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THE ECONOMIC VALUE OF CARBON SEQUESTRATION THROUGH TREE PLANTING IN LAOS



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ABSTRACT

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Because tree plantations in Laos show that, despite high profitability, tree farmers and private companies face many challenges, including low timber quality, low timber prices, and slow plantation expansion, the aim of this study is to evaluate the social costs and benefits from private tree plantations by considering both market and non-market values, specifically for carbon sequestration. A policy decision tool - specifically cost-benefit analysis - was employed. Existing data from Laos and other locations were used to investigate the economic and social aspects of government policy implications for forest plantation for eucalyptus and teak. A dual-discounting approach was applied to discount future net benefits of market and non-market components to arrive at a present value. We found the monetary benefit of carbon sequestration of teak and eucalyptus tree plantations to be \$472.8 million (2020 dollars) over 30 years. It is concluded that the government should intervene by improving systems and regulations that can increase the private rate of return and eventually incentivize the private sector to plant more trees.

Contribution/ Originality: This study is one of very few to include non-market social values in cost-benefit analysis for tree plantations in developing countries. The focus is on the value of carbon sequestration in addressing climate modification, with an aim to guide government policy in private tree markets and generate net economic benefits.

1. INTRODUCTION

Carbon dioxide is a greenhouse gas (GHG) attributed with causing the most global climate modification. In the case of Laos (officially Lao's People Democratic Republic (Lao PDR)), a study of the impacts of climate change using a computable general equilibrium model, show that changes in crop yields and commodity prices would decrease gross domestic product by 2.8%, which is equivalent to \$80 million in 2050 with the base year of 2004 (Kyophilavong & Takamatsu, 2011). Many small countries like Lao PDR are climate-vulnerable even though their emission share is minimal compared to global GHG emissions.

Although it is well known that trees provide natural carbon dioxide sequestration, the benefit to society is often not accounted for in the evaluation of private investment. Tree plantation investments in Laos PDR are an example of profits driving investment decisions and provide a unique setting for a cost-benefit analysis of governmental intervention. First, tree plantations are part of rural livelihoods. Second, tree farmers face challenges; in particular, their selling prices are lower compared to other countries in the same region. Finally, to date, no study has explored the benefits to society stemming from tree plantations in Lao PDR, such as the natural sequestration they provide, and how accounting for missing societal benefits may justify the need for government intervention.

In the past, the Lao Government has made investments in tree plantations. To recover the destroyed forest cover, the Lao Government allocated 500,000 hectares (ha) for tree plantations in 2005 and an additional 700,000 ha in 2018, resulting in the plantation target of 1.2 million ha to be completed by 2030. Nevertheless, the tree farmers in Lao PDR face many challenges, including low timber quality, low timber prices, high costs of plantations and transportation, and official and unofficial charges. Also, private companies have encountered resistance for plantation expansions among local communities (Phimmavong, Maraseni, Keenan, & Cockfield, 2019). Trees are also cut earlier than their optimal age due to the impatience of owners who plant trees as part of their rural livelihoods. Recent studies on financial returns for teak and eucalyptus in Lao PDR show high financial returns from timber compared to costs of plantations in present value terms (Maraseni et al., 2018; Phimmavong et al., 2019) which suggests that the plantation investments are profitable. However, the plantation expansion has been slowed, and wood production to meet future demand is uncertain; indicating that the tree market is not operating efficiently. Further work needs to be done to evaluate the need for government intervention.

2. LITERATURE REVIEW

Climate change has extensively been linked to increased greenhouse gas concentration in the atmosphere, resulting in increases in the average global temperature, causing physical and economic damage to society. Some regions may benefit from climate change through increasing crop yields (Cosentino, Testa, Scordia, & Alexopoulou, 2012), and energy-saving for heating (Gonseth, Thalmann, & Vielle, 2017) particularly in the upper northern hemisphere. Environmental policy internalizing carbon externalities into the decision-making process became a priority for most countries around the world through international agreements such as the recent Paris Agreement in 2016.

