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THE BIOLOGICAL BOND:

TIMBERLAND INVESTMENTS AS FIXED-INCOME INSTRUMENTS

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Executive Summary

Timberland investment can be categorized into a variety of asset classes. Among them, we can argue that timberland belongs in fixed income. Like a bond, timberland can provide a schedule of cash payments throughout its investment term. These cash payments are based on the biological growth and harvest of timber. Since tree growth can be projected with a reasonable degree of accuracy and is not influenced by outside market forces, it can be argued that timberland behaves more like a bond than a stock. Another similarity to fixed income instruments is that timber prices move inversely to interest rates, duration and risk. Furthermore, the passive and active strategies that are used in the management of fixed income portfolios can be applied directly to forest assets. For example, passive strategies that bonds and timberland share include asset allocation, diversification, and immunization. A number of active bond strategies that take advantage of inefficiencies in the market can be applied to forest investments as well. What differentiates timberland investments from fixed income instruments is that unlike bonds, timberland investors can actually have a direct influence on the returns. Knowing how to grow trees faster and better can be considered an inefficiency that can be unlocked.

Introduction: Can Timberland be Considered a Bond?

A New Asset class

When someone mentions timberland, what comes to mind? For many of us, it conjures up the image of thousands of acres of forest owned by lumber and paper companies. These are the forests that firms like Weyerhaeuser and International Paper own and manage in order to supply their lumber and paper mills.

That image is becoming an anachronism in the 21st century. The truth is paper and forest product companies only own about 13 percent of the 503 million acres of timberland in the United States.[1] Taking out the 29 percent in public lands, that leaves 58 percent in the hands of non-industrial landowners, or NILs. These NILs include private and institutional investors who hold

[1] *2000 Resource Planning Act Assessment*, USDA Forest Service.

forestland not for personal enjoyment, but to receive a financial return. That number will only grow in the years ahead as forest product companies divest their forest assets to focus on their core business of manufacturing.

The new emerging owner of timberland is the investor – both the private individual and the institutional investor. Notable examples of the latter include the Harvard Management Company, which manages Harvard University's $17.5 billion endowment, and the California Public Employees' Retirement System (CalPERS), which is the largest U.S. public employee pension fund with $166 billion in assets.[2] Such investors as a group are estimated currently to hold $10 billion worth of timberland in the U.S. and $12 billion worldwide.[3] However, timberland has gained acceptance as an investment asset class only in the past two decades. As a fairly new asset class, investors often carry widely divergent views of how to categorize it in their portfolios. Depending on whom you ask, you can find it placed in a wide range of investment categories. Private equity, real estate, natural resources and alternative investments are some of the popular choices. While not immediately obvious, some investors classify it as fixed-income. In other words, timberland can be thought of as a bond.

Seeing the Bonds from the Trees

Relating timberland to the fixed-income asset class sounds strange at first, but it actually makes sense upon closer examination. At its core, what is a bond? Functionally, a bond is a claim on a specified periodic stream of income. Timberland, being a biologically growing asset, is well suited for such a role. When you hold timberland, the trees grow and are harvested, thus generating income. As long as you do not over harvest, the forest asset will retain its value; hence, at the end of the investment term, the investor regains the "principal" from the sale of the timberland, just as he or she would with a typical bond.

What makes timberland more like a bond than a stock is that forest science has the ability to project the growth

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[2] For June 30, 2004

[3] These investments are commonly made through an investment advisor known in industry parlance as timberland investment management organizations or TIMOs.

and harvest of trees for many years in advance. Tree growth and harvests, of course, form the basis of value and income, respectively, for a timberland asset. Since trees grow independently of any market or economic factors, we can have a reasonable degree of confidence in projected cash flow streams given expected trends in timber prices.

While the ability to project future cash flows makes timberland like a bond, there are certain features that make timberland unlike a bond. We need to be aware of these differences before we go further. Three essential differences are: (1) timberland cannot enter into default for nonpayment; (2) timberland is not as liquid as most fixed-income instruments; and (3) timberland harvests may create uneven coupons for the investor.

