Reducing Indonesia's Deforestation-based Greenhouse Gas Emissions*

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Abstract

Indonesia has set the target that by the year 2020 its emissions of greenhouse gases will be reduced by 26 per cent relative to business-as-usual conditions. This paper analyzes the effectiveness of a subsidy to the use of land in forestry as a means of achieving this goal. The analysis uses a general equilibrium model of the Indonesian economy characterized by explicit treatment of land use, disaggregated by industry and by region. The results of the analysis indicate that the subsidy cost of permanently reducing carbon emissions by 26% is a little over US$1 per metric tonne of carbon emissions abated. This cost needs to be compared with that of alternative instruments and with the price of carbon that might be agreed under the proposed REDD scheme (Reducing Emissions through Deforestation and Land Degradation), to be administered through the World Bank and the UN.

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1. Introduction

In September 2009 the President of Indonesia announced to the G-20 international leaders summit in Pittsburgh that Indonesia had an ambitious goal for reducing its emissions of greenhouse gases (GHGs). By 2020 the carbon dioxide equivalent of these emissions would be reduced by 26 per cent relative to what would otherwise have happened under business-as-usual (BAU) conditions. Moreover, with appropriate international assistance these emissions would be reduced by an additional 15 per cent, leading to a total reduction of 41 per cent, relative to BAU.[1] Finding the means by which these ambitious goals could be achieved in practice is a challenging task for policy analysts and is the subject of this paper.

A major source of Indonesia's total emissions of GHGs is the carbon dioxide released into the atmosphere when forests are converted to agricultural land. This conversion of land use is occurring rapidly and the term 'business-as-usual' implies its continuation. Indonesian sources have estimated the current rate of conversion of forest to agricultural land at 1.32 million hectares per year.[2] Slowing the rate at which land under forest is converted to agricultural land is central to achieving the President's announced targets. Indeed, it is a necessary condition because land use change accounts for four fifths of Indonesia's total emissions.

Table 1 provides data on GHG emissions by source. Indonesia's total emissions account for 5.9 per cent of global emissions from all sources. At a global level, emissions from land use change and forestry account for 16.3 per cent of total emissions, but at 1,459 million metric

[1] The President's speech was delivered on 25 September 2009. A transcript is available at: http://redd-indonesia.org/publikasi/detail/read/indonesia-presidents-speech-on-climate-change-at-2009-g-20-meeting-1/ [accessed 8 August 2010]

[2] Presentation by Ruandha Agung Sugardiman, Ministry of Forestry, Government of Indonesia, 'Defining the National Reference Emission Level - Forestry Sector' at the Monitoring, Reporting, and Verification meeting

tonnes per year, Indonesia's estimated emissions from land use change account for 80.4 per cent of its total emissions of 1,815 million metric tonnes and 27.1 per cent of global emissions from land use change. Emissions deriving from land use change in Indonesia alone therefore account for 4.7 per cent of global emissions from all sources combined. Its importance in this respect is exceeded only by Brazil, which accounts for 6.6 per cent of total emissions from all sources and 34 per cent of all emissions arising globally from land use change. Brazil's emissions from land use change represent 84 per cent of its total emissions.

[Table 1 about here]

A mechanism has been proposed by which the international community might assist nations like Indonesia to reduce the very large effect that changes in land use have on emissions of GHGs. The scheme is called REDD (Reducing Emissions from Deforestation and Forest Degradation).[3] Under this scheme, which would be administered by the World Bank in collaboration with the United Nations, countries will be compensated for slowing the rate at which forests are cleared. Although the details of the scheme remain tantalizingly unclear, the question arises of how Indonesia might respond to it. How might the existence of REDD payments to the Indonesian central government be translated into changes in incentives at the local level and thereby influence the actual rate of land conversion?

In the case of land use change, the international REDD administrators will determine these payments through data on vegetation cover, obtained through computerised analysis of satellite imagery. This study explores a price-based instrument though which emissions from land use change might actually be reduced sufficiently to achieve the President's targets. The mechanism is in two parts: (i) an enforced prohibition on conversion of protected native

of UNREDD countries in Mexico, June 2010. It is possible that the 1.32 million hectares refers only to legally sanctioned land conversions and that it thereby understates the total rate of conversion.

[3] The website noted above contains a great deal of information on REDD and its relevance for Indonesia.

forests to other uses; and (ii) a subsidy to the retention of land under commercial forest rather than conversion to agricultural use.[4] The purpose of the subsidy is to discourage conversion of land from production forest to crops. It is assumed that the payment of this proposed subsidy would be based upon satellite imagery, in parallel with the operation of the REDD scheme itself.

Section 2 of the paper discusses the possible impact of these policy instruments on the target of emissions reduction. Section 3 makes the case for using a general equilibrium treatment of these issues in empirical applications and then summarizes the general equilibrium model of the Indonesian economy that is to be used in the analysis. Section 4 describes the simulations performed and the results are discussed in Section 5, focusing on the budgetary cost of the subsidy to forest land that would be required to achieve the President's announced goals. Section 6 concludes.

2. Land use change and GHG emissions

The importance of the major categories of land use are summarised in Table 2. The first column shows official Indonesian records on land use in the year 2003, derived from the Indonesian Ministry of Forestry. According to these data, non-cultivated natural forest (native forest) occupies 49.4 million hectares and production forest an additional 83.7 million hectares. Conversion of forest land to agricultural uses occurs primarily in the production forest, but not all of this land officially classified as production forest is legally available for conversion to agricultural use. The legally convertible portion is only 22 million hectares. Assuming that the current conversion of 1.32 million hectares per year cited above occurred

[4] A longer paper (Warr and Yusuf 2010) also analyses other possible policy instruments for achieving the President's target: an output tax on palm oil and a reduction in the forestry output levy that currently finances Indonesia's Reforestation Fund. It concludes that the land use subsidy to forestry considered in this paper is a more effective instrument than either of these alternatives.

only in the legally convertible forest, this portion would be exhausted after 17 years from 2003 – ironically the year 2020, the year specified in the President's targets.

Satellite-based data on actual vegetation cover gives a bleaker picture of Indonesia's actual forest cover. These data, summarized in the second column of Table 2, show non-cultivated natural forest occupying 33.7 million hectares and production forest an additional 50.1 million hectares. Rather than a total of 133 million hectares under forest cover in 2003 (non-cultivated natural forest plus production forest), as indicated by the official data, the satellite data reveal a total of 83.8 million hectares. The difference of 50 million hectares lies almost entirely in the category of 'other land', which consists mainly of partially degraded land. Official data classifies this land as forested, whereas satellite imagery reveals it to be only partially covered by forest. These satellite-derived data are used as the basis for the analysis of this paper.

[Table 2 about here]

Figure 1 illustrates in stylised form the effect of the policy instrument analysed in this study. Line A shows a hypothetical time path of total Indonesian emissions of CO_2 arising from changes in land use under business-as-usual (BAU) conditions. These emissions should be regarded as additions to the global stock of atmospheric CO_2. They arise because as land is moved from forestry to agricultural uses, total emissions rise. The slope of line A is the annual addition to the global stock of CO_2 arising from changes in land use within Indonesia. This slope depends on the rate at which land is reallocated each year from forestry to agricultural use under BAU conditions and the change in emissions that occurs when one hectare of land is reallocated in this way.

Suppose this annual rate of BAU emissions from land use change (the slope of path A) is a. Now suppose that at time T_0 the Indonesian government introduces a policy measure that reduces the rate at which land is moved from forestry to agricultural production, thereby reducing the annual volume of emissions arising from land use change. If the policy remains in place permanently, the time path of emissions from land use change becomes line B. Let the proportional reduction in annual emissions resulting from this policy measure be λ, implying that the slope of line B is $a(1-\lambda)$.