Methods for economic valuation of environmental and resource values, including carbon sequestration, are classified into two broad categories; stated-preference and revealed-preference approaches (Tietenberg & Lewis, 2018). The latter is mainly linked to human behavior and uses the costs such as traveling expenses as a proxy for market prices. Therefore, it cannot estimate non-use values (Hanley & Barbier, 2009). In the case of non-use values such as GHG emission removal benefits to society, the contingent valuation method (CVM), a stated-preference method, is mostly used to estimate willingness to pay (WTP) to avoid damage. A successful WTP survey must have credible information with defensible results. However, the method has its drawbacks; notably, respondents are affected by their knowledge, perception of issues, occupations, stated political orientation, and incomes (Hanley & Barbier, 2009).

Some studies try to capture the total economic value using CVM for climate change policy. For example, Kotchen, Boyle, and Leiserowitz (2013) found that Americans are willing to pay \$71 per household per year for ten years to reduce US emissions by 17% by 2020. A recent WTP study by the same lead author shows that Americans are willing to pay \$190 per household per year to support a carbon tax (Kotchen, Turk, & Leiserowitz, 2017). Despite a possible debate on bias, stated-preference surveys are the only type of method to estimate total economic value, and techniques are widely used in regulatory impact analysis and to evaluate public opinion. Unfortunately, very few WTP studies to estimate the economic value of GHG emission reduction exist.

Estimating the social cost of carbon (SCC) is done as an alternative approach to estimate the global economic value of carbon dioxide. SCC is defined as an estimate of the potential economic damage due to emitting an additional ton of greenhouse gases into the atmosphere in present value (Anthoff, Tol, & Yohe, 2009a, 2009b). The most cited estimation methods for deriving the SCC are integrated assessment models (IAMs). The Interagency Working Group on the Social Cost of Greenhouse Gases (IWG) under the Obama administration updated the SCC values using IAMs to \$12, \$42, and \$62 per tCO₂ for emissions in 2020 for 5%, 3%, and 2.5% discount rates, respectively (Interagency Working Group, 2016).

Examples of some studies of tree plantations in Lao PDR include Phimmavong et al. (2019); Maraseni et al. (2018); Manivong and Cramb (2008) and Phimmavong (2004), who focus on private plantations. However, cost-benefit analyses of private investment in the region are limited at best and generally unavailable. It can be assumed that non-market values or social values external to private market transactions might be neglected or completely ignored from analyses for private investment. Nevertheless, the results of the financial analysis of tree plantations in the region, which is not the same as CBA, show a positive net present value, even in the absence of non-market values.

3. MATERIALS AND METHODS

The private sector manages most tree plantations in Lao PDR; therefore, some components of CBA in this study take a different approach than a conventional CBA. Eucalyptus and teak plantations were chosen for this study because of the availability of recent data on costs and prices of timber by Phimmavong et al. (2019) and Maraseni et al. (2018). No primary data collection was done in this study. Other necessary and relevant data were gathered from several sources. We begin with a description of the underlying equation of a CBA and the efficiency criteria to justify government intervention; then the study setting, and parameter values for costs, benefits, and the discount rate are described.

3.1. Net Present Value

In general, an investment is efficient when benefits are greater than costs. The equations used for net present value, land expectation value, and net future value for this study are shown in Equations 1 through 3.

$$NPV = \sum_{t=0}^T \frac{R_t}{(1+r)^t} - \sum_{t=0}^T \frac{C_t}{(1+r)^t} + \sum_{t=0}^T \frac{B_t}{(1+SDR)^t} \quad (1)$$

where NPV is the net present value (dollars), R_t is revenue at time t (dollars), C_t is total cost at time t (dollars), B_t is benefits from CO₂ sequestration at time t (dollars), r is the real interest rate (%), SDR is the social discount rate (%), t indexes a specific year, and $T+1$ is the total period (years, starting at zero).

$$NFV = \sum_{t=0}^T R_t * (1+r)^t - \sum_{t=0}^T C_t * (1+r)^t \quad (2)$$

$$LEV = \frac{NFV}{(1+r)^t - 1} \quad (3)$$

where LEV is land expectation value (dollars), and NFV is the net future value of one timber rotation (dollars).

