Impact of international emission reduction on energy and forestry sector of Indonesia

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Abstract

We extended the MERGE model to develop a set of energy projections for a reference and various mitigation scenarios to the year 2100. We included coal as a tradable good. In Indonesia, oil imports will increase while coal exports will decrease. If the OECD countries reduce their emissions, oil price would fall, Indonesia would import more oil but less gas and its per capita income would fall slightly. With international trade in emission permits, Indonesian energy development is similar to the earlier scenario, but Indonesia would gain some income. If all countries reduce their emissions, Indonesia would export more coal and would substitute coal by gas and carbon free technologies in energy consumption. If Indonesian commits to emissions reduction, per capita income would slightly fall. Population and economic growth are the driving forces of deforestation. In the reference scenario, deforestation increase by 60% in 2020 relative to today, indicating that Indonesia has large potential to mitigate emissions in the forestry sector. International climate policy would slightly increase the deforestation rate, mainly because of more rapid economic growth. Indonesia would gain from the sale of emission permits from reduced deforestation.

Keywords

Emission reduction; deforestation; Indonesia

1. Introduction

Indonesia holds a special position in international climate policy. On the one hand, it exports oil and coal, a business it could lose under stringent emission reduction On the other hand, Indonesia has gas reserves as well, the demand for which would grow. Furthermore, Indonesia could use the money of the Clean Development Mechanism to slow deforestation and avoid carbon dioxide emissions. This paper seeks to shed light on the implications of international climate policy on Indonesia, and particularly its energy and forestry sectors.

Indonesia has significant reserves of oil, gas, and coal. The Government of Indonesia estimates its gas reserves at 170 trillion standard cubic feet (TCSF) or around 180 exajoules, of which 95 TCSF are proven and 75 TCSF are probable (EUSAI, 2001), as seen in Figure 1a. Gas reserves are three times larger than oil reserves. Coal deposits are estimated at 39 billion metric tonnes, or around 1,000 exajoules, of which 12 billion metric tonnes are classified as measured and 27 billion metric tonnes as indicated. Indonesia's crude oil reserves amount to 9.6 billion barrels or around 57 exajoules, with proven reserves of 5 billion barrels. Oil production, at 3.2 exajoules per year in 2000, dominates the energy sector of Indonesia; this leaves Indonesia with 17 years of production. Gas production was around 2.6 exajoules per year in 2000, so that gas can be supplied for another 69 years at current production rates. Coal production was 2 exajoules per year, as shown in Figure 1b, so that reserves would last another 500 years. Recently, Indonesia produced 1.15 million barrels oil per day, decreasing by 5 percent per year since 1998. Gas and coal production increased significantly; the export of coal increased to 1.5 exajoules per year in 2000.

The energy sector in Indonesia has been a dominant factor in the overall economic development of Indonesia. The oil and gas exports contribute significantly to securing foreign exchange revenue of the country. As the country is still striving to develop its industrial sector, foreign exchange revenue is an important ingredient to the acquisition of technology from foreign sources. In the domestic sector, oil has dominated for the past 30 years and is likely to continue to dominate in the immediate future. In recent years, however, the share of oil in domestic consumption is slightly declining due to significant increase in the role of gas, which now takes a second position in the energy mix.

Indonesia consumed 3.9 quadrillion British thermal unit (Btu) of energy, 95 percent of energy consumption is currently supplied by fossil fuel (DGEED, 2000). Oil is the dominant fuel (see Figure 2) accounting for 56% of 2000 total energy consumption in Indonesia, followed by natural gas and coal (31% and 8%, respectively). In 2000, total CO_2 emissions from energy demand sectors amount to 228 million metric tonnes of carbon dioxide, of which 42% are from the energy-industry sector (including power plants), 25% from industry, 24% from transport, and 9% from households; see Figure 3. The growth rate of CO_2 emissions from the energy industry at 7% per year, is the highest; all sources average to 3.3% per year.

