An analysis of forest property tax burdens under a land and reforestation tax system: a western Washington case study

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A per acre property tax model is proposed for taxing plantation-grown timber in western Washington State. The taxable assets consist of the bare land value plus the reforestation investment necessary to establish the timber stand. Under this system, an annual ad valorem property tax, or a harvest yield tax that substitutes for all, or part, of the annual ad valorem tax is levied on the full value of the tax base. Thus, unlike the traditional case where an annual property tax is levied on modified bare land and timber values to reduce the deferred yield bias associated with long-lived timber crops, the tax base under the proposed system requires no comparable modification. A variety of input scenarios are used to compare the numerical consequences of applying the proposed tax system with those of a land only, a land plus timber, and a harvest yield tax system; all levied at full value. Further comparisons with Washington's existing forest tax system, which is composed of an annual ad valorem property tax on a legislatively mandated statutory bare land value and a 5% harvest yield tax imposed in lieu of an annual ad valorem property tax on maturing timber, demonstrates how highly modified Washington's current system has become to accommodate forest owners and temper the deferred yield bias the property tax theoretically fosters.

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L'auteur propose un modèle de fiscalité foncière afin de taxer le bois provenant de plantations localisées dans la région ouest de l'État de Washington. La valeur du fonds, majorée par le montant des investissements requis pour y établir un peuplement forestier, fournit la base fiscale du modèle. Il s'agit de substituer, en tout ou en partie, la taxe ad valorem qui est annuellement imposée sur la pleine valeur d'une base fiscale donnée par une taxe foncière annuelle ad valorem ou une taxe sur le produit des récoltes. Ainsi, contrairement au cas traditionnel où le montant de la taxe foncière est calculée annuellement à partir des valeurs combinées du fonds et des bois qui sont ajustées afin de réduire le biais induit par la longueur du cycle de production, la base fiscale retenue dans le modèle proposé permet d'éviter de tels ajustements. Plusieurs scénarios d'aménagement sont utilisés pour illustrer de façon concrète les répercussions du modèle proposé en comparaison de trois régimes fiscaux différents. Le premier s'appuie uniquement sur la pleine valeur du fonds. Le deuxième utilise conjointement les pleines valeurs du fonds et des bois. Le dernier se fonde sur le rendement en matière récoltable. L'auteur complète son étude en comparant son modèle avec le régime présentement en vigueur dans l'État de Washington. Il explique que celui-ci repose sur une taxe annuelle ad valorem imposée sur une valeur du fonds décrétée législativement et qui, en surcroît, implique une taxe de 5% sur le produit des récoltes. Il montre comment ce régime a été adopté afin d'accomoder les propriétaires forestiers et de limiter le biais à l'égard du long terme qu'entretient théoriquement une taxe foncière.

[Traduit par la revue]

Introduction

Concern and debate over the taxing of Washington State's timber and timberlands have been ongoing activities throughout this century, and each major period of debate has culminated in new forest tax legislation. The Reforestation Act of 1931, the Deferred Timber Tax of 1941, and the Forest Tax Act of 1971 are examples of such legislation, with each making significant changes in the forest tax system in Washington (Conklin 1980). Recent debates over tax policy did not subside with passage of the Forest Tax Act of 1971, but continued until 1984 when a permanent excise (yield) tax rate required by the 1971 act was set by the legislature. In addition to the tax rate question, between 1971 and 1984 there was great discord in Washington State related to issues of timberland valuation, timber tax revenue distribution, composition of the appropriate forest property tax base, and the taxing of nonprivate timber.

This paper examines the land valuation, yield tax rate, and tax base composition issues using a proposed property tax model. Analytical results derived from this model are presented in Appendix 2 and empirical results under a variety of input scenarios are presented in the text. The basic thesis concerning the composition of the property tax base follows the proposal of Klemperer (1982) and Waggener et al. (1983), wherein maturing timber is exempt from the annual ad valorem tax and is, therefore, excluded from the tax base. Only the value of bare timberland and the investment necessary to reforest the land remain in the tax base and are subject to an annual ad valorem property tax.[1] Various scenarios involving harvest yield taxes that substitute for these property taxes are also reported.

Under the Forest Tax Act of 1971, timber in Washington State is subject to an excise (yield) tax of 5% of the estimated stumpage value at time of harvest. In addition to this yield tax (levied in lieu of an annual ad valorem property tax on maturing timber), timberland is taxed annually. The annual

[1]Naturally endowed stands of mature timber, such as old growth and unmanaged young growth, remain in the tax base and are subject to the annual ad valorem property tax. As these stands are harvested, they are excluded from the tax base and only the bare land and reforestation investment are taxed.

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ad valorem land tax is levied on a set of statutorily determined bare land values that exclude any value other than that derived from the production and harvesting of forest crops. The statutory bare land values depend on site quality, access, and topography and are updated annually by formula. As Conklin (1987) states, "No one knows—or seems to care—whether the values bear any resemblance to true and fair market value." The estimated stumpage values used in the yield tax calculation are updated semiannually and depend on timber species, quality, location, and type of silvicultural operation. A comparison of tax burdens under the current tax system with those of the proposed bare land plus reforestation system is presented later in the text.

Literature review

A review of the forest tax literature published during the past 50 years reveals that there is no single forest tax theory embraced by all tax analysts. To the contrary, analysts have reached conflicting conclusions regarding the following: the composition (i.e., land or land plus timber) of the appropriate property tax base; the best form of property tax to apply to forests (i.e., ad valorem, yield or severance); the appropriate criterion to judge both the efficiency and equity of alternative property tax systems; the incidence of the property tax; and the number of acres to consider (i.e., a single acre or a regulated forest). Because a detailed review of these issues is beyond the scope of this paper, only the major conclusions related to each are presented below.

Property tax base

Dowdle (1980) argues that maturing timber should be excluded from the forest property tax base leaving only the bare land value as the taxable asset. Other analysts have examined this proposal (i.e., Fairchild et al. 1935; Gaffney 1980; and Klemperer 1982) and generally conclude that this biases land use in favor of forestry relative to agricultural or rental properties where improvements are taxed annually. Thus, such a tax base would be inequitable across these forms of property. However, these same analysts also point out that although both land and maturing timber should remain in the tax base, the full value of the timber should not necessarily form the basis for computation of the annual ad valorem property tax. Instead, assessed timber values could be set at less than their full value. In addition, annual property taxes could be deferred (with interest) until harvest time or a harvest yield tax could be substituted in lieu of the ad valorem property tax on maturing timber. However, depending upon the rate, a substitute yield tax may not impose the same tax burden[2] as the ad valorem tax it replaces. Further, analysts recognize that the deferred yield bias generated by annually taxing maturing timber at full value each year prior to its realization as revenue works against long-rotation forestry.

Efficiency and equity

An economically efficient property tax system is one that has little or no impact on timber production decisions, such as rotation length or level of silvicultural input, and does not encourage timberland to shift to another use (Waggener et al. 1983). Most property tax systems are not neutral with respect to one (or more) of these criteria and thus introduce inefficiencies into the timber production process.

