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A DEA approach to assess the efficiency of radiata pine logs to produce New Zealand structural grades

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ABSTRACT

An efficiency analysis revealed the relative magnitude of wood traits that distinguishes efficient radiata pine logs to produce New Zealand structural grades. Technical and cost efficiencies were obtained by using data envelopment analysis (DEA). Wood trait prices used to perform the cost efficiency corresponded to economic weights derived from a partial regression. These values were 1.1, 29.7, 0.3 and −0.4 NZ $/m^3 for small end diameter (cm), stiffness (GPa), basic density (kg/m^3) and largest branch (mm) respectively. The most efficient logs were those with the highest difference between recovery value and price. There were positive and significant correlations between technical efficiency and wood stiffness (0.46, $p < 0.05$) and between cost efficiency and log recovery value (0.85, $p < 0.05$). The most efficient logs had a ratio of 1:4 between stiffness and small end diameter whereas logs that did not generate structural lumber presented ratios close to 1:8. This information will inform the development of breeding objectives, and help segregating and pricing logs by using traits patterns that result in efficient logs for the production of structural wood.

Introduction

Lumber specifications present important challenges to breeders, who must focus on multiple attributes to achieve the quality thresholds required by consumers. For instance, improving wood

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stiffness has become imperative in New Zealand since the introduction of the standard NZS3622:2004, which demands verification of structural lumber properties. Consequently, in recent years the New Zealand radiata pine (*Pinus radiata* D. Don) breeding program has emphasized work on traits such as stiffness (Shelbourne, 1997; Jayawickrama and Carson, 2000; Kumar et al., 2002). Furthermore, growers are also looking for combinations of genetic material and silvicultural regimes that improve the structural characteristics of logs according to market demands (Waghorn et al., 2007a). Tree breeders are expected to increase wood quality, defined as the relative magnitude of log traits that generate high value lumber. Breeding could then be approached as a production system where the inputs are both wood traits and the relationships among them, while the outputs are logs that generate a high recovery value at the mill. Under this framework the relative contribution of traits would be a key element in assessing the productive efficiency of logs. A log would be an efficient unit of lumber production as long as its traits were able to generate a high recovery of the most valuable lumber.

The efficiency of units of production, such as logs, can be analyzed by the efficiency frontiers approach which includes two methods, data envelopment analysis (DEA) which is a non-parametric deterministic model, and the stochastic frontier which is a parametric production function (Coelli et al., 2005; Van Biesebroeck, 2007).

DEA analyses the efficiency of a production unit in using and combining inputs to produce a given level of output (Farrell, 1957; Charnes et al., 1978; Färe et al., 1985; Xue and Harker, 1999; Coelli et al., 2005). DEA has been usually applied to decision-making units such as firms to detect inefficiencies and reduce them by adjusting the use of inputs (e.g., Carter and Cubbage, 1995; Chakraborty et al., 2002). Estimating the efficiency of logs to produce lumber may seem unusual, since it is not possible to have control over their use of inputs. Nevertheless, breeding and silviculture can be used to change the relative magnitude of wood traits by targeting the genetic material to be deployed, stocking and site selection (e.g., Jayawickrama, 2001; Lasserre et al., 2004; Waghorn et al., 2007b).

Furthermore, there are examples of using efficiency frontiers to characterize radiata pine logs. Thus, Todoroki and Carson (2003) used DEA to identify the most efficient logs to produce appearance grades looking for traits that could be manipulated in a breeding program. Alzamora and Apiolaza (2012) applied a stochastic frontier to analyze the mix of wood traits in the most efficient logs to produce structural grades.

DEA generates measures of technical, allocative and economic efficiencies. Technical efficiency is concerned with producing the maximum output with the available inputs, or minimizing the use of inputs to achieve a given output level. Allocative efficiency deals with the optimal combination of inputs, given the input prices. Economic efficiency, or cost efficiency, represents the total efficiency of a production system (Farrell, 1957; Färe et al., 1985; Jahanshahloo et al., 2008).

Obtaining cost efficiency requires input prices; however, this information is not commonly available for wood traits. Instead, economic weights used by breeders to develop breeding objectives and to build selection indices can be used as plausible prices. The economic weight of an attribute is defined as the net increase in production system profit for each unit of improvement of the attribute (Hazel, 1943). Economic weights would represent the implicit cost of traits when breeding efficient logs. Thus, based on efficiency criteria, breeders should produce logs that maximize the value of output with a given level of input. Accordingly, breeding programs should target those logs that achieve the highest efficiency scores. The relative magnitude of traits in those logs could be useful information to improve silvicultural regimes as well as to design protocols for segregation and classification of logs.

Bioeconomic models and partial regressions are two common approaches for the estimation of economic weights (e.g., Borralho et al., 1993; Greaves et al., 1997; Aubry et al., 1998; Apiolaza and Garrick, 2001; Berlin et al., 2009). Bioeconomic models consider the value of a trait as the change in profitability of a forest production system due to a change in that trait. The modeling requirements for Bioeconomic models are complex and costly, for this reason a substantial part of the models has been based on large numbers of assumptions. On the other hand, Bioeconomic models offer a framework to assess the impact of breeding decisions across all the production chain, allowing analyze the sensitivity of several system elements (Amer et al., 1997; Jones et al., 2004).

Partial regressions link wood traits from logs with volume and value of products obtained at the mill. Partial coefficients derived from partial regressions correspond to the economic weights (Talbert, 1984; Cotterill and Jackson, 1985a,b; Ernst and Fahey, 1986; Aubry et al., 1998). The major limitation