Finally, suppose that the emissions reduction policy is discontinued after t years, at time $T_1 = T_0 + t$, and is not reinstated thereafter. After this, the annual path of emissions diverges from path B and reverts to the same slope as path A. This path is shown by line C. It is parallel to path A beyond time T_1, meaning that, beyond this time, paths A and C differ only by their vertical value. The existence of the emissions reduction policy meant that total emissions over the period T_0 to T_1 was $ta(1-\lambda)$, whereas if BAU had prevailed over this same period emissions would have been ta, a difference of $ta\lambda$. The longer the policy remains in place, the larger is *t* and the greater is this vertical difference. This vertical difference between paths A and C persists permanently, meaning that the existence of the emissions reduction policy for t years produced a permanent reduction in Indonesia's total emissions of $ta\lambda$ tonnes.[5] If the annual subsidy cost is S the total cost is tS and the subsidy cost per tonne of CO_2 sequestered permanently is $S/a\lambda$.

[Figure 1 about here]

[5] An important assumption of this discussion is that the BAU rate of conversion of forest land to agricultural land continues to remain feasible within the period of the analysis. If forest land becomes exhausted within the period of the analysis path A becomes horizontal. In that case, the policy of subsidizing forest land will

3. The INDONESIA E3-L Model

3.1 Overview: the value of a general equilibrium treatment

The effect that tax or subsidy interventions may have on land use and therefore on carbon emissions is not simple and involves the way that enterprises respond to changes in their incentive structure. These responses may be far from uniform across the country, because different regions face very different agro-ecological conditions. The responses of firms affect factor returns, including returns to land, capital and labour. If subsidies are involved, and Indonesian taxpayers are required to finance these subsidies, a complete analysis needs to take account of the economic effects of raising these funds through increased taxes. Policy analysts are also interested in the broader economic effects of such interventions, especially those relating to the core economic objectives of the government. For example, what is the trade-off, if any, between achievement of the President's goals on carbon emissions and the maintenance of food security?

An analysis is needed which takes account of these issues within a theoretically coherent and data-consistent framework. The economic consequences of large interventions of the kind discussed above are inherently general equilibrium issues. In this section we describe a general equilibrium model of the Indonesian economy, the INDONESIA E3-L (Economy-Equity-Environment-Land) model, designed specifically for the analysis of these phenomena, with a strong emphasis on land use and its economic determinants at a national and regional

delay the time at which this exhaustion occurs but will not permanently prevent it because path B will eventually intersect the horizontal portion of path A provided its slope is positive.

level, along with the implications of land use for greenhouse gas emissions.[6] The advantage of working with a disaggregated general equilibrium model is that it becomes possible to conduct controlled experiments, which focus on the consequences for land use and emissions that arise from different economic shocks, taken one at a time. It is also possible to consider the effect of alternative assumptions about key economic parameters.

3.2 Model structure

As well as disaggregating land use by region, INDONESIA E3-L has a disaggregated industry and commodity structure, with 43 industries and 43 corresponding commodities. Most of its structural features are standard for general equilibrium models of this type. The microeconomic behaviour assumed within it is competitive profit maximization on the part of all firms and competitive utility maximization on the part of consumers. Economic agents are thus assumed to be price-takers, with producers operating in competitive markets with zero profit conditions, reflecting the assumption of constant returns to scale. Markets for final outputs, intermediate goods and factors of production are all assumed to clear at prices that are determined endogenously within the model. The nominal exchange rate between the Indonesian currency (the rupiah) and the US dollar is fixed exogenously.

The 43 sectors comprise agriculture (16), other primary industries (5), forestry (1), industry (16), including utilities and construction, and services (5). The theoretical structure of the model is based on the ORANI-G model (Horridge 2000) with several modifications, of which the most important is the multi-region land allocation feature, described more fully below, which is fully integrated within the general equilibrium structure.

[6] The analysis builds upon an earlier model named INDONESIA-E3, described in Yusuf (2008), but adds to it a detailed treatment of land use and a regionally disaggregated level. Readers wishing a fuller description of the

[Figure 2 about here]

The theoretical structure of INDONESIA E3-L includes the following major components:

- A land allocation system recognising that land is imperfectly mobile between economic activities, represented by elasticities of transformation that can be varied parametrically.
- A production structure that disaggregates agriculture (16 sectors) and forestry (one sector) into five regional components.
- A factor demand system, based on the assumption of CES production technology, that relates the demand for each primary factor to industry outputs and prices of each of the primary factors, reflecting the assumption that factors of production may be substituted for one another in ways that depend on factor prices and on the elasticities of substitution between the factors.
- A distinction between four kinds of labour: skilled and unskilled, each of which is divided into paid and unpaid, which are 'nested' within the industry production functions. In each industry, all four kinds of labour enter a CES production function to produce 'labour', which itself enters a further CES production function for industry output.
- The household supplies of each of the four kinds of labour are assumed to be exogenous.
- Leontief assumptions for the demand for intermediate goods. Each intermediate good in each industry is thus demanded in a fixed proportion to the gross output of the industry.
- A household consumption demand system, derived from the linear expenditure system.
- Demands for imported and domestically produced versions of each good, incorporating Armington elasticities of substitution between the two.
- A set of export demand functions, indicating the elasticities of foreign demand for Indonesia's exports.

features of the model, except for land use, are referred to Yusuf (2008).

- A set of equations determining the household incomes from their (exogenous) ownership of factors of production, reflecting data derived from the 2003 *Social Accounting Matrix*, the (endogenous) rates of return to these factors, and any net transfers from elsewhere in the system.
- Rates of import tariffs, excise taxes and subsidies across commodities, rates of business taxes, value added taxes and corporate income taxes across industries, and rates of personal income taxes across household types which reflect the structure of the Indonesian fiscal system, using data from the Indonesian Ministry of Finance.
- A set of macroeconomic identities ensuring that standard macroeconomic accounting conventions are observed.

3.3 Social accounting matrix

In contrast to other ORANI-G based CGE models, which are based solely on an Input-Output table, this model requires additional information available only from an enhanced Social Accounting Matrix. The Indonesian Social Accounting Matrix 2003 serves as the core database for the INDONESIA E3-L model, combined with official Indonesian data on land use allocation across industries, disaggregated by the five regions identified in the model: Sumatra, Java-Bali, Kalimantan, Sulawesi and Eastern Indonesia. Analyses of the land use implications of economic policies have in the past been constrained by the absence of a Social Accounting Matrix (SAM) with disaggregated regions and explicit treatment of land allocation. The database of the model relates to 2003.

3.4 Factors of production

The mobility of factors of production is a central feature of any general equilibrium system. 'Mobility' refers here to the capacity of the factor to be reallocated across economic activities

(industries) in response to changes in rates of return. It may or may not entail geographical mobility. The greater the factor mobility that is built into the model, the greater is the economy's simulated capacity to respond to changes in the economic environment. It is clearly essential that assumptions about the mobility of factors of production be consistent with the length of run that the model is intended to represent.

Four types of labour are identified, ‘unskilled’ and ‘skilled’, based on the educational characteristics of the workforce, each of which is divided into ‘paid’ and ‘unpaid’. Skilled labour is defined as those workers with lower secondary education or more. The paid and unpaid categories are based on the Indonesian *Labour Force Survey*. Unpaid labour means labour supplied within the household and therefore not paid a formal wage. In the construction of the database, unpaid labour is paid an imputed wage, whose total value for each industry is subtracted from the ‘operating surplus’ category in the input output table.