In the case of potential defaults, timberland investments differ from most fixed-income instruments in that there is typically no formal contract that legally binds the schedule of payments for the investor. Simply put, there can be no default. Functionally, however, this difference is somewhat academic, since investors base their decisions on cash flow risk and expected values, regardless of a legally binding contract or not.

The second difference is that timberland is less liquid relative to most fixed-income instruments. Positions in many bonds can be added or removed in a couple of business days. In contrast, timberland – similar to private placement bonds - can take several weeks or more to acquire or liquidate.

Finally, timberland differs from bonds in that the periodic cash flow payments – or “coupons” – may be uneven. Typically, bonds have constant coupon payments, unless they are asset backed, tracking or indexed bonds. With timberland, constant cash flows are not common. On many forest properties, there is an uneven assortment of trees in each age class. Harvests each year will naturally vary, therefore, resulting in uneven income. (An exception would be a plantation where there is an even distribution of trees in all age classes. This exception is discussed further below.) Like the case of default, however, this difference with bonds is largely academic as investors are concerned with the yield to maturity and not the uniformity of coupons.

To review, **Table 1** below summarizes the common traits and the key differences between timberland and bonds.

Table 1. Fundamental similarities and differences between bonds and timberland

Bond		Timberland
Ask price	=	Net acquisition cost for timberland
Coupon	=	Net revenue from projected harvests
Coupon schedule	=	Multi-year timber harvest & sale plan
Principal / par value	=	Net proceeds from sale of timberland
Default	≠	Payments not legally binding
Transactions close <3 days	≠	Transactions close in several weeks
Constant coupons *	≠	Uneven coupons

** Exceptions are indexed bonds and tracking bonds as well as some types of asset-backed bonds. An example is the Treasury Inflation-Protected Securities (TIPS) CPI-indexed bond.*

Explaining Timberland Assets through Bond Features

Basic Features of Timberland in Bond Terms

If you break down a bond into its core components, its return can be derived from only two possible sources: (1) the coupon, and (2) the terminal value. Of course, the terminal value is the bond's principal or par value if held to maturity. But if the bond is sold before maturity, then the terminal value is the going bid price in the market. In the case of timberland, you can think of the income generated from timber harvests as the coupon. Likewise, the terminal value would be the price received when the timberland is finally sold.

The Age Structure of Timberland Dictates its Coupon Structure

Using this analogy, timberland investments become easier to understand. A young plantation of timber that is sold before any of the timber is harvested can be considered a zero coupon bond. In contrast, a plantation with an even distribution of trees in all growth stages, and which the owner plans to harvest accordingly, will have constant *coupons* and a *par value* equal to its purchase price (assuming interest rates and timber prices are held steady).

As a rule of thumb, timberland with young trees will have a *coupon rate* lower than its expected yield to maturity because there is little to harvest. Its terminal value will be higher than the purchase price. Conversely, timberland with more mature trees will have a *coupon rate* higher than its expected yield to maturity, as harvest

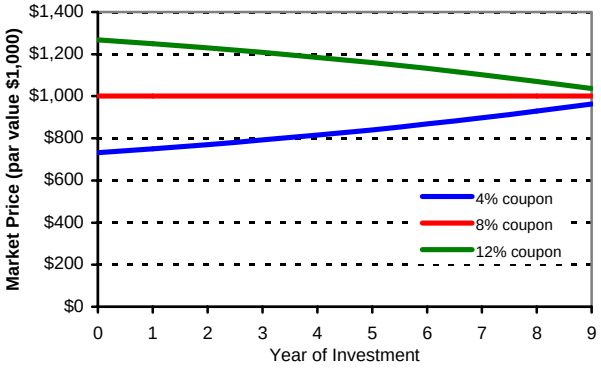

Figure 1a. Market price of 10-year bonds of different coupons. Market rates of interest are held constant at 8.0%