The equity of a forest tax system is measured by the tax burden it generates relative to some other system. Forest tax analysts generally use either the tax ratio[3] (Fairchild et al. 1935), site burden[4] (Klemperer 1974, 1978; Rideout and Hof 1986), or excess burden[5] criterion (Gamponia and Mendelsohn 1987). These criteria are also used as equity guides when comparing tax burdens across different land uses. Further, some analysts have examined the tax burden consequences of equating annual tax revenues under different tax systems in a regulated forest (Klemperer 1976, 1987), whereas others use a per acre model (Chang 1982; Klemperer 1974).

Tax form and incidence

Many forest tax systems have been recommended as substitutes for the unmodified annual ad valorem property tax on the full value of both land and timber. Well-known examples are site value taxation, yield tax, and several forms of deferred taxation (Fairchild et al. 1935). However, depending upon their intended purpose and implementation, these alternatives may not alleviate the non-neutrality of the unmodified ad valorem tax. Tax incidence has been studied by Trestrail (1969), Pasour and Holley (1976), and Stier and Chang (1983). For empirical reasons, tax analysts (other than Pasour and Holley 1976) assume that higher (lower) property taxes are largely capitalized into lower (higher) land values.

Single- versus multi-acre models

Some tax analysts consider both a single and multi-acre forest model (Klemperer 1976, 1982; Dowdle 1980), whereas others consider only a single-acre model (Gamponia and Mendelsohn 1987). Surprisingly, different results are often reported when the focus shifts from the single acre to the regulated forest. This, Dowdle (1980) argues, is the result of an error committed by Fairchild et al. (1935), which has since been perpetuated in numerous studies, wherein legitimate interest charges on annual ad valorem property taxes are not properly accounted for in the regulated forest model. This omission led Fairchild to incorrectly conclude that a deferred yield bias only exists for the single-acre model but not for the regulated forest model. This overlooks the

[2]Tax burdens are not defined uniformly by tax analysts. In this paper, the present value of property taxes at rotation start is used as an equity guide across different tax systems for a given class of land. Since rotational impacts of different tax systems are considered, this measure is equivalent to the excess burden criterion used by Gamponia and Mendelsohn (1987).

[3]Fairchild's tax ratio is the ratio of the present value of property taxes to the present value of gross income net of reforestation costs. This assumes that the first reforestation investment permanently improves the land, whereas subsequent reforestation expenses are written off against harvest income. As Klemperer (1974) points out, this is not a useful ratio if the purpose of the analysis is to compare alternative tax systems in terms of the resulting bare land values generated.

[4]Site burden is the percent tax-induced reduction in the no tax bid price of land. It corrects Fairchild's tax ratio to correctly account for the reforestation investment. However, as pointed out by Rideout and Hof (1986) it does not always reflect tax-induced rotational impacts.

[5]Tax burden is defined as the sum of the present value of taxes plus the excess burden; where excess burden is the lost present value due to a tax-induced change to suboptimal management (i.e., a change in rotation).

obvious fact that a regulated forest is made up of a collection of single acres and hence should exhibit identical tax burdens. In fact, Faustmann (1849) clearly pointed this out in his famous paper on forest valuation.

Model development

In developing the forest tax model proposed below, it is necessary to draw some conclusions from the literature review. Therefore, the following assumptions are incorporated into the model: (*i*) property taxes are fully capitalized into land values and are not passed along to consumers in the form of higher product prices; (*ii*) a single-acre model is utilized and all calculations are performed at rotation start; (*iii*) the tax base consists of only bare land and the necessary reforestation investment, which are subject to either an annual ad valorem property tax at full value or a harvest yield tax substituted either for deferred annual taxes on the reforestation component of the tax base and (or) the land taxes; (*iv*) tax burdens under land only and land plus timber tax systems are also included for comparative purposes; (*v*) the present value criterion is used when computing tax burdens involving alternative forms of forest tax systems; and (*vi*) no federal taxes are considered in the analysis (Appendix 1 contains a discussion of model changes required if federal income taxes are included).

Because the tax base includes only land and the required reforestation investment, the maturing timber asset is excluded from property taxation. Such a form of taxation is to be applied to plantations where a conscious investment in timber establishment is incurred. The bare timberland value subject to taxation is based on the net present value of timber harvest income less costs of timber growing and property taxes. The magnitude of the reforestation investment included in the tax base is that amount that maximizes the after-tax bare land value. Further, the computed after-tax bare land value and the appropriate reforestation investment are assessed at full value using prevailing ad valorem property tax rates.

As discussed in more detail later, existing old-growth and mature unmanaged young-growth stands of timber are not covered under this proposed tax system. Instead, they remain in the property tax base where they are subject to the general annual ad valorem property tax (or its yield tax equivalent) until harvested. As new plantations are established, they become subject to the proposed bare land and reforestation tax system. Existing plantations are subject to the proposed land and reforestation tax system, but different assessed values (or tax rates) might be needed for these forest lands. If, under existing property tax law, these plantations have already incurred tax obligations higher (or lower) than under the proposed system, new assessed values will be needed. Thus, care must be exercised to insure that any sudden implementation of the proposed land and reforestation system does not generate undue tax burdens for this class of forest property. In effect, a dual-track system of forest property taxation is suggested during the transition to managed plantations.

An annual ad valorem tax on bare timberland value plus the investment in reforestation is an equitable form of forest taxation because it recognizes that except for a longer growing period, timber crops and agricultural crops have much in common. However, whereas agricultural crops are not taxed annually, the maturing tree usually is. It is this repeated taxing that creates the deferred yield bias discussed earlier. A relevant side issue is that standing timber is legally classified as real property and is included in the tax base. On the other hand, agricultural crops are usually classified as personal property (i.e., goods in process) and are excluded from the tax base. To be consistent, plantation-grown timber could be reclassified as personal property.

Another issue is that each year's tree growth is automatically reinvested and accumulated as capital. Since the income is not realized, it is not subject to income taxation. Further, it should not be subject to property taxation each year because this creates the deferred yield bias previously discussed. This is unlike agricultural crops wherein the annually realized yield is subject to income taxation. However, it is left to the farmer's discretion as to whether this annual yield will be reinvested in improvements, subject to the property tax, or some form of nontaxable property. Klemperer (1982) analyzed the land and reforestation tax and concluded that "One means to this end (sic, to avoid the grossest non-neutralities between annual income producing properties and deferred yield forests) would be to tax only the forest land, establishment costs, plus other improvements and exempt the remaining timber value, thus bringing forest property tax site burdens to the lower end of the range likely to be found for most competing land uses." By taxing both bare timberland and the reforestation investment, we are conceptually treating timber production and other forms of income-producing property on equal terms.

Exempting standing timber from property taxation is not a recent idea, as several states currently have some form of a timber exemption law. Specific laws vary as to the length of time timber is exempt and the type of timber exempted (i.e., all standing timber or only plantation-grown timber) (Condrell 1984). Other states (e.g., California) have repealed timber exemption laws and now tax standing timber through a yield tax.