All four categories of labour are assumed to be mobile across all sectors while capital is immobile across sectors. These features imply an intermediate-run focus for the analysis. Issues of climate change have both intermediate-run and long-run dimensions. The present analysis is focused on achieving the Indonesian President’s intermediate-run policy goals, cited above, and the assumptions on factor mobility reflect this focus.

Within each region, land is imperfectly mobile across sectors, depending on returns to land in these sectors and the finite elasticities of transformation between effective units of land in different uses. Land is not homogeneous. For example, as land is converted from production forest to a cropping activity such as palm oil, the suitability of the land for the new use declines as more land is converted. It is helpful to think of a production possibilities frontier for *effective units of land* that is concave to the origin. ‘Effective units’ means that the area of

land is adjusted by its productivity in the use concerned. Figure 2 illustrates this treatment. Effective units of land in forestry production is on one axis and on the other is effective units of land in crop production. The concavity of the frontier means that the marginal productivity of each physical hectare of forest land converted to crops declines as more such land is converted. The rate at which this diminishing productivity occurs is measured by the elasticity of transformation.

If land was perfectly mobile between the two activities with no diminishing marginal productivity the production possibility frontier would be linear and the elasticity of transformation would be infinite. If land was completely immobile between the two, as in the case where forest land was totally unusable for crop production, the production possibility frontier would be a right angle and the elasticity of transformation would be zero. In between are the realistic cases of diminishing productivity, implying a concave production possibility frontier and a positive but finite elasticity of transformation.

To illustrate, consider a shock that changes the relative returns to land facing producers from p_A to p_B. The shock illustrated in the figure raises the profitability of forestry relative to palm oil, inducing a movement from land use allocation A to allocation B, away from palm oil and towards forestry, relative to what would otherwise have occurred.

[Figure 2 about here]

The full treatment of land in the model is summarised in Figure 3. The top and bottom halves of the diagram describe, respectively, the nested treatment of the supply of land to each crop in each region, and the corresponding demand for it. The total availability of land in each region appears at the top of the diagram, taking one region, Kalimantan, as an example. This

land is imperfectly mobile between forestry and crop agriculture in Kalimantan, with its allocation depending on rates of return to land in each of these activities and the elasticity of transformation between them, represented by a constant elasticity of transformation (CET) process. This cropland is then further allocated among individual crops, again depending on rates of return in these various activities and the CET elasticity of transformation among them. The result is the supply of land to each industry in each region.

[Figure 3 about here]

Turning to the demand for land, the total area of land devoted within Indonesia to a particular crop, say crop *i*, appears at the bottom of the diagram. This total amount of land devoted to crop *i* can be imperfectly reallocated among regions by reallocating the production of crop *i* among the islands of Indonesia. This reallocation depends on rates of return to land in production of crop *i* in the individual regions and the elasticity of substitution among them. This sub-module generates the demand for land in each industry (crop) within each region.

Solution of the model involves equating supply and demand for land in the production of each crop within each region, generating the quantity of land allocated to each of these activities and its corresponding rate of return. Land then substitutes for other factors of production, labour and capital, within each crop and region, within the familiar constant elasticity of substitution (CES) production technology.

Table 3 summarizes the importance of the factors of production discussed above within the context of the cost structures of the major industry categories. ‘Skilled’ labour is unimportant in agriculture and although paid labour is more important than unpaid labour for the Indonesian economy as a whole, the reverse applies within the agricultural and forestry

sectors. Table 4 summarises initial land allocation by 17 sectors (the 16 agricultural sectors plus forestry) disaggregated by region. The forestry sector is concentrated in Eastern Indonesia, Kalimantan and Sumatra.

[Table 3 about here]

[Table 4 about here]

Table 5 summarises data on the carbon content of one hectare of land in different uses. The actual carbon content of a particular land use, say production forest, depends on local conditions. The data are presented as averages by land use type, such as forest use or crop and by region. The available data do not differentiate fully between all of the crops identified in the INDONESIA E3-L model, so some land use types shown in the table use the same data. On average, forest land sequesters about twice as much carbon as crop land. A useful 'back of the envelope' number is that for Indonesia as a whole, the average difference between the amount of carbon sequestered in one hectare of production forest and one hectare of crop land is around 316 metric tonnes (expressed as carbon dioxide equivalent). This means that when one hectare of forest is cleared and converted to crops an average of 316 metric tonnes of carbon dioxide is released into the atmosphere.

[Table 5 about here]

3.5 Parametric assumptions

On the supply side, estimates in the literature of the elasticity of transformation for land use between forestry and crop production suggest values of about 0.5. An example is Lee, *et al.* (2009). However, this key parameter must be considered uncertain and in the results section

of the paper its assumed value will be varied over a wide range to see how the results depend on the particular value that is used. The second elasticity of transformation mentioned above, that between crops, is assumed to be somewhat higher, at 0.75. On the demand side, because of the heterogeneity of Indonesia's major regions, the CES elasticity of substitution shown at the bottom of Figure 3 is presumed to be low, at 0.1. Finally, the CES elasticity of substitution between different factors of production used in forestry and in crops also seems important and it will also be varied parametrically in the results section of the paper.

4. Simulations

4.1 The shocks

The policy shock applied to the model is a subsidy applied to land use in production forest, calculated as a subsidy to the rental of land in that use. The size of the subsidy is endogenously calculated within the model to be sufficient to induce an exogenously specified reduction in total carbon emissions of 26 per cent. According to Table 1, total carbon emissions under 'business-as-usual' conditions are 1,459 million metric tonnes per year. The required reduction in emissions is therefore 379 million metric tonnes per year. All of the simulations in Simulation set A (left hand panel of each table of results) reported in the paper are constrained to achieve that outcome.

Since the President's speech also specified that a 41 per cent reduction in emissions would be attained if international assistance was available, Simulation Set B (right hand panel of each table of results) analyses the effect of an additional subsidy, financed by an unrequited inflow from abroad, sufficient to achieve a 15 per cent *further* reduction in emissions, starting from the outcome of the corresponding simulation in Simulation Set A. The total cost of a 41 per cent reduction is therefore the sum of these two amounts.

4.2 Model closure

The simulations are conducted with balanced trade (exogenous balance on current account). This ensures that the potential effects of the shock being studied do not flow to foreigners, through a current account surplus, or that increases in domestic consumption are not achieved at the expense of borrowing from abroad, in the case of a current account deficit. For the same reason, real government spending and real investment demand for each good are each fixed exogenously. The government budget deficit is held fixed in nominal terms, achieved by endogenous across-the-board adjustments to the rate of commodity taxes so as to restore the base level of the budgetary deficit. The combined effect of these features of the closure is that the full effects of changes in policy are channeled into household expenditures – the variable on which our welfare measure is based – and not into effects, such as changes in the balance of trade, which would be relevant for long-term economic welfare, but which are not captured within the single period focus of the model.

Skilled and unskilled wages and returns to capital and land in each industry are determined endogenously. Because both categories of labour are mobile across industries and capital stocks are fixed by industry, the simulations reflect an intermediate-run period of adjustment. Skilled and unskilled wages are each equated across industries, but not rates of return to capital or land. Reflecting Indonesia's ban on rice imports above a minimal level (Warr 2005; Fane and Warr 2008) the level of rice imports is fixed exogenously in the simulations and the domestic price of rice is determined endogenously. Discouragement of the conversion of land from forest to crops will impact on food security through its effect on the domestic consumer price of rice in particular, given the partially effective ban on rice imports.

4.3 Sensitivity to parametric assumptions

Two parametric assumptions seem particularly important: the elasticity of transformation between land use in production forest and crops and the CES elasticity of substitution between factors of production in the forestry and crops sectors. The assumptions are listed at the top of Tables 6 and 7. Simulation sets A1 and B1 are those considered by the authors to be most reasonable, but in the results shown below these two parameters are varied widely.