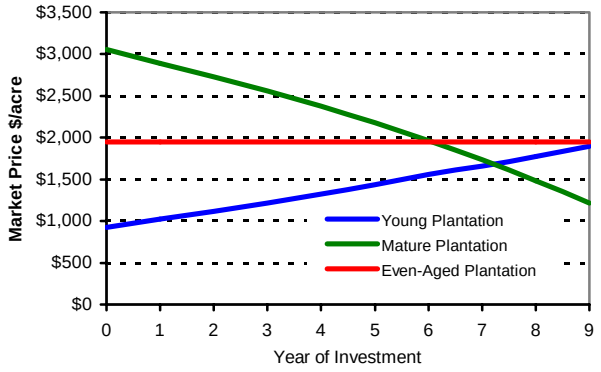

Figure 1b. Market price of U.S. South plantations of different ages. Market rates of interest are held constant at 8.0%

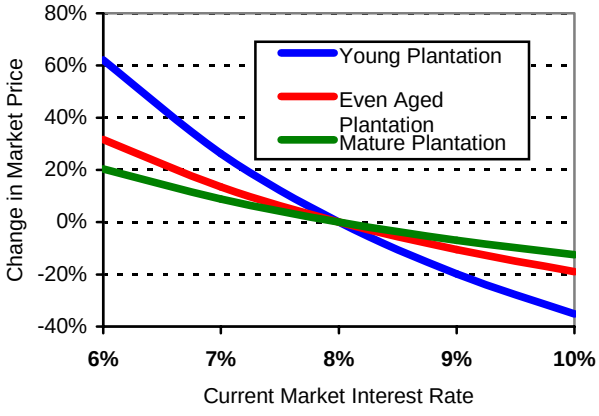

Figure 2. Adjustment of the market value of different Southern pine plantations across a range of market interest rates with a 10-year investment horizon. Discount rate at acquisition was a target of 8%. All other parameters such as prices and costs are held constant.

rates are potentially higher. Terminal value will be lower than the purchase price. To help illustrate this feature, take a look at the comparative charts in **Figures 1a** and **1b**. On top, **Figure 1a** shows the market price of 10-year bonds of different coupon yields over a 10-year investment horizon. Interest rates are held constant in this illustration. For comparison, the **Figure 1b** on the right is the same type of chart, but timberland of different ages is substituted for bonds. Basically, the older the plantation, the more the forest investment will behave like a high coupon bond. Older plantations rely more on harvest income (or *coupons* in bond terminology) and less on the sale value to generate their target return. Younger plantations rely less on income and more on the final sale for their return.

An important next step in understanding timberland investments is to recognize what drives its price. Like bonds, timberland prices are affected by four major factors: interest rate, risk, duration and liquidity. We will cover each of these drivers in the next section.

Decomposing the Pricing of Timberland in Bond Terms

Interest Rate Effect on Price

Bond prices are established in accordance with market interest rates. Timberland is no different. Like bonds, the price of timberland moves in the opposite direction to interest rates. As interest rates fall, bond holders and timberland investors experience capital gains. Likewise, as interest rates rise, bond holders and timberland investors experience capital losses.

This relationship between interest rates and prices depends, of course, on the cash flow schedule of the investment. For bonds, the higher the coupon rate, the less effect interest rates have on price. The same applies to timberland. Forests with strong harvest revenue in the early years are less sensitive to market shifts in interest rates than forests with low initial harvests. We can see this relationship in **Figure 2**, which shows how the price of different types of timberland is effected by the interest rate. This relationship logically leads to the topic of duration, which we discuss next.

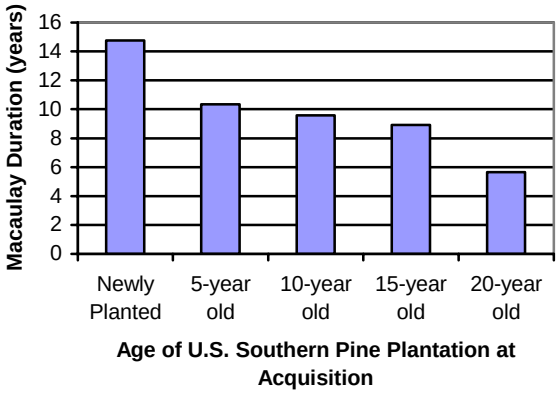

Figure 3. Duration of different ages of Southern pine plantation in the U.S. South for a 10-year holding period. Target rate of return in 8%.