One possible means of administering a bare land and reforestation tax is to levy an unmodified annual ad valorem tax on the bare timberland value plus the reforestation investment. A second means is to defer property taxes on the bare land and reforestation investment during the rotation and substitute a yield tax at the time of harvest to compensate the taxing authority for tax revenues forgone on the bare land, the reforestation investment, and the interest charges on both. A third means is to retain bare timberland on the tax rolls and tax it annually using the ad valorem property tax. A yield tax at the time of harvest could be imposed to compensate the taxing authority for tax revenues forgone on the reforstation investment plus interest charges.

It is important to recognize that these in lieu of yield tax rates are set at a level to generate a tax burden equivalent to the annual ad valorem land plus reforestation tax in terms of rotation-start present values. This use of the yield tax is conceptually distinct from Washington State's current excise tax system, which is imposed in lieu of a highly modified annual ad valorem property tax on standing timber. Furthermore, the bare timberland value being taxed under the proposed forest tax system is the economic value of bare timberland and not the statutory bare land value as under the current system. Any suggestion for repealing Washington

State's current yield tax must be accompanied by a significant modification in bare land values.

The basic model developed for this analysis follows.

Bare land value per acre before property tax (B_0):

$$[1]\quad B_0 = [(H(T) - Ce^{rT})/(e^{rT} - 1)] - [A/(e^r - 1)]$$

Bare land value per acre after property tax on bare land only (B_L):

$$[2]\quad B_L = B_0 - g\int_0^\infty B_L\, e^{-rt}\, dt$$
$$= (rB_0)/(r + g)$$

Bare land value per acre after property tax on bare land plus reforestation investment (B_{L+C}):

$$[3]\quad B_{L+C} = B_0 - g\int_0^\infty B_{L+C}\, e^{-rt}\, dt - g\int_0^\infty C\, e^{-rt}\, dt$$
$$= [r/(r + g)](B_0 - gC/r)$$
$$= B_L - [gC/(r + g)]$$
$$= (rB_0 - gC)/(r + g)$$

Bare land value per acre after property tax on bare land and maturing timber (after Fairchild et al. 1935) (B_{L+T}):

$$[4]\quad B_{L+T} = [(H(T) - C\, e^{xT})/(e^{xT} - 1)] - [A/(e^x - 1)]$$

Bare land value per acre after yield tax levied in lieu of one of the ad valorem systems described by eqs. 2–4 (B_Y):

$$[5]\quad B_Y = \{[(1 - Y)H(T) - C\, e^{rT}]/(e^{rT} - 1)\} - [A/(e^r - 1)]$$

where

$H(T) = S\, e^{pT}Q(T,C)$ = harvest income per acre at time T

C = per acre reforestation investment

S = stumpage price at present for E-year-old trees ($/Mbf)[6]

T = number of years between harvests ($T = E + R - N$)

T_j^* = the T that maximizes the appropriate bare land value (B_0^*, B_L^*, B_{L+C}^*, B_{L+T}^*, or B_Y^*) (where, $T_j^* = T_0^*$, T_L^*, T_{L+C}^*, T_{L+T}^*, or T_Y^*)

E = total tree age at harvest

R = years reforestation delayed

N = age of planting stock

$Q(T,C)$ = volume of timber at harvest time T for a given per acre reforestation investment C

A = per acre annual cost

i = effective annual real interest rate ($i = e^r - 1$)

r = instantaneous real rate of interest [$r = \ln(1 + i)$]

g = instantaneous real rate of ad valorem property taxation ($g = ar/i$)

a = effective annual real rate of ad valorem property taxation

e = base of natural logarithms (ln)

q = effective annual real stumpage price appreciation rate ($q = e^p - 1$)

p = instantaneous real rate of stumpage price appreciation [$p = \ln(1 + q)$]

x = combined instantaneous real rate of interest and ad valorem property taxation [$x = \ln(1 + i + a)$]

Y = yield tax rate, where $0 \le Y \le 1$

These equations assume a timber management regime consisting of a reforestation investment followed by a clear-cut with no intervening management activities. The formulae are modified if other silvicultural activities such as thinnings are included.

Equations 1–4 illustrate the calculations required to determine before- and after-tax bare land values in the presence of alternate property taxes. Equation 4 is included to illustrate the consequences of taxing both bare land and maturing timber under an unmodified annual ad valorem property tax.

Realizing the cash flow hardships that an annual ad valorem property tax imposes on some owners of forest land, it may be desirable to substitute a yield tax at the time of harvest in lieu of the annual ad valorem property tax on one or more of the components included in the tax base. This requires that some portion of the forest tax base be removed from the property tax roll, and it is just one of several ways to lighten the cash flow hardship of an annual ad valorem tax.

The following equations calculate the in lieu of yield tax rates (Y_j^*) that fully substitute for an annual ad valorem property tax on the bare timberland value, the bare timberland value plus the reforestation investment, and the bare timberland value plus maturing timber, while producing an equivalent tax burden (i.e., generate the same rotation-start present value of taxes) given the respective tax base.

Yield tax rates that fully substitute for annual ad valorem property taxes on bare land, bare land plus the reforestation investment, or bare land plus the maturing timber:

$$[6]\quad Y_j^* = [B_0(e^{rT_Y^*} - 1) - B_j(e^{rT_Y^*} - 1)]/H(T_Y^*)$$
$$= \{1 - [Ce^{rT_Y^*}/H(T_Y^*)] - [A(e^{rT_Y^*} - 1)/[(e^r - 1)(H(T_Y^*))]] - [B_j^*(e^{rT_Y^*} - 1)/H(T_Y^*)]\}$$

where, Y_j^* and B_j^* represent the equivalent yield tax rate and bare land value, respectively, and j represents the subscripts L, L+C, and L+T. This equation is obtained by setting $B_j^* = B_Y^*$ and solving for Y_j^*. Recognition that T_Y^* may change is also included in this determination.

The resulting yield tax rates generate the same tax burden (i.e., the same present value of taxes at rotation start) and the same after-tax bare timberland value as an annual ad valorem property tax on the comparable forest tax base. As shown in Appendix 2, T_j^* for the no tax, land only, and land plus reforestation tax systems are identical. Thus, these tax systems are neutral with respect to rotation age. However, this neutrality is not retained for the land and timber tax system. Further, the rotation lengthening impacts of the yield tax are incorporated into the analysis, thus recognizing one of the criticisms raised by Rideout and Hof (1986) and Gamponia and Mendelsohn (1987).

Another cash flow situation is to tax annually the bare land value using the annual ad valorem property tax, but to defer the property taxes on the reforestation investment until the date of harvest, at which time a yield tax is imposed to compensate the taxing authority for both the deferred taxes and interest. Equation 7 shows the formula required

[6] Mbf, 1000 board ft (1 board ft = 2.360 dm^3).

to compute this yield tax rate while preserving the tax burden of the proposed land plus reforestation tax system.

$$[7] \quad Y_p^* = [(gC/r)\,(e^{rT_Y^*} - 1)]/H(T_Y^*)$$

Finally, to complete the definition of the model, the tax burden associated with the current forest tax system as implemented under the Forest Tax Act of 1971 is considered. Using statutory bare timberland values (B_{SL}) instead of the economic bare timberland values (B_{L+C}) computed for the proposed bare land plus reforestation tax system, eq. 8 shows the yield tax rate needed to generate a tax burden equivalent to that of the proposed tax system assuming that an annual ad valorem tax continues on the statutory bare land value

$$[8] \quad B_{L+C} = \{[(1 - Y_S^*)H(T_Y^*) - C\,e^{rT_Y^*}]/(e^{rT_Y^*} - 1)\} - [A/(e^r - 1)] - gB_{SL}/r$$

Or, solving for Y_S^*

$$Y_S^* = [(B_0 - B_{L+C} - (gB_{SL}/r)) \times (e^{rT_Y^*} - 1)]/H(T_Y^*)$$

where B_{SL} is the per acre statutory bare timberland value.