3.2. Government Intervention

Criteria for government intervention in private tree plantations adapted from Warner (2013) are:

- (1) The social rate of return is higher than the private rate of return.

(2) The private rate of return is less than the market interest rate.

The second criterion demonstrates that if the private rate of return is higher than the market interest rate, the private sector will voluntarily invest. We use the first equimarginal principle together with the Pigouvian subsidy rule to provide rationale for when government intervention can improve market efficiency. The first equimarginal principle states that total net benefits are maximized when marginal cost equals marginal social benefit.

3.3. Description of the Study Setting

We consider two species in Lao PDR: eucalyptus (either *E. camaldulensis* or *E. tereticornis*) and teak (*T. grandis*). Eucalyptus is the most common species planted by multinational companies, mainly in central and southern parts of Lao PDR. Teak plantations, however, have been extensively planted by the smallholders in the northern part of the country (Phimmavong, Ozarska, Midgley, & Keenan, 2009). There are no available growth and yield data specifically for Lao PDR, so data on rotation ages and growth rates from previous studies by Phimmavong et al. (2019) and Maraseni et al. (2018) were used. To compare CBA results of different tree species with different rotation ages, thirty years was used as the investment period for both plantations. The consideration of a 30-year period for the CBA reflects the current Law on Land (2013): Lao citizens are allowed to lease a piece of land from the Government for 30 years. A description of CBA input parameters is shown in Table 1.

3.4. Costs of Tree Plantations

Costs of tree plantations for teak and eucalyptus are taken from previous studies by Phimmavong et al. (2019) and Maraseni et al. (2018). Costs of eucalyptus plantations (\$6,333/ha) are higher than the costs of teak plantations (\$1,149/ha); likely because smallholders manage teak, while private companies manage eucalyptus. A private company is required to bear other costs, including a concession payment and development funds for local communities.

Table-1. Input parameters for cost-benefit analysis.

Component	Teak	Eucalyptus
Mean annual increment (m ³ /ha/year)	12.2	28.6
Timber price (\$/m ³)	93.8	55.6
Social cost of carbon (\$/tCO ₂)	1	1
Rotation age (years)	18	7
CO ₂ sequestration function (tCO ₂)	$CO_{2seq} = 10.96 * Age^{1.43}$	$CO_{2seq} = 12.77 * Age^{1.54}$
Concession period (years)	30	30
Nominal interest rate (%)	12	12
Real interest rate (%)	8.3	8.3
Social discount rate (%)	6.9	6.9

Source: Maraseni et al. (2018); Vongsikeo (2020).

A smallholder of teak plantations does not pay for harvesting costs, except plantation registration costs. Transportations costs were not included. All costs in the CBA are converted to current costs by adjusting them with the consumer price index (CPI). Costs of plantations occur every rotation until the end of the concession period. It is assumed that the real costs of plantations do not change over time.

3.5. Benefits of Tree Plantations

There are two categories of benefits derived from tree plantations: market and non-market. The market value of timber harvesting is accrued as financial returns to an investor, while benefits from carbon sequestration are non-market values accrued to society. In many research studies the amount of “carbon sequestration” is measured in units of carbon dioxide (tCO₂), while other studies measure carbon sequestration in units of carbon (tC). For consistency, carbon dioxide (CO₂) sequestration will be used herein to refer to an amount of CO₂ removed from the

atmosphere by tree absorption, expressed as tons of carbon dioxide per hectare (tCO₂/ha). We describe how we represent the market and non-market benefits in our CBA next.

