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A comprehensive analysis of teak plantation investment in Colombia

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ABSTRACT

A financial assessment of forest investments is comprehensive if the analysis includes reliable yield estimates, land expectation value (*LEV*) and risk calculation. All of these aspects were considered and applied to teak plantations in Colombia, an emergent economy where high forest productivity, low opportunity cost of land, and decreased financial/economic risk have substantially contributed to promote forest investments. The von Bertalanffy non-linear mixed effect model was used to estimate forest yields using data collected from 31 permanent sample plots, measured over a 17 year period. A stochastic version of *LEV* along with other financial criteria was calculated by using a computer algorithm and Monte Carlo simulation. Finally, probabilities obtained from stochastic financial calculations were used in *logistic* models to estimate probabilities of success for a forest plantation project, a measure of risk assessment, after changing land prices. Results suggest that the potential forest productivity (i.e., the biological asymptote) ranges from 93 to 372 m^3 ha^{-1}. The mean annual increment is 27.8 m^3 ha^{-1} $year^{-1}$, which is attained 6 years after the forest plantation is established. Profitability analyses for teak plantations in Colombia suggest a *LEV* of US\$7000 ha^{-1}. The risk analyses indicate negligible financial risk for forestlands whose prices are lower than US\$2000 ha^{-1}.

1. Introduction

Forest management is likely to be influenced by both variables related to the production process (e.g., species type, yield prediction, silvicultural treatments, harvesting rates) and exogenous factors (e.g., public policy, macroeconomics, and performance of global forest product markets). Although exogenous factors are crucial to evaluate the potential success of forest investments, these factors are not determined by landowner decisions. Unlike exogenous factors, some technical and financial variables related to forest production seem to be more influenced by forest product producers. Two critical technical issues are the estimation of forest yield and its corresponding uncertainty, and a robust analysis of techniques and their outcomes.

Forest yield estimation is appropriately determined by using biologically-based statistical methods. An empirical and well-known method is the von Bertalanffy model (Fekedulegn et al., 1999; Moser and Hall, 1969; Pienaar and Turnbull, 1973; Pienaar, 1979; Torres, 2004; Torres and del Valle, 2007; Zapata, 2007; Zeide, 1993). The von Bertalanffy model is based on a biological theory which conceives that the growth of any organism is the result of two main and opposite forces known as anabolism and catabolism (Pienaar and Turnbull, 1973). Likewise, forest growth could be thought of as the outcome of two opposite factors, the unlimited trend of growth or biotic potential and the growth constraints imposed by the environment (Zeide, 1993). Both biotic potential and environmental constraints are related to site specific factors such as climate, soil and topography or physiography (Bravo-Oviedo et al., 2007; Clutter et al., 1992; Günter et al., 2009; Lugo et al., 1988; Louw and Scholes, 2002, 2006; Vanclay, 1992; Walters et al., 1989; Wang et al., 2005). All these factors can be included in the von Bertalanffy model to express forest growth and yield as a function of covariates in the mixed effect models (Bravo-Oviedo et al., 2007; Hall and Bailey, 2001; Louw and Scholes, 2006; Wang et al., 2005).

On the other hand, in order to calculate economically optimal rotation lengths and investment profitability, financial analysis is essential. Even though some researchers have used different financial criteria to assess the economic performance of forest projects, the Faustmann formula is, indeed, the correct solution (Amacher et al., 2009; Diaz-Balteiro, 1997; Newman, 2002; Samuelson, 1995). The Faustmann formula, or land expectation value (*LEV*), allows for calculation of net present value (*NPV*) of infinite rotations and represents the maximum amount of money that an investor ought to pay for a unit of land and earn the minimum acceptable rate of return (Klemperer, 2003). The age at which *LEV* attains its maximum value corresponds to the optimal economic rotation, and indicates the appropriate time to harvest a stand. Other important financial criteria, such as *NPV* and *IRR*, are also used in forest financial analyses, providing complementary and useful information to evaluate the forest investment performance.

Forest financial analyses should not be considered exhaustive without a risk evaluation. Risk is especially important when returns to forest investments are reaped many years after establishing a forest plantation. This unique and crucial characteristic of forest investments has, essentially, two important features. First, investors would feel that forest

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investments often seem riskier than other types of investments (Ashton et al., 2001). Second, economic analysis may be difficult due to uncertainties related to financial variables such as price and interest rate (Hildebrandt and Knoke, 2011). A method commonly used in risk evaluations is the Monte Carlo simulation (Acuña and Drake, 2003; Reeves and Haight, 2000; Rodríguez and Diaz-Balteiro, 2006). Using this computational procedure, samples of input variables are randomly generated by assuming probability distributions and then computing a matrix of outcomes that represent the possible values of *LEV* and other financial criteria.

This research aims to propose a comprehensive approach to estimate yield, rotation age, and profits based on biology and economic theory. To the best of our knowledge, this research is likely the first in Latin America that explicitly deals with a complete forest investment analysis, including a financial risk assessment. Indeed, profitability analyses tend to be scarce or limited and few research have been done in Colombia (Cubbage et al., 2010; Henao, 1982; López et al., 2007, 2010; Restrepo, 2010; Restrepo et al., 2012), and risk evaluation is virtually nonexistent. Estimations of forest yield and optimal rotations are complemented with uncertainty analyses using Monte Carlo simulation. This approach was applied to analyze both technical and economic issues for forest plantations of teak (*Tectona grandis*) in Colombia, using a reliable and unique dataset consisting of biometric measurements over a 17 year period.