Model inputs

The tax model defined in eqs. 1–8 requires numerous inputs. For the numerical results reported later, the following assumptions are made. The physical production function $Q(T,C)$ is estimated for poor, average, and good sites (i.e., site indices 85, 105, and 125, respectively) using the USDA Forest Service DFSIM Douglas-fir Simulator (Curtis et al. 1981). Scribner board foot yields for ages 30–90, in five year increments, are obtained for two timber management regimes: (*i*) planting 2-0 stock with a 0-year regeneration delay leading to 300 established trees per acre followed by a clear-cut final harvest at time T; and (*ii*) planting 2-0 stock with a 0-year regeneration delay leading to 300 established trees per acre followed by commercial thinnings beginning at age 25–35 (depending upon site quality) and at regular 5-year intervals thereafter until final clear-cut harvest at time T. The cost of reforestation (C) is fixed at \$165/acre and involves both site preparation and the planting expense. With C held constant, the maximization of eqs. 1–5 is performed solely with respect to time for a given regime.

Stumpage prices (S) are estimated as an increasing function of tree age using a simple linear regression equation of the form $S = z - w(1/E)$, where z and w are estimated from domestic and foreign export stumpage price data. Representative stumpage prices for tree ages from 30 to 90 years are shown in Table 1. Stumpage prices for commercial thinnings are \$25/Mbf lower than those shown in Table 1, largely reflecting higher logging costs as a consequence of smaller average piece size and lower harvest volumes per acre. An annual cost (A) for administration, road maintenance, and bookkeeping is estimated at \$5/acre, and the annual property tax rate (a) is set equal to 1.26%, the 1986–1988 Washington State average. Three real annual interest rates (i = 6, 7, and 8%) and three real annual stumpage price appreciation rates (q = 0, 1, and 2% over the first rotation) are also used when computing the tax burdens shown below.

All assumptions are based on a variety of sources and reflect past trends as well as current conditions as they relate to stumpage prices, interest rates, and costs of intensive management.

TABLE 1. Stumpage prices as a function of tree age

Tree age (years)	Stumpage price (\$/Mbf)
30	63
35	109
40	144
45	171
50	193
55	210
60	225
65	238
70	248
75	258
80	266
85	273
90	279

NOTE: Stumpage prices for thinnings are \$25/Mbf lower.

Results of calculations for western Washington State

The results of the analysis are shown in Tables 2–7. Tables 2 and 3 contain the following information: the optimal rotation age (E) for the no tax, land only tax, and land plus reforestation tax cases; the no tax economic bare timberland value (B_0^*); the economic bare timberland value after imposition of an annual ad valorem property tax on the after-tax bare timberland value only (B_L^*) and the harvest yield tax that fully substitutes for this tax (Y_L^*); the economic bare timberland value after imposition of an annual ad valorem property tax on the after-tax bare timberland value and the reforestation investment (B_{L+}^*, and the harvest yield tax that fully substitutes for this tax (Y_{L+C}^*); the optimal rotation age for the land plus timber annual ad valorem tax, the economic bare timberland value after imposition of an annual ad valorem property tax on the after-tax bare timberland value, and the full value of the maturing timber (B_{L+T}^*); and the harvest yield tax that fully substitutes for this tax (Y_{L+T}^*).

Results shown in Tables 1 and 2 are organized by site index, annual effective real rate of interest (i), and annual real price appreciation rate (q). If the no tax bare timberland value (B_0^*) is negative, after-tax bare timberland values and equivalent yield tax rates are not shown for the land only or land plus reforestation tax systems. As shown in Appendix 2, the land only and the land plus reforestation tax systems are neutral with respect to rotation age, for a fixed reforestation investment. Although not observed for the input parameters used in this study, this latter tax system is not neutral with respect to land use since it may drive after-tax bare land values negative or below those of the next best use. Furthermore, although the reforestation cost was held constant at \$165/acre, results shown in Appendix 2 demonstrate that for a fixed rotation age, the land plus reforestation tax system encourages a smaller investment in reforestation effort than either the no tax or land only tax system.

Because of the greater tax burden generated by the unmodified land and timber tax system and the non-neutrality of this system with respect to rotation age and

TABLE 2. Results for western Washington Douglas-fir

Interest rate,[a] % (i)	Stumpage rate,[b] % (q)	Rotation age,[c] years (E)	No tax,[d] $/acre ($B_0^*$)	Land only[e]		Land plus reforestation[f]		Land plus timber[g]		
				$/acre ($B_L^*$)	% (Y_L^*)	$/acre ($B_{L+C}^*$)	% (Y_{L+C}^*)	Rotation years (E)	$/acre ($B_{L+T}^*$)	% (Y_{L+T}^*)
Site index[h] 85										
6	0	60	−76	—	—	—	—	55	−144	38.1
6	1	60	63	52	3.5	23	12.5	55	−79	44.7
6	2	70	335	277	9.9	248	14.8	60	41	50.0
7	0	55	−134	—	—	—	—	50	−171	34.2
7	1	60	−58	—	—	—	—	55	−132	40.3
7	2	60	81	69	3.9	44	11.7	55	−65	45.8
8	0	55	−166	—	—	—	—	50	−184	45.6
8	1	55	−121	—	—	—	—	50	−161	36.8
8	2	60	−44	—	—	—	—	55	−121	41.7
Site index 105										
6	0	55	77	64	4.0	35	12.6	50	−57	40.2
6	1	60	311	257	9.5	228	14.6	55	58	44.8
6	2	65	754	624	13.0	595	15.9	55	260	49.1
7	0	50	−37	—	—	—	—	50	−114	37.3
7	1	55	96	82	4.4	56	11.8	50	−43	41.2
7	2	60	332	281	8.9	256	13.3	55	74	45.1
8	0	50	−102	—	—	—	—	45	−145	33.7
8	1	50	−22	—	—	—	—	50	−102	38.4
8	2	55	113	98	4.5	75	11.0	50	−30	41.8
Site index 125										
6	0	50	279	231	9.0	202	14.3	50	57	41.3
6	1	55	632	523	12.4	494	15.6	50	239	44.3
6	2	60	1279	1057	14.5	1029	16.4	55	545	47.9
7	0	50	92	78	4.2	53	11.7	45	−34	37.6
7	1	50	297	252	8.4	227	13.1	50	73	41.4
7	2	55	653	553	11.1	528	14.0	50	256	44.3
8	0	45	−14	—	—	—	—	45	−92	35.1
8	1	50	109	94	4.4	72	10.9	45	−21	38.3
8	2	50	315	272	7.8	250	12.0	50	89	41.4

NOTE: Based on planting 300 trees/acre, performing no commercial thinning, and performing a clear-cut for the final harvest.