3.5.1. Timber Harvest Benefits

Two pieces of information are needed to estimate benefits from selling timber: the price of timber and volume of a tree stand at rotation age. Trees are priced primarily on timber quality, diameter, and length. Tree volumes at rotation age are typically estimated using a growth function. To maximize long-term wood production, trees are theoretically harvested at a biological rotation age or when the growth rate, or the mean annual increment (MAI), starts to decline. The MAI is calculated by dividing yield with stand age. Generally, teak has the highest MAI at the age of 40 - 60 years (Ball, Pandey, & Hirai, 1999), while the MAI is highest for eucalyptus at 7-15 years (Lamprecht, 1990) based on its location, spacing, site properties, and plantation management. In the case of developing countries, selected rotation age tends to be shorter than biological rotation age. Presumably, the private owners aim to maximize financial returns based on current timber prices. For example, the reported rotation age for teak in Lao PDR is 18 - 24 years while the rotation age for eucalyptus is 7 years (Maraseni et al., 2018; Phimmavong et al., 2019). Unfortunately, it is not currently possible to estimate functions for yield or growth rate with regression analysis due to discrepancies in reported characteristics. Therefore, this study uses data provided by previous literature (Maraseni et al., 2018; Phimmavong et al., 2019), and estimates the volume of tree stands at a rotation by multiplying MAI with a harvesting age. MAI for teak is 12.2 m³/ha/year for the 18-year rotation age, while 28.6 m³/ha/year of MAI is selected for eucalyptus for the 7-year rotation age.

3.5.2. Benefits from CO₂ Sequestration

We perform a regression analysis to estimate the natural log of CO₂ sequestration as a function of the natural log of the age of a tree stand. A log-log functional form was selected to approach zero sequestration when a tree is first planted (and age approaches zero). The mathematical model for regression analysis is shown in Equation 4.

$$\ln CO_2 seq = b_0 + b_1 \ln(Age) \quad (4)$$

where $CO_2 seq$ is CO₂ sequestration (tCO₂/ha), Age is the stand age of tree (years), and b_0 and b_1 are the estimated coefficients. The regression results have high R-squared statistics of 0.87 and 0.70 for teak and eucalyptus, respectively. In both models, the estimated coefficients are statistically significant at a 95% confidence level. The regression models for both tree species are also efficient and unbiased estimators based on tests for normality, heteroscedasticity, non-linearity and model specification. The log-log model was transformed into a linear-power function using smearing retransformation (Vongsikeo, 2020). The results of CO₂ sequestration functions are shown in Equations 5 and 6.

$$CO_2 \text{ sequestration for teak:} \quad CO_2 seq = 10.96 * Age^{1.43} \quad (5)$$

$$CO_2 \text{ sequestration for eucalyptus:} \quad CO_2 seq = 12.77 * Age^{1.54} \quad (6)$$

The above functions show that at a stand age of one, eucalyptus sequesters 12.77 tCO₂/ha, which is higher than 10.96 tCO₂/ha for teak. Eucalyptus sequesters more than teak as stand age increases. To calculate the economic value of CO₂ sequestration in a value of dollars per hectare, CO₂ sequestration based on a stand age is multiplied by the value of SCC.

SCC estimates are ambiguous and highly controversial, even for the global estimates. However, it is an essential metric for climate policies. Without SCC, the benefits of CO₂ sequestration from tree plantations are implicitly assigned a value of zero. In practice, many countries set their ex-ante SCC, specifically for carbon tax rates, from \$3 to \$168/tCO₂ in 2015 (World Bank Group, 2017). The SCC is expected to increase over time based on a country's effort to reduce carbon dioxide. In the case of Lao PDR, using a country-level SCC estimated by

Ricke, Drouet, Caldeira, and Tavoni (2018) results in a SCC less than \$1/tCO₂, which is on the very low end of the spectrum. Although the real figure is unknown, this study assumes \$1/tCO₂ for CO₂ sequestration from tree plantations as the base case to be conservative. A sensitivity analysis is performed later to evaluate the impact of SCC choice.

