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Profitability and risk sources in global timberland investments

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ABSTRACT

As a long-term investment, timberland investments offer financial benefits including portfolio diversification, attractive risk/return profile, an inflation hedge, and the potential of cash flow. Based on interviews with experts regarding ranges of input parameters used in single-hectare financial models and Monte Carlo simulation method, we examine what are the main factors that influence internal rates of returns (IRRs) in several global timber plantation investment opportunities: loblolly pine on the U.S. Atlantic coastal plain; Douglas-fir plantations in the western U.S.; loblolly pine and eucalyptus plantations in Brazil; radiata pine and eucalyptus plantations in Chile; and pine and oak stands in Poland. The results show that excluding the price of land, biological growth and timber prices were the most influential variables that impacted the IRRs across global timberland investments. In addition, some country-specific factors, such as planting costs (Chile) and management costs (Poland and the U.S.), were identified as crucial when considering timberland investments in these countries. Investments in South America's pine plantations are characterized by the same level of returns as eucalyptus opportunities, but with lower risk. The same was found for Douglas-fir investments in the Pacific Northwest compared to loblolly pine in the U.S. South. If Poland were an investable alternative, which is not the case so far, any investments in oak and pine stands are not recommended yet, given that for the same level of risk, better returns may be achieved in Douglas-fir plantations in the U.S. PNW. The Monte Carlo method utilized provides easily interpretable representation of the robustness of timberland investment estimates in selected regions and should become standard practice in forest-business decision making. However, more accurate probability density functions need to be determined in further research, using, for instance, historical data and kernel density estimation, rather than "lack of information" (triangular) distributions.

1. Introduction

Timberland investments can offer competitive returns, inflation hedging and low correlation to other asset classes. In general, timberland investments are exposed to various sources of risk, such as material and environmental risk, timberland supply/demand and fluctuation of land and timber prices (Healy et al., 2005; Lutz, 2014). These potential risks could lead to undesirable results if not accounted carefully by the timberland investors. Having a complete assessment of returns and risk may not only encourage more investments in poorer rural areas but might also help governments build forest institutions and increase operational capacity.

Lönnstedt and Sedjo (2012) noted that foresters tend to think of timberland investments as being relatively risky because of hazards such as wildfire, insects, and disease. Others claim that historically, losses occurring from natural events are quite low (HTRG, 2013), and forests may even reduce risk in the context of diversified investment portfolio (e.g., Lönnstedt and Svensson, 2000; Wan et al., 2015) since returns on timberland investments tend to run counter to the returns realized through many other types of investments, or at least uncorrelated with stocks (Lutz 2018). Investors indicate that they particularly feel hampered by their limited ability to accurately assess the associated risks with timberland investments (Glauner et al., 2012). Factors such as lack of access to and cost of information, market organization, and lack of experience were mentioned as key investment barriers.

To date, however, the application of scholarly research on risk to operational timberland investment problems has been limited. This is particularly valid with respect to forest investments in emerging markets where standardized risk assessment methodologies are rarely

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available and investments are mainly based on the risk assessment of the investment manager or investor (Glauner et al., 2012). For instance, Pricewaterhouse-Coopers (PWC, 2019) has developed a toolkit for risk assessments in the context of sustainable forest finance. However, these approaches are generally too broad to serve as precise and project-specific risk evaluation strategies (Glauner et al., 2012).

Only a few very recent studies considered the variation in input parameters on timberland investment profitability. In one of the early studies, Aronow et al. (2001) analyzed the effects of uncertain future timber prices on the value and performance of timberland investments. Mei et al. (2013) extended this research and, in addition to risks in timber prices, took into account risk in tree growth, yield, and bare land value. In quite recent research, for loblolly pine in the U.S. South, Mei et al. (2019) analyzed various factors affecting forest investment decisions as well, including management costs, growth and yield, and land costs, using Monte Carlo simulation for growth and yield and a real options / contingent claims approach for investment decisions under prospects of climate change. They addressed climate change impacts, not the primary investment factors per se. They found that climate change would not affect most decisions (97 % would remain the same) to invest in or divest of timberland. In a series of analyses of input costs and timber prices in the U.S. South, with different discount rates ranging from 3 % to 7 %, Callaghan et al. (2019a, 2019b) found that timber prices were generally more important than establishment and planting costs in determining the net present value of timber investments. Input costs for labor and mechanical site preparation had risen the most for their time series from 1952 to 2016, but decreases in other costs had kept total timber management costs relatively stable in real inflation-adjusted terms throughout the period. Chudy et al. (2019) also found that in addition to wood prices and yields, the land cost has a significant impact on the profitability of timberland investments. In the analysis about hybrid poplar feedstock production system in the western U.S., they found that increasing land cost by 30 % decreases real IRR by around 0.5 %.

These prior studies focused mostly on the U.S., and used methods based on discounted cash flow and capital budgeting analyses. In this study, we performed parallel and independent research on timberland investment risks using a consistent approach of Monte Carlo simulation with variation in all the input costs and for timber prices, for various countries, regions, and species combinations throughout the world: loblolly pine in the U.S. Atlantic coastal plain; Douglas-fir plantations in the western U.S.; loblolly pine and eucalyptus plantations in Brazil; radiata pine and eucalyptus plantations in Chile; and pine and oak stands in Poland. Although Poland is currently not considered as an investable alternative due to state-owned forestry sector (see e.g., Chudy et al., 2016b), these two options of typical oak and pine species and long rotations were analyzed and presented in this study as a benchmark of Central and Eastern European investments.

2. Methods and data

We analyzed returns to timberland investments excluding the price of land in prior research with deterministic discounted cash flow/capital budgeting models (Cubbage et al., 2007, 2010, 2014), and have extended that in another article in this Special Issue. Chudy et al. (2016a) described an algorithm how to incorporate a risk component into deterministic models (Chudy et al., 2016a), and we apply that procedure here to the models by Cubbage et al. The forest management, cost, and price data in the Cubbage et al. investment series were estimated by timberland investment reporters (TIRs) who are experts in each country. Those estimates included a range of costs by practice, which we then extended to estimate the variability for ranges of input parameters used in single-hectare financial models and Monte Carlo simulation method. Monte Carlo (MC) simulation is broadly used for risk assessment in financial evaluations due to its ability to incorporate different uncertain inputs but is also common in applications for risk assessment in other domains (Hildebrandt and Knoke, 2011).

According to Chudy et al. (2016a) the procedure to investigate risks in deterministic models is: First, determine which parameters are most important and use them to estimate financial returns in a deterministic model. Second, perform sensitivity analyses to identify the most important parameters. Third, estimate probability distributions for these parameters based on historical variations and simulate them in a Monte Carlo simulation until their distributions converge. Finally, analyze the model results. In reality, one would most often have to make modifications in these steps according to data availability, model capacity and skills, but the procedure can still be useful with some adjustments (Chudy et al., 2016a, 2019).

The first step drew on analyses by Cubbage et al. (2014, 2010, 2019)Cubbage et al., 2014Cubbage et al. (2014, 2010, 2019)Cubbage et al., 2014Cubbage et al. (2014, 2010, 2019), with detailed and consistent templates for timberland investment calculations[1] at the forest stand level in various countries. The templates represent discounted cashflow (DCF) models, where silvicultural treatments, costs, and benefits are explicitly specified by timberland investment opportunity. We calculated these returns in Cubbage et al. (2019) and in this analysis without the cost of land as the base case. The DCF model calculates the internal rate of return (IRR), the rate of return on capital deployed in an investment opportunity, for each timberland investment, as well as other capital budgeting criteria. We used IRR as our financial criterion since it was easiest to use to compare the model forests in different countries, with vastly different rotation lengths — from 6 to more than 100 years. It also is the metric most commonly used to compare different investments in the applied finance literature and investment discussions. The IRR also was relied on as our basis for subsequent Monte Carlo simulations.

Investment returns were calculated using capital budgeting techniques for typical forest management practices, and include all the base factor costs, production rates, timber stumpage prices, and land costs. Taxes or other government policy interventions were not included. All models were prepared as single-hectare models, assuming all costs and benefits were estimated on a per hectare basis.

Based on the existing DCF models for selected forest plantations/stands, we ran a sensitivity analysis by increasing the value of the main input variables in the cash flow analysis by ±5 % until it reaches ±30 % from the baseline value and calculated the IRR for each step, variable, and region. This approach helped us to analyze five factors in order to rank their relative impacts on IRR.

The Monte Carlo simulation technique was applied, for each of the factors identified that could affect investment returns, using a symmetric triangular distribution. To determine the realistic current minimum (a) and maximum (b) values that models' input parameters could take, the knowledge of local experts or estimation of certain percent changes to mean values were applied. The symmetric triangular distribution is characterized by the peak (c) equal to $c = (a + b) / 2$, which is the mode (exactly in the middle of the interval) and which corresponds to the distribution of the mean of two standard uniform variables, where where a and b are two independent random variables with standard uniform distribution in the half-open interval [0, 1).

To perform Monte Carlo simulations, a random number generator together with a data table functions were applied to Excel spreadsheets to generate uniform statistically independent values that were used as inputs to calculate internal rates of returns using the XIRR Excel's function. Table 1 presents the values for the base case DCF models, together with minimum and maximum values and their estimation criteria for five most decisive input variables (described in detail in results section) for each investment opportunity.