5. Results

Tables 6 to 9 summarise the results. The subsidy causes the land allocated to forestry to rise, relative to what it would otherwise have been, and the output of forestry similarly to rise, reducing the price of forestry products. Other potential uses of the land are reduced. Because these other land uses are more labour-intensive than forestry, on average, real wages decline. It should be noted that the declines in the return to capital summarised in Table 7 are *average* returns across all industries. Some industry-specific rates rise while others fall. The same point applies to the increased returns to land.

The core result, from Table 6, is that the subsidy on land used in forestry implies a budgetary cost of Rp. 9,786 per tonne of carbon dioxide emissions abated. This corresponds to about US$1.08 at current exchange rates. The total annual subsidy cost to the Indonesian government is Rp. 3,712 billion, equivalent to about US$408 million. An additional 15 per cent reduction financed from abroad requires a further annual subsidy of Rp. 1,909 billion, equivalent to US$210 million. These amounts are substantial but seemingly feasible, given sufficient political commitment.

[Tables 6 to 9 about here]

The budgetary cost of the subsidy is larger than its net welfare cost, because part of the subsidy is a pure transfer from some Indonesians (taxpayers) to others (production forest landowners) and these transfers do not represent a net welfare cost or benefit to Indonesia. The model closure adopted in this study, as reviewed above, ensures that the net welfare cost to Indonesia is the reduction in aggregate real consumption in Indonesia that results from applying the subsidy.[7] These results are provided in the last two rows of Table 6. The President's 26% emissions reduction target can be achieved at a net welfare cost to Indonesia of about US 30 cents per tonne of emissions abated. If foreign entities can be persuaded to fund the budgetary cost of achieving an additional 15% of emissions reduction there would be a small net welfare gain to Indonesia.

The subsidy leads to a reduction in the annual rate of land conversion of 1.2 million hectares, corresponding to a reduction in emissions associated with land use change of 379 million metric tonnes per year, all relative to what would have happened under BAU. It is important that these are *annual* outcomes and that they are *cumulative*. It is helpful to refer again to Figure 1. The annual subsidy to production forest results in path B rather than path A (BAU). The *slope* of path B (the annual rate of emissions) is lower than that of path A by 379 million metric tonnes per year, corresponding to 1.2 million hectares that is not converted from forestry to crops but which would have been converted under BAU.

By remaining on path B for, say, ten years, the area of land that is *not* converted from forest to crops, but which would have been converted under BAU, is 12 million hectares, leading to $10 \times 379 = 3{,}790$ million metric tonnes of CO_2 equivalent that is not emitted but which would have been emitted under BAU. Given that Indonesia's estimated annual emissions from land use change are 1,459 million metric tonnes, the existence of this subsidy for 10

[7] This calculation makes no allowance for any environmental benefit Indonesians might derive from lower Indonesian emissions. These benefits are considered small because the benefits from lower emissions arise

years would reduce Indonesia's accumulated emissions from land use change by an amount equivalent to 2.6 years of its total emissions from land use change.

If the subsidy was later discontinued – after, say, ten years – the outcome would thereafter be path C, the slope of which is the same as BAU. The annual rate of emissions would then revert to the BAU annual rate. Nevertheless, the fact that the subsidy had been in place for ten years would have meant a lower rate of emissions during that period, permanently reducing Indonesia's total, accumulated emissions from land use change by 3,790 million metric tonnes. The key point is that the lower rate of annual emissions continues for as long as the subsidy remains in place and the permanent reduction in total emissions from land use change relative to BAU accumulates accordingly.

How sensitive is the subsidy cost of CO_2 equivalent to the key parametric assumptions of the model? When the parametric assumptions are varied as shown in the first two rows of the table, the subsidy cost per tonne rises to as much as $1.24. Figure 4 summarises the effects of varying the two parameters concerned systematically across a wide range. The figure relates to Simulation Set A only. A total of 400 simulations were performed to derive this diagram. At very low values of the elasticity of transformation between forestry and crops it is costly to use price incentives to encourage use of land in forestry because a large price intervention is then required to move land from crops to forestry (or to prevent movement in the other direction that would otherwise have occurred). Even under the extreme assumption of a value of this elasticity below 0.05 the subsidy cost per tonne of carbon dioxide abated does not reach US$3.50.

[Figure 4 about here]

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globally, not locally.

The subsidy on use of land in forestry reduces the amount of land that would otherwise be available for rice cultivation and this impacts on Indonesia's food security objectives. In Simulation A1 the use of land in paddy production declines by 2.3 per cent (Table 9) and the consumer price of rice increases by 1.97 per cent (Table 8). This may be compared with the effect on the consumer price index of 0.27 per cent (Table 7). The real consumer price of rice thus increases by 1.7 per cent and this may be considered a moderate decline in food security.

6. Conclusions

Deforestation is the main source of carbon emissions in Indonesia and the principal source of deforestation is the conversion of commercial forest to the production of crops such as palm oil. This paper argues that a subsidy to the use of land in production forest combined with an enforced prohibition on conversion of protected natural forest to other uses could achieve the President's announced goals at a seemingly feasible (but still substantial) cost, measured as the budgetary cost of the subsidy required and the impact on food security. Under this scheme, the total amount of land diverted from conversion of forest to crops is 1.2 million hectares per year (Table 9). That is, 1.2 million hectares that would otherwise be converted from forest to crop use each year is retained as forest under this policy. The effect is cumulative. For example, after ten years of applying the subsidy 12 million hectares of land currently forested, and which would otherwise have been converted to crop use, is retained as forest.

We estimate that Indonesia could achieve the President's stated goal of a 26 per cent reduction in emissions relative to business-as-usual at an annual subsidy cost to Indonesian taxpayers equivalent to US$ 408 million, or $ 1.08 per tonne of carbon dioxide emissions abated. The estimated net welfare cost to Indonesia is around one third of this amount. Estimates of the price of carbon that might emerge under the REDD scheme have varied from

US$5 to US$10 per metric tonne of carbon dioxide equivalent – several times the costs estimated above. Accordingly, a subsidy to land use in production forests seems worthy of consideration by Indonesian policy makers.

Actual implementation of such a subsidy would require a careful review of the costs of administering it and the demands it would place on governance, issues which cannot be addressed in this paper.[8] The problems include the identification of relevant landowners, the auditing of payments made to them, minimization of associated corruption, and accurate monitoring of actual land use in compliance with the requirements of the scheme. Satellite imagery combined with computerized image analysis offers a seemingly promising technology for dealing with the last of these issues, but several other practical difficulties of implementation remain to be resolved.

[8] Angelsen (2009) contains useful discussions of many of these implementation issues.

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Table 1 Greenhouse Gas Emissions (Carbon Dioxide equivalent) by Sector in 2005, including land use change (millions of tonnes)

	Energy	Electricity & Heat	Manufacturing & Construction	Transport	Other Fuel Combustion	Fugitive Emissions	Industrial Processes	Land-Use Change & Forestry	Total
Indonesia	338.9	125.3	93.1	73.9	38.7	8	16.9	1,459.0	1,814.8
Brazil	331.5	58.6	97.3	137.1	34.1	4.5	18.3	1,830.0	2,179.8
China	5,059.8	2,668.1	1,594.0	332.1	465.6	--	532.6	-47.3	5,545.1
Australia	387.5	243.1	46.5	79.1	18.4	0.4	4.5	--	392
USA	5,808.9	2,732.9	627.3	1,806.0	618.2	24.3	50.3	-117.1	5,742.1
European Union	3,273.3	1,249.7	541.6	834.6	644	3.5	101.8	--	3,375.1
World	26,400.1	12,335.8	5,230.1	5,369.0	3,270.9	194.2	1,172.5	5,376.2	32,948.8

Source: *Climate Analysis Indicators Tool (CAIT)* (2010). version 7.0. World Resources Institute, Washington, D.C.
The CAIT data are derived from the following sources:
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Table 2 Land Use, 2003 (million hectares)

Land use	Official data	Satellite-based data
Non-cultivated natural forest	49.4	33.8
Cultivated land	125.3	91.7
Production forest	83.7	50.1
Paddy	11.5	11.5
Other crops	9.1	9.1
Estate crops	21.0	21.0
Other land	13.1	62.3
Total	187.8	187.8

Source: Official data are from *Statistics of Forestry*, Ministry of Forestry 2003 and from Ministry of Agriculture: Agriculture Statistics Database at http://database.deptan.go.id [accessed June, 2010].