Relationship Between Price and Duration

Those familiar with fixed-income financial theory know that duration is a measure of the effective maturity of a bond. Knowing the duration of a bond, we can measure its price vulnerability to interest rates. Similarly, timberland of different ages, growth rates and species exhibit different effective maturities (i.e., duration). Identifying the duration of a timberland investment, therefore, aids us in measuring its interest rate sensitivity, and guides us on the appropriate discount rate to use. Just as high duration bonds should receive a higher market yield than a low duration bond, timberland is no different. For instance, when comparing two timberland investments of the same holding period, the younger, low-harvest timberland should carry a higher hurdle rate of return than the mature, high-harvest timberland. The reason is because the former has a higher duration than the later. **Figure 3** illustrates the association between the age of the timberland and its duration.

Table 2 illustrates the association between the forest productivity and duration. Notice that two forest investments of the same species, age, and rate of return can still have different durations if the land of one forest is more productive than the other.

Table 2. Comparison of a 10-year investment of a 10-year old U.S. South Loblolly pine plantation under three different levels of land productivity, from poor to exceptional quality. Target internal rate of return is 8.0%.

Financial Parameter	Average Cash Yield	Duration	Liquidation Value to Purchase Ratio
Equivalent Fixed Income Term	Coupon Rate	Duration	Par Value to Purchase Price Ratio
Low productivity (site index 60)	0.4%	10.2 yrs	2.11
Good productivity (site index 75)	2.0%	9.6 yrs	1.97
High productivity (site index 85)	14.4%	9.3 yrs	1.47

The application is that you should understand the duration - or effective maturity - of a timberland investment before acquiring it. Otherwise, you risk setting the wrong hurdle rate. Overestimating the effective maturity will cause you to undervalue the timberland, and hence, fail to purchase the property. On the other hand, underestimating the effective maturity could cause you to over-pay.

Below are some general guidelines regarding timberland and duration:

- Plantations on highly fertile or productive lands will have a lower duration.
- Using genetically improved, faster growing trees will increase productivity and therefore lower duration.
- Using intensive forest management, such as herbicides, fertilization and thinnings will generally lower the duration if it raises productivity and shortens the period till harvest. However, if the costs of active forest management are high, it may, in certain cases, actually lengthen the duration.
- Having more mature timber per acre will lower the duration.
- Harvesting less and allowing the forest asset to build up will raise the duration.
- The more high-priced or valuable the timberland is per acre, the higher the duration.

Effect of Risk on Price

Duration and interest rates are not the only price determinants of both bonds and timberland. A third key driver is risk. The greater the perceived risk, the greater the risk premium an investor will demand. The risk premium is the additional rate of return added to the risk-free interest rate that discounts the expected cash flows of an investment instrument – whether it is a stock, bond, or timberland. Thus, riskier investments mean a higher hurdle rate. This relationship is reflected in a lower price for the asset.

For bonds, the dominant form of risk is default risk. It is also known as credit risk. Effectively, it is the risk that expected future cash flows will fall short of what is

promised by the bond issuer. The greater the perceived default risk, the higher the risk premium needed to entice the investor to purchase the bond. In practice, the issue of risk is no different for timberland.

As mentioned earlier, timberland is not typically structured as a debt instrument, so there is no technical default at risk. But for practical purposes, "default risk" is real. Realized future cash flows from timber harvests and land sales can indeed fall short of forecast. The source of risk can be natural, man-made, or market-related. Natural sources include harsh weather and outbreaks of tree diseases. Man-made sources involve errors in the judgment or execution of managing the timberland. Finally, market-based risks involve the volatility of timber prices.

Unfortunately, timberland investors do not have the benefit of a credit rating agency to assess that risk for them, as we commonly see in market-traded bonds. There is no independent third party equivalent of a Fitch, Moody's, or Standard & Poor's for the timberland asset class. Hence, the responsibility lies with the timberland investor to properly assess the risk of each potential investment.

Effect of Liquidity on Price

A fourth factor that affects the pricing of bonds as well as timberland is liquidity. Bonds that are thinly traded in the debt markets must offer a liquidity premium over the market return offered by bonds of large issuers. The same should apply to timberland.