These data means and ranges were collected by local timber

[1] Template is available online as a suplementary material to the article published by (Cubbage et al., 2014)

Table 1
Input data for Monte Carlo simulation with symmetric triangular distribution assumption. Silvicultural and management costs are expressed in USD/ha, growth rates in m^3/hectare/year and wood prices in USD/m3.

Investment Opportunity	Variable	Base Case	Min	Max	Criterion
USA South loblolly pine Medium Site Productivity	Growth Rate	10.00	6.00	20.00	TIR
	Site Preparation Cost	530.65	451.05	610.25	TIR
	Small Sawntimber Price	33.25	24.94	41.56	± 25 %
	Pulpwood Price	13.30	9.98	16.63	± 25 %
	Management Cost	35.00	29.75	40.25	± 15 %
USA South loblolly pine High Site Productivity	Growth Rate	13.00	6.00	20.00	TIR
	Site Preparation Cost	530.65	451.05	610.25	± 15 %
	Small Sawntimber Price	33.25	24.94	41.56	± 25 %
	Pulpwood Price	13.30	9.98	16.63	± 25 %
	Planting Cost	444.60	377.91	511.29	± 15 %
USA Douglas-fir Medium Site Productivity	Growth Rate	10.30	16.70	5.90	TIR
	Sawlog Price (Grade 3)	69.33	58.93	79.73	TIR
	Site Preparation Cost	197.60	167.96	227.24	TIR
	Planting Cost	766.00	650.85	880.56	± 15 %
	Management Cost	67.31	57.21	77.40	± 15 %
USA Douglas-fir High Site Productivity	Growth Rate	16.70	8.80	20.88	TIR (base and min)/ + 25 % (max)
	Planting Cost	765.70	650.85	880.56	± 15 %
	Sawlog Price (Grade 3)	69.33	58.93	79.73	TIR
	Sawlog Price (Grade 2)	70.67	60.07	81.27	± 25 %
	Management Cost	67.31	57.21	77.41	± 15 %
Brazil eucalyptus pulpwood	Pulpwood Price	14.00	10.50	17.50	± 25 %
	Growth Rate	40.00	30.00	50.00	TIR
	Planting Cost	1304.50	1108.83	1500.18	± 15 %
	Management Cost	69.81	59.34	80.28	± 15 %
	Herbicide/Cleaning Cost	58.90	50.07	67.74	± 15 %
Brazil loblolly pine	Growth Rate	30.00	15.00	35.00	TIR
	Chip-N-Saw Price	21.67	16.25	27.09	± 25 %
	Planting Cost	650.00	552.50	747.50	± 15 %
	Small Sawtimber Price	28.33	21.25	35.42	± 25 %
	Management Cost	62.00	52.70	71.30	± 15 %
Chile radiata pine sawtimber	Growth Rate	30.00	10.00	35.00	TIR
	Planting Cost	389.00	312.00	480.00	TIR
	Site Preparation Cost	365.00	150.00	510.00	± 25 %
	Pulpwood Price	11.80	8.85	14.75	± 25 %
	Biomass Fuel Price	5.50	4.13	6.88	± 25 %
Chile radiata pine pulpwood	Growth Rate	20.00	16.00	25.00	TIR
	Planting Cost	325.00	240.00	435.00	TIR
	Pulpwood Price	11.80	8.85	14.75	± 25 %
	Chip-N-Saw Price	31.50	23.63	39.38	± 25 %
	Site Preparation Cost	365.00	150.00	510.00	TIR
Chile eucalyptus globulus	Growth Rate	25.00	12.00	32.00	TIR
	Pulpwood Price	25.40	19.05	31.75	± 25 %
	Herbicide/Cleaning Cost	82.00	50.00	120.00	TIR
	Site Preparation Cost	430.00	150.00	600.00	TIR
	Planting Cost	402.00	300.00	515.00	TIR
Chile eucalyptus nitens	Growth Rate	30.00	15.00	40.00	TIR
	Pulpwood Price	15.30	11.48	19.13	± 25 %
	Management Cost	20.00	17.00	23.00	± 15 %
	Site Preparation Cost	430.00	150.00	600.00	TIR
	Planting Cost	325.00	240.00	435.00	TIR
Poland pine	Planting Cost	1506.92	1160.97	1852.87	TIR
	Growth Rate	9.30	7.60	11.50	TIR
	Pulpwood Price	42.78	32.09	53.48	± 25 %
	Sawlog Price	74.87	56.15	93.58	± 25 %
	Management Cost	151.46	128.74	174.17	± 15 %
Poland oak	Growth Rate	8.00	7.00	12.00	TIR
	Sawlog Price	188.76	141.57	235.94	± 25 %
	Pulpwood Price	41.05	30.78	51.31	± 25 %
	Planting Cost	2894.78	2293.68	3495.87	TIR
	Management Cost	151.46	128.74	174.17	± 15 %

Note: Base Case corresponds to the arithmetic average between Min and Max value when the value of the input parameter was assumed in a certain range, i.e., ± 15 or 25 %. TIR represents data from the local country Timberland Investment Reporter (TIR), drawn from Cubbage et al., 2019. With respect to Douglas-fir, there are four principal log grades that are based on the small-end diameter and log quality. For more information about log grades for Douglas-fir, please refer to Barbour and Parry (2001).

investment reporters (TIRs) for each country in Cubbage et al. (2019). There are very little secondary sources for forest management costs in most countries, so the TIRs collected data and reported ranges when available. The U.S. South has had a long-running forestry cost series published in the Forest Farmer /Forest Landowner magazine (see Callaghan et al., 2019a for a summary and analysis of these data trends), and data for 2016 were used for loblolly pine price series in the U.S. South. The ranges from this secondary data source were also used to inform the percentage variations of the amount of input costs when there were no ranges reported by the TIRs.

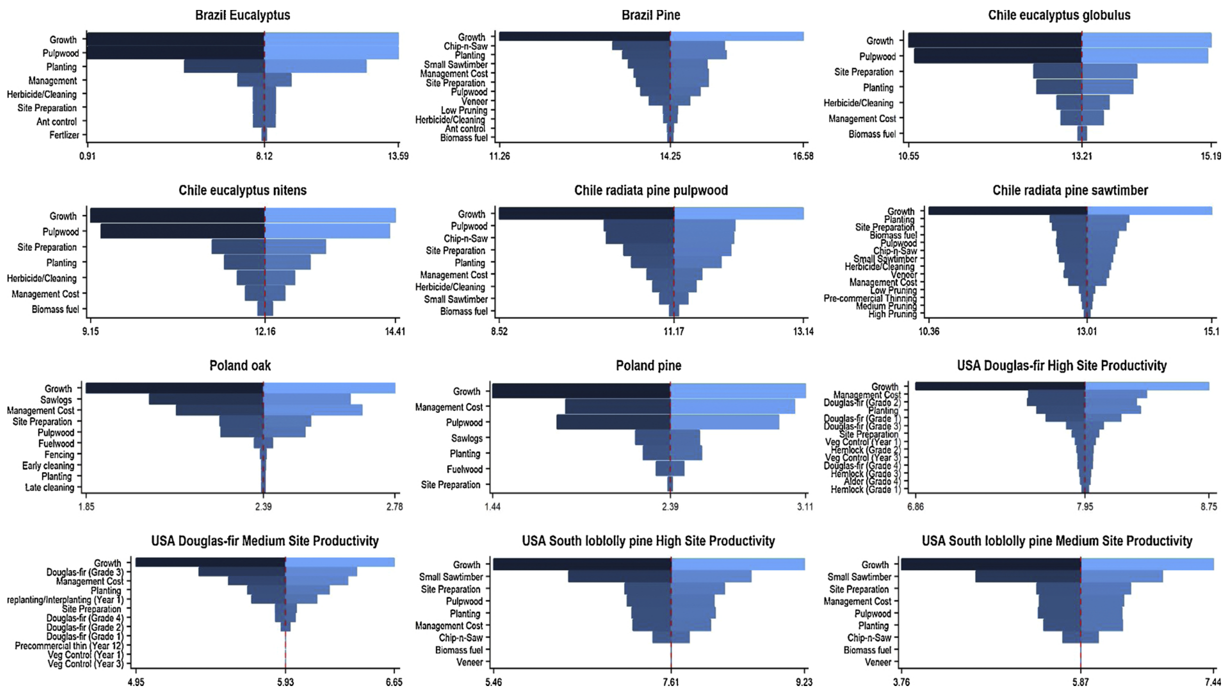


Fig. 1. Tornado graphs of timberland investment IRRs by timber input factor, country, and species.

3. Results

The results from the Monte Carlo risk analyses for the range of the different factors consist of more than 10,000 runs of the DCF models, and about 50 sets of scenarios for differences in factors. For ease of interpretation, we first discuss the results of the sensitivity analyses of the effect of different factor and price combinations, and then the Monte Carlo results, in the following graphs and discussion.

3.1. Sensitivity analysis

Fig. 1 shows the tornado graphs with the minimum, maximum and median IRR statistics for the timberland investment returns, not including the cost of land, and the ranked impact of each variable in every region from the highest to the lowest output variation calculated as ($|IRR_{max} - IRR_{min}|$).