Table 3 Factor Costs and Cost Shares

	Unskilled Paid	Unskilled Unpaid	Skilled Paid	Skilled Unpaid	Capital	Land	Total
Billion Rp. (2003 prices)							
Crops	42,273	93,787	2,932	155	38,843	35,860	213,849
Forestry	3,303	4,465	627	118	5,098	4,993	18,604
Other primary	39,430	39,326	9,802	735	176,545	-	265,838
Industry	170,719	46,680	58,368	9,384	432,534	-	717,685
Services	47,752	23,562	252,004	112,232	359,518	-	795,070
Total	303,477	207,819	323,733	122,624	1,012,539	40,854	2,011,045
Cost share (%)							
Crops	19.8	43.9	1.4	0.1	18.2	16.8	100
Forestry	17.8	24.0	3.4	0.6	27.4	26.8	100
Other primary	14.8	14.8	3.7	0.3	66.4	-	100
Industry	23.8	6.5	8.1	1.3	60.3	-	100
Services	6.0	3.0	31.7	14.1	45.2	-	100
Total	15.1	10.3	16.1	6.1	50.3	2.0	100

Source: Authors' calculations using data from Government of Indonesia, Central Bureau of Statistics and Ministry of Agriculture. Data relate to the year 2005.

Table 4 Land Area by Crops (thousand hectares)

Crop	Sumatra	Java-Bali	Kalimantan	Sulawesi	Eastern Indonesia	INDONESIA
Paddy	3,055.5	5,521.3	879.7	1,247.7	540.7	11,244.8
Maize	664.9	1,937.9	48.0	398.4	299.5	3,348.8
Root crops	492.5	1,192.2	59.8	144.8	229.2	2,118.5
Beans	69.8	579.9	9.3	61.8	146.1	866.9
Veg. & fruits	414.8	855.7	83.4	140.5	156.1	1,650.5
Rubber	2,309.8	130.7	819.1	24.1	6.5	3,290.1
Sugar cane	110.1	208.6	2.2	17.0	-	337.9
Coconut	1,356.2	967.2	283.3	764.6	541.8	3,913.1
Oil palm	4,079.6	25.4	1,001.9	126.8	49.8	5,283.6
Other estate crops	10.5	291.2	3.5	255.5	256.2	817.1
Tobacco	5.1	225.6	-	1.5	24.7	256.9
Coffee	800.9	189.7	47.0	149.9	99.0	1,286.4
Tea	19.7	122.0	-	1.9	-	143.6
Cloves	63.1	151.1	4.3	156.4	67.4	442.3
Cacao	139.2	65.8	45.8	589.9	118.3	959.0
Other agriculture	439.9	82.6	48.1	151.6	180.9	903.0
Forestry	7,204.0	1,055.0	18,144.0	3,227.0	20,481.0	50,111.0
Total	21,235.6	13,601.9	21,479.4	7,459.5	23,197.3	86,973.6

Source: Authors' calculations using data from Government of Indonesia, Ministry of Agriculture. Data relate to the year 2005.

Table 5 Carbon Content of Crops and Forest (metric tonnes per hectare)

	Regjon 1 Sumatra	Region 2 Java-Bali	Region 3 Kalimantan	Region 2 Sulawesi	Region 2 Eastern Indonesia
1 Paddy	322	217	436	412	258
2 Maize	394	301	404	431	423
3 Root crops	394	301	404	431	423
4 Beans	394	301	404	431	423
5 Veg. & fruits	394	301	404	431	423
6 Rubber	270	359	261	352	440
7 Sugar cane	270	359	261	352	440
8 Coconut	270	359	261	352	440
9 Oil palm	270	359	261	352	440
10 Other estate crops	270	359	261	352	440
11 Tobacco	270	359	261	352	440
12 Coffee	270	359	261	352	440
13 Tea	270	359	261	352	440
14 Cloves	270	359	261	352	440
15 Cacao	270	359	261	352	440
16 Other agriculture	394	301	404	431	423
17 Livestock	0	0	0	0	0
18 Forestry	661	378	701	635	661

Source: Authors' calculations using data from Government of Indonesia, Ministry of Forestry, *Forest Statistics*, 2003.

Table 6 Results: Effects on the Subsidy Cost of Emission Abatement

	Simulation Set A: 26% Emissions Reduction Using Domestic Resources					**Simulation Set B: Additional 15% Emissions Reduction With International Assistance**				
	Sim-A1	Sim-A2	Sim-A3	Sim-A4	Sim-A5	Sim-B1	Sim-B2	Sim-B3	Sim-B4	Sim-B5
Parametric assumptions										
Sigma-Crops	0.750	0.600	0.900	0.750	0.750	0.750	0.600	0.900	0.750	0.750
Sigma-Forest-Crops	0.500	0.500	0.500	0.300	0.700	0.500	0.500	0.500	0.300	0.700
Changes in CO2 emissions resulting from land use change										
% change	-26.0	-26.0	-26.0	-26.0	-26.0	-20.27	-20.27	-20.27	-20.27	-20.27
Million tonnes CO2	-379	-379	-379	-379	-379	-218.8	-218.8	-218.8	-218.8	-218.8
Subsidy to forestry use of land										
Rate of subsidy (%)	55.7	55.8	55.6	60.8	53.4	16.5	16.5	16.5	16.3	16.5
Subsidy cost (billion Rp)										
Sumatra	387.8	388.9	386.9	448.4	361.9	114.7	115.1	114.4	137.0	105.3
Java-Bali	49.3	49.3	49.2	57.0	46.0	10.5	10.5	10.6	12.9	9.6
Kalimantan	1,426.7	1,430.7	1,423.9	1,639.7	1,335.5	777.9	780.1	776.3	897.4	726.7
Sulawesi	188.2	188.8	187.9	217.3	175.8	64.7	64.9	64.6	76.5	59.7
Eastern Indonesia	1,660.1	1,664.8	1,656.8	1,906.8	1,554.4	940.9	943.6	939.0	1,083.4	879.8
INDONESIA	3,712.14	3,722.47	3,704.64	4,269.26	3,473.67	1,908.7	1,914.2	1,904.8	2,207.2	1,781.1
Subsidy cost per tonne of CO2 abated – Indonesia										
Rp. / tonne	9,786	9,813	9,766	11,254	9,157	8,722	8,747	8,704	10,086	8,139
$US/ tonne	1.08	1.08	1.07	1.24	1.01	0.96	0.96	0.96	1.11	0.90
Welfare cost per tonne of CO2 abated – Indonesia										
Rp. / tonne	2,760	2,796	2,760	2,760	2,760	-1,470	-1,100	-1,840	-810	1,100
$US/ tonne	0. 30	0.31	0.30	0.30	0.30	-0.16	-0.12	-0.20	-0.09	0.12

Note: US dollar calculations are based on an exchange rate of Rp. 9,091=$US1.
Source: Authors' calculations.