2. Material and methods

2.1. Model estimation

von Bertalanffy's model can be expressed as:

$$f(T) = A(1-\exp(-kT))^n, \text{with}\, n = (1-m)^{-1}, \quad (1)$$

where $f(T)$ represents the yield ($m^3\ ha^{-1}$), A is the asymptote ($m^3\ ha^{-1}$), T is the time or the stand age (years), k is the intrinsic growth rate, n is a shape parameter and m is an allometric constant. The value of the parameter m indicates how a specific forest species reproduces and survives (González, 1994). Thus, the m value indicates the photosynthetic ability, being specific for each organism and environment (Pienaar and Turnbull, 1973). The parameter m generally has a range of [0,1) and (1,3] (González, 1994), which also makes von Bertalanffy's model more flexible. A value of m greater than 1 corresponds to a logistic shape for the yield curve; when m is less than 1, it corresponds to the well-known and concave *Mitscherlich* curve; when m is equal to 1, the model takes the name of the *Gompertz* function (Pienaar and Turnbull, 1973; Zapata, 2007). Additionally, the m parameter is related to the curve's inflection point and represents the age at which the maximum current annual increment is attained, thereby influencing the rotation age. The parameter A is consistent with the equifinal principle of system general theory. It suggests that stands with the same site quality in a wide range of tree densities would approach similar yields, given time (Pienaar, 1979). Finally, parameters A and k represent potential environmental effects on growth and yield since they are related to metabolic outcomes of resource availability (Brown and Lugo, 1982; González, 1994; Lugo et al., 1988; Pienaar, 1979; Restrepo and Alviar, 2010).

The mixed effect models are often one of the statistical methods used to estimate forest yield (Bravo-Oviedo et al., 2007; Calegario et al., 2005; Diéguez-Aranda et al., 2006; Hall and Bailey, 2001; Hall and Clutter, 2004; Torres, 2004; Torres and del Valle, 2007; Torres et al., 2012; Wang et al., 2007; Zapata, 2007), and can be written as:

$$y_{ij} = f\left(\phi_{ij}, \upsilon_{ij}\right) + \varepsilon_{ij}, i = 1, \ldots, M; j = 1, \ldots, n_i \quad (2)$$

where M is the number of groups, n_i is the number of observations in each group, ϕ_{ij} is a vector of fixed parameters and random values, v_{ij} is a vector of covariates, and ε_i is the error term, assumed to be distributed as $\varepsilon_i \sim N(0,\sigma^2 I)$. The ϕ_{ij} vector might be specified as:

$$\phi_{ij} = X_{ij}\beta + W_{ij}b_i, \quad (3)$$

where X_{ij} and W_{ij} are matrices of covariates and groups of random effects, respectively, β is a fixed effect vector and b_i is a random effect vector. It is usually assumed that all b_i are independent, are uncorrelated with the error term, are distributed as $N(0,\sigma_b^2)$ and have $E[b] = 0$ (McCulloch and Searle, 2001). Following the mixed effect model theory, the von Bertalanffy model can be written as:

$$f\left(\phi_{ij}, \upsilon_{ij}\right) = A\left(\phi_{ij}\right)\left(1-\exp\left(-k\left(\phi_{ij}, \upsilon_{ij}\right)T\right)\right)^{n\left(\phi_{ij}\right)}. \quad (4)$$

Maximum likelihood estimation methods are used to estimate Eq. (4), and the statistical performance is evaluated using the *Schwarz Bayesian Criteria* (SBC) (Pinheiro and Bates, 2000), expressed as:

$$\begin{aligned} AIC &= -2\,\text{logLik} + 2n_{par}, \\ BIC &= -2\,\text{logLik} + 2n_{par}\log(N), \end{aligned} \quad (5)$$

where *AIC* is the Akaike Information Criterion, *BIC* is the Bayesian Information Criterion, n_{par} is the number of parameters included in the model, N is the number of observations and *log* represents the natural logarithm of the likelihood function.

2.2. Rotation age and profit calculations

An important aspect in forest economics and management is the determination of the time at which the forest or stand should be harvested (Romero, 1997; Samuelson, 1995). This time corresponds to the age that maximizes the *LEV*, denoted as (Amacher et al., 2009):

$$LEV = (1-\exp(-rT))^{-1}[pf(T)\exp(-rT)-c], \quad (6)$$

where *LEV* is the land expectation value (US$ ha^{-1}), p is the stumpage price (US$ m^{-3}), $f(T)$ is a yield function ($m^3\ ha^{-1}$), r is the discount rate, and c is the establishment costs (US$ ha^{-1}). The present value of management cost is also included in Eq. (6).

2.3. Financial risk determination

Most of the empirical literature tends to calculate *LEV* in a deterministic way (Amacher et al., 2009; Samuelson, 1995). However, the dynamic nature of some relevant variables (e.g., prices, yields, interest rate), would lead to assess the potential effect of changes in those variables. A method commonly reported in the literature to accomplish this type of analysis is the Monte Carlo simulation with which it is possible to calculate a stochastic *LEV*. Moreover, it is possible to evaluate the potential success of a forest investment, calculated as the probability that stochastic LEV_{max} exceeds a determined land price. The calculated probability is considered as a measurement of success for a forest investment, and also can be considered a risk measurement (Clutter et al., 1992; Klemperer, 2003).

An algorithm written in *Visual Basic for Applications* was used to calculate both deterministic and stochastic *LEV*, rotation age, *NPV*, *IRR*, and their corresponding confidence intervals and success probabilities. The algorithm does not use a fixed number of iterations. On the contrary, each simulation stops when a criterion of variance stabilization is met, which implies a distinct number of iterations in each simulation. The variance stabilization criterion used was the following:

$$\Delta s^2 = abs\left[{s_i^2 - s_{i-z}^2}\Big/{s_{i-z}^2}\right] \le \epsilon \quad (7)$$