Biological growth was by far the variable that affected the IRR the most. Regions with faster growth rates, like Brazil and Chile, were more sensitive to a variation in productivity. For instance, the IRR ranged from 0 % to 13.5 % (13.5 % percentage points) in Brazil (eucalyptus), from 11.2% to 16.6% (5.4 %) in Brazil (pine) and from 9 % to 14 % (5 %) in Chile (Eucalyptus nitens - pulpwood). On the other hand, growth rates in slow growth forests did not alter their financial returns as much—from 1.4 % to 3.1 % (1.7 %) in Poland (pine) and 1.8%–2.3% (0.5 %) in Poland (oak). The returns from timberland investments in the U.S. followed the same trend, with a lower impact in the Douglas-fir (V1 - medium site and V2 - high site) than in the U.S. South (medium and high growth rates). The greater variation of returns due to faster growth does not necessarily translate into higher risk. In fact, shorter rotations will lead to less exposure to biological and climate threats (diseases, drought periods, storms etc.) and market fluctuations. However, in the case of lower expected prices, producers might have to thin or clearcut their assets in order to avoid marginal costs that may exceed marginal returns. In this case, fast growing forests show disadvantages because their window to postpone harvesting or thinning operations is smaller. On the other hand, a slow growth forest could wait even decades to avoid a period of low price if the opportunity costs are low enough.

Timber prices had the second highest impact on IRR in every region and investment except for Chile (radiata pine - sawtimber), Poland (pine) and U.S. PNW (Douglas-fir V1/medium site), where planting costs (Chile) and management costs (Poland and the U.S. PNW) were ranked on the second position. The impact of timber prices is directly related to the final management goals; forests managed strictly for the pulpwood market like Brazil (eucalyptus), Chile (Eucalyptus globulus and nitens) had their returns affected by changes in timber prices as much as due to changes on biological growth. This relationship could be expected for the short rotation plantations since the discount rate has a smaller effect on timber prices and volume harvested is supplied to only one market. In longer rotations, and/or forest managed for multiple products, the risk of price fluctuation is likely minimized by the volume allocated to other products as well as their final price.

The other variables that affected the IRR were less economically significant, and their impact did not diverge much from the average returns. Fast growth plantations in Chile and Brazil seem to require more caution in every operation. Substantial negative changes in input costs of prices could reduce the IRR by 3%–5%, which might discourage risk-averse new private investors. However, most of these pulpwood plantations are currently owned and managed by large vertically integrated forest products firms, which would have both less risk of wide variation in input costs dues to their extensive management experience, and less price risk since those prices are largely transfer prices within the company. On the other extreme, Poland has the lowest returns (IRR = 2.3 %) but also not much variation due to any variable (~ 1.5 %). Investments in the U.S. are characterized by relatively lower but still attractive returns (IRR = 5%–7%) and tend to have low variations across market changes (~ 3 %), which is likely to be appreciated by timberland investors and managers. Next, we discuss the Monte Carlo simulation results.

3.2. Monte Carlo (MC) simulations

Table 2 presents the descriptive statistics for the internal rate of return excluding land costs based on MC simulations (1000 iterations). Values have been sorted in descending order from highest to lowest standard deviations for each region and variable.

Table 2
Descriptive statistics for internal rate of return based on MC simulations (1000 iterations).

Investment Opportunity	Variable	Mean	Standard deviation	Coefficient of Variation	Median	Min	Max
USA South loblolly pine Medium Site Productivity	Growth Rate	6.97 %	1.974 %	28.32 %	7.27 %	2.56 %	9.83 %
	Small Sawtimber Price	5.62 %	0.528 %	9.38 %	5.65 %	4.60 %	6.46 %
	Pulpwood Price	5.62 %	0.237 %	4.22 %	5.63 %	5.21 %	6.03 %
	Management Cost	6.00 %	0.183 %	3.05 %	5.99 %	5.61 %	6.41 %
	Site Preparation Cost	5.62 %	0.151 %	2.69 %	5.61 %	5.37 %	5.90 %
USA South loblolly pine High Site Productivity	Growth	7.09 %	2.056 %	28.98 %	7.41 %	2.70 %	10.07 %
	Small Sawtimber Price	7.37 %	0.534 %	7.25 %	7.42 %	6.36 %	8.21 %
	Pulpwood Price	7.39 %	0.256 %	3.46 %	7.41 %	6.94 %	7.81 %
	Site Preparation Cost	7.39 %	0.165 %	2.23 %	7.39 %	7.10 %	7.68 %
	Planting Cost	7.39 %	0.140 %	1.89 %	7.39 %	7.15 %	7.63 %
USA Douglas-fir Medium Site Productivity	Growth Rate	6.04 %	0.812 %	13.45 %	6.14 %	4.38 %	7.24 %
	Sawlog Price (Grade 3)	5.82 %	0.155 %	2.67 %	5.82 %	5.54 %	6.08 %
	Management Cost	5.82 %	0.116 %	1.99 %	5.82 %	5.63 %	6.02 %
	Planting Cost	5.82 %	0.078 %	1.33 %	5.82 %	5.69 %	5.96 %
	Site Preparation Cost	5.82 %	0.020 %	0.35 %	5.82 %	5.79 %	5.86 %
USA Douglas-fir High Site Productivity	Sawlog Price (Grade 2)	7.95 %	0.070 %	0.88 %	7.96 %	7.83 %	8.07 %
	Sawlog Price (Grade 3)	7.95 %	0.101 %	1.27 %	7.96 %	7.77 %	8.12 %
	Growth Growth	7.5.4 %	0.756 %	10.08 %	7.615 %	5.992 %	8.633 %
	Management Cost	7.95 %	0.130 %	1.63 %	7.95 %	7.64 %	8.25 %
	Planting Cost	7.94 %	0.113 %	1.42 %	7.93 %	7.76 %	8.14 %
Brazil eucalyptus pulpwood	Pulpwood Price	7.65 %	2.995 %	39.14 %	7.77 %	2.35 %	12.76 %
	Growth Rate	7.96 %	3.007 %	37.79 %	8.08 %	2.30 %	12.76 %
	Planting Cost	8.17 %	1.053 %	12.89 %	8.14 %	6.41 %	10.05 %
	Management Cost	8.12 %	0.310 %	3.82 %	8.13 %	7.58 %	8.66 %
	Herbicide/Cleaning Cost	8.12 %	0.133 %	1.64 %	8.12 %	7.89 %	8.34 %
Brazil loblolly pine	Growth Rate	12.50 %	1.997 %	15.98 %	12.76 %	8.58 %	15.59 %
	Chip-N-Saw Price	14.22 %	0.479 %	3.37 %	14.20 %	13.41 %	15.05 %
	Small Sawtimber Price	14.23 %	0.331 %	2.33 %	14.22 %	13.65 %	14.79 %
	Planting Cost	14.25 %	0.266 %	1.87 %	14.24 %	13.82 %	14.72 %
	Management Cost	14.26 %	0.191 %	1.34 %	14.26 %	13.93 %	14.58 %
Chile Eucalyptus globulus	Growth Rate	11.92 %	2.084 %	17.48 %	12.06 %	7.79 %	15.07 %
	Pulpwood Price	13.17 %	1.085 %	8.24 %	13.25 %	11.14 %	14.85 %
	Site Preparation Cost	13.62 %	0.845 %	6.21 %	13.58 %	12.25 %	15.19 %
	Planting Cost	13.45 %	0.829 %	6.17 %	13.41 %	12.10 %	14.96 %
	Herbicide/Cleaning Cost	13.17 %	0.321 %	2.44 %	13.18 %	12.62 %	13.75 %
Chile Eucalyptus nitens	Growth Rate	11.22 %	2.271 %	20.24 %	11.54 %	6.38 %	14.63 %
	Pulpwood Price	12.02 %	1.182 %	9.83 %	12.07 %	9.87 %	13.99 %
	Site Preparation Cost	12.57 %	1.034 %	8.23 %	12.41 %	10.98 %	14.67 %
	Planting Cost	12.08 %	0.434 %	3.59 %	12.07 %	11.37 %	12.84 %
	Management Cost	12.16 %	0.102 %	0.84 %	12.15 %	11.99 %	12.34 %
Chile radiata pine pulpwood	Growth Rate	11.30 %	0.983 %	8.70 %	11.37 %	9.51 %	12.84 %
	Site Preparation Cost	11.45 %	0.817 %	7.13 %	11.38 %	10.18 %	13.00 %
	Pulpwood Price	11.15 %	0.483 %	4.33 %	11.16 %	10.30 %	11.95 %
	Chip-N-Saw Price	11.17 %	0.475 %	4.25 %	11.19 %	10.32 %	11.93 %
	Planting Cost	11.21 %	0.320 %	2.86 %	11.19 %	10.67 %	11.79 %
Chile radiata pine sawtimber	Growth Rate	10.47 %	2.520 %	24.07 %	10.81 %	5.30 %	14.20 %
	Site Preparation Cost	13.23 %	0.600 %	4.53 %	13.20 %	12.26 %	14.39 %
	Planting Cost	12.97 %	0.269 %	2.07 %	12.96 %	12.52 %	13.46 %
	Biomass Fuel Price	13.03 %	0.243 %	1.87 %	13.03 %	12.59 %	13.44 %
	Pulpwood Price	13.01 %	0.237 %	1.82 %	13.03 %	12.58 %	13.42 %
Poland oak	Growth Rate	2.55 %	0.256 %	10.04 %	2.56 %	2.03 %	3.04 %
	Sawlog Price	2.38 %	0.143 %	5.99 %	2.39 %	2.11 %	2.61 %
	Management Cost	2.39 %	0.102 %	4.26 %	2.39 %	2.15 %	2.63 %
	Pulpwood Price	2.39 %	0.061 %	2.55 %	2.38 %	2.28 %	2.49 %
	Planting Cost	2.39 %	0.053 %	2.22 %	2.38 %	2.30 %	2.48 %
Poland pine	Growth Rate	2.45 %	0.317 %	12.95 %	2.48 %	1.85 %	2.96 %
	Pulpwood Price	2.39 %	0.286 %	11.94 %	2.40 %	1.88 %	2.88 %
	Management Cost	2.39 %	0.173 %	7.23 %	2.39 %	2.10 %	2.71 %
	Sawlog Price	2.39 %	0.082 %	3.45 %	2.39 %	2.24 %	2.52 %
	Planting Cost	2.39 %	0.069 %	2.89 %	2.39 %	2.28 %	2.52 %

