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Carbon offset as another driver of timberland investment returns in the United States

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ABSTRACT

Timberland investment has three return drivers: biological growth, timber price change and land value appreciation. The interaction of the three drivers determines the total timberland investment returns. Recent public attention to climate change resulting from excessive greenhouse gas emissions, nonetheless, has led to more discussion of forests as a natural carbon sink. With carbon sequestration, landowners should be compensated for keeping trees alive. The cash flows associated with forest carbon present an opportunity for timberland investors to potentially generate extra returns. For an afforestation investment and at the current carbon price of about $20 per metric ton in the voluntary market, forest carbon has a moderate contribution of about 21% to the total timberland investment return with a return premium is about 115 basis points. However, for a regeneration investment in which only additional carbon sequestration beyond the baseline is credited, the impact of forest carbon on total timberland investment return is minor yet positive. Overall, the return contribution of forest carbon is positively related to carbon price, interest rate, and investment horizon. As the pressure from global warming tightens, demand for nature-based carbon storage tends to increase, leading to higher carbon prices. Meanwhile, concerns about additionality often result in longer-term carbon contracts. All these would boost the influence of forest carbon on total timberland investment returns in the future.

Keywords

alternative asset, climate change, forest carbon, return forecasting, uncertainty

Citation

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INTRODUCTION

It is well known in the forest investment field that timberland investment has three return drivers: biological growth, timber price change, and land value appreciation (Caulfield 1998). Biological growth includes both physical growth in total biomass volume and value growth from a lower- to a higher-valued product, e.g., from pulpwood to sawtimber. Hence, as trees grow, both the volume and value of timber increase. The independence of biological growth from the financial market makes timberland a unique asset class that offers diversifications in portfolio investments. Also, biological growth has the ability to buffer the negative impact of declining timber prices on timberland investment returns, and therefore protect investors during a lackluster timber market. It is found that biological growth is the dominant return driver, contributing more than 60% of the total timberland investment returns regardless of the timber market cycles (Caulfield 1998; Mei et al. 2013).

Timber price change refers to the variation of timber prices during the holding period of a timberland investment. Given the long-term nature of a timberland investment (typically more than 10 years, especially in the private-equity market), dramatic price changes are likely. For example, pine sawtimber prices peaked at around $45 per green ton in the late 1990s, primarily because of the reduced timber harvest in the west coast due to the spotted owl being listed as an endangered species. The shifted demand from the west to the south thus boosted stumpage prices in the southern timber market. In the last 15 years or so, however, pine sawtimber price has been gradually declining to about $25 per green ton because of extensive plantings as well as the supply overhang triggered by the most recent housing bubble during 2007-2009 (TMS 2023). Therefore, timber price can have either a positive or negative contribution to timberland investment returns depending on the time horizon under investigation.

Bare land, being a scarce resource, had an average value appreciation rate of about 5% between 1995 and 2010 (Mei et al. 2013). It is posited that available land is likely to further decrease due to an increasing global population and climate change, resulting in land value growing faster than inflation (Cubbage et al. 2020). Hence, this return driver partly explains timberland's capability in hedging against inflation, as found in Washburn and Binkley (1993) and Wan et al. (2013). Overall, land value appreciation contributes 6%-23% to total timberland investment returns contingent upon the state of the timber market (Caulfield 1998; Mei et al. 2013).

Forests not only produce fiber and fuel but also store the vast majority of the total terrestrial carbon. Indeed, covering 65% of the total land surface, forests retain 90% of the total vegetation carbon, hold 80% of the total soil carbon, and contain 67% of CO_2 assimilated from the atmosphere by all terrestrial ecosystems (Harris et al. 2021; Hou et al. 2020; Landsberg and Gower 1997; Sedjo and Sohngen 2012). In the last century, nonetheless, CO_2 concentration in the atmosphere has surged by more than 30% (Wenzel et al. 2016), which has been deemed as the primary cause of global warming. Consequently, more discussion has been devoted to forest carbon as a possible solution to climate change (Sohngen and Mendelsohn 2003; van der Gaast et al. 2018).

It is claimed that planting trees is the most cost-efficient way to reduce or remove atmospheric CO_2 than developing and implementing technologies or carbon taxes to reduce the emission of existent industries (Dang Phan et al. 2014; Li et al. 2022; Lin and Ge 2019). At least, carbon sequestration through forests can help stabilize atmospheric carbon in the next few decades, granting time for the advance of more fundamental technological solutions (Sedjo 2001). With respect to compensation to forest landowners, in the literature, carbon credits are typically recognized based on marginal forest growth, whereas a carbon release penalty incurs at the final harvest (e.g., Ning and Sun 2019; Sun et al. 2022). Therefore, incremental cash flows associated with forest carbon can affect the financial returns of a timberland investment.

In this study, a loblolly pine plantation in Georgia is used to demonstrate how forest carbon contributes to total timberland investment returns. Both afforestation and reforestation scenarios are analyzed. Results can help investors understand the role that forest carbon plays in timberland investments, and hence facilitate their return expectation and the design of the corresponding forest management practice. Given that managing forests to enhance carbon offset remains a strategy for mitigating future climate change (Grassi et al. 2017), this study can also help policy makers, investors, managers, landowners, as well as the general public understand the socioeconomic aspect of forest carbon programs and policies.