[a] Effective annual real interest rate.

[b] Effective annual real stumpage price appreciation rate.

[c] Tree age to the nearest 5 years. Length of investment determined by subtracting 2 years (the age of the planting stock). No regeneration delay assumed. This is the optimal rotation age for the no tax, land-only tax, and the land plus reforestation tax cases.

[d] No tax bare land value.

[e] Bare land value after payment of annual ad valorem property tax on only bare timberland value followed by the harvest yield tax that fully substitutes for this tax. Tax-induced rotational impacts are reflected in Y_L^*.

[f] Bare land value after payment of annual ad valorem property tax on bare timberland value and reforestation investment followed by the harvest yield tax that fully substitutes for this tax. Tax-induced rotational impacts are reflected in Y_{L+C}^*.

[g] This is the optimal rotation age when an annual ad valorem property tax is paid on both bare timberland and the full value of maturing timber. Also shown are the bare land value after payment of annual ad valorem property tax on bare timberland value and full market value of the standing timber followed by the harvest yield tax that fully substitutes for this tax. Tax-induced rotational impacts are reflected in Y_{L+T}^*.

[h] 50-year base age.

level of reforestation investment (see Appendix 2), a separate set of shorter rotation ages, bare timberland values (B_{L+T}^*), and substitute yield tax rates (Y_{L+T}^*) are shown. This facilitates comparison with the rotation age and bare land values for the other tax systems and illustrates the deferred yield bias discussed earlier.

For example, consider Table 2, site index 105 (average site productivity): 7% interest rate and 1% annual price appreciation rate. The no tax bare timberland value is $96/acre, and the optimal rotation age is 55 years. If a land only tax system is assumed and taxes are assessed annually on the after-tax bare timberland value, the rotation remains at 55 years, the bare timberland value falls to $82/acre, and the yield tax rate needed to generate an equivalent tax burden is 4.4%. Under a bare land plus reforestation tax system, the rotation remains at 55 years, the after-tax bare timberland value falls to $56/acre, and the yield tax rate needed to generate an equivalent tax burden rises to 11.8%. An examination of Table 2, column 8 shows that for this latter (and preferred) tax system, equivalent yield tax rates range from 11 to 16%, generally increasing with increasing site productivity, decreasing with increasing rates of inter-

TABLE 3. Results for western Washington Douglas-fir

Interest rate,[a] % (i)	Stumpage rate,[b] % (q)	Rotation age,[c] years (E)	No tax,[d] $/acre ($B_0^*$)	Land only[e]		Land plus reforestation[f]		Land plus timber[g]		
				$/acre ($B_L^*$)	% (Y_L^*)	$/acre ($B_{L+C}^*$)	% (Y_{L+C}^*)	Rotation years (E)	$/acre ($B_{L+T}^*$)	% (Y_{L+T}^*)
Site index[h] 85										
6	0	60	−65	—	—	—	—	55	−140	39.4
6	1	70	90	74	4.6	45	13.0	60	−69	46.6
6	2	80+	409	338	10.8	310	15.1	70	63	52.5
7	0	60	−129	—	—	—	—	55	−167	34.7
7	1	60	−48	—	—	—	—	55	−127	41.4
7	2	70	110	93	4.8	68	12.1	60	−56	47.6
8	0	55	−162	—	—	—	—	50	−183	30.6
8	1	60	−116	—	—	—	—	55	−158	37.1
8	2	60	−33	—	—	—	—	55	−117	42.6
Site index 105										
6	0	55	82	68	4.2	39	12.7	55	−55	40.5
6	1	60	319	264	9.7	235	14.7	55	63	44.7
6	2	75	808	667	13.2	639	16.0	60	270	50.8
7	0	55	−34	—	—	—	—	50	−111	37.1
7	1	55	100	85	4.5	60	11.9	55	−41	41.4
7	2	70	341	289	9.0	264	13.3	55	79	45.3
8	0	50	−99	—	—	—	—	50	−144	34.1
8	1	55	−19	—	—	—	—	50	−100	38.3
8	2	60	117	101	4.6	79	11.1	55	−28	41.9
Site index 125										
6	0	55	259	214	8.7	185	14.3	50	49	40.7
6	1	60	601	497	12.2	468	15.6	55	221	44.4
6	2	70	1266	1046	14.5	1018	16.4	60	519	49.2
7	0	50	82	69	3.8	44	11.6	50	−42	38.1
7	1	55	279	236	8.2	211	13.0	50	65	41.1
7	2	60	625	529	11.0	504	13.9	55	240	44.5
8	0	50	−22	—	—	—	—	45	−95	34.8
8	1	50	98	85	4.0	62	10.9	50	−29	38.6
8	2	55	298	258	7.7	235	11.9	50	80	41.4

NOTE: Based on planting 300 trees/acre, performing commercial thinning, and performing a clear-cut for the final harvest.
[a-h]See Table 2 footnotes.

est, and increasing with increasing price appreciation rates. Thus, tax equity across differing site classes can only be achieved by implementing differential yield tax rates across site class.

When the annual ad valorem property tax is assessed on both the after-tax bare timberland value and the full value of maturing timber, the after-tax bare timberland value falls to −$43/acre, the optimal rotation drops to 50 years, and the yield tax rate needed to generate an equivalent tax burden rises to 41.2%. Under this tax system, the acre is forced out of timber production.

A comparison of results shown in Tables 2 and 3 illustrates that the commercial thinning regime (Table 3) is superior to the no thinning regime (Table 2) for poor and average sites but not for good sites. However, for the preferred land plus reforestation tax system, the equivalent yield tax rates shown in column 8 of the two tables agree closely; ranging from 11 to 16%. Further, results in both tables show the consequence of including the reforestation investment in the tax base relative to the land only tax o the land plus timber tax systems.

With the exceptions noted below, the optimal rotatio ages T_Y^*, obtained when the equivalent yield tax rat shown in Tables 2 and 3 are calculated, remain unchange from the no tax optimal rotation age. Because rotation ag are only determined to the nearest 5 years, the rotatio lengthening effect of the the yield tax is visible only in a fe cases. The first, in Table 2, is for site index 85 under a 7 percent interest rate and a 2% price increase. For the lan plus reforestation system, the optimal rotation age shift from 60 to 65 years when the equivalent yield tax rate i calculated. Similarly, for the land and timber tax system, the optimal rotation age increases to 65 years when the equivalent yield tax rate is calculated. In both instances, the rotation lengthening effect is observed only if the yield tax exceeds 11.7%. In Table 3, the only case where the equivalent yield tax extends the rotation by 5 years is for site index 105 under a 7% interest rate and a 1% price increase. Here,

TABLE 4. 1989 statutory bare timberland values under the Forest Tax Act of 1971

Site index, 50-year base	Bare land value, $/acre
85 (poor)	60
105 (average)	79
125 (good)	100

NOTE: Represents average value for stable soils with slopes less than 65%.

for the land and timber tax system, the optimal rotation age shifts from 55 to 60 years if the yield tax rate exceeds approximately 32%. For yield tax rates less than this, no rotation lengthening is observed. All equivalent yield tax rates shown in Tables 2 and 3 reflect the rotation ages equal to the no tax case, except as noted.