Based on the coefficient of variation, the highest impact on the internal rate of return was the variation of pulpwood prices in Brazil (39.14 %), followed by quite wide variations in growth rates (13–38 %) for Brazilian eucalyptus, U.S. loblolly pine, Chile radiata pine, Chile eucalyptus, Brazil pine, U.S. Douglas-fir and Poland's pine. Next, the Monte Carlo simulation revealed that planting costs in Brazilian's eucalyptus (12.89 %) caused significant IRR variation, followed by Poland's pine pulpwood prices (11.94 %) and again growth rates in US Douglas-fir V2/high and Poland's oak being equal to roughly 10 %. The rest of the factors had a coefficient of variation below 10 %.

Generally, the group of timber management factors with the lowest coefficient of variations were site preparation and silvicultural and management costs. However, some factors revealed low variations and their impact on IRRs, such as wood prices (Douglas-fir prices, pulpwood and biomass prices in Chile, small sawtimber prices in Brazil or pine pulpwood and sawlog prices in Poland). The key message is that growth and wood price variations are key for timberland investments. Other timber management factors affecting returns, measured by IRR, are less important, but they are very country specific. Nonetheless, a difference of a few percentage points (several hundred basis points) is still huge for a timberland investment of tens of millions of dollars, so should be closely taken into account by managers and investors in investment

Table 3
Overall Average, Min, Max, Median and Standard Deviation across 5 most decisive factors on IRR for each investment opportunity.

Investment Opportunity	Mean	Min	Max	Median	Standard Deviation
USA South loblolly pine Medium Site Productivity	5.97 %	4.67 %	6.93 %	6.03 %	0.61 %
USA South loblolly pine High Site Productivity	7.33 %	6.05 %	8.28 %	7.40 %	0.63 %
USA Douglas-fir Medium Site Productivity	5.86 %	5.40 %	6.23 %	5.88 %	0.24 %
USA Douglas-fir High Site Productivity	7.91 %	7.73 %	8.09 %	7.88 %	0.23 %
Brazil eucalyptus pulpwood	8.00 %	5.30 %	10.51 %	8.05 %	1.50 %
Brazil loblolly pine	13.89 %	12.68 %	14.95 %	13.94 %	0.65 %
Chile eucalyptus globulus	13.07 %	11.18 %	14.77 %	13.10 %	1.03 %
Chile pinus radiata sawtimber	12.54 %	11.05 %	13.78 %	12.60 %	0.77 %
Chile eucalyptus nitens	12.01 %	10.12 %	13.69 %	12.05 %	1.00 %
Chile radiata pine pulpwood	11.26 %	10.20 %	12.30 %	11.26 %	0.62 %
Poland oak	2.42 %	2.17 %	2.65 %	2.42 %	0.12 %
Poland pine	2.40 %	2.07 %	2.72 %	2.41 %	0.19 %

analyses as also indicated in the sensitivity analysis. Table 3 shows an overall Average, Minimum, and Maximum across 5 most decisive factors on IRR for each investment opportunity.

Taking the average of five most significant factors into account for each investment opportunity, it seems that the largest internal rates of return may be achieved in the southern hemisphere (Brazil and Chile, between 8 and 14 %), which aligns with the deterministic rankings found in Cubbage et al. (2019), in a companion article in this Special Issue. These investment opportunities are followed by timberland returns in U.S. Pacific Northwest and the South. Reflecting the slow growth and long rotation management of Europe, the investment results for Poland were characterized by the lowest IRR rates ranging from 2 to 3 %.

To illustrate the tradeoff between risk and return, we draw a relationship between these two characteristics on the same graph using Monte Carlo overall estimates for each investment opportunity (Table 3). Returns are drawn as IRR means and risk is measured by the standard deviation (Fig. 2). Thresholds were set as 8 % and 0.80 % for return and risk (standard deviation), respectively.

First, no timberland investment opportunity was located in the IV quadrant, meaning that for a certain level of risk (>0.8 %), the investigated timberland investments do not have IRRs of less than 8 %. With such level of risk, it may be expected that timberland investments may provide between 8 and 13 %, not including land costs, and are mostly focused on investments in eucalyptus plantations in Brazil and Chile. Nevertheless, returns at such levels may be achieved with lower risk (<0.8 %) if investors decide to invest in pine plantations in Brazil or Chile instead. Finally, for investors who are more risk averse, it seems that returns up to around 8 % are possible in the U.S. Pacific Northwest and the U.S. South. Investments in Poland are not found very attractive as with roughly the same level of risk investors may achieve better returns in the U.S. PNW.

Based on such a risk-return classification, Brazil and Chile pine plantations give similar returns to Chile eucalyptus plantations, but with a lower level of risk. U.S. Douglas-fir and Brazil eucalyptus may produce an internal rate of return at around 8 % level; however, it seems that the investment in the U.S. is preferable given a lower level of risk. Comparison of timberland investment between U.S. PNW and U.S. South, for Douglas-fir and loblolly pine plantations respectively, put the Pacific Northwest region in a better position due to the same level of returns but significantly lower risk.

The returns from investments in Poland might provide poor returns, but they presented one of the lowest risks.

We should warn that this classification is based on the cash flow analysis with pure finance results without the cost of land and does not consider important macroeconomic aspects that could define international investments (see, e.g., Kanieski da Silva et al., 2017). Ideally, a time series with the returns of every investment could be used for this type of analysis. However, our study gives an initial overview of forest investment tradeoffs and can be used as a reference to a portfoliomanager.

4. Discussion and conclusions

This research provided a detailed analysis of the effect of various biological growth, factor cost, and timber prices on timberland investment returns. It extended the prior literature on the subject beyond the common discounted cash flow analyses and U.S. timberland portfolios. We analyzed the largest timber producing countries, species, and portfolios in the United States and South America, and used data and

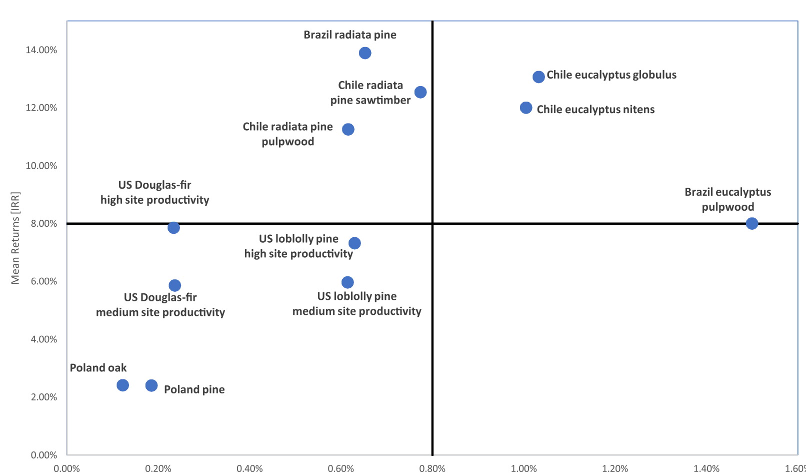


Fig. 2. Risk and return relationships for global timberland investment opportunities.

forests in Poland as a proxy for plantation returns of native species in Europe. This adds to the literature and practice of forest economics and timberland investments literature by explicitly considering the main risk factors affecting internal rates of returns in timberland investments across multiple countries and species.

This application of standard and harmonized financial models to the evaluation and analysis of timberland investment opportunities across different countries and species complements other methods used in previous studies. For instance, in previous U.S. research, which was conducted only based on U.S. markets, the expected returns were often calculated based on either index, mathematical formulas or discounted cash flow models. Two return indices commonly used in the timberland investment literature are National Council of Real Estate Investment Fiduciaries (NCREIF) Timberland Index (NTI) and timber firm index. NTI approximates private-equity timberland returns achieved by major timberland investment management organizations (see e.g., Sun and Zhang, 2001).

Wan et al. (2015) used the NCREIF Timberland Index as a proxy of the returns for private-equity timberland investments in the U.S. On the other hand, timber firm index approximates public-equity timberland returns achieved by a group of publicly-traded timber firms (e.g., Mei and Clutter, 2010). Although NTI tracks total returns from a large sample of geographically diverse timberland properties in the U.S., it has some limitations. Among others, a number of acres, properties, shares of the investable universe across the U.S., or acres represented by U.S. regions, which are used to calculate the index, have been changing over time, impacting index reliability, transparency and comparison in different time periods. In consequence, some recommend avoiding using NCREIF returns as a stand-alone measure of timberland manager performance (FORISK, 2015).