Voluntary carbon market

Pricing carbon provides a market-oriented solution to mitigate climate change and promote the transition to a circular economy. In general, carbon credits and carbon emission taxes are the two main market-based approaches for emission reductions. A carbon credit is a certificate of one ton of CO_2 equivalent that is prevented from emission or removed from the atmosphere, whereas a carbon emission tax is a tax levied by the government on emitters for each ton of emission. Here, carbon credits, especially voluntary carbon credits, are elaborated further.

Carbon credits can be based on either a mandatory (compliance) scheme or a voluntary system. A compliance carbon credit is issued through a compliance process and regulated by mandatory international, national, or regional carbon reduction regimes, such as Clean Development Mechanism, California's Compliance Offset Program, and Australia Emissions Reduction Fund. In contrast, a voluntary carbon credit is issued on a voluntary basis via an independent market program, such as Verified Carbon Standard, Gold Standard, and the American Carbon Registry, which can be purchased with no intended use for compliance purposes.

While compliance carbon credits might be purchased by non-regulated entities, voluntary carbon credits are not permitted to meet the compliance market demand unless they are accepted into the compliance regime. For instance, California's Compliance Offset Program allows up to 4% of compliance obligations to be fulfilled by voluntary carbon credits from nature-based climate solutions, whereas The European Union's Emissions Trading System does not allow such offset credits (Busby and Macpherson 2022). Some countries, e.g., Mexico and South Africa, also take offset credits from voluntary programs as an effective means of complying with carbon tax obligations (Carbon Offset Guide 2022).

The voluntary carbon market began to develop in 2005, as the Clean Development Mechanism became more recognized and the corporate social responsibility community started to realize the demand for offset credits beyond regulated companies and countries to the Kyoto Protocol (Carbon Offset Guide 2022). The market value of voluntary carbon has grown rapidly in the past few years to reach $1 billion in 2021 (Ecosystem Marketplace 2022). The financial services industry is the largest driver of demand, purchasing about 50% of all nature-based climate solutions, followed by the chemicals and oil and gas industries. Future demand for voluntary carbon credits will originate from decarbonization across all industries in the economy, which is estimated to be 2-13 gigatons per year by 2050, or 15-100 times as high as 2020 demand (Busby and Macpherson 2022).

The supply of voluntary carbon credits mainly comes from independent crediting mechanisms. The top two standards, Verified Carbon Standard and Gold Standard, accounted for more than 50% of all carbon credits issued between 2019 and 2021, with forestry and land use credits being the major sources of supply, contributing 40% of the total (Ecosystem Marketplace 2022). As aforementioned, the dominance of forestry and land use credits in the voluntary carbon market is primarily because of the proven technologies of such emission reductions and removals, and the lower cost. It is anticipated that independent crediting systems will continue to be the primary source of supply, given the rising demand for credits from net zero commitments and the increasing incorporation of independent standards into compliance schemes (Busby and Macpherson 2022).

Figure 1 describes the carbon crediting and sales process in the voluntary forestry and land use credit market. A carbon credit is an unusual commodity as its quality is challenging for market participants to assess. Thus, standard-setting organizations have been founded to control the quality of carbon offsets. In general, carbon offset programs have three functions (Broekhoff et al. 2019): (1) Developing and approving standards for the quality of carbon offset credits; (2) Reviewing and verifying carbon projects, often with the help of third-party verifiers; and (3) Operating registry systems that issue, transfer, and retire offset credits. In addition, brokers, exchanges, or retailers usually work with carbon offset programs to connect and match credit sellers and buyers.