Table 7 Results: Macroeconomic Effects (per cent change from base unless otherwise stated)

	Simulation Set A: 26% Emissions Reduction Using Domestic Resources					Simulation Set B: Additional 15% Emissions Reduction With International Assistance				
	Sim-A1	Sim-A2	Sim-A3	Sim-A4	Sim-A5	Sim-B1	Sim-B2	Sim-B3	Sim-B4	Sim-B5
Parametric assumptions										
Sigma-Crops	0.750	0.600	0.900	0.750	0.750	0.750	0.600	0.900	0.750	0.750
Sigma-Forest-Crops	0.500	0.500	0.500	0.300	0.700	0.500	0.500	0.500	0.300	0.700
Macroeconomic results (per cent change)										
Real GDP	-0.050	-0.050	-0.050	-0.050	-0.050	-0.037	-0.037	-0.037	-0.037	-0.037
Real household consumption	-0.075	-0.076	-0.075	-0.075	-0.075	0.004	0.003	0.005	0.022	-0.003
Export volume index	-0.010	-0.010	-0.010	-0.016	-0.008	-0.036	-0.036	-0.037	-0.050	-0.031
=Import volume index	-0.013	-0.013	-0.013	-0.020	-0.010	0.129	0.128	0.129	0.160	0.116
GDP price index	0.158	0.160	0.156	0.164	0.155	0.166	0.168	0.165	0.187	0.158
Consumer price index	0.264	0.267	0.261	0.269	0.262	0.258	0.261	0.257	0.281	0.248
Real factor returns										
Wage: skilled	-0.601	-0.606	-0.597	-0.627	-0.590	-0.320	-0.325	-0.317	-0.312	-0.324
Wage: unskilled	-0.414	-0.414	-0.414	-0.446	-0.401	-0.221	-0.220	-0.221	-0.228	-0.218
Capital	-0.477	-0.480	-0.475	-0.505	-0.466	-0.269	-0.271	-0.267	-0.274	-0.266
Land	10.425	10.505	10.366	10.408	10.431	7.894	7.956	7.847	7.892	7.894
Change in nominal GDP (Rp billion)										
Consumption	2,638	2,680	2,607	2,716	2,604	3,677	3,699	3,661	4,246	3,434
Investment	-177	-175	-178	-140	-192	-85	-85	-85	-31	-108
Stock	-43	-41	-43	-41	-43	-71	-70	-72	-80	-68
Government	-144	-145	-144	-137	-147	10	9	11	56	-9
Net export	0	0	0	0	0	-803	-797	-807	-1,020	-710
Total	2,274	2,319	2,241	2,398	2,221	2,728	2,756	2,708	3,171	2,539

Source: Authors' calculations.

Table 8 Results: Effects on Producer Prices by Industry and the Consumer Price of Rice (per cent change)

	Simulation Set A: 26% Emissions Reduction Using Domestic Resources					Simulation Set B: Additional 15% Emissions Reduction With International Assistance				
	Sim-A1	Sim-A2	Sim-A3	Sim-A4	Sim-A5	Sim-B1	Sim-B2	Sim-B3	Sim-B4	Sim-B5
Producer price (per cent change)										
Paddy	2.379	2.426	2.345	2.375	2.381	1.883	1.923	1.855	1.910	1.872
Maize	1.671	1.708	1.644	1.671	1.671	1.374	1.404	1.352	1.402	1.361
Root crops	2.656	2.694	2.629	2.654	2.657	2.214	2.246	2.190	2.246	2.199
Beans	1.618	1.619	1.617	1.623	1.616	1.382	1.380	1.383	1.402	1.373
Veg. & fruits	1.751	1.758	1.746	1.750	1.751	1.454	1.459	1.449	1.482	1.442
Rubber	1.932	1.929	1.934	1.922	1.936	1.458	1.456	1.459	1.466	1.455
Sugar cane	0.185	0.231	0.152	0.183	0.186	0.129	0.164	0.104	0.152	0.119
Coconut	2.927	2.906	2.942	2.929	2.926	2.175	2.159	2.187	2.194	2.167
Oil palm	1.960	1.955	1.964	1.961	1.960	1.407	1.403	1.410	1.421	1.401
Other estate crops	1.263	1.263	1.262	1.269	1.260	1.038	1.037	1.038	1.047	1.034
Tobacco	0.177	0.193	0.165	0.183	0.174	0.231	0.243	0.223	0.252	0.222
Coffee	1.169	1.123	1.204	1.172	1.167	1.007	0.967	1.039	1.068	0.981
Tea	-1.013	-0.939	-1.070	-1.025	-1.008	-0.724	-0.673	-0.763	-0.709	-0.731
Cloves	1.825	1.761	1.874	1.831	1.822	1.370	1.316	1.413	1.388	1.362
Cacao	4.688	4.676	4.695	4.685	4.689	3.282	3.281	3.281	3.292	3.277
Other agriculture	3.133	3.137	3.129	3.135	3.132	2.385	2.393	2.380	2.407	2.376
Livestock	0.117	0.121	0.115	0.121	0.116	0.148	0.151	0.146	0.172	0.138
Forestry	-2.836	-2.837	-2.836	-2.845	-2.832	-1.321	-1.320	-1.321	-1.325	-1.319
Consumer price (per cent change)										
Milled rice	1.969	2.007	1.941	1.975	1.966	1.536	1.568	1.513	1.562	1.525

Source: Authors' calculations.

Table 9 Results: Effects on Land Use - Indonesia ('000 Ha.)

	Simulation Set A: 26% Emissions Reduction Using Domestic Resources					Simulation Set B: Additional 15% Emissions Reduction With International Assistance				
	Sim-A1	Sim-A2	Sim-A3	Sim-A4	Sim-A5	Sim-B1	Sim-B2	Sim-B3	Sim-B4	Sim-B5
Land use change: INDONESIA (000 Ha)										
Paddy	-227.9	-231.8	-225.1	-228.1	-227.8	-128.0	-130.5	-126.1	-127.7	-128.1
Maize	-58.9	-60.0	-58.0	-58.9	-58.8	-33.8	-34.5	-33.3	-33.7	-33.8
Root crops	-43.5	-44.1	-43.2	-43.6	-43.5	-25.3	-25.6	-25.0	-25.2	-25.3
Beans	-22.4	-22.3	-22.4	-22.4	-22.4	-14.5	-14.4	-14.5	-14.5	-14.4
Veg. & fruits	-44.3	-44.4	-44.3	-44.3	-44.3	-26.8	-26.8	-26.8	-26.7	-26.9
Rubber	-155.7	-155.4	-155.9	-155.8	-155.7	-88.9	-88.7	-89.0	-89.1	-88.8
Sugarcane	-1.7	-1.9	-1.6	-1.7	-1.7	-0.6	-0.7	-0.5	-0.6	-0.6
Coconut	-178.9	-177.5	-179.9	-178.9	-178.9	-105.7	-104.8	-106.4	-105.7	-105.7
Oil palm	-247.1	-246.4	-247.6	-246.9	-247.3	-142.6	-142.2	-142.9	-142.5	-142.7
Other estate crops	-33.4	-33.4	-33.4	-33.4	-33.3	-20.1	-20.1	-20.1	-20.2	-20.1
Tobacco	-1.4	-1.6	-1.4	-1.5	-1.4	-0.8	-0.9	-0.8	-0.8	-0.8
Coffee	-71.1	-69.1	-72.6	-71.1	-71.1	-43.5	-42.1	-44.6	-43.7	-43.5
Tea	1.1	0.9	1.2	1.1	1.1	0.9	0.7	1.0	0.8	0.9
Clove	-26.2	-25.3	-26.8	-26.2	-26.2	-16.5	-15.9	-16.9	-16.5	-16.4
Cacao	-46.9	-46.8	-47.0	-47.0	-46.9	-26.0	-26.0	-26.0	-26.1	-26.0
Other agriculture	-42.2	-42.2	-42.2	-42.2	-42.2	-23.4	-23.4	-23.4	-23.4	-23.4
Forestry: Indonesia	1,200.6	1,201.2	1,200.2	1,201.0	1,200.4	695.7	696.0	695.4	695.8	695.6
Sumatra	463.6	463.5	463.6	463.4	463.6	276.4	276.4	276.5	276.4	276.5
Java-Bali	88.8	89.1	88.6	89.1	88.6	54.7	54.9	54.6	54.9	54.6
Kalimantan	260.5	260.6	260.4	260.3	260.5	143.7	143.8	143.6	143.7	143.7
Sulawesi	172.4	172.5	172.4	172.5	172.4	101.5	101.5	101.4	101.5	101.5
Eastern Indonesia	215.4	215.5	215.3	215.6	215.3	119.3	119.3	119.3	119.3	119.3
TOTAL	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Source: Authors' calculations.