In addition, Mei et al. (2013) noticed also that both indices, NCREIF, and timber firm index, do not necessarily represent the investment returns of nonindustrial private forest landowners managing small tracts of land. With respect to mathematical formulas, Lönnstedt and Svensson (2000) calculated annual returns for timberland based in Europe on a formula that took into account the total net felling, land value according to the Faustmann formula, standing value of the forest and costs of silviculture. However, the division between sawtimber and pulpwood was not taken into account due to data limitations.

The results of our study show that overall biological growth and timber prices were the most influential variables that impacted the IRRs across global timberland investments, which was also reflected in previous studies (e.g., Aronow et al., 2001; Chudy et al., 2019; Mei et al., 2013). In addition, some additional and country-specific factors, such as planting costs (Chile) and management costs (Poland, the U.S.), were identified as crucial when considering timberland investments. Although the impact of growth rates and timber prices on IRRs is well known, i.e., higher growth and timber prices trigger higher IRRs, the relation between price and growth is not always straightforward for forest growers. Higher growth rates, due to, e.g., genetic selection or silvicultural practices (e.g., fertilization, irrigation, genetic engineering), inflate rates of returns due to higher yields at a rotation age.

Considering everything else constant including demand[2], when higher growth rates appear at the regional scale, the effect on forest owners may be opposite because of the decrease in prices caused by an outward shift of the wood supply curve. The same applies to wood prices and their effects on supply in the region. Higher wood prices may encourage more timberland investments, but also high wood prices may adversely impact the wood industry and in consequence oppose policies which induced these prices (Chudy et al., 2013). Thus, the cyclical fluctuations of supply and prices in forest-products markets should be taken into account by portfolio managers and investors, who perform financial analyses regularly. This overall effect of market supply and demand is important and could bear a separate market analysis in each country and each region identified, but is so substantial it would require separate research by itself, so we had to assume current timber prices and costs for this analysis.

With respect to planting and management costs, which affect IRRs inversely, timberland investors should continue to look for more economical ways to reduce these costs. Callaghan et al. (2019a) analyzed trends in management costs in the U.S. South from the 1950s to 2016 and assessed their impact on timber investment returns as well (2019b). In the cost trend analysis, they found that, forest management costs were relatively stable in real terms, but there were some increases in various subcomponents, such as labor, fuel and large equipment costs. Nonetheless, total costs increased only slightly due to some decrease in factors such as chemicals and increased factor productivity (Callaghan et al., 2019a).

In a set of simulations using this rich data set, Callaghan et al. (2019b) also found that timberland investment returns in the U.S. South also were more sensitive to changes in timber price than in management costs—at least within the range of variation in costs and prices for the U.S. South data that they examined. This is somewhat surprising, since most management costs occur at planting or early in the rotation and might be expected to affect present values and IRRs more. However, the differences still only occur in magnitudes of a few hundred dollars per hectare. Timber prices, however, might swing returns by as much as a thousand dollars or much more per hectare, and increased growth and yield have a similar impact.

Our broad findings of the importance of growth and timber prices are logical, seem robust, and do conform with and extend the findings from the modest amount of prior literature, and should be useful for investors. Of course, each investment should be looked at individually, and good timberland management is a key in any country. Reasonable returns can be achieved in most countries if local markets have good timber prices, and if costs are controlled well. Furthermore, silviculture is perhaps more predictable in the U.S. and Europe, than in South America with more vigorous weed, ant, and other competition as well as better timber growth, although by no means guaranteed in any country.

A comparison between our Monte Carlo results and the deterministic results from Cubbage et al. (2019) in this Special Issue found fairly similar outcomes. It is not surprising that our results, in general, are slightly lower than reported by Cubbage et al. (2019), although the differences were less than 0.5 % percentage points, or even as few as 0.1 % points. The reason behind this result is most likely related to the assumption of triangular probability density function applied in the Monte Carlo simulations, a variation of most decisive factors on IRR by the same percentage in plus and in minus and taking the total mean averages for each investment opportunity. In other words, minimum and maximum values applied for five the most decisive factors in MC method “canceled” each out and resulted in values close to the mean. Such assumptions lead towards the same results no matter the deterministic or semi-stochastic model is applied (see the Appendix).

Thus, if managers know that investigated parameters vary within a certain range, using the deterministic DCF models due to their simplicity and quickness is advisable. However, when managers are more concerned about the impact of certain parameters (wood prices, growth rates), ceteris paribus, on financial returns, it seems that semi-stochastic models may be helpful as at first, these will show which input parameters are the most significant for examined investment opportunity and second, what minimum and maximum IRRs values may be achieved due to changes in examined parameters, keeping everything else constant.

[2] The rationality of assuming constant demand in short and middle term is because of the high entry investment costs necessary to build a new, or expand, pulpmill or sawmill. Although alternative wood usage like pellets is becoming popular, mainly in the US South, it is not clear that this trend will spread to other countries, and even there it has largely just supplanted decreases in pulpwood consumption.

Overall, for our analyses, looking at the each factor level, the following IRRs ranges were identified: Brazil eucalyptus (2.30–12.76 %), Brazil pine (8.58–15.59 %), Chile eucalyptus globulus (7.79–15.19 %), Chile eucalyptus nitens (6.38–14.67 %), Chile radiata pine for pulpwood production (9.51–13.00 %), Chile radiata pine for sawtimber production (5.30–14.39 %), Poland oak (2.03–3.04 %), Poland pine (1.85–2.96 %), U.S. loblolly pine high intensity (2.70–10.07 %), U.S. loblolly pine medium intensity (2.56 %–9.83 %), U.S. Douglas-fir medium site (4.38–7.24 %), U.S. Douglas-fir high site (5.99–8.63 %). The impact of each factor on IRRs for every investment opportunity is presented in the Appendix.

These ranges together with their associated risks, overall have shown that investments in South America pine plantations currently are superior to their eucalyptus alternatives. Next, we identified better returns, given the same amount of risk, for timberland investments in the Pacific Northwest than the U.S. South. Finally, IRR and risk levels in Poland were found the lowest. Poland is not currently considered as timberland investment region, most likely due to unfavorable law and forest policy towards forest owners and monopolistic position of State Forests (Chudy et al., 2016b).

Drawing from Cubbage et al. (2019), we did not include the price of land, which is apt to decrease overall returns for these country/species scenarios anywhere from 3 % less for loblolly pine in the U.S. South to 8 % less for eucalyptus pulpwood in Brazil. Land was excluded because there is much more variation on land prices and site quality across even one country than there is in timber management costs and timber prices. But the results provide robust stochastic comparisons among core forest management yields and costs among the countries selected.

Including land costs would make returns less attractive across the board. Previous timberland investors in the 1990s or before may well have captured excess economic rents in timberland by investing early, but forest land prices have increased throughout the globe. Thus, new investors will need to be cautious in analyzing timberland returns with the various factor costs, timber prices, and land costs. The land costs also would need the most careful additional analyses of the subsequent sale assumptions and land inflation rate, which are crucial for this large component of the total transaction expenses and returns.

The incorporation of risk component into deterministic DCF models assist investors to better understand the risk factors behind the investments; they may know what expected returns might be if values of specific factors turn out not to be as assumed at the beginning of the investment, and also may know where they should focus in order to improve potential financial results. Based on such knowledge, the management strategies leading to increases in revenues and decreases in costs may be analyzed and introduced into the practice. Nevertheless, our study may be improved by applying close-to-real probability density functions to each specified factor, for instance, using historical data and kernel density estimation, instead of "lack of information" (triangular) distribution.