Discussion of numerical results

Taxing the after-tax economic bare timberland value plus reforestation investment is proposed as an equitable solution to the forest property tax problem. As the analysis demonstrates, by exempting maturing timber from property taxation and only taxing the bare land and the reforestation investment (both at full value), we generate a tax system that does not strongly bias land use away from forest production to other competitive uses. Further, it does not unduly favor forest production over other uses. Although it is possible for this tax system to produce submarginal forest land (see Appendix 2), the results indicate that this is not common, at least for the input parameters used in this study.

It bears repeating that the above analysis assumes that an unmodified annual ad valorem property tax of 1.26% is levied on the full after-tax economic bare timberland value plus the reforestation investment. Such a tax system is totally different from the current tax system used in Washington State. Under the Forest Tax Act of 1971, an annual ad valorem property tax is levied on a statutory bare timberland value and a yield tax is levied on the gross income of the timber harvest. Further, under the current system, the yield tax is levied (conceptually) in lieu of a highly modified annual ad valorem timber tax. Under the tax system proposed in this paper, maturing timber is exempt from any form of property taxation. However, this does not imply that the forest owner's property tax bill will decline under the proposed system. A comparison of tax burdens imposed by the current system with the proposed bare land value plus reforestation tax system is presented and discussed below.

Comparing proposed and current tax burdens

Below, tax burdens generated by the current forest property tax system in Washington State are compared with burdens shown for the proposed annual ad valorem bare land plus reforestation tax system. It is assumed throughout that the tax burden generated by the bare land plus reforestation tax system is the standard against which the tax burden generated by the current tax system is to be judged.

Currently, an annual ad valorem property tax is levied on statutory bare forest land values originally established during the 1981 legislative session and first used in the 1982 assessment year. The 1989 statutory bare land values used in the comparative analysis discussed below are shown in Table 4 and result from the use of a formula update of the previous year's values. These statutory bare land values reflect the average value for stable soils with slopes less than 65% for the three site classes used in this paper.

TABLE 5. Yield tax rate needed under current system of forest taxation to generate a tax burden equivalent to that of a tax on reforestation costs plus bare land value

Interest rate,[a] % (i)	Stumpage rate,[b] % (q)	Site index,[e] ft	Rotation age,[c] years (E)	Equivalent yield tax,[d] % (Y_S^*)
6	0	85	60	—
6	1	85	60	8.5
6	2	85	70	12.7
7	0	85	55	—
7	1	85	60	—
7	2	85	60	8.3
8	0	85	55	—
8	1	85	55	—
8	2	85	60	—
6	0	105	55	7.6
6	1	106	60	11.7
6	2	105	65	14.2
7	0	105	50	—
7	1	105	55	7.6
7	2	105	60	10.8
8	0	105	50	—
8	1	105	50	—
8	2	105	55	7.4
6	0	125	50	10.4
6	1	125	55	13.2
6	2	125	60	15.0
7	0	125	50	6.3
7	1	125	50	9.7
7	2	125	55	11.9
8	0	125	45	—
8	1	125	50	6.3
8	2	125	50	9.1

NOTE: Based on planting 300 trees/acre, performing no commercial thinning, and performing a clear-cut for the final harvest.

[a]Effective annual real interest rate.

[b]Effective annual real stumpage price appreciation rate.

[c]Tree age to nearest 5 years. Length of investment was determined by subtracting 2 years (the age of the planting stock). No regeneration delay was assumed. This is the optimal rotation age for the land and reforestation tax case.

[d]Harvest yield tax that when combined with an annual ad valorem tax on the statutory bare land value generates a present value of taxes equal to that of an annual ad valorem property tax on bare land plus reforestation investment (i.e., Table 2, column 7). No tax-induced rotational impacts were observed in T_S^*.

[e]Fifty-year base age.

By applying the same input assumptions as shown earlier, eq. 8 is used to compute the harvest yield tax, which, when combined with an annual ad valorem property tax on the statutory bare land value, generates a rotation-start present value of taxes that equals that of the bare land plus reforestation tax system. The results of these calculations are shown in Tables 5 and 6. For example in Table 5, for site index 105 (7% rate of interest and 1% price appreciation rate), an equivalent yield tax of 7.6% is shown. This is the yield tax rate that Washington State should use for new plantations if the statutory bare land values shown in

TABLE 6. Yield tax rate needed under current system of forest taxation to generate a tax burden equivalent to that of a tax on reforestation costs plus bare land value

Interest rate,[a] % (i)	Stumpage rate,[b] % (q)	Site index,[c] ft	Rotation age,[c] years (E)	Equivalent yield tax,[d] % (Y_S^*)
6	0	85	60	—
6	1	85	70	9.3
6	2	85	80+	13.2
7	0	85	60	—
7	1	85	60	—
7	2	85	70	9.0
8	0	85	55	—
8	1	85	60	—
8	2	85	60	—
6	0	105	55	7.8
6	1	105	60	11.8
6	2	105	75	14.4
7	0	105	55	—
7	1	105	55	7.7
7	2	105	70	11.0
8	0	105	50	—
8	1	105	55	—
8	2	105	60	7.5
6	0	125	55	10.2
6	1	125	60	13.1
6	2	125	70	15.0
7	0	125	50	6.0
7	1	125	55	9.6
7	2	125	60	11.9
8	0	125	50	—
8	1	125	50	6.1
8	2	125	55	9.0

NOTE: Based on planting 300 trees/acre, performing commercial thinning, and performing a clear-cut for the final harvest.

[a]Effective annual real interest rate.

[b]Effective annual real stumpage price appreciation rate.

[c]Tree age to nearest 5 years. Length of investment was determined by subtracting 2 years (the age of the planting stock). No regeneration delay was assumed. This is the optimal rotation age for the land and reforestation tax case.

[d]Harvest yield tax that when combined with an annual ad valorem tax on the statutory bare land value generates a present value of taxes equal to that of an annual ad valorem property tax on bare land plus reforestation investment (i.e., Table 3, column 7). No tax-induced rotational impacts were observed in T_S^*.

[e]Fifty-year base age.

Table 4 remain in effect. Under this combination of inputs, the tax burden generated is the same as for the proposed bare land plus reforestation tax system. The 7.6% yield tax rate is less than the 11.8% rate shown in Table 2 because the statutory bare land value ($79/acre) is greater than the $56/acre bare land value generated under the proposed tax system.

Currently, a 5% yield tax rate is levied in lieu of an annual ad valorem property tax on maturing timber. By comparing the equivalent yield tax rates shown in Tables 5 and 6, the degree of modification in the current system is evident. It is clear that even with the elimination of maturing timber from the proposed tax base, the required yield tax rate is greater than that imposed under current law. This comparison assumes that both tax systems are employed over an entire rotation. Note that no equivalent yield tax rates are shown in Tables 5 and 6 if the no tax bare land value is negative. Further, the optimal rotation age associated with these yield taxes is always equal to the no tax case. Thus, there are no tax-induced rotation changes observed.