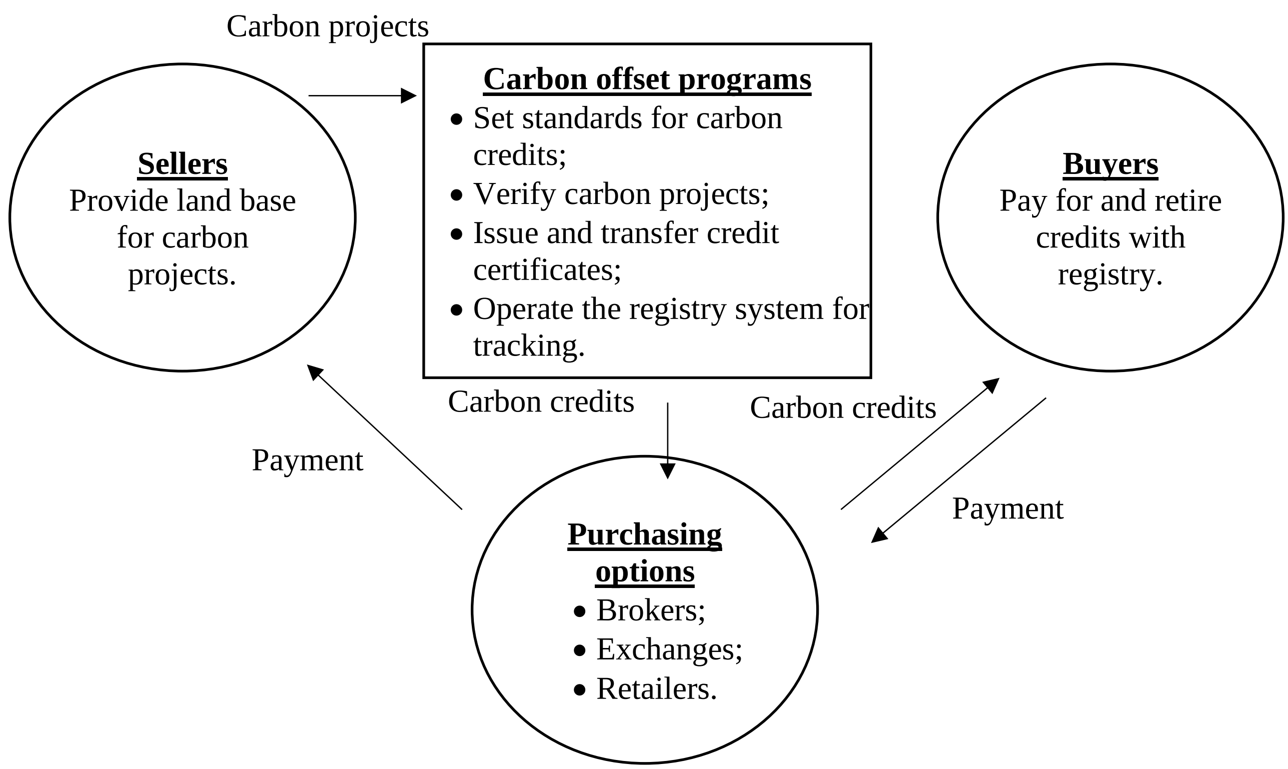


Figure 1. Carbon crediting and sales process in the voluntary forestry and land use credit market.

Regardless of the intermediate steps, eventually, offset credits flow from carbon sellers to buyers, and payments flow from carbon buyers to sellers when a carbon credit transaction is completed.

Specifically, credit sellers or participating landowners provide a land base for greenhouse gas reduction or removal projects. Once a carbon project is independently verified, the corresponding carbon offset program issues credit certificates and maintains a certificate registry for tracking. Credit buyers or greenhouse gas emitters pay for the certificates for carbon offsets and retire credits with the registry after their uses.

MATERIAL AND METHODS

The analysis is based on a loblolly pine plantation in the state of Georgia for both afforestation and reforestation opportunities. Timber yield data are generated from the Plantation Management Research Cooperative forest growth and yield simulator with a site index of 65 for a base age of 25 and a planting density of 680 trees per acre (PMRC 2022). Such a loblolly pine plantation is representative of the region, as the average site index of timberland in the US South is about 60-80 (Gopalakrishnan et al. 2019; Zhao et al. 2016a). According to TimberMart-South's delineation of timber products by the diameter at breast height, total timber yield is divided into three products as pulpwood (6 inches and up), chip-n-saw (8 to 11 inches), and sawtimber (12 inches and up) (TMS 2023). Marginal yield is the annual change in total yield.

The return analysis is for a 15-year investment horizon, acquiring the loblolly pine plantation at age 15 and divesting it at age 30. Annual return (R) from inception is calculated as the geometric mean $R = \sqrt[T]{V_T / V_0} - 1$, where the acquisition cost (V_0) includes the values of both the stumpage and the bare land, while the proceeds from the disposition (V_T) includes the values of the stumpage, the bare land, and forest carbon, and T is the holding period in years. Total stumpage value is timber price times yield and summed up across the three products. Timber prices are obtained from TimberMart-South (TMS 2023). Bare land value is assumed to be $800 per acre at the inception year and grows with inflation at 2% per year (Cubbage et al. 2020; Mei et al. 2013). All values are nominal.

Annual carbon credit is calculated as marginal forest carbon (annual incremental carbon sequestered in the forest) multiplied by carbon price. A carbon price of $20 per metric ton (or $5.45 per ton of CO_2 equivalent) is used built on recently traded prices in the voluntary market for forestry and land use carbon credits (Donofrio et al. 2021; Ecosystem Marketplace 2022).

To calculate total aboveground weight of forest carbon, Equation 1 is used.

$$W_C = TY \times BEF \times (1 - MC) \times CT \tag{1}$$

where W_C is forest carbon in metric tons, TY is total yield of timber in green tons, BEF is biomass expansion factor (the ratio of forest biomass to timber biomass), MC is moisture content, and CT is carbon content. Based on the literature (PMRC 2022; Smith et al. 2006; Zhao et al. 2016b), the following parameter values are used: BEF = 1.20, MC = 0.54, and CT = 0.47.