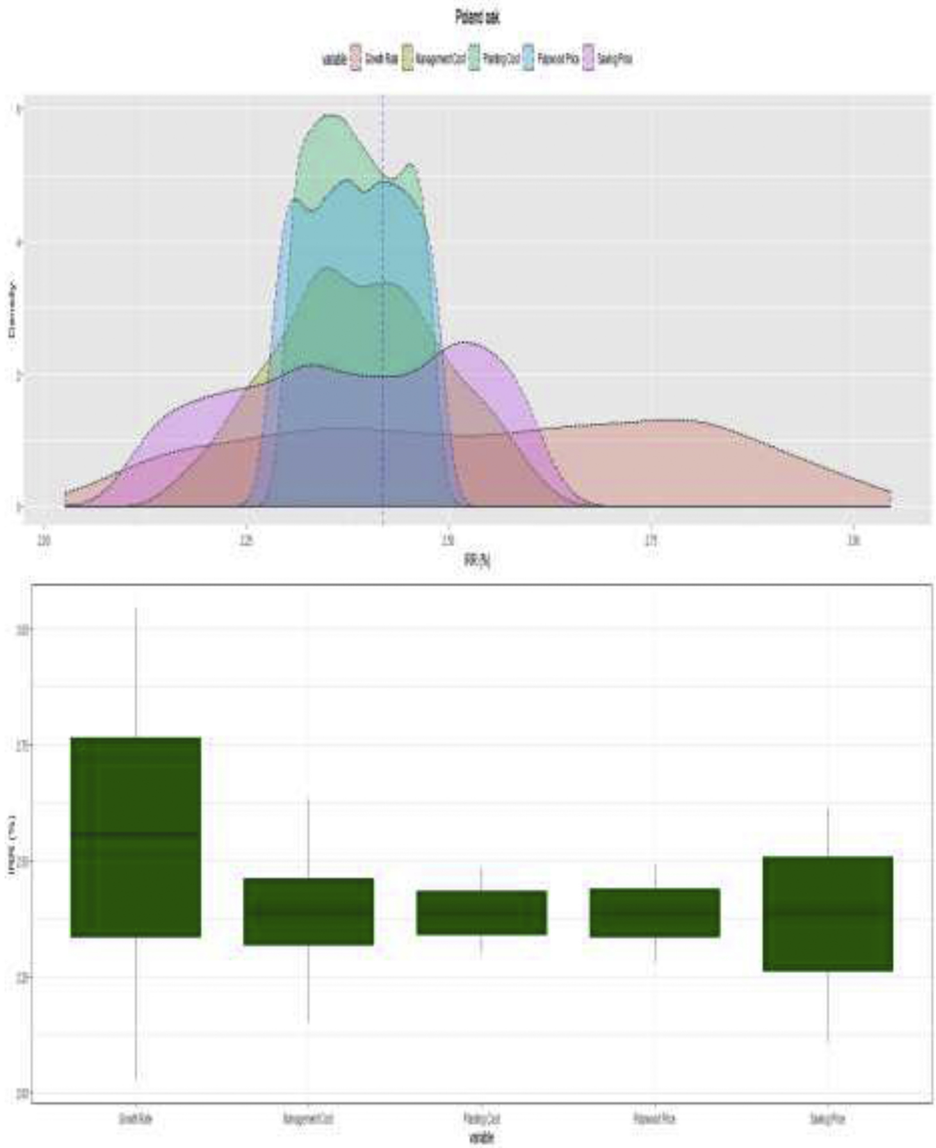
In conclusion, this research should expand the amount of information on global timber investment opportunities and the effect of the key factors that affect timberland investment returns. Vertically integrated forest products firms (VIPFCs) led such investments in the 1950s and since in the Americas, and before that in Europe. They have been supplanted by TIMOs and REITs in North America, but not in South America nor Europe. These analyses should help such investors or others use better analytical techniques to assess the merits of timberland investments and risk in most of the major western hemisphere continents in the world.

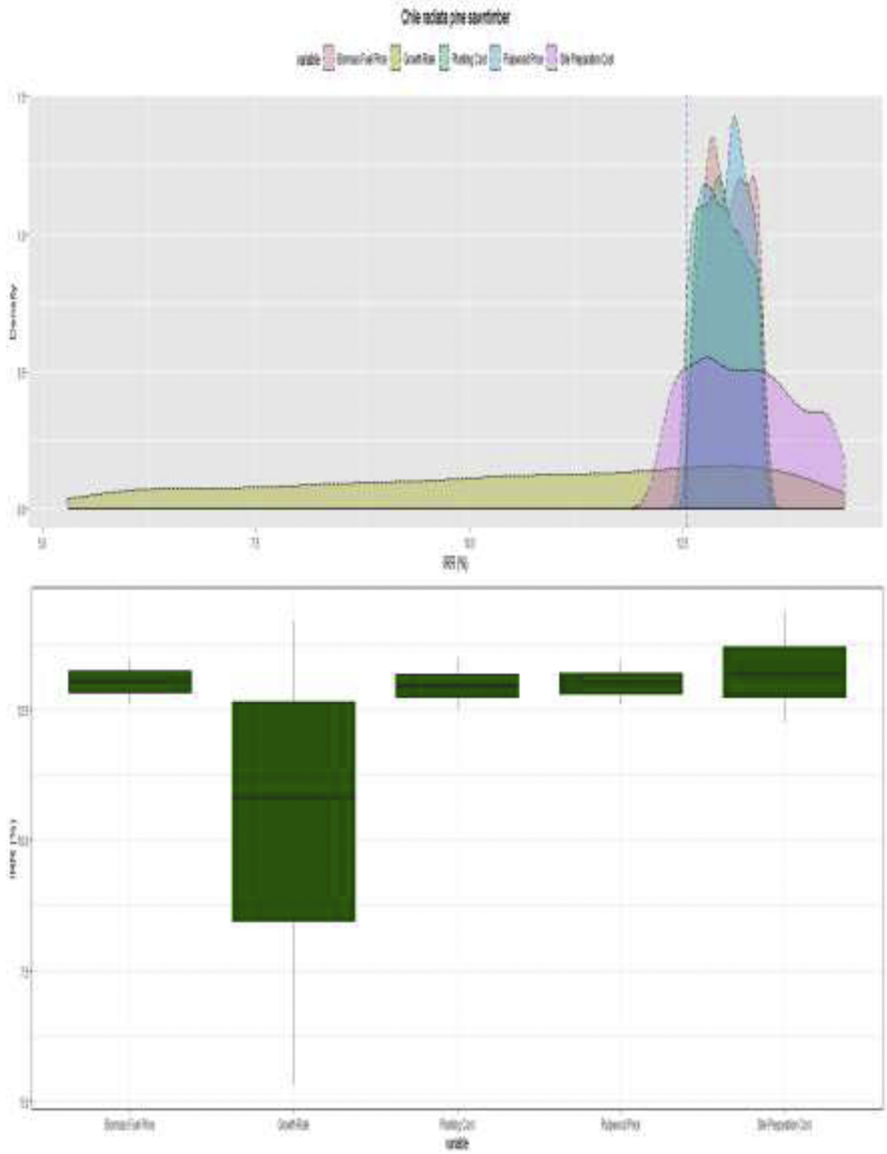
Declaration of Competing Interest

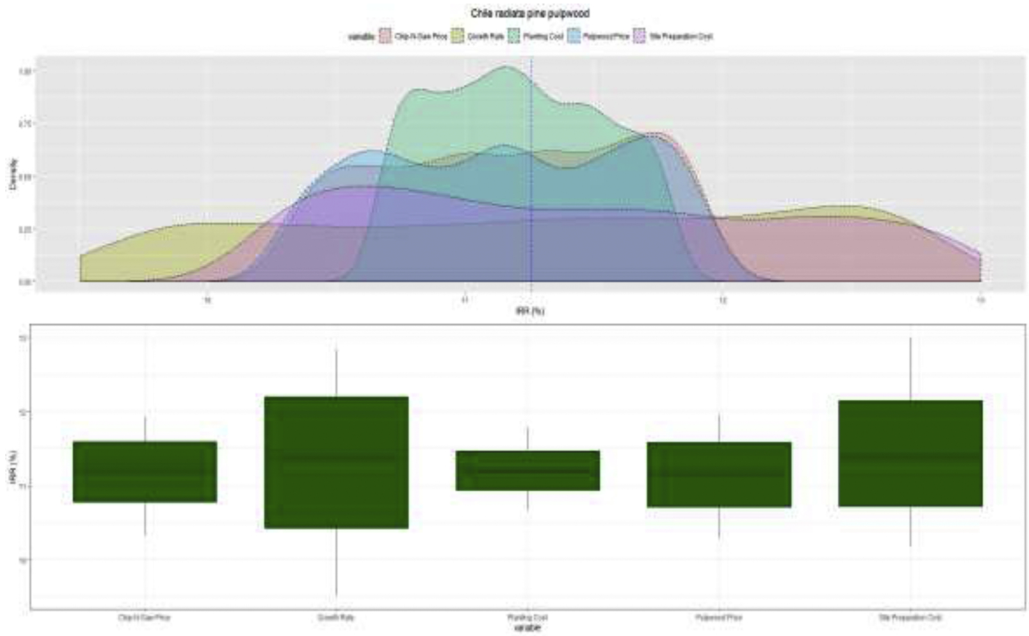
We confirm that this work is original and has not been published elsewhere, nor is it currently under consideration for publication elsewhere. We have no conflicts of interest to disclose.

Appendix A

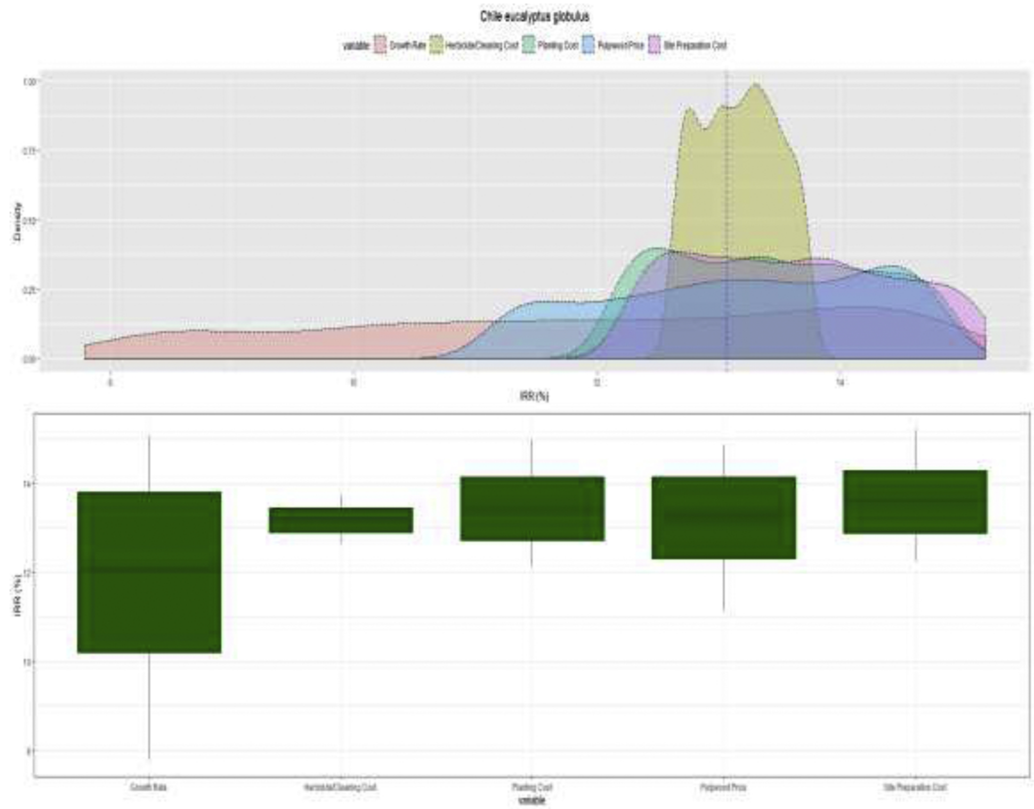
The impact of the five most decisive factors on IRR for each investment opportunity
Plots 3a,b–14a,b