It is important to again point out the conceptual differences that exist between the two property tax systems being compared in Tables 5 and 6. Embedded in eq. 8 are the following assumptions: (*i*) bare land is taxed annually over the entire rotation using the statutory land values shown in Table 4 and the current 1.26% annual property tax rate; (*ii*) future timber yields, prices, and costs of management assumé that all timber stands are being managed under one of the two timber regimes previously defined; and (*iii*) the base of comparison is the proposed bare land plus reforestation tax system.

Thus, the tax burdens implied by use of eq. 8 apply to plantations, and not old-growth or unmanaged young-growth stands that are still being harvested today. For this reason, the tax burdens associated with the equivalent yield tax rates shown in Tables 5 and 6 do not apply to all timberland acres existing in western Washington State. However, it is necessary to consider plantations when discussing tax burdens under the current property tax system to preserve comparability with the tax burdens under the proposed bare land plus reforestation tax system that is designed for managed stands.

A review of the equivalent yield tax rates shown in Tables 5 and 6 leads one to conclude that the tax burdens associated with the current implementation of the Forest Tax Act of 1971 are lower than those of the proposed bare land plus reforestation tax system. Thus, yield tax rates in excess of 5% are necessary to compensate for tax revenues (plus interest) foregone because of the use of statutory land values in place of the after-tax economic bare timberland values. This is somewhat surprising given that maturing timber is excluded from the tax base under the proposed system. These results hold across the wide range of interest and price appreciation rates that result in a positive no tax bare land value. Also, it is evident that the land value gradient generated by the statutory land values is flat when compared with that of the proposed tax system. This can be seen in Tables 5 and 6 by observing that the equivalent yield tax rates increase with increasing site quality. This reflects two things. First, the statutory bare land values for average and good sites are too low, whereas the opposite is true for low sites. Second, a flat 5% yield tax rate applied across all classes of land is not capable of generating an equitable tax burden.

As previously discussed in connection with Tables 2 and 3, a differential yield tax is required across site qualities to achieve equity. For example, in Table 5, for a 6% interest rate and a 1% price appreciation rate, the required equivalent yield tax rate rises from 8.5 to 13.2% as site index increases from 85 to 125, respectively. Thus, differing site qualities with different bare timberland values require different yield tax rates. Although administrative difficulties might arise, these should not be more burdensome than the current system, which assigns different bare land values based on site quality, and different stumpage values based on location, species, and timber quality. However, an average yield tax rate could be calculated if deemed necessary for administrative purposes.

Under the proposed bare land plus reforestation tax system, the taxing authority might choose to defer the annual ad valorem property tax on the reforestation investment

TABLE 7. Yield tax rate needed to generate a tax burden equivalent to that of a tax on reforestation costs plus bare land value if the annual ad valorem property taxes on bare land are paid annually but the annual ad valorem property taxes on the reforestation investment are deferred until harvest

Interest rate,[a] % (i)	Stumpage rate,[b] % (q)	Site index,[c] ft	Equivalent yield tax, % Y_p^{*d}	Y_p^{*e}
6	0	85	—	—
6	1	85	10.9	10.2
6	2	85	5.9	5.3
7	0	85	—	—
7	1	85	—	—
7	2	85	9.3	8.5
8	0	85	—	—
8	1	85	—	—
8	2	85	—	—
6	0	105	10.4	10.3
6	1	105	6.1	6.0
6	2	105	3.4	3.3
7	0	105	—	—
7	1	105	8.8	8.7
7	2	105	5.2	5.1
8	0	105	—	—
8	1	105	—	—
8	2	105	7.6	7.5
6	0	125	6.4	6.7
6	1	125	3.9	4.1
6	2	125	2.3	2.3
7	0	125	8.9	9.2
7	1	125	5.5	5.7
7	2	125	3.3	3.4
8	0	125	—	—
8	1	125	7.6	7.9
8	2	125	4.8	4.9

[a]Effective annual real interest rate.
[b]Effective annual real stumpage price appreciation rate.
[c]Fifty-year base age.
[d]Harvest yield tax that when combined with an annual ad valorem tax on bare land generates a present value of taxes equal to that of an annual ad valorem property tax on bare land plus reforestation investment as shown in Table 2, column 7 (the no commercial thinning regime). No tax-induced rotational impacts were observed in T_p^*.
[e]Same as described in footnote *d* except for the commercial thinning regime shown in Table 3, column 7.

until harvest. If so, a yield tax can be imposed to compensate the taxing authority for the revenues forgone with interest. Equation 7 summarizes the calculation required and Table 7 shows the numerical results. Using the same inputs as described earlier, columns 4 and 5 summarize the equivalent yield tax rates needed to make up for the removal of the reforestation investment from the tax rolls and still generate the same bare land values as shown earlier (Tables 2 and 3, column 7) for the case where the annual ad valorem property tax is applied to both the bare land value and the reforestation investment. Equivalent yield tax rates range from 2 to 11% and decrease with increasing site quality, interest rates, and price appreciation rates. No tax-induced increases in the optimal rotation over the no tax case are observed.

Taxing existing stands of mature timber

An important point mentioned earlier that requires further investigation is the continued taxation of existing stands of mature timber and the transition to the proposed bare land plus reforestation tax system as these mature timber stands are harvested. Waggener et al. (1983) conclude that naturally endowed stands of mature timber (i.e., old-growth or unmanaged young-growth stands) should remain classified as real property and be subject to some form of property taxation until harvested. However, as new stands of timber are established, the bare land plus reforestation tax system should take effect and become the preferred system of property taxation.

The Forest Tax Act of 1971 does not distinguish between existing stands of naturally endowed timber and future stands of plantation-grown timber. However, it is necessary to make this distinction if an equitable forest property tax system is to be developed. This suggests that a dual-track system of taxation may be necessary as existing timber stands undergo conversion to managed plantations.

Recognizing the theoretical advantage of a dual tax system, but also recognizing the administrative problems associated with such a system, it may be more practical to either (*i*) immediately convert all timber stands to the bare land plus reforestation tax system and establish a flexible system of yield tax rates that recognizes the accrued tax burden of previous taxes, or (*ii*) treat mature timber stands (i.e., over 90 (say) years of age) under a bare land plus severance tax system and tax all other timber stands under the bare land plus reforestation tax system. This severance tax could be assessed on a dollar per unit volume of output basis and could be administered like a severance tax on any nonrenewable natural resource. Severance tax levels could be set to preserve equity with tax burdens on plantation-growth timber stands.

Summary

This paper presents a brief history of the timber tax debate in Washington State and how it has evolved since passage of the Forest Tax Act of 1971. Based upon a review of relevant forest tax literature, a tax model is proposed to examine the numerical consequences of alternative forest tax systems. This model embodies the following assumptions: (*i*) the present value criterion is used to compute the tax burden on a single acre; (*ii*) the tax base consists of the bare economic timberland value plus the reforestation investment necessary to establish the stand; (*iii*) maturing timber is exempt from taxation; (*iv*) an unmodified annual ad valorem tax is applied to the full after-tax economic value of bare land plus reforestation investments; (*v*) all calculations are conducted at rotation start and property taxes are fully capitalized into land values; and (*vi*) no federal taxes are considered. The model also allows for equivalent yield taxes to be fully substituted for either the annual ad valorem property tax on the bare land value plus the reforestation investment, or only for taxes on the latter component of the tax base. If bare land remains subject to an annual ad valorem tax using statutory bare land values, an equivalent yield tax rate can be computed to create a tax burden equivalent to the bare land plus reforestation tax system. Appropriate equivalent yield tax rates under either scenario are shown for the assumed input conditions. Tax-induced rotational impacts are accounted for in determin-

ing these equivalent tax rates. For comparative purposes, tax burdens for a land only tax and an unmodified bare land and timber tax are also shown.