As selection rotation age of either tree species approaches 30 years, the total as well as average CO₂ sequestration potential dwindles. Some selections of rotation age result in zero CO₂ sequestration at the end of year 30. Given the concession of 30 years and rotation ages of teak and eucalyptus plantations of 18 years and 7 years, respectively, CO₂ is sequestered from the atmosphere at about 1002 tCO₂/ha for teak plantations and 962 tCO₂/ha for eucalyptus plantations. Similar sequestration values are due to the contrasting attributes of the low growth rate with the longer selected rotation age for teak plantations compared with the high growth rate but the shorter selected rotation age for eucalyptus plantations. On average, the annual CO₂ sequestration for both plantations is 32 tCO₂/ha/year, while the CO₂ sequestration of natural forests is only 2.45 tCO₂/ha/year based on a study done by Yen and Wang (2013) in Taiwan. Thus, society gets more sequestration benefits from tree plantations than natural plantations in terms of CO₂ sequestration potential.

3.6. Discounting Approach

Unlike the World Bank's recommended discount rate of 10 to 12% for project appraisal in developing countries (Bonzanigo & Kalra, 2014) this study employs a dual discounting approach to discount financial returns and benefits of CO₂ sequestration separately. There are two discount rates used in this CBA; the real interest rate for discounting cash flows of financial returns and the growth-rate-adjusted social discount rate (SDR) for discounting benefits of CO₂ sequestration. The real interest rate is calculated by subtracting the inflation rate from the nominal interest rate. A nominal interest rate of 12% was used based on the borrowing interest rate from the Agriculture Promotion Bank, which is the only state bank that gives loans for agriculture and forestry investment projects in Lao PDR. The inflation rate, estimated from the CPI from 2010 – 2019, is 3.7% on average. Thus, the real interest rate of 8.3% was applied for financial analysis. The high real interest rate in developing countries such as Lao PDR is likely due to the limited availability of credit provided by banks and a default risk inducing banks to charge a high interest rate.

In contrast, the SDR is estimated based on the consumption discount rate equation developed by Ramsey (1928). The SDR estimate represents intertemporal equity, defined as the amount society weighs today's consumption compared to the consumption of future generations. It is also assumed to differ from country to country. The SDR in developing countries is expected to be higher than in developed countries. This is not entirely associated with higher risks due to unpredictable politics in developing countries, but mainly due to a higher real GDP per capita growth rate in emerging economies. Based on nine-year data on real GDP per capita from 2010 - 2019 in a local currency, Lao PDR has a real GDP per capita growth rate of 5.9% on average. Therefore, according to Ramsey's equation, assuming a pure rate of time preference of 1.0% and a wealth effect of 1.0, the social discount rate is 6.9% (Vongsikeo, 2020). The social discount rate of 6.9% is high compared with studies done in other developed and developing countries, which lead to a more conservative estimate of intertemporal benefits, but is still lower than a general SDR applied by developing countries, which ranges between 8-15% (Zhuang, Liang, Lin, & De Guzman, 2007).

4. RESULTS AND DISCUSSION

The results of the CBA provided in this section include: (1) the cost-benefit analysis for private tree plantations for two tree species (teak and eucalyptus) in Lao PDR, (2) the impact of the change in social discount rate and social cost of carbon on the net present values of non-market benefits, and (3) the results of different policy and anticipated damage scenarios in terms of how they affect policy priority and budgets of government intervention.

4.1. Cost-Benefit Analysis for Private Tree Plantations

Table 2 gives results showing that total costs for eucalyptus is higher than teak.

Table-2. Results of the cost-benefit analysis over 30 years (in 2020).