Poland oak

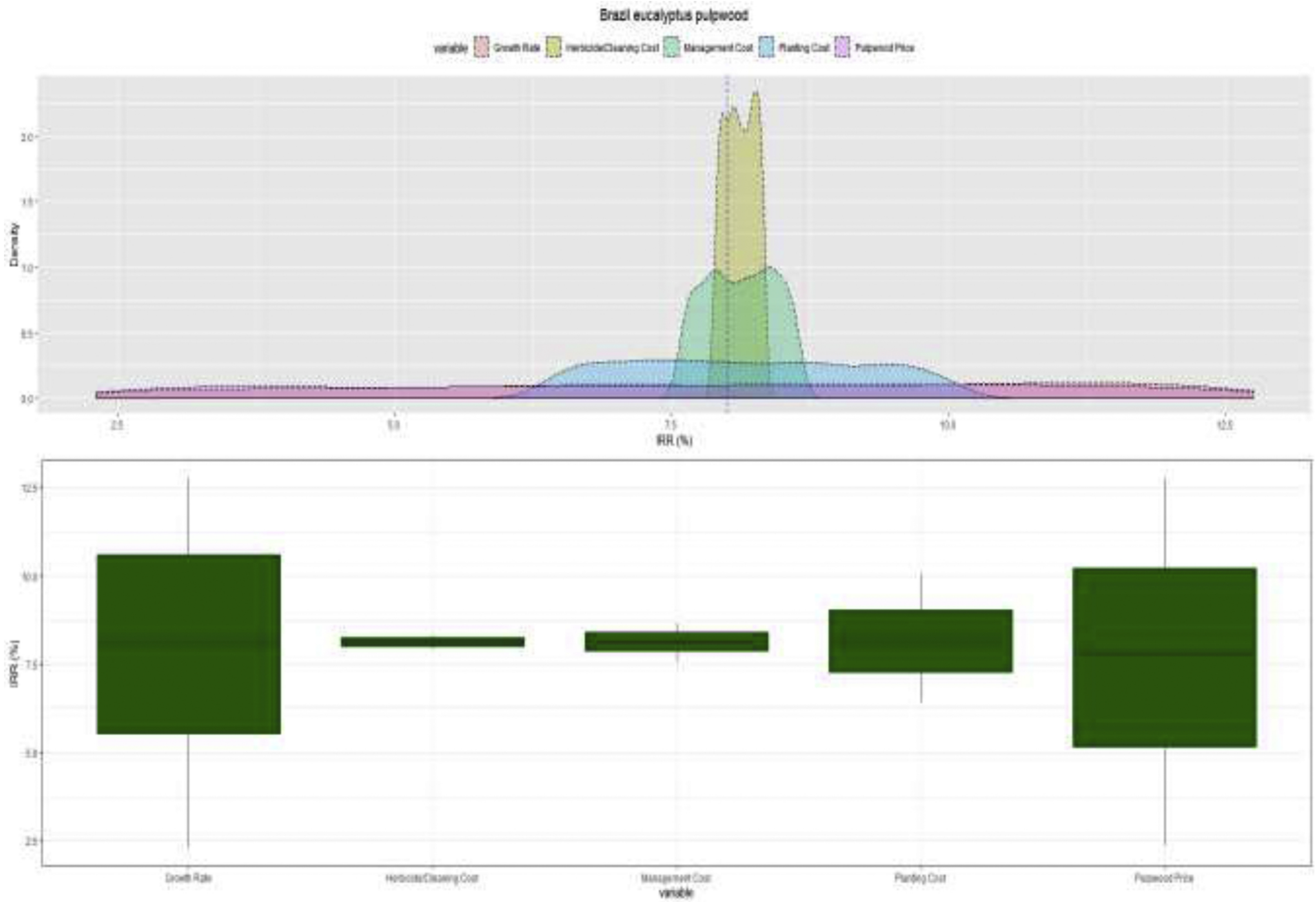

Chile radiata pine sawtimber

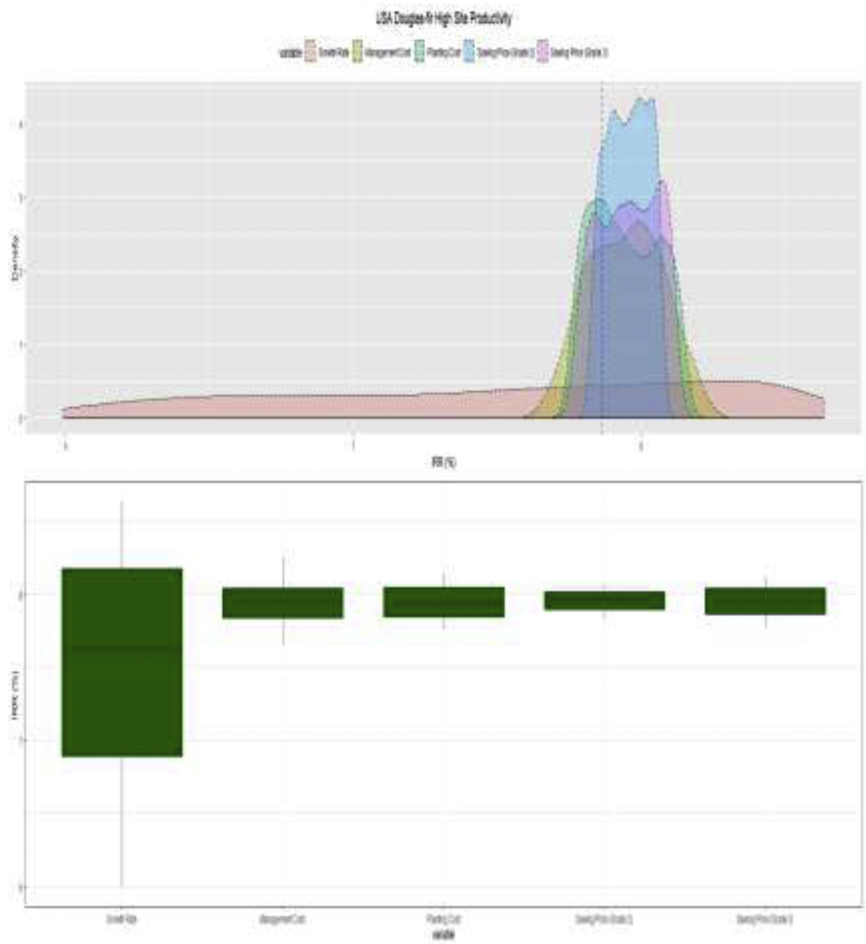

Chile radiata pine pulpwood
variable
Chip-N-Saw Price
Growth Rate
Planting Cost
Pulpwood Price
Site Preparation Cost
Density
IRR (%)
variable