A timberland investment can constitute thousands or even tens of thousands of acres. These investments require time to acquire and sell, making them illiquid relative to most market-traded securities. In this sense, timberland is analogous to real estate, hedge funds and venture capital. Accordingly, the timberland investor should expect roughly the same illiquidity premium over blue chip stocks and investment grade bonds.

Special Bond Features Exhibited by Timberland

Beyond the common link of timberland to the universal bond features of interest rates, duration, risk, and liquidity, there are some special features of timberland that only certain types of bonds carry.

Put Option of Extension

One of the notable features of many timberland investments is its open-ended lifespan. For example, at the time of purchase, an investor may intend to hold a timberland property for a ten-year term. At the end of ten years, however, he may find the productivity of tree growth improving dramatically and he wishes to capture that gain by extending the investment for another five years.

In that sense, timberland investments are like a puttable bond, a.k.a. extendable bond. A put provision for extension gives the bond holder the option to extend the life of a bond beyond its maturity date. In such a case, the bond investor would exercise the option if the coupon rate exceeds current market yields. Similarly, a timberland owner would extend the investment when expected cash flows from future timber harvests or land sales would exceed current market returns.

However, it should be noted that this feature is not available to all timberland investments. It depends upon how that investment is structured. Some timberland investments, for example, are made through a commingled fund that carries a fixed lifespan. In such cases, the put option for extension may be limited or nonexistent. Nor will the extension option be available if the timberland investment holds only the trees, but no land (known as a timber cutting right). This type of investment will be the next topic of discussion.

The Amortizing Timberland Investment

Bonds come in many flavors. One flavor is the amortizing bond. Unlike the typical bond where the entire principal or face value is paid on the maturity date, the principal on an amortizing bond is paid over its lifespan. Interestingly, there is an equivalent product in the timberland investment universe. This product is known as the timber cutting right or simply, timber right. As the name indicates, a timber right gives ownership only to the standing trees and only for a limited term. When the trees are harvested or when the contract expires, the land underneath the trees reverts back to the seller of the timber right.

Since there is no land to sell at the end of the timber right, the only asset (i.e. principal) is the standing trees. They, therefore, effectively become an amortizing security. When all the trees are harvested, there is no asset left. Investors who are attracted to the features of

an amortizing bond likewise may be attracted to a timber right type of investment.

Deferred Coupon Feature of Timberland

One prominent feature of timberland is its biological growth. Trees that are not harvested will continue to grow. They "accrue interest", so to speak, if harvest is delayed. This feature makes a timberland investment behave like a deferred coupon bond. For those unfamiliar with deferred coupon bonds, they are used by corporations who need to borrow funds but may face periods where they have difficulty making debt payments. Not surprisingly, it is firms facing leveraged buyouts (LBOs) and recapitalizations that would rely on debt issues with deferred coupon structures.

Deferred coupon bonds come in various types. The type that fits timberland investments is the payment-in-kind (PIK) bond. These bonds give the option of substituting a coupon cash payment with a similar bond. This bond has the coupon rate and par value fixed so that it is equal to the coupon payment it is substituting.

A timberland asset is like a payment-in-kind bond because if for some reason harvest is reduced or missed, the trees that were not cut will continue to grow. As they grow they appreciate in value. What is not cut now will be worth more in the future as compensation for the missed cash distribution (or coupon payment). Other alternative investments such as real estate, minerals, or oil & gas lack this feature. As such, the "deferred coupon" feature is an advantage timberland investments carry over other alternative hard-asset classes.

Applying Fixed-Income Strategies onto Timberland

At this point, we have discussed the similarities between timberland and bonds. With these in mind, we can apply many of the common strategies used in fixed-income portfolio management to timberland investments.

These fixed-income strategies fall into two general styles: passive strategies and active strategies. A passive investment strategy tries to assemble a bond portfolio with the desired risk-to-return balance. An active investment strategy, on the other hand, tries to beat market returns through some type of inside advantage, such as market insight or intelligence.