At harvest, some carbon is released back from the forest biomass into the atmosphere. Following Creedy and Wurzbacher (2001) and Ning and Sun (2017), a carbon release factor of 0.65 is used in this study. That is, 65% of forest carbon is emitted during the clear cut. As such, the total carbon value is calculated as the net future value (NFV) of annual carbon payment up till the final harvest minus the value from carbon release, as shown in Equation 2,

$$TCV(T) = \sum_{1}^{T} CR_t (1+r)^{T-t} - CRP_T \tag{2}$$

where $TCV(T)$ is the total carbon value up to year T, CR_t is carbon credit at year t, r is the discount rate, and CRP_T is the carbon release penalty for the harvest at year T. For timberland investment in the US South, a nominal discount rate of 5% is used in this study (Buongiorno and Zhou 2020; Cascio and Clutter 2008; Sun et al. 2022).

In the static analysis, an investment window of 2006-2021 is examined with actual timber prices in Georgia used for the return analysis. This allows us to study the historical returns of investing in loblolly pine plantations. Looking forward, a Monte Carlo simulation is conducted with the inception year of 2021. A Monte Carlo simulation is a computational algorithm in which iterative random sampling is used to get numerical results. The logic is to make use of randomness to solve problems that might be deterministic in nature so that uncertainty is incorporated into the simulation. The dynamic analysis facilitates our expectation of future timberland investment returns.

The initial timber prices are set to be those in 2021, i.e., \$15.13 per green ton for pulpwood, \$22.34 per green ton for chip-n-saw, and \$28.96 per green ton for sawtimber. For future timber prices, both random walk and mean-reverting processes are considered, given the mixed findings of timber price behavior in the literature (Mei et al. 2010). A random walk is a mathematical formulization of a trajectory that takes successive random steps. It is a widely used stochastic process in financial and economic analysis when the market is efficient. In this study, random timber prices are modelled by a geometric Brownian motion shown in Equation 3,

$$dP_t = \alpha P_t dt + \sigma P_t d\omega_t \tag{3}$$

where P_t is timber price at time t, dP_t is the instantaneous change of timber price for an infinitesimal change in time, α and σ are the drift and volatility parameters, and $d\omega_t$ is the increment of a Wiener process, i.e., $d\omega_t = \varepsilon_t \sqrt{dt}$ with ε_t being standard normal. Mean-reverting timber prices are modelled by a modified Ornstein-Uhlenbeck process shown in Equation 4,

$$dP_t = \eta(\bar{P} - P_t)dt + \delta P_t d\omega_t \tag{4}$$

where $\bar{P}$ is the long-run equilibrium level that timber prices revert to, η is the speed of reversion, δ is the volatility parameter, and others are similarly defined as in Equation 3. The modified Ornstein-Uhlenbeck process differs from the geometric Brownian motion in the drift parameter. The former has a constant drift, whereas the sign of the latter's drift depends on the deviation of the current price to the long-term mean. The key parameter values for the geometric Brownian motion and the modified Ornstein-Uhlenbeck process are summarized in Table 1.[1] Considering the linkages among different markets, price correlations among the three timber products are also built into the simulation.

The starting bare land value is assumed to be $800 per acre (Mei et al. 2013). For future bare land values, the mean is again assumed to hedge an expected inflation of 2% per year, while the lower and upper limits are 5% below and above the mean in a triangular distribution. This allows us to examine the impact of most likely bare land values on investment returns. Likewise, timber yield is simulated by a triangular distribution with the most likely values being those in the static analysis and the maximum and minimum values being 5% above and below the most likely values. The starting carbon price is assumed to be $20 per metric ton. Future carbon price is assumed to follow a random walk process with a drift rate of 0.010 and volatility of 0.050. Given the emerging status of the voluntary carbon market in the U.S., this specification provides a conservative outlook of the carbon price.

[1] The technical details of estimating the parameters of the random walk and mean-reverting processes are omitted here but are available in Mei et al. (2013).

Table 1. Parameter estimates for random and mean-reverting timber prices.

	Pulpwood	Chip-n-saw	Sawtimber
Random walk (Geometric Brownian motion)			
Drift	0.042	0.026	0.036
Volatility	0.210	0.174	0.166
Mean-reverting (Modified Ornstein-Uhlenbeck process)			
Mean-reverting speed	0.254	0.189	0.150
Long-term mean	10	23	33
Volatility	0.207	0.172	0.163
Correlation			
Pulpwood	1		
Chip-n-saw	0.8	1	
Sawtimber	0.4	0.6	1

RESULTS AND DISCUSSION

Columns 2-4 of Table 2 lays out the timber yield in green tons per acre in three products from the loblolly pine plantation. Column 5 is the total yield or the sum of yield by product in green tons per acre. Column 6 is the marginal yield or the annual change in total yield in green tons per acre. Columns 7-9 are timber prices in dollars per green ton in Georgia during 2006-2021. Column 10 is the total timber value in dollars per acre. Column 11 is the bare land value in dollars per acre. Column 12 is carbon weight in metric tons. Column 12 is carbon payment in dollars per acre. Column 14 shows the net future value of annual carbon payments in dollars per acre, up to age T compounded at an interest rate of 5%.[2] Column 15 is the value of carbon release at harvest in dollars per acre. Column 16 is the total forest value with carbon in dollars per acre, or timber value (Column 10) plus land value (Column 11) plus NFV of carbon credits (Column 14) minus carbon release (Column 15) for age 16-30. Similarly, Column 18 is the total forest value in dollars per acre without carbon, or timber value (Column 10) plus land value (Column 11). Columns 17 and 19 are the average annual returns from the inception in percentage with and without forest carbon.

