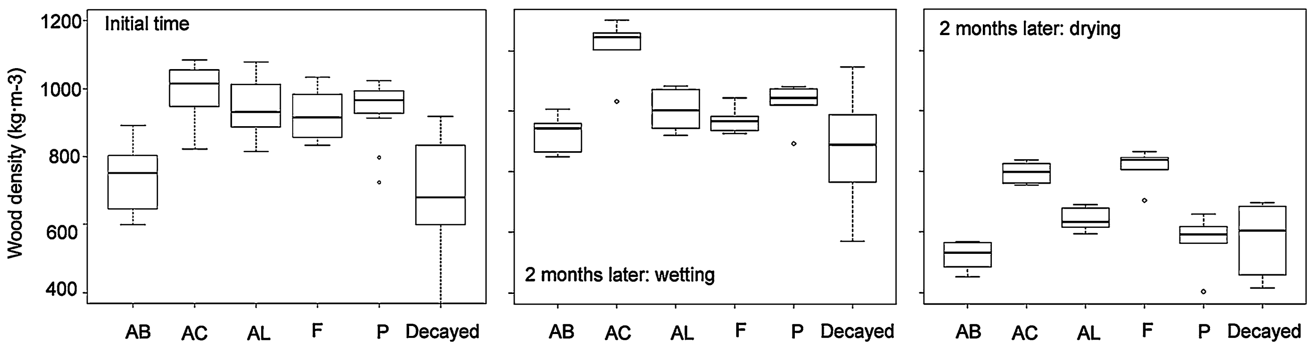

Fig. 33.1 Average wood density at the time of sampling for *Abies* (AB), *Acer* (AC), *Alnus* (AL), *Fraxinus* (F), *Populus* (P) and the decayed wood from Genissiat dam (all species combined), and after 2 months of wetting and drying process

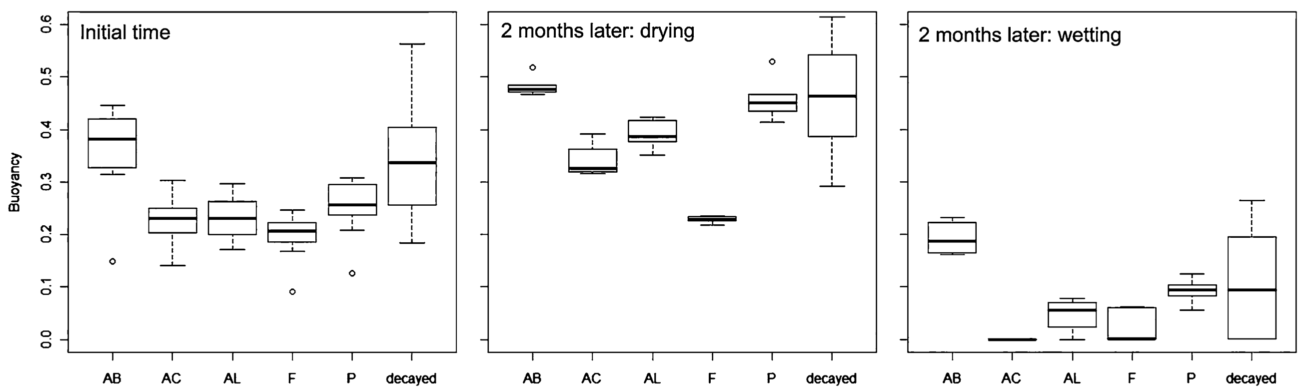

Fig. 33.2 Buoyancy rate (h/D) at initial time and after 2 months of wetting and drying processes

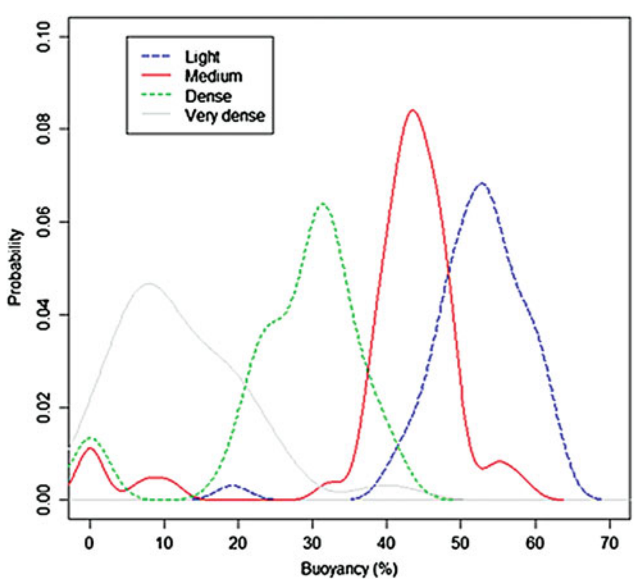

Fig. 33.3 Probability density functions of buoyancy (%) for different ranges of average wood density (*light* 360–500 kg m^{-3}; *medium* 500–700 kg m^{-3}; *dense* 700–900 kg m^{-3}; *very dense* >900 kg m^{-3}

analyse how the buoyancy varies among these groups calculating the probability density functions (Fig. 33.3).

We observed a significant negative correlation between wood density and buoyancy (linear R^2 ranging from 0.51 to 0.86, exponential R^2 ranging from 0.58 to 0.84, p-value <0.002; Fig. 33.4).

However, further research is needed to better understand this relationship and the effects on wood entrainment and transport.

33.4 Preliminary Conclusions

Despite the fact that limited number of samples has been selected is unlikely to be representative for all different tree species and forest types, samples permitted analysis of different behaviors of wood in water in terms of buoyancy depending on 5 freshly cut species, decayed wood and different water content. The obtained results so far reveal a strong correlation between wood density and buoyancy, but further research is still needed in this respect.

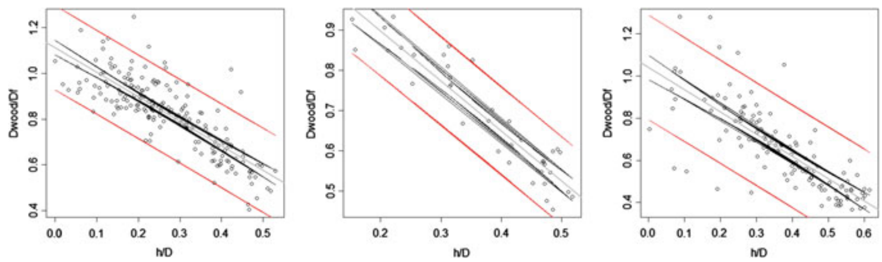

Fig. 33.4 Correlations between wood density and buoyancy for the 5 species of green wood (*left*), for *Abies* (*center*) and for Genissiat samples (*right*). *Grey line* linear regression; *black lines* confidence intervals 95 %; *red lines* predict intervals

In order to analyse wood decay process a climatic chamber will be used. Thin slices from green wood will be placed in the chamber directly (clean wood) and part of them are placed together with soil and fungi (dirty wood) to accelerate the decomposition process. Then an extreme climatic scenario (extremely high temperature and humidity) will be selected to analyse wood decay. In addition, a detailed characterization of wood extracted from Genissiat dam is in progress to better set buoyancy in real in-stream wood.

In conclusion, results from this work will help to improve measurements of wood pieces from video cameras for wood budgeting and prediction of wood movement in hydrodynamic models.

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