Passive Strategy to Manage Risk and Return

Passive management accepts bond prices in the market as given, and seeks to build a diversified portfolio through sophisticated risk management and immunization strategies. To give an example, a U.S. investor holds foreign bonds from Germany and Japan denominated in their native currencies. To reduce exposure to volatile foreign exchange rates, she may use currency hedging to insulate her portfolio from the currency risk associated with the coupon and principal payments from these Euro and Yen denominated bonds. Foreign exchange options or futures will meet this objective. Similarly, an investor's timberland portfolio may include forest investments in Chile and New Zealand. To reduce the currency exposure to those international properties, the investor could apply currency hedging of the Kiwi dollar and the Chilean peso against the expected timber harvest proceeds he or she plans to repatriate back to the U.S.

Another example of passive management is to match one's assets with one's liabilities. An investor cannot have an overweighting of long-term assets, such as 30-year bonds, in his portfolio when he has short term cash flow obligations. Therefore he employs gap management, where the goal is to reduce the "gap" between assets and liabilities. Suppose, for instance, a university forecasts that it will need to build a new lecture hall in eight ten years. The school will need to fund it by tapping into its endowment. In order prevent a "gap" in its budget at the time the lecture hall needs to be built, it may convert some of its equity holdings and place them in a timberland fund that has an eight-year duration. The university recognizes that stocks are volatile and there is less assurance the right amount of funds will be available in eight years with a stock investment than compared to a timberland investment.

In addition to gap management, investors regularly use a variety of other passive strategies to manage their portfolio. Among these are: asset allocation, value-at-risk (VAR) assessments, and interest rate immunization - all of which can be effectively applied to timberland investments as well.

Active Management to Capture Above-Market Returns

A fixed-income portfolio manager with an active strategy uses proprietary information and analyses to identify sectors in the fixed-income market that are mispriced.

To illustrate, an investor may believe that the credit risk of a corporate bond is lower than what the market is pricing. He sells the other bonds in his portfolio and purchases the underpriced bond with the expectation that the credit rating will later improve, thereby raising the bond's price.

The above illustration is an example of a "substitution swap" and is one of three common active strategies that have applications to timberland investments. The other two are the "intermarket spread swap", and the "rate anticipation swap". Such strategies to generate above-market returns are applicable to the timberland investment asset class.

Substitution Swap

A substitution swap exchanges one bond for another bond that has a similar coupon, maturity and credit rating. This swap is performed when in investor believes that one of the two bonds is temporarily mispriced. An example of this strategy in the context of timberland investments could be a Southern yellow pine plantation in the Piedmont of the Carolinas that is lower priced than a comparable plantation in the coastal plains of Louisiana. The prescient investor divests her holdings in the higher priced coastal plain and purchases properties in the lower priced Piedmont with the expectation that they will later converge.

Intermarket Spread Swap

The intermarket spread swap is used when the price spread between two classes of bonds (such as between US Treasuries and corporate bonds) is temporarily too wide or too narrow. Applied to timberland, the investor may believe the price gap between Douglas Fir and Loblolly pine plantations is too narrow. The investor acquires more Douglas Fir plantations in anticipation that the significant premium Douglas fir has over Loblolly pine will return.

Rate Anticipation Swap

A bond investor will use a rate anticipation swap when he or she believes a macroeconomic factor (such as interest rates) will shift. For timberland, anticipating a drop in interest rates means moving out of mature timberland and acquiring more of the younger plantations that offer a longer duration. We are not limited, however, to interest rates. Anticipation of other factors such as regional timber demand by mills,

regional forest inventory, and housing starts can be exploited in a similar fashion.

An Added Dimension of Under Priced Timberland

These three bond swap strategies are not the only market based active tools available to timberland investors. There is an important added dimension to timberland that is not resident to actively managed bonds: Fixed-income holders cannot influence the yield of their bonds. Timberland investors, however, can influence the yield from their timberland by altering how the trees are managed and harvested. In effect, one could influence the productivity and growth of the investment to improve one's financial return.

This added dimension brings new meaning to the concept of "active management" for timberland. Remember that the Holy Grail of active management is to take advantage of any proprietary information and unique insight in order to capture above-market returns. If that information allows you to grow trees faster and better than anyone else, then you have an advantage. Hence, from the investor's point of view, the timberland is an under priced asset.

Summary

Let us summarize our discussion of the bond-like features of timberland investments. In **Table 3** below, we list the various features of a timberland investment on the left, and the equivalent in fixed-income terminology on the right.