[2] The value of $352.2 per acre at age 15 is net future value of all carbon credits from age 1 to 15. It is assumed that the seller transfers all carbon credits up till age 14 to the buyer, and thus is not subject to carbon release penalty at harvest. Timber yield data for age 1-14 are not shown here but are available from the author upon request.

Table 2. Return analysis based on an investment in a loblolly pine plantation.

	Timber yield green tons/acre					Timber price $/green ton			Timber Value $/acre	Land value $/acre	Carbon				With carbon		Without carbon	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Age	PW	CNS	ST	Total	Mar-ginal	PW	CNS	ST			Wei-ght	Credit	NFV	Rel-ease	Total value	Return	Total value	Return
15	69.3	18.5	0.0	87.8	8.8	6.7	25.5	45.6	933	800	2.28	45.7	352.2		1734		1734	
16	71.9	24.2	0.0	96.1	8.3	7.1	19.8	39.6	989	816	2.15	43.1	412.9	324.1	1894	-9.27	1806	4.15
17	73.5	30.1	0.4	104.0	7.9	7.2	16.6	32.6	1045	833	2.05	41.0	474.6	350.8	2002	7.46	1878	4.08
18	74.4	36.4	0.7	111.5	7.5	8.6	15.6	28.8	1229	849	1.95	38.9	537.2	376.1	2239	8.90	2078	6.22
19	74.6	42.8	1.3	118.7	7.2	10.8	17.9	31.4	1613	866	1.87	37.4	601.4	400.3	2681	11.51	2480	9.36
20	74.4	49.1	2.0	125.5	6.8	9.7	15.2	25.8	1515	884	1.76	35.3	666.8	423.3	2642	8.79	2398	6.71
21	73.7	55.3	3.1	132.1	6.6	10.1	15.3	24.6	1667	901	1.71	34.3	734.4	445.5	2857	8.68	2568	6.77
22	72.8	61.2	4.5	138.5	6.4	12.3	18.0	29.5	2134	919	1.66	33.2	804.3	467.1	3391	10.06	3054	8.42
23	71.5	66.7	6.2	144.4	5.9	14.9	20.7	30.1	2631	938	1.53	30.6	875.1	487.0	3957	10.86	3568	9.44
24	70.1	71.7	8.4	150.2	5.8	14.8	21.4	28.6	2811	957	1.50	30.1	949.0	506.6	4211	10.36	3768	9.01
25	68.5	76.1	11.0	155.6	5.4	14.3	20.9	26.6	2863	976	1.40	28.0	1024.4	524.8	4338	9.61	3838	8.27
26	66.8	79.9	14.1	160.8	5.2	13.5	20.3	26.7	2903	995	1.35	27.0	1102.6	542.3	4459	8.97	3898	7.64
27	65.0	83.1	17.7	165.8	5.0	13.9	20.2	28.3	3084	1015	1.30	25.9	1183.7	559.2	4724	8.71	4099	7.43
28	63.2	85.6	21.8	170.6	4.8	15.0	20.8	27.5	3328	1035	1.25	24.9	1267.8	575.4	5056	8.58	4364	7.36
29	61.4	87.5	26.3	175.2	4.6	13.2	20.5	27.0	3312	1056	1.19	23.9	1355.1	590.9	5132	8.06	4368	6.82
30	59.6	88.7	31.3	179.6	4.4	15.1	22.3	29.0	3790	1077	1.14	22.8	1445.7	605.7	5707	8.27	4867	7.12

Note: PW for pulpwood, CNS for chip-n-saw, and ST for sawtimber. Timber prices (Columns 7-9) are those for Georgia during 2006-2021 reported by TimberMart-South. Carbon weight (Column 12) is in metric tons per acre, and the carbon price is fixed at $20 per metric ton. Net future value in dollars per acre (NFV, Column 14) is calculated at an interest rate of 5% for annual carbon payments up to age T. The value of $352.2 per acre at age 15 is the net future value of all carbon credits from age 1 to 15. It is assumed that the seller transfers all carbon credits up till age 14 to the buyer, and thus is not subject to carbon release penalty at harvest. Timber yield data for age 1-14 are not shown here but are available from the author upon request. Carbon release in dollars per acre (Column 15) is 65% of total forest carbon value at harvest. Total forest value with carbon in dollars per acre (Column 16) is timber value (Column 10) plus land value (Column 11) plus NFV (Column 14) minus carbon release value (Column 15) for age 16-30. Total forest value without carbon (Column 18) is timber value (Column 10) plus land value (Column 11). Return (Columns 17 and 19) is annual return from inception in percentage.

The initial investment cost ($1,734 per acre) includes those for timber ($933 per acre) and land ($800 per acre). At exit, the total cash inflows are $5,707 per acre with forest carbon and $4,867 per acre without forest carbon, respectively. Therefore, with forest carbon, the average annual return is $(5{,}707 / 1{,}734)^{(1/15)} - 1 = 8.27\%$, or 115 basis points higher than the $(4{,}867 / 1{,}734)^{(1/15)} - 1 = 7.12\%$ return without forest carbon. The breakdown of each return driver's contribution over 15 years is shown in Table 3.