	Teak 18-year rotation age			Eucalyptus 7-year rotation age		
	Market	Non-market	Total	Market	Non-market	Total
Timber yield (m ³ /ha)			354			772
CO ₂ sequestration (tCO ₂ /ha)			1,002			962
Cost	\$2,470	0	\$2,470	\$19,791	0	\$19,791
Benefit	\$33,180	\$1,002	\$34,182	\$42,930	\$962	\$43,891
Net benefit	\$30,710	\$1,002	\$31,711	\$23,139	\$962	\$24,101
Net present value	\$4,696	\$397	\$5,093	\$4,574	\$391	\$4,965
Rate of return	18.0%	-	19.0%	18.0%	-	18.7%
Land expectation value	\$6,176	-	-	\$10,731	-	-

4.2. Timber Yields and CO₂ Sequestration

Being characteristically fast growing, eucalyptus plantations yield higher wood production of 772 m³/ha compared to teak of 354 m³/ha for a 30-year plantation, even with a shorter rotation period, 7 years, compared to teak's 18 years. Due to more frequent rotations, eucalyptus plantations sequester slightly less CO₂ than teak plantations: 962 tCO₂/ha and 1,002 tCO₂/ha, respectively. However, because using different rotation periods will change these results, here we only consider the current practice rotation periods presented in previous studies.

4.2.1. Net Benefits without Discounting

We find social net benefits are greater than private net benefits for both species: \$31,711/ha and \$24,101/ha for teak and eucalyptus plantations, respectively. By using the social cost of carbon of \$1/tCO₂, the non-market value for CO₂ sequestration from both tree species is not much different; \$1,002/ha for teak and \$962/ha for eucalyptus, which is about 3.2% and 4.0% of total benefits. Therefore, by taking an average of net benefits from both types of plantations, society accrues net benefits from tree plantations of about \$930/ha/year for 30 years, which accounts for 3.5% of the total net benefit. This is lower than the total undiscounted net benefit Guo, Xiao, Gan, and Zheng (2001) found for natural forests in China, which is \$1,199/ha/year (undiscounted numbers are considered here for a direct comparison with Guo). However, recall that Guo et al. (2001) included non-market values beyond carbon sequestration.

4.2.2. Net Present Value

It is not surprising to find positive private (market) NPV for teak and eucalyptus plantations: \$4,696/ha and \$4,574/ha, respectively. The positive market NPV is consistent with previous studies (Maraseni et al., 2018; Phimmavong et al., 2019). With long-term evaluation, we find the LEV for eucalyptus is higher compared with teak: \$10,731/ha versus \$6,176/ha. Note that the LEV is a means to measure for financial analysis only; thus, it is only calculated from market value. The difference of LEV implies that eucalyptus plantations provide a higher long-term return on investment. However, care should be taken when interpreting the LEV results. This analysis did not consider the possible increase in the real price of timber in the future. Given the slow growth rate of teak, and a likely higher future demand, the real price of teak is expected to increase faster than that of eucalyptus, so the long-run value of teak plantations may be higher than \$6,176/ha. The social (total) NPV is also slightly higher than the private NPV for both plantations. The social NPVs for teak and eucalyptus are \$5,093/ha and \$4,965/ha, respectively. Recall that the non-market values of CO₂ sequestration of the tree species are fairly similar, with an average of \$394/ha in a present term, or about 7.8% of the average social NPV.

4.2.3. Rate of Returns

A similar conclusion is drawn for the rate of returns: the social rate of return (SRR) is slightly higher than the private rate of return due to the integration of non-market value. The SRR is 19% and 18.7% for teak and eucalyptus plantations, while the private rate of return is 18.0% for both plantations. The SRR would likely be higher than what we found in this study if other non-market values were included. Recall government intervention is efficient, yielding positive net benefits, when the SRR is greater than the private rate of returns and the private rate of return is less than the market interest rate.

4.3. Impact of Social Cost of Carbon and Social Discount Rate

4.3.1. Impact of SCC on the non-market NPV

The ex-ante SCC is set at \$1/tCO₂. The sensitivity analysis was performed by varying the percentage change in SCC. It is not surprising to find a linear relationship between the SCC and the non-market NPV, because the non-market NPV uses a constant SCC in the calculation. It can be concluded that a percent increase in the SCC results in a percent increase in the non-market NPV of equal magnitude.