Figure 1 Effects on emissions of a subsidy to production forest

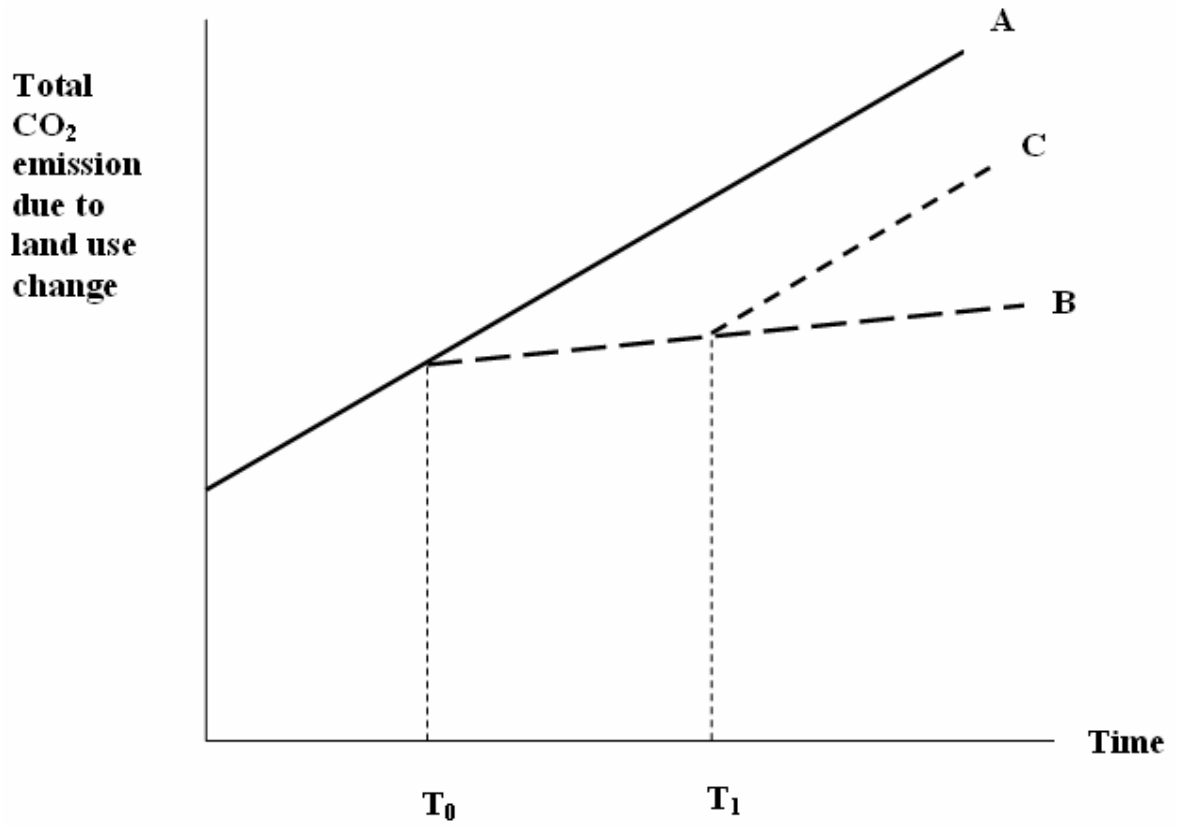


Figure 2 Modeling Land Mobility Between Forestry and Crops

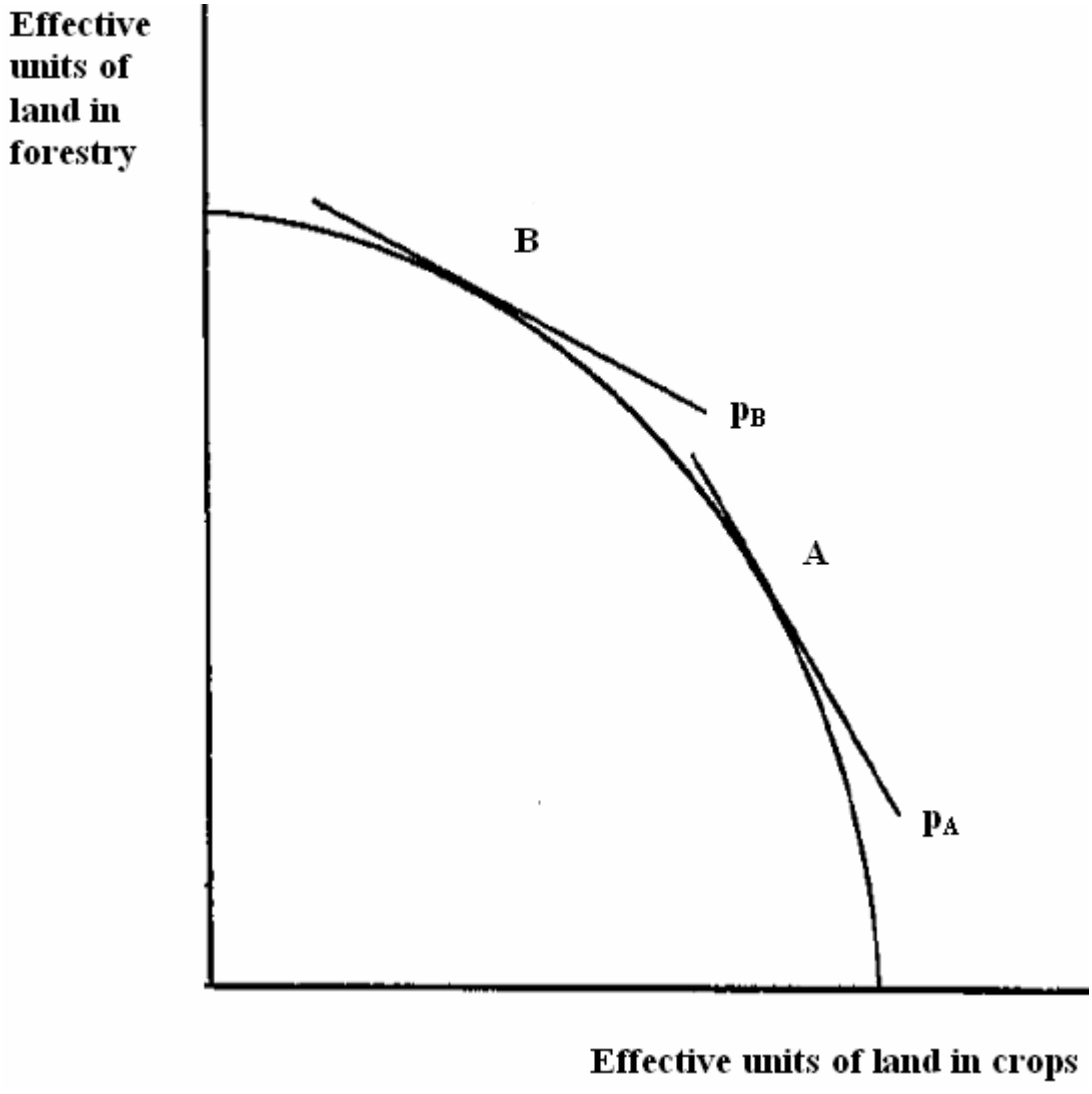