Table 3. Breakdown of each driver to total timberland investment returns.

	Total value	Biological growth and timber price	Biological growth	Timber price	Land	Carbon
With carbon						
Age 15	1,734	933	933	–	800	–
Age 30	5,707	3,790	4,089	–	1,077	–
Change	3,973	2,857	3,156	-299	277	840
Contribution	100.00%	71.89%	79.43%	-7.54%	6.97%	21.14%
Without carbon						
Age 15	1,734	933	933	–	800	–
Age 30	4,867	3,790	4,089	–	1,077	–
Change	3,133	2,857	3,156	-299	277	–
Contribution	100.00%	91.16%	100.72%	-9.56%	8.84%	–

Note: Carbon contribution corresponds to carbon credits accumulated over age 1-30. It is assumed that the seller transfers all carbon credits up till age 14 to the buyer, and thus is not subject to carbon release penalty at harvest.

Total value change with carbon between age 30 and 15 is 5,707 – 1,734 = $3,973 per acre. Out of the total, the interaction between biological growth and timber price change contributes 3,790 – 933 = $2,857, land value appreciation contributes 1,077 – 800 = $277, and carbon contributes $840, or 71.89%, 6.97%, and 21.14%, respectively. Then, the contribution of biological growth is separated from that of timber price change as follows. First, timber prices are fixed at their levels of year 2006 (age 15). That is, if timber prices were constant, timber value at age 30 would be $59.6 \times 6.7 + 88.7 \times 25.5 + 31.3 \times 45.6 = \$4{,}089$ per acre. So, the pure contribution from biological growth would be 4,089 – 933 = $3,156 per acre. Then, timber price change should have contributed 2,857 – 3,156 = -$299 per acre. In percentage, biological growth and timber price change have respective contributions of 79.43% and -7.54%. Each return driver's contribution is demonstrated in Figure 2.