4.3.2. Impact of the Growth Rate of Per Capita Consumption on the Non-Market NPV

Based on macroeconomic data, the real growth rate of per capita consumption for Lao PDR ranges between 3.1% to 9.3%, with an average of 5.9%. A sensitivity analysis of the change in growth rate of per capita consumption was also performed, as shown in Table 3. The SDR was recalculated based on Ramsey's equation (a pure rate of time preference of 1.0% and the risk aversion of 1.0). The non-market NPV was also recalculated. The results show that the non-market NPV for teak plantations is slightly more sensitive to a change in the growth rate of per capita consumption than eucalyptus plantations. When the growth rate of per capita consumption increases by 10%, the non-market NPV decreases by 6.3% and 5.9% for teak and eucalyptus, respectively.

4.3.3. Impact of the SCC on the SRR

The social rate of return (SRR) was recalculated with changes in the SCC by holding other input parameters constant – the results are in Table 4. By holding other input parameters constant, only the non-market component of the social NPV changed and the market NPV remains the same at \$4,696/ha and \$4,574/ha for teak and eucalyptus, respectively. Note that the SRR is calculated from net benefits (not present values of net benefits); therefore, the change of SDR does not affect the SRR. The results show that the SRR is not sensitive to the SCC. A ten percent increase in the SCC results in a 0.5 percent increase in the SRR for teak plantations and 0.38% for eucalyptus plantations. This is likely because the benefits of the non-market value of tree plantations are minimal compared to market value; on average, the non-market value accounts for 3.5% of the total net benefits or 7.8% of the social net present values.

Table-3. Impact of the growth rate of per capita consumption on the net present value (NPV) of non-market component.

SDR (%)	SDR scenarios				
	5.72	6.31	6.90	7.49	8.79
(% change of growth rate of per capita consumption)	(-20%)	(-10%)	(0%)	(+10%)	(+20%)
NPV for teak	\$455	\$424	\$397	\$372	\$325
(% change of NPV for teak)	(+14.6%)	(+6.8%)	(0%)	(-6.3%)	(-18.1%)
NPV for eucalyptus	\$445	\$416	\$391	\$368	\$324
(% change of NPV for eucalyptus)	(+13.8%)	(+6.4%)	(0%)	(-5.9%)	(-17.1%)

Note: percent differences to the base case are in parentheses.

Table-4. Impact of the social cost of carbon (SCC) on the social rate of return (SRR).

SCC (\$/tCO ₂)	SCC scenarios				
	0.8	0.9	1	1.1	1.2
(% change of SCC)	(-20%)	(-10%)	(0%)	(+10%)	(+20%)
SRR for teak	18.82%	18.91%	19.01%	19.10%	19.20%
(% change of SRR)	(-1.00%)	(-0.50%)	(0%)	(+0.50%)	(+1.00%)
SRR for eucalyptus	18.52%	18.59%	18.67%	18.74%	18.81%
(% change of SRR)	(-0.76%)	(-0.38%)	(0%)	(+0.38%)	(+0.76%)

Note: percent differences compared to the base case are in parentheses.

5. CONCLUSIONS AND RECOMMENDATIONS

The implications of this study for policymakers can be summarized as follows.

- (1) Government intervention in the private tree plantations market is justified because the social rate of return is higher than the private rate of return, while it might not be efficient when the private rate of return is greater than the market rate of return.
- (2) The social rate of return is not very sensitive to the economic value of carbon sequestration in private tree plantations, because the benefits of carbon sequestration are small compared to financial benefits from selling timber.
- (3) The intervention budget is estimated at \$472.8 million in today's value for 30 years, which is 2.3% of the gross domestic product in 2020. The result of this study is based on the current land allocation for tree plantations by the Government.
- (4) To achieve the current objective of allocating 1.2 million hectares to increase forest cover as well as wood production, eucalyptus investments should be given priority.
- (5) If the government decides that CO₂ sequestration is the primary objective for tree plantations, then it is more beneficial to consider enhancing the teak plantation industries.
- (6) The government should intervene by improving systems and regulations that can increase the private rate of return and eventually incentivize the private sector to plant more trees.

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