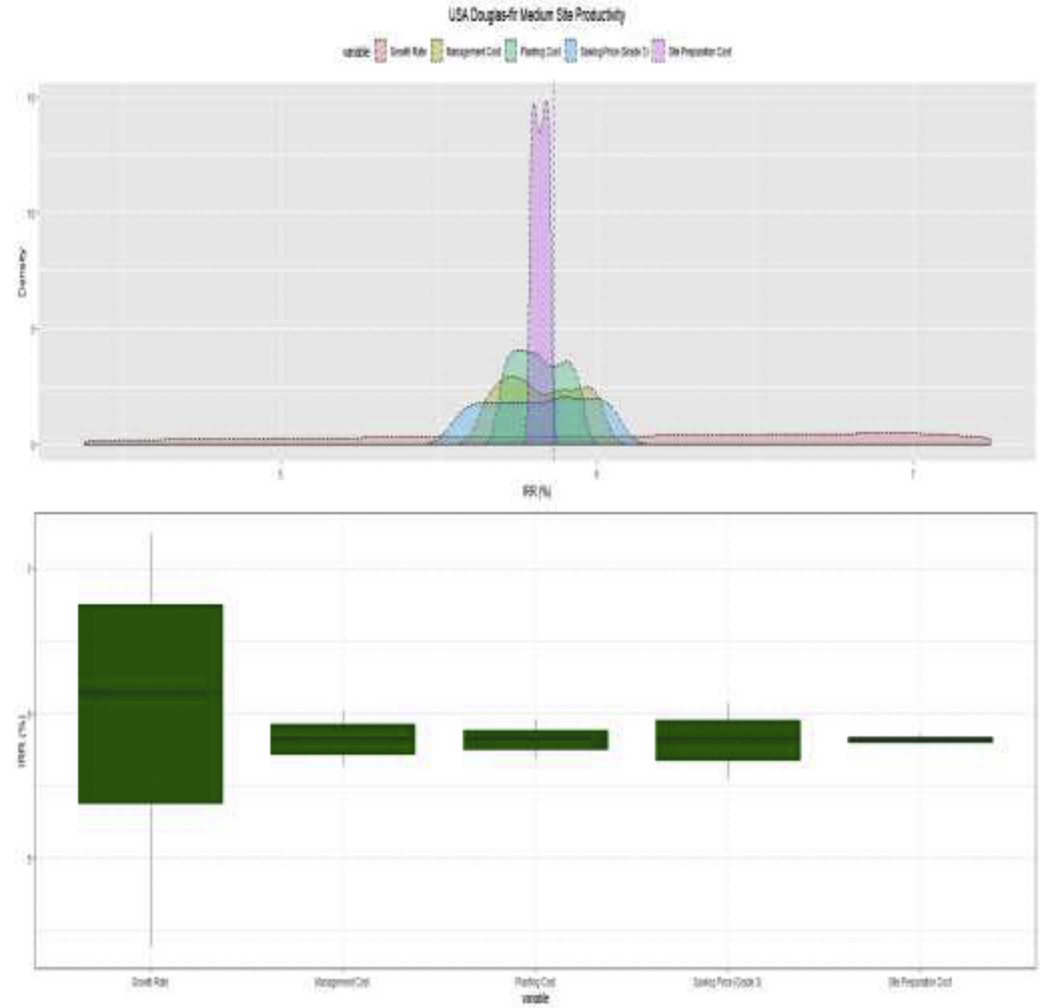

Chile eucalyptus nitens
variable
Growth Rate
Management Cost
Planting Cost
Pulpwood Price
Site Preparation Cost
Density
IRR (%)
variable


Chile eucalyptus globulus
variable
Density
IRR (%)
IRR (%)
variable

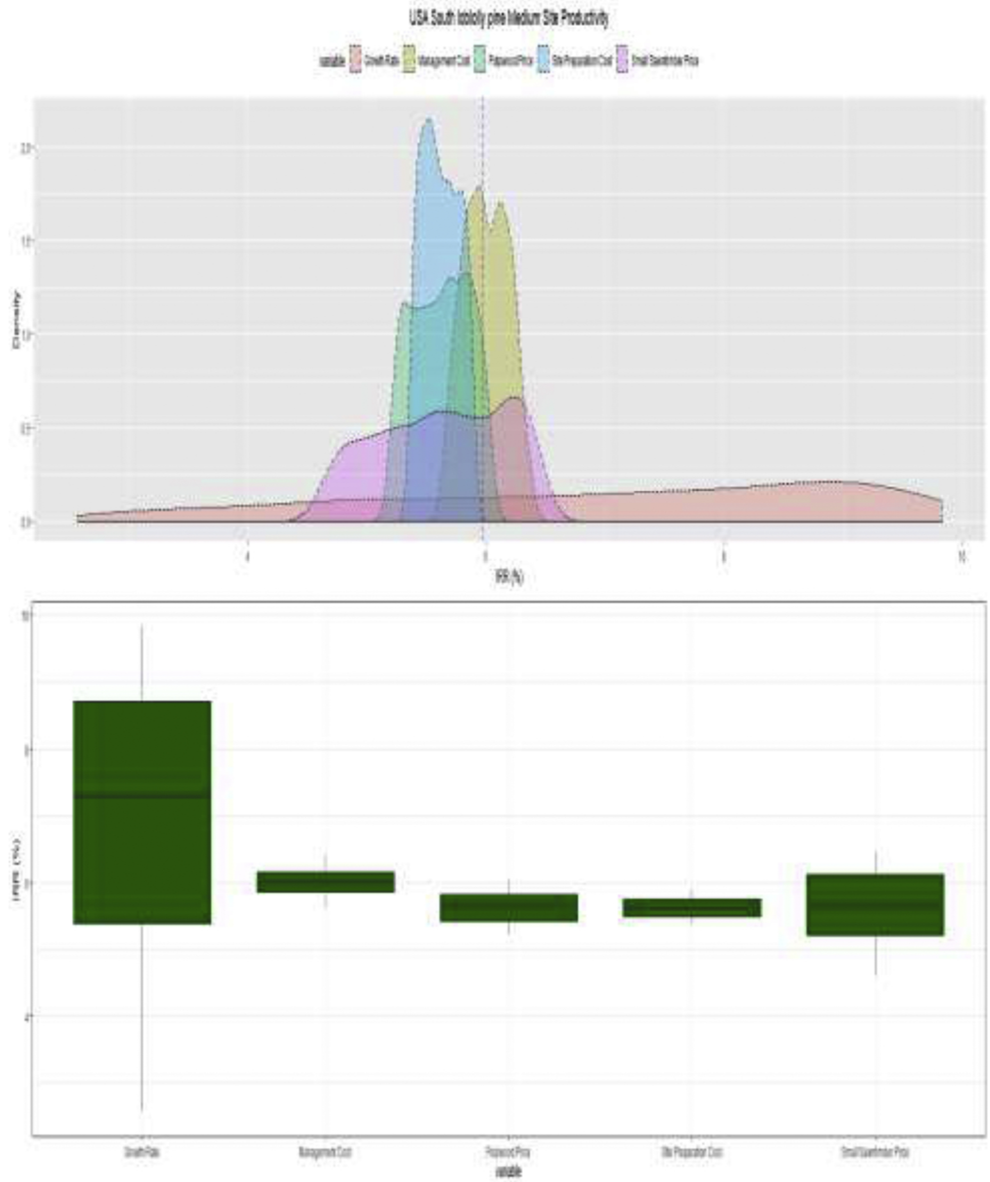

Brazil loblolly pine
variable
Density
IRR (%)
IRR (%)
variable

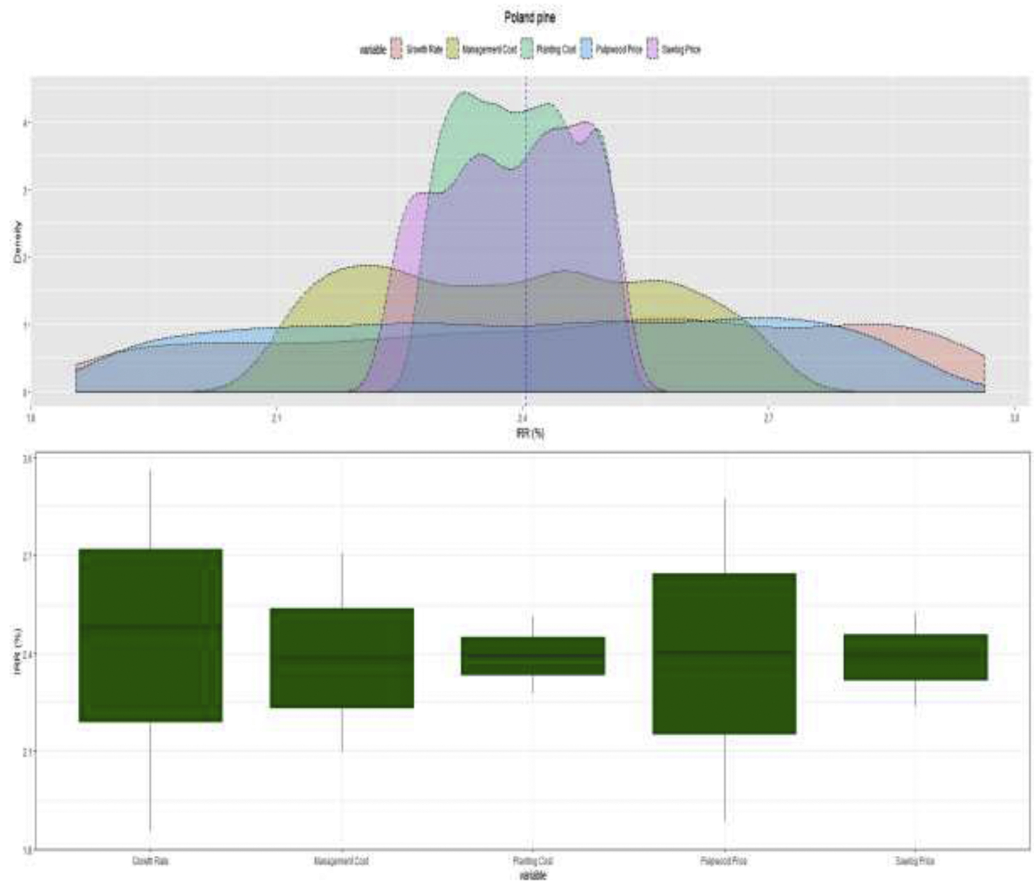

Brazil eucalyptus pulpwood
variable
Growth Rate
Herbicide/Cleaning Cost
Management Cost
Planting Cost
Pulpwood Price
Density
IRR (%)
variable


USA Douglas-fir High Site Productivity


USA Douglas-fir Medium Site Productivity
Density
IRR (%)
variable


USA South loblolly pine High Site Productivity
Density
IRR (%)
variable


USA South loblolly pine Medium Site Productivity
Density
IRR (%)
variable



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