Table 3. Summary of timberland investment characteristics defined in bond terms

Timberland Feature	*Equivalent Bond Characteristic*
Basic Bond Characteristics	
Cash distributions from timber revenue	Coupon
Harvest schedule with price forecasts	Coupon schedule
Proceeds from liquidation of timberland property	Principal / par value
Holding period of investment	Maturity
Internal rate of return (IRR)	Yield to maturity (YTM)
Age Structure	
Mature timberland	High coupon bond
Young or emerging timberland	Low coupon bond
Newly established timberland sold before first harvest	Zero coupon bond
Interest Rates	
Timberland price is inversely related to interest rates	Bond prices are inversely related to interest rates
Mature, highly productive timberland is less sensitive to interest rate movements	High coupon bonds are less sensitive to interest rate movements
Duration (i.e. Effective Maturity)	
Higher return premium for longer duration investments	Higher return premium for longer duration bonds
Highly productive timberland is of lower duration	High coupon bonds are of lower duration
Young timberland is of higher duration	Low & zero coupon bonds are of higher duration
Delaying harvests will generally raise duration	Deferred coupon bonds are of higher duration
Risk	
Assessment of risk rests on the investor	Bond issue with no independent credit rating
Risk that timber revenue may fall short of plan	Default or credit risk (where promised payments may fall short)
Special Characteristics	
The ability to extend the holding period	Put option of extention (“extendable bond”)
Timber cutting right which owns the trees, not the land	Amortizing bond
Withholding harvest allows the trees to grow another year	Payment-in-kind (PIK) bond
Passive Strategies	
Build timber portfolio with a risk-to-return target	Built bond portfolio with a risk-to-return target
Reduce the “gap” between timberland and liabilities	Reduce the “gap” between bonds & liabilities
Active Strategies	
A plantation is mispriced relative to market	Substitution swap in bonds
A region or species is mispriced relative to another	Intermarket spread swap in bonds
Buy or sell timberland ahead of interest rates, housing starts, changes in regional mill capacity, etc.	Rate anticipation swap in bonds

Figure 1a

The bond used in the illustration has a face value of $1,000 with annual coupon payments. Pricing of the bond is based on the following formula:

Equation 1.

$$P = \sum_{t=1}^{n} \frac{C}{(1+y)^t} + \frac{M}{(1+y)^n}$$

Where:

P	=	price of the bond
C	=	coupon interest per payment period
M	=	maturity value, or par value paid at the maturity date of the bond
n	=	number of periods to maturity
y	=	market interest rate

Source: Fabozzi, Frank J. Bond Markets, Analysis and Strategies, 4th Edition. Page 37.

Figure 1b

The represented forest plantations are modeled after Loblolly pine plantations in the lower coastal plan of the U.S. South on a "plantation quality" site index of 75 on a 25-year basis. A site index is a measure of how many feet a particular species of tree will grow in 25 years. The higher the index, the more productive the land is for tree growth.
The market value of a given acre of plantation is determined on a discounted cash flow (DCF) basis. The discount rate used is the assumed market rate of 8.0%. The plantation land is assumed to be managed in perpetuity as commercial timberland, even after it is sold to the new owner at the end of the 10-year investment.
A full growth cycle (or "rotation") of the plantation is 25 years, from planting to final harvest. A thinning is made at age 15. At the thinning, saleable timber of 26.8 tons of pulpwood and 8.7 tons of chip n' saw and 0.6 tons of sawtimber are produced per acre. At the final clearcut harvest, 39.6 tons of pulpwood, 22.6 tons of chip n' saw and 80.4 tons of sawtimber are produced per acre.
No inflation of prices or costs is assumed. No taxes are applied. Prices and costs are assumed as follows:

Costs per acre:

Site preparation (year 0)	$90.00
Seedlings (year 0)	$24.00
Plantings (year 0)	$33.00
Herbicide treatment (year 1)	$35.00
Forest management (every year)	$7.50/year

Revenue from sale of timber per ton:

Pulpwood (logs <8" in diameter)	$4.00 thinning	$5.00 final harvest
Chip n' Saw (logs between 8" & 12")	$16.00 thinning	$18.00 final harvest
Sawtimber (logs >12" diameter)	$40.00 thinning & final harvest	