In addition to the carbon emissions from fossil fuels, the forest sector also has high emissions, mostly as a result of deforestation. In Indonesia's National Communication under UNFCCC (SME-ROI, 1999a), it was found that, in 1994, Indonesia's net emissions from land use change and forestry sector reached 156 million metric tonnes of net carbon dioxide emissions. Activities that contribute to increase of deforestation are agricultural expansion, shifting cultivation, transmigration, illegal logging and forest fires. According to several studies, the rate of deforestation in Indonesia has increased, although estimates differ among these studies (Boer, 2001). In the early 1990s, the rate of deforestation reached a level of 1.3 million ha per year (FAO, 2001). Based on 1997 satellite imagery, the ministry of Forestry and Estate Crops estimated that nationwide annual deforestation rate is more than 1.5 million ha. For 1998 – 2002, Sari et al. (2001) estimated the rate of deforestation in Indonesia at about 2–2.4 million ha per year.

In this paper, we study the impact of international climate policy on the energy sector of Indonesia and study the interaction between the forest sector and energy policy. Emission reduction policy elsewhere would increase the demand for Indonesian gas, and decrease the demand for its coal. We analyze the implications of emission reduction in Annex B countries, without and with emission trade, on the energy sector and the causes of deforestation. Finally, we analyze the direct effect of international climate policy on deforestation in Indonesia, for instance through potential projects under the UNFCCC Clean Development Mechanism.

This paper expands the work of Susandi and Tol (2002) in three ways. Firstly, we make coal an internationally tradable good. In the original model, coal is not traded internationally. This may not matter on a global scale, but it does matter to Indonesia. Secondly, we updated the fossil fuel reserves. Thirdly, we add avoided deforestation as a way to reduce carbon dioxide emissions, and allow for trade of such permits.

The remainder of this paper is organized in the following way. Section 2 presents a brief overview of the MERGE model, and specifies the changes we made to the model. Section 3 presents and discusses the model results for reference and mitigation scenarios. Section 4 describes the forest land use change and the interactions between the new forest sub-model and the rest of MERGE; Section 4 also assesses slowing deforestation. Section 5 contains conclusions.

2. MERGE – with coal as tradable good

In this analysis, we use version 4.3 of the MERGE model, originally developed by Alan S Manne from Stanford University and Richard G. Richels from the Electric Power Research Institute. MERGE (Model for Evaluating the Regional and Global Effects of greenhouse gas reduction policies) is an inter-temporal general equilibrium model, which combines a bottom-up representation of the energy supply sector with a top-down perspective on the remainder of the economy. See Manne and Richels (1992) and Manne et al. (1995) for a detailed description. MERGE consists of four major parts: (1) the economic model, (2) the energy model, (3) the climate model and (4) the climate change impact model. The model is calibrated with energy and economic data to the year 2000. The economy is modelled through nested constant elasticity production functions. The model also has international trading of gas, oil and energy intensive goods. We extended MERGE to include coal as a tradable good.

In the original version of the model (MERGE 4.3), supply and demand for coal are equated at the regional level. We allow for international trade in coal. The production costs of coal is assumed to be 2-3 US$/GJ, compared to 3-5 US$/GJ and 2-4 US$/GJ for oil and gas, respectively. Interregional transport costs are proportional to net exports; we assume that unit cost of coal export is 0.67 $x10^{-3}$ US$/GJ; the unit transport cost of coal is higher than the transport cost of oil but lower than the unit transport cost of gas. Production, consumption, and export of coal are calibrated to observations for the year 2000.

The energy model distinguishes between electric and non-electric energy. There are 10 alternative sources of electric generation (hydro; remaining initial nuclear; gas fired; oil fired; coal fired; gas advanced combined cycles; gas fuel; coal fuel; coal pulverized; integrated gasification and combined cycle with capture and sequestration), plus two "backstop" technologies: high and low-cost advanced carbon-free electric generation. There are four alternative sources of non-electric energy in the model (oil, gas, coal, and renewables) plus a backstop technology.

The climate sub-model is confined to the three most important anthropogenic greenhouse gas: carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O). The emissions of each gas are divided into two categories: energy related and non-energy related emissions. The climate damages of the model is divided into market and non-market damages, which enter in the regional and overall welfare development.