Figure 3 Analytical structure of land use module

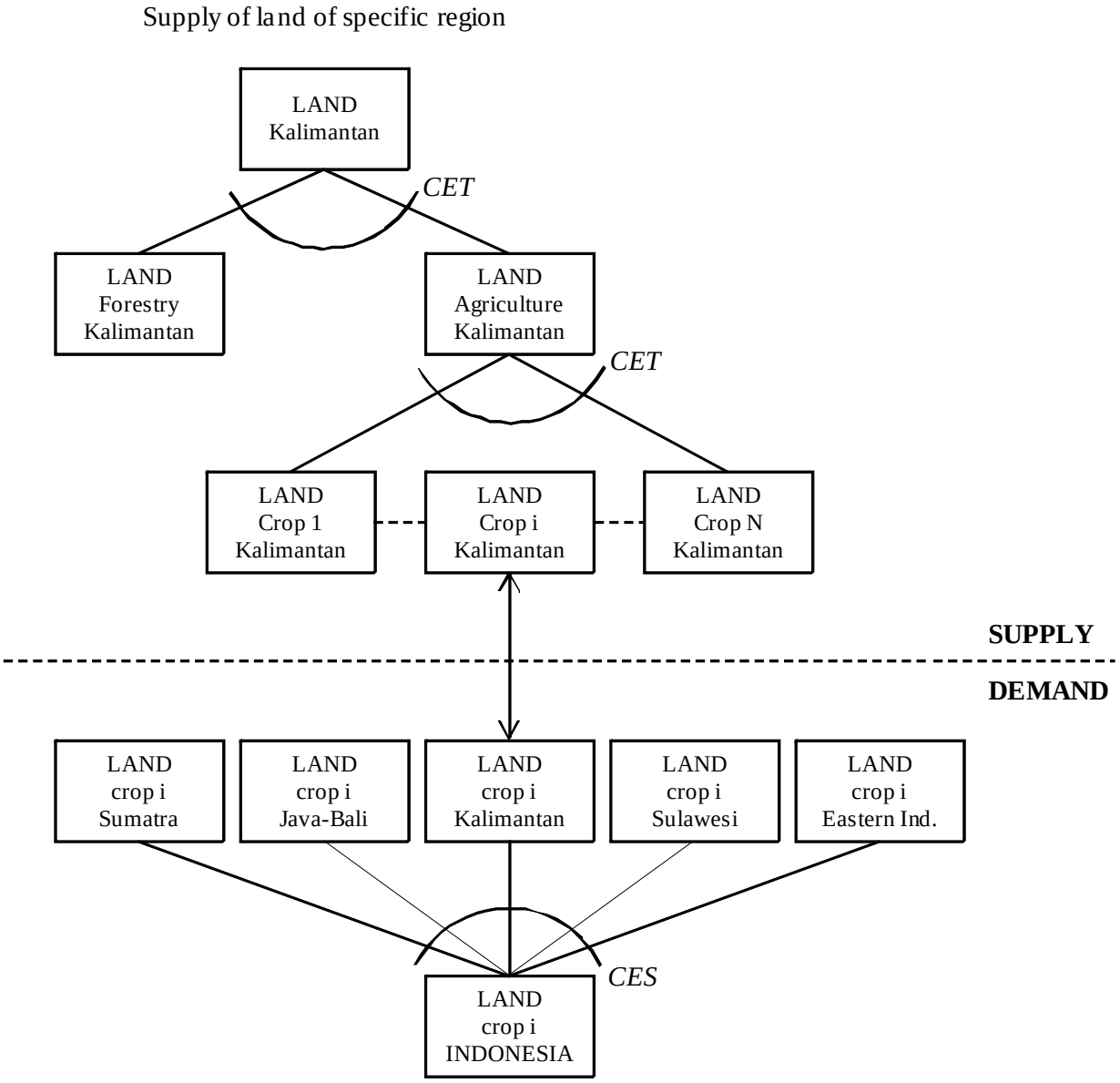
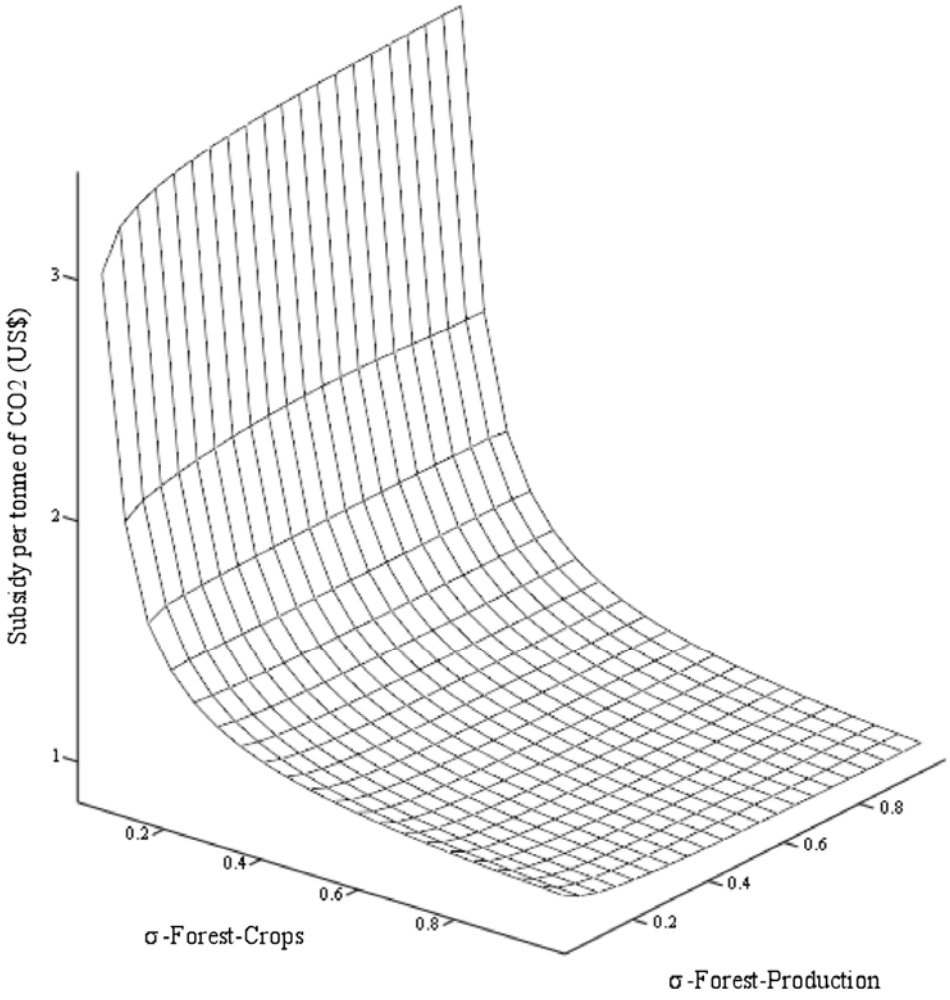


Figure 4 Sensitivity Analysis



Source: Authors' calculations.