The real cash flows per acre of a 85-site index Loblolly pine plantation for a full growth cycle from planting to harvest is therefore modeled as follows:

Year	Cash flow	Year	Cash flow	Year	Cash flow
0 inception	(147.00)	9	(7.50)	18	(7.50)
1	(35.00)	10	(7.50)	19	(7.50)
2	(7.50)	11	(7.50)	20	(7.50)
3	(7.50)	12	(7.50)	21	(7.50)
4	(7.50)	13	(7.50)	22	(7.50)
5	(7.50)	14	(7.50)	23	(7.50)
6	(7.50)	15	264.10	24	(7.50)
7	(7.50)	16	(7.50)	25	3,812.14
8	(7.50)	17	(7.50)		

Young plantation: At the point of investment, the acreage is evenly divided among trees from zero (0) years old (i.e. newly planted) to nine (9) years old. In other words, 10% of the acres are in each age-class of tree from freshly planted to 9-year old juvenile trees.

Mature plantation: At the point of investment, the acreage is evenly divided among trees from sixteen (16) years old to twenty-five (25) years old.

Even-aged plantation: At the point of investment, the acreage is evenly divided among trees of all age classes in the growth cycle, from zero (0) years old to twenty-five (25) years old.

Table 2

The costs, prices and forest management prescriptions, unless otherwise noted, are the same as those used in Figure 2b. The values are based on a Loblolly plantation in the lower coastal plan of the U.S. South purchased at 10 years of age and sold 10 years later. Values at purchase and sale, as in Figure 1b, are based on discounted cash flows of land held in perpetuity in commercial timber production.

Low productivity – site index 60: Thinning is performed at age 17, yielding 15.96 tons of pulpwood, 2.49 tons of chip n' saw and 0.25 tons of sawtimber per acre. Final harvest is performed at age 25, yielding 35.53 tons of pulpwood, 30.59 tons of chip n' saw and 25.81 tons of sawtimber per acre.

Good productivity – site index 75: Same as the timberland modeled in Figure 1b.

High productivity – site index 85: There are two thinnings. The first thinning is performed at age 12, yielding 23.68 tons of pulpwood, 5.10 tons of chip n' saw and 0.13 tons of sawtimber per acre. The second thinning is performed at age 19, yielding 19.94 tons of pulpwood, 13.43 tons of chip n' saw and 26.03 tons of sawtimber per acre. The final harvest is performed at age 25, yielding 35.32 tons of pulpwood, 11.56 tons of chip n' saw and 100.89 tons of sawtimber per acre.

Figure 2.

The same Loblolly pine plantation modeled in Figure 1b is used. As in the previous figure, the pricing is determined on a discounted cash flow basis, where the discount rate is the current market interest rate. Cash flows are derived from the management of the property as a commercial plantation through perpetuity.
The same terms for young, even-aged and mature plantations used in Figure 1b also apply.

Figure 3.

The same Loblolly pine plantation modeled in Figure 1b is used. Macaulay duration is calculated from the net annual cash flows expected from the pine plantation over the 10-year holding period. Market interest rate is held constant at 8.0%.

It is interesting to note that some timberland investments, such as a newly planted plantation, carry a duration that is longer than their maturity. This situation could occur when there are negative cash flows during the holding period. It is not uncommon for timberland to have negative cash flows, because each year there are fixed costs, which accrue from managing the timberland. These management costs could at times exceed the revenue generated from timber sales, particularly for young or newly planted plantations.

The formula used to calculate the Macaulay Duration is:

Equation 2.

$$\text{Macaulay duration} = \frac{\sum_{t=1}^{n} \frac{tC}{(1+y)^t} + \frac{nM}{(1+y)^n}}{P}$$

Where:

P	=	current market price of the investment instrument
C	=	coupon interest per payment period
M	=	maturity value, or terminal value paid at the end of the investment period
n	=	number of periods to maturity
y	=	market interest rate

Source: Fabozzi, Frank J. Bond Markets, Analysis and Strategies, 4th Edition. Page 62.

Additional Information

Further information and full details of the calculations and models used in producing the figures and tables are available upon request.

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