A comparison of tax burdens under the proposed bare land plus reforestation tax system with those existing under current law demonstrates that for the assumed input conditions, owners of plantations are better off under the current system. This suggests the degree to which the current system has been modified to achieve political stability. This further implies that either the statutory bare land values are out of line with the derived economic bare timberland values computed in this paper and (or) the current 5% harvest yield tax is too low. These conclusions presume that all tax burden comparisons are made at rotation start and are applied on a per acre basis. It is also evident that a single yield tax rate applied across all classes of site quality cannot generate an equitable tax burden.

Appendix 1

As discussed in this paper, all calculations and results presented exclude the effects of federal income taxation. Because some readers may wish to calculate the impacts of federal income taxes on the profitability of timber investments, the following model supplements are provided.

The following equation assumes that all operating costs are fully deductible against income from any source the year incurred. In the absence of any annual property taxes, but including federal income taxes, eq. 1 becomes

$$B_{0T} = [(H(T)(1 - j) + jC - Ce^{rT})/(e^{rT} - 1] - [A(1 - j)/(e^{r} - 1)]$$

where

B_{0T} = bare land value per acre before property tax but after federal income tax
j = federal income tax rate

All other symbols are as defined in the text.

The value for B_{0T} can be substituted into eqs. 2–3 to obtain the economic bare land value in the presence of both federal income as well as property taxes. However, the instantaneous real rate of ad valorem property taxation (g) must be modified to recognize that like annual expenses, property taxes also can be expensed annually against other income. The equation for B_{0T} also must be modified if other intensive management practices are included. These modifications might take the form of including the amortization of qualifying reforestation and fertilization expenditures, investment tax credits for reforestation, and cost-sharing payments. Because specific consequences differ for corporate and individual tax payers, it is difficult to offer general conclusions concerning the ultimate effect of these modifications.

Appendix 2

In this appendix the following analytical issues are discussed: (*i*) a statement of the first-order necessary conditions for determining the optimal rotation age for a fixed reforestation investment and the optimal level of reforestation investment for a fixed rotation age (both situations are examined under conditions of no tax, a land only tax, a land plus reforestation tax, a land plus timber tax, and a yield tax system) and (*ii*) the effect of these tax systems on land use.

Assuming that the reforestation investment is fixed, the optimal rotation age must satisfy the following first-order necessary conditions when maximizing the appropriate bare land value.

Land value to maximize	Necessary condition
B_0	$Q_{T\bullet}/Q = rM_r(1 - Z) - p$
B_L	$Q_{T\bullet}/Q = rM_r(1 - Z) - p$
B_{L+C}	$Q_{T\bullet}/Q = rM_r(1 - Z) - p$
B_{L+T}	$Q_{T\bullet}/Q = xM_x(1 - Z) - p$
B_Y	$Q_{T\bullet}/Q = rM_r\{1 - [Z/(1 - Y)]\} - p$

where

$Q_{T\bullet}$ = partial derivative of Q with respect to time
$M_r = e^{rT_j^*}/(e^{rT_j^*} - 1)$
$M_x = e^{xT_j^*}/(e^{xT_j^*} - 1)$
$Z = C/(SQ\, e^{pT_j^*})$

All other terms are as defined in the text.

The necessary conditions confirm the well-known facts that for a given reforestation investment, the land only tax system is neutral with respect to rotation age, the yield tax system extends the no tax rotation age, and the land and timber tax system leads to shorter rotation ages than any of these systems (Chang 1982; Hyde 1980). Since $x > r$, this last conclusion follows from the necessary conditions shown earlier. Of prime importance is that the land plus reforestation tax system is also neutral under these conditions.

If the rotation age is fixed but the level of the investment in reforestation is variable, the following first-order necessary conditions must hold when maximizing the appropriate bare land value. The tax model defined in eqs. 1–3 is slightly modified to permit C to be a variable and not a parameter. This is facilitated by replacing C everywhere with kC_0, where k represents the per unit cost of reforestation effort (i.e., the cost per seedling) and C_0 represents the number of units expended (i.e., the number of seedlings planted per acre). With this modification, we obtain the following results.

Land value to maximize	Necessary condition
B_0	$Q_{C\bullet} = W_r$
B_L	$Q_{C\bullet} = W_r$
B_{L+C}	$Q_{C\bullet} = W_r + (g/r)[W_r - k/(S\, e^{pT_{L+C}^*})]$
B_{L+T}	$Q_{C\bullet} = W_x = ke^{xT_{L+T}^*}/(S\, e^{pT_{L+T}^*})$
B_Y	$Q_{C\bullet} = W_r/(1 - Y)$

where

$Q_{C\bullet}$ = The partial derivative of Q with respect to C
$W_r = k\, e^{rT_j^*}/(S\, e^{pT_j^*})$

The necessary conditions show that only the land tax system is neutral. Neither the land plus reforestation, the land and timber, nor the yield tax systems exhibits neutrality with respect to the optimal level of reforestation effort.

To investigate this further, consider the necessary condition for the land only tax system: $Q_{C\bullet} = k\, e^{rT_L^*}/(S\, e^{pT_L^*})$. This can be rewritten as $k = (S\, e^{pT_L^*} Q_{C\bullet})/e^{rT_L^*}$. For the land

plus reforestation tax system, the necessary condition involves W_r plus an additional term: $gW_r/r - gk/(rS\,e^{pT_L \cdot c})$. As this latter term is always ≥ 0, it serves to increase W_r from its base value under the land only (or no tax) case. This results in a reduced reforestation effort relative to the land only tax (or no tax) situation. Thus, for a fixed rotation, the land plus reforestation tax encourages land owners to practice less intensive forest management relative to the land only or no tax cases.

Similarly, the optimal level of reforestation effort under either the bare land and timber or yield tax systems relative to either the no tax or the land only tax system is at a reduced level for a given cost of a unit of effort (k) and a fixed rotation.

Another desirable feature of the land only tax is that it is neutral with respect to land use. That is, if the no tax bare land value (B_0^*) is positive, the annual ad valorem property tax will not drive the after-tax bare land value (B_L^*) negative. However, this desirable feature is not present under either the land plus reforestation or the land and timber tax systems. By solving eq. 3 for C it can be shown that $B_{L+C}^* \geq 0$ so long as $C \leq (r/g)B_0^*$. An examination of Tables 2 and 3 verifies that for the values of g, r, and C used in this study, B_{L+C}^* was never driven below zero by the property tax. However, the land and timber tax did drive many positive B_0's negative. Thus, this tax system impacts land use much harder than does the proposed land plus reforestation system.

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