To analyze the impact of international climate policy on energy production and net exports of Indonesia, we developed four scenarios, specified in Table 1. We assume that all Annex B countries (with the exception of the USA) adopt the Kyoto Protocol and reduce their emissions by 5 percent per decade in the years after 2010. Indonesia is assumed to accept a target in 2050. After 2050, Indonesia's emission falls by 5 percent per decade.

3. Results of MERGE

3.1 Reference scenario

In 2000, Indonesia's population was about 212 million and is projected to grow to 389 millions in 2100. The growth rate of the population was 1.6 percent in the period of 1990 – 2000. Indonesia's economic growth increased modestly in 2002 due to the continuing global economic slowdown. In 2000, per capita gross domestic product (GDP) was some US$ 722 at market exchange rate. GDP grew at a rate of 3.7% in

2002, and 3.1% in 2001. In the MERGE model, growth continues, reaching a per capita GDP level of US$ 19.8 thousand[1] in 2100.

Between 1990 and 1994, emissions of carbon dioxide, methane and nitrous oxide from households, transport and industry grew at a rate of 1.8 percent per year; these sectors are responsible for 35–60 percent of total Indonesian emissions from fossil fuel combustion. In 1999, the energy industry contributed a further 29 percent of total carbon dioxide emissions from fuel combustion (SME-ROI, 1999b). Without emission reduction policies, carbon dioxide emissions grow from 64 million tonnes in 2000 to 172 million tonnes in 2100.

In energy production, Indonesia ranked 17th among world oil producers in 2000, with approximately 1.9 percent of the world's production. Current trends suggest that oil production will fall (EUSAI, 2001). In our model, oil production falls rapidly until 2020, and gradually thereafter (Figure 4, Reference scenario). Gas production is projected to increase substantially during the first half of the century, but falls after that. Coal production grows gradually to cover the shortfalls in domestic and foreign energy demand. Coal will be the dominant fuel after 2040 in Indonesian energy production as the others sources of fuels get more and more depleted. Carbon-free technologies are the dominant energy source at the end of the century. To fulfil its oil demands, Indonesia imports oil. Oil imports increase to 2040, then fall slightly, and reach a new peak in 2070 (Figure 5, Reference scenario). Indonesia will be a net importer of gas after 2040;

[1] Without international trade in coal, per capita GDP reaches US$ 19.5 thousand in 2100, or 1.6% less than with trade.

gas imports increase substantially to 2060, and then decrease to the end of century. Coal is the only energy export of Indonesia, increasing a little to 2020 – a continuation of recent years – and then falling gradually till 2070.

3.2 Mitigation Scenarios

In this section, we explore greenhouse gas emission reduction in the OECD and elsewhere and its effects on Indonesia. If the OECD countries were to reduce their emissions as specified above, the price of gas on the world market would rise while the oil price would fall. Indonesia responds to this in the first half of the 21st century by importing less gas while increasing the production of gas to meet domestic demand; at the same time, oil imports are increased (Figure 5). This extends the life time of oil production, as shown in Figure 4. Coal production is slightly higher than in the reference scenario in the second half of century. Although coal exports fall after 2020, this is offset by a domestic increase in coal use. Indonesian energy consumption is almost the same as in the reference scenario, except in the final decade of this century. Indonesian GDP per capita drops by 0.14% from reference in 2020, primarily because of reduced coal exports, but per capita GDP more than catches up later, primarily because of decreased gas imports (Figure 7). Emission control in the OECD affects Indonesian emissions only slightly (Figure 6); carbon leakage, at least to Indonesia, is minimal.

With international trade in emission permits, results are essentially the same as in the previous scenario, but slightly less pronounced as total emission reduction costs in the OECD are lower.