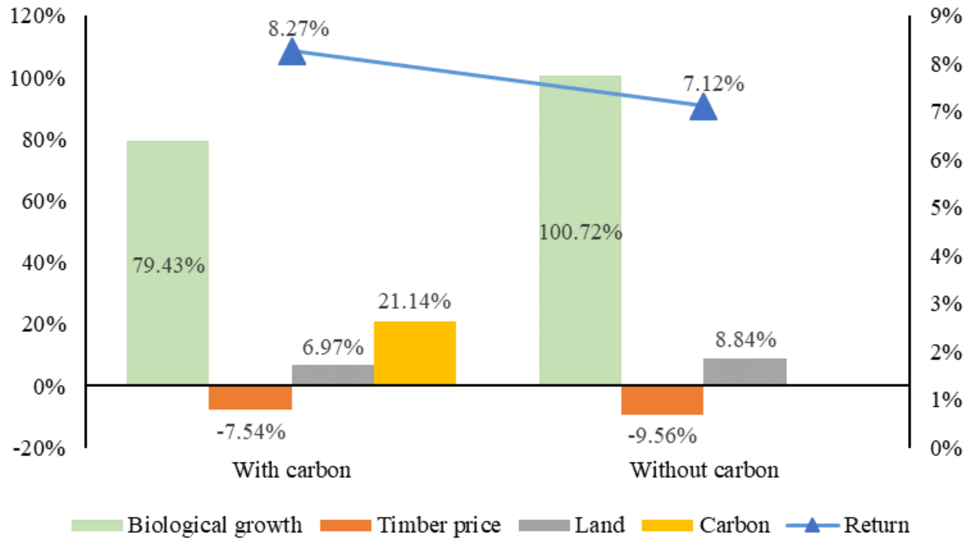


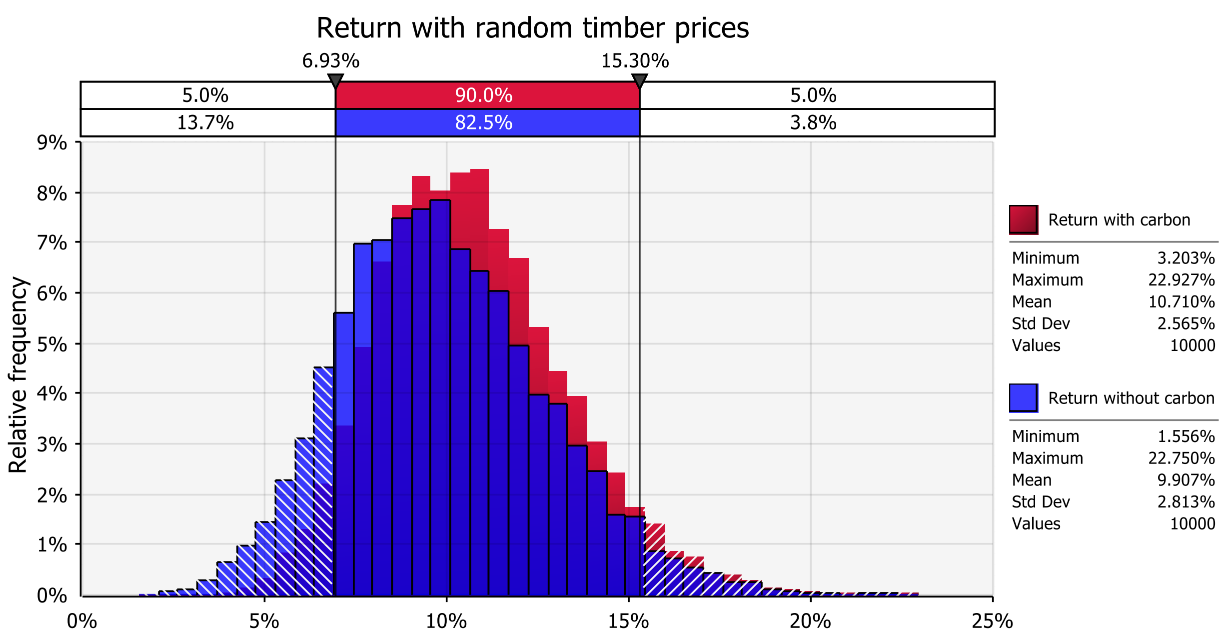
Figure 2. Contribution of each return driver (left Y-axis) to the annualized return (right Y-axis) on an afforestation investment of a loblolly pine plantation over 2006-2021.

Next reported are results from the sensitivity analysis on the key variables. When carbon price increases from \$20 to \$30 per metric ton, the average annual return with carbon increases to 8.33%, and the contribution of carbon rises to 8.84%. When the interest rate increases to 6%, the average annual return with carbon increases to 8.51% and the contribution of carbon rises to 24.85%. When the investment horizon is lengthened from 15 to 20 years (i.e., between age 10 and 30), the average annual return with carbon increases to 8.73% and the contribution of carbon is 18.12%.

With a total of 10,000 iterations, simulated returns for future investment in a loblolly pine plantation under the same framework as the static analysis are presented in Figure 3. When timber prices are random, the average annual return with carbon from the inception in 2022 has a mean of 10.71% with a standard deviation of 2.57%, while the return without carbon has a mean of 9.91% with a standard deviation of 2.81%. When timber prices are mean-reverting, the return with carbon has a mean of 7.18% with a standard deviation of 0.17%, while the return without carbon has a mean of 6.83% and a standard deviation of 0.12%. Therefore, carbon tends to enhance the return as well as reduce the risk of future timberland investment if timber prices are random, whereas carbon increases both return and risk of future timberland investment if timber prices are mean-reverting. Compared with the timber-only scenario, the return premium of forest carbon is about 35-80 basis points, less than that in the static analysis. Overall, timberland investment returns are higher but more volatile, with or without carbon, when timber prices are random rather than mean-reverting.

Regarding the contribution of forest carbon to the total timberland return, the mean is 14.06% with a standard deviation of 6.46% when timber prices are random, while the mean is 20.73% with a standard deviation of 1.88% when timber prices are mean-reverting. Thus, carbon tends to play a more important role in generating returns if timber prices are mean-reverting. Nevertheless, in either scenario, the mean contribution of carbon is less than that in the static analysis.

The above analysis corresponds to an afforestation investment, in which all carbon sequestered is additional. In case of a reforestation investment, a baseline needs to be defined first. With a regeneration cost of $300 per acre, a discount rate of 5%, and average stumpage prices of $10 per green ton for pulpwood, $20 per green ton for chip-n-saw, and $25 per green ton for sawtimber, the optimal rotation is determined to be 27 years. That is deemed to be business as usual without forest carbon, and the corresponding net present value of cash flows (cash inflows for marginal carbon sequestration and cash outflows for carbon release penalty at harvest) associated with forest carbon can be calculated, which serves as the baseline carbon sequestration.