In the last scenario, not only the OECD countries but also all other countries commit to limiting their emissions. Under this scenario, Indonesian fossil-fuel, particularly gas, production would be brought forward in time (Figure 4). Gas would dominate domestic energy use during the first half of the century. Furthermore carbon-free technology would be increasingly adopted as the growth in domestic energy consumption exceeds the rate of emission reduction. Oil production is approximately the same as in the reference scenario. Coal production increases slightly to the end of century, but is lower than in the other scenarios. However, Indonesian coal exports are stable till 2070 as the suppressed coal price offsets the carbon penalty. The pattern of oil imports is approximately the same as in the previous two scenarios, but with lower quantities. Indonesia exports gas in the first decades, and then becomes a net importers. The total quantity of gas imports is slightly lower than in the reference scenario. GDP per capita increases after 2030 and slightly declines relative to the reference after 2050, the date that Indonesia accepts its emission target; it falls by less than 0.2% (Figure 7). Carbon dioxide emissions from energy consumption would reach 129 million tonnes of carbon by 2050 and would then fall to 44 million tonnes in 2100 (Figure 6), reflecting the switch from coal to gas to carbon-free fuel in power generation.

4. *Forest land-use change*

Indonesia has the second largest tropical forest after Brazil, that is, about 144 million ha or about 10% of global area (Trisasongko and Raimadoya, 2002). Forest products are significant in the Indonesian economy. The forestry sector is the second highest contributor to foreign exchange after the oil and gas sector (BPS, 2000). However, the large timber trade is poorly regulated and eventually leads to climate changes as well as species extinction and disruption of the water cycle. The forest sector is the second largest contributor to Indonesia's carbon emissions. Emissions resulting from changes in land use fluctuated strongly due to changes in the rate of forest harvesting, but the Indonesian forest area decreases substantially from year to year. The World Bank (2000) estimates that the rate of deforestation now stands at 2 million ha per year, as also reported by Sari et al. (2001). The causes of forest degradation and loss are complex and vary widely from place to place. Major causes of forest degradation are expansion of agriculture, transmigration, development of infrastructure, shifting cultivation, illegal logging and forest fire (Boer, 2001).

Anticipating continued deforestation, the Indonesian government has regulated that the area of conservation, protection and production forests have to be maintained, while only so-called conversion forests can be converted into other uses, such as industrial timber plantation, non-forest tree plantations, transmigration programs, etc. However, a reduction of one hectare conversion forest into non-forest land has to be compensated by the conversion of two hectares non-forest land into forest land (ALGAS, 1997a).

With this regulation, in the long run total area of forest land would be expected to increase.

Existing policies to mitigate carbon emissions in Indonesia include forest plantation and timber estate, afforestation, reforestation, enhanced natural regeneration, forest protection, bioelectricity, reduced impact logging. The potential of each option to avoid emissions or sequester carbon vary considerably, ranging from 37 to 218 Mg C per ha (Boer, 2001). Reforestation activities have the highest potential and plantation the lowest (Boer, 2001).

4.1 Interaction between direct and indirect causes of deforestation

Causes of tropical deforestation have been classified into direct and indirect. Direct causes can be grouped into two classes: pressure from forest products for consumption and exports, and pressure from alternative land uses, particularly agriculture. Indirect causes of deforestation relate to population, gross domestic product, external debt and government policies. The rate of deforestation is expressed as a function of the direct causes, each of these expressed as a function of the indirect causes. Kant and Redantz's (1997) model assume that deforestation is caused by roundwood consumption, export of forest products, conversion to crop land, and conversion to pasture land.

We modified the econometric model of tropical deforestation by Kant and Redantz (1997) for Indonesia. ALGAS (1996) reports deforestation from crop land conversion (including transmigration and infrastructure development) at 838,000 ha per year during

1982 – 1990. We extrapolate this to increase to 938,560 ha per year in 2000, assuming 1.2% annual increase during 1990 – 2000 (FWI/GFW, 2002). Boer et al. (1998) identify agriculture development as the main cause of deforestation in Indonesia. Roundwood consumption and forest-product export are the next main causes of deforestation in Indonesia. Deforestation rate due to roundwood consumption was 377,000 ha per year during 1982 – 1990 (ALGAS, 1996). A report by the Ministry of Forestry in July 2000 indicates that, in a survey of nearly 47 million ha of forest land for export, about 30 percent had been degraded during the previous 20 years, or around 705,000 ha per year. The main destination countries for Indonesian forest-product export are Japan, United States, China and the Europe Union (Kartodihardjo, 1999). It is estimated that forest loss due to illegal logging was minor (Dick, 1991; FAO and MoF, 1990; Angelsen and Resosudarmo, 1999).

Pasture land or natural grassland develops as a result of shifting cultivation and degradation of forest (Deptan ROI, 1988) and is maintained by grazing and (uncontrolled) burning (forest fire). The average area of grassland burnt was 6,120 ha per year (ALGAS, 1996). The total area of grassland in Indonesia is about 10.2 million ha. Large areas of natural grassland are found in Sumatera, Kalimantan, Sulawesi, Nusa Tenggara and Irian Jaya (Ivory and Siregar, 1984). We substituted conversion to pasture land as a direct cause of deforestation with forest fire, which occurs mostly every year in Indonesia. Forest fires have caused considerable damage to economy and environment. The causes of fires are largely due to changes in land use, such as shifting cultivation and crop land conversion (START, 2000). Most fires are in agricultural lands rather than in forest lands (KMNLH and UNDP, 1998). Based on the forest fire data from 1982-1990, the average area affected by forest fire was about 100,000 ha per year (Bappenas, 1992). In the El-Niño years of 1991, 1994 and 1997, the forest area burnt amounted to 119,000, 162,000, and 265,000 ha, respectively (Dirjen PHPA, 1997). In 1998, the largest known forest fire ever in the world burnt 514,000 ha (Dirjen PHPA, 1999). DGFPNC (2003) reports that the extent of forest fire was 44,090, 3,016, 14,330, and 35,497 ha for the years of 1999, 2000, 2001, and 2002, respectively. Based on these data from 1991-2000, the average area affected by forest fire was about 184,518 ha per year.

Understanding the linkages between the direct causes and the indirect ones is also important. The interactions between direct and indirect causes are shown in Figure 8. We used the population and GDP growth as indirect causes of deforestation. We calculated the elasticity (e) of deforestation (D) with respect to the population (P), $e = (\delta D / D)/(\delta P / P)$, and GDP growth ($Y$), $e = (\delta D / D)/(\delta Y / Y)$ for Indonesia, based on deforestation data between 1990 and 2000, as suggested by Kant and Redantz (1997); see Table 2.

Formally, deforestation follows

$$D_t = D_t^{roundwood} + D_t^{export} + D_t^{cropland} + D_t^{fire} \qquad (1)$$

with

$$D_t^{roundwood} = \left(\frac{P_t}{P_{t-1}}\right)^{0.06509} D_{t-1}^{roundwood} \qquad (2)$$

$$D_t^{\exp ort} = \left(\frac{\dot{Y}_t^W}{\dot{Y}_{t-1}^W} \right)^{0.00668} D_{t-1}^{\exp ort} \qquad (3)$$

$$D_t^{cropland} = \left(\frac{\dot{Y}_t}{\dot{Y}_{t-1}} \right)^{0.06171} D_{t-1}^{cropland} \qquad (4)$$

$$D_t^{fire} = f(t) D_{t-1}^{fire} \qquad (5)$$

where

D_t	is total deforestation in year *t*
$D_t^{roundwood}$	is deforestation of roundwood consumption in year *t*
$D_t^{\exp ort}$	is deforestation of forest-products export in year *t*
$D_t^{cropland}$	is deforestation of cropland in year *t*
D_t^{fire}	is deforestation of forest fire in year *t*
P_t	is the total population of Indonesia in year *t*
$\dot{Y}_t^W$	is the GDP growth of the rest of the world in year *t*
$\dot{Y}_t$	is the GDP growth of Indonesia in year *t*

The specification of the above Equations (2)-(4) follows Kant and Redantz (1997). Splitting GDP into population and GDP per capita does not improve the description of the data. We assume that D_t^{fire} falls gradually over time by 5% per decade in the years after 2000, based on the average forest fire in last decade, because of an increasing effort in forest fire prevention.

4.2 The effects of fossil fuel emission reduction on deforestation

The results are given in Figure 9. In the reference scenario, population and economic growth lead first to increasing deforestation, rising from 2.3 million ha per year in 2000 to 3.6 million ha per year in 2020, then falls to 2.4 million ha per year in 2030, and decreasing gradually to 2.3 million ha per year in 2100 (Figure 9). Cropland is the main contributor to the rate of deforestation, increasing by a factor of 2.4 between 2000 and 2020, corresponding to about 2.2 million ha per year of deforestation in 2020; this falls to 1.0 million ha per year in 2030, later decreasing gradually to 0.9 million ha per year in 2100. Forest-product export is the second contributor to deforestation, with some 705,000 ha per year in 2000, rising to 723,000 ha per year in 2010, falling to 700,000 ha per year in 2030, and fluctuating until the end of century, reaching 702,000 ha per year in 2100. Deforestation of roundwood consumption increases substantially from 422,000 ha per year in 2000 to 627,000 ha per year in 2100. Deforestation due to forest fires falls from 185,000 ha per year in 2000 to 110,000 ha per year in 2100.

If the OECD countries reduce their emission as in the KAB scenario described above (Table 1), the rate of deforestation changes. The rate of deforestation is slightly below the reference deforestation, but slightly above the reference deforestation in the KBG and KAT scenarios (Figure 9). Figure 10 shows the corresponding emissions of carbon dioxide.

4.3 The economic gain of slowing deforestation

Changes in the use and management of forests can make a meaningful contribution to emission reduction (IPCC, 2001). Mitigating carbon emissions in the forestry sector can be divided into three categories: slowing deforestation, reforesting degraded lands, and adoption of sustainable agriculture practice (Niles et al., 2001). Government policy can help by slowing deforestation. The best mitigation options in this sector seem to be sustainable forest management, afforestation, reforestation and agroforestry. Although developing countries have no specific emission targets under current climate policy agreements, there are many opportunities for mitigating carbon emission by sustainable land management in developing countries (IPCC, 2000a, b); these options could be harnessed through the Clean Development Mechanism or, later, an international system of tradable carbon permits.

We estimate the cost of slowing deforestation from Indonesian forest based on the optimal rate of slowing deforestation. The optimal rate is achieved at the point where the marginal costs of slowing deforestation equal the shadow price of carbon. We use the marginal cost of slowing deforestation as reported in ALGAS (1997b). We use the shadow price of carbon in the KBG and KAT emission reduction scenarios. From these, we derive the costs, revenues and profits of slowing deforestation to reduce net carbon emissions in Indonesia.

The cost of slowing deforestation in Indonesia increases exponentially from US$ 12.3 million in 2010 to US$ 2.0 billion in 2100 (Figure 11 on the right-hand axis) if the OECD countries reduce their emission and all countries participate in global trade as in the KBG scenario. Indonesia would have large profits since revenues would be much greater than the costs of slowing deforestation. The profits increase exponentially from US$ 1.7 million in 2010 to US$ 10.7 billion in 2100 (Figure 12). If all countries commit to limiting their emission as in the KAT scenario, the cost of slowing deforestation is higher than in the previous scenario; that is, US$ 49.3 million in 2010 rising to US$ 2.3 billion in 2100. Nonetheless, the price of carbon is higher, so that Indonesia would receive higher profits, that is, US$ 75.5 million in 2010 rising to US$ 12.2 billion in 2100. These profits would amount to 0.14% of the GDP of Indonesia in 2100 in the KBG scenario, and to 0.16% in the KAT scenario.

5. Conclusions

In this paper, we extend the MERGE model to analyse the impact of international emission reduction on the energy and forestry sectors of Indonesia. In contrast to the standard version of MERGE, coal is internationally traded in the same manner as oil, gas and other sources of energy. The impact of international emission reduction on the energy sector indicates that Indonesia would produce more gas earlier than in the reference scenario. Oil imports would increase gradually to 2040, and increase substantially to 2070 because the oil price is falling as a result of reduced demand in the

OECD countries. With international emissions permits trade, oil imports are essentially the same as in the last scenario. Coal production increases gradually to the year 2100 in all scenarios, but would be slightly lower if all countries, including Indonesia, have emission reduction targets.

We further extend MERGE to include a forest model, in order to assess the impact of international climate policy on the rate of deforestation in Indonesia. If international climate policy is implemented, the total rate of deforestation would be slightly higher than in the reference scenario. However, slowing deforestation would be a profitable option for Indonesia if it can sell the resulting emission permits.

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