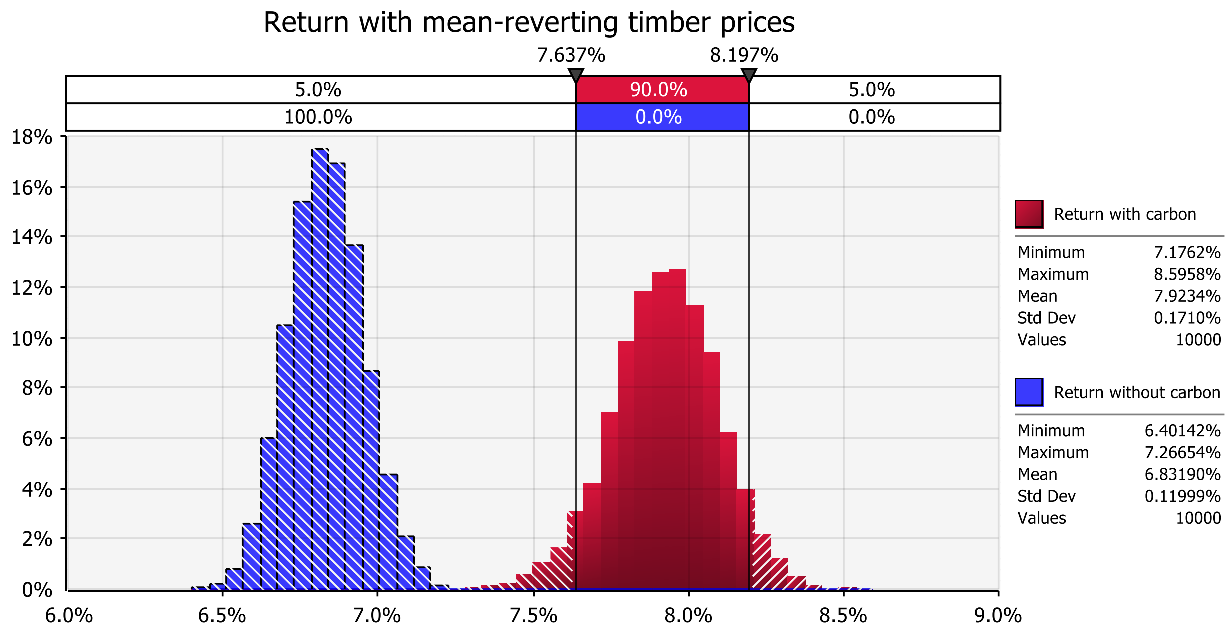


Figure 3. Simulated average annual returns from an investment in a loblolly pine plantation.

With the current investment strategy, the loblolly pine plantation will be held till age 30, or three more years than optimal. Then, additionality is calculated as the difference between the net present value of forest carbon for 30 years and the baseline, which is $27 per acre in present value or $117 per acre in future value at year 30. Further, assuming this externality is fully internalized, the additional value of carbon sequestration ($117 per acre) is added to the stumpage and land value of the plantation at age 30 to back out the total exit value for this 15-year holding period. Accordingly, the annualized return is calculated to be 7.29%, or 17 basis points higher than the benchmark 15-year timberland investment without forest carbon. When additionality is addressed in the reforestation scenario, forest carbon has a much less impact on total timberland investment returns.

CONCLUSIONS

As an alternative asset, timberland has three return drivers that traditional timberland investors are familiar with. These are biological growth, timber price change and land value appreciation. The interaction of the three drivers determines the total timberland investment returns, from more than 14% per year during the late 1990s when timber prices soared to their record high to less than 7%

per year in the 2010s when timber prices are mostly flat or declining (Caulfield 1998; Mei et al. 2013). Recent public attention to climate change resulting from excessive greenhouse gas emissions has led to more discussion of forests as a natural carbon sink. With forest carbon being a public good, the externality needs to be internalized for landowners to provide such an ecosystem service. The cash flows associated with forest carbon present an opportunity for timberland investors to potentially generate extra returns, which has been examined here using a loblolly pine plantation with a 15-year holding horizon for both afforestation and reforestation scenarios.

At the current price of about $20 per metric ton in the voluntary market, forest carbon has a moderate contribution of 21% to the total return of an afforestation investment, with a corresponding premium of about 115 basis points. For a reforestation investment, however, the contribution of forest carbon to total investment return is lower at 17 basis points when only additional carbon sequestration is accounted for. Therefore, forest carbon has a moderate to minor impact on total timberland investment returns. Furthermore, the contribution of forest carbon to total timberland investment returns is positively related to carbon price, interest rate, and investment horizon. As more efforts are made toward greenhouse gas mitigation, demand for nature-based carbon storage would increase, pushing carbon price higher. In addition, concerns about additionality often require an extended forest rotation (Sedjo and Sohngen 2012). All these are expected to increase the impact of forest carbon on future timberland investment returns.

In principle, additionality is defined by the difference in the carbon storage between the current model and the business as usual or the baseline model (e.g., Kerchner and Keeton 2015; Nepal et al. 2013). However, the choice of the baseline model may differ in the empirical analyses, resulting in different conclusions. Regardless, cash flows associated with forest carbon will be reduced when additionality is addressed, leading to a lower percentage contribution as well as a lower premium of forest carbon to total timberland investment returns. In addition, carbon released from the harvest can be stored in wood products, from short-lived (e.g., pulp and paper) to longer-term (e.g., lumber and panel) pools, and ultimately disposed as solid waste in landfills. Therefore, the life cycle and the substitution effect of forest carbon in wood products on timberland investment returns deserve further investigation.

The ability of timberland to simultaneously produce timber products and carbon credits provides investors further diversification benefits as the carbon market is not much correlated with other financial or commodity markets (Yuan and Yang 2020). Moreover, managing forest carbon does not necessarily reduce commercial timber values significantly in many cases (Sun et al. 2022), or the inclusion of monetized carbon credits can more than offset the decline in the profit from timber production (Mei and Clutter 2022). Hence, forest carbon remains a viable option for timberland owners or investors, especially when the voluntary carbon market is still in its merging status with many speculations and when carbon price is volatile. Looking forward, improved transparency, credibility, accountability, integrity, and standardization across carbon offset programs and market participants will facilitate carbon credit transactions and ultimately play a crucial role in the future growth of the voluntary carbon market.

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CONFLICT OF INTERESTS

The author declares no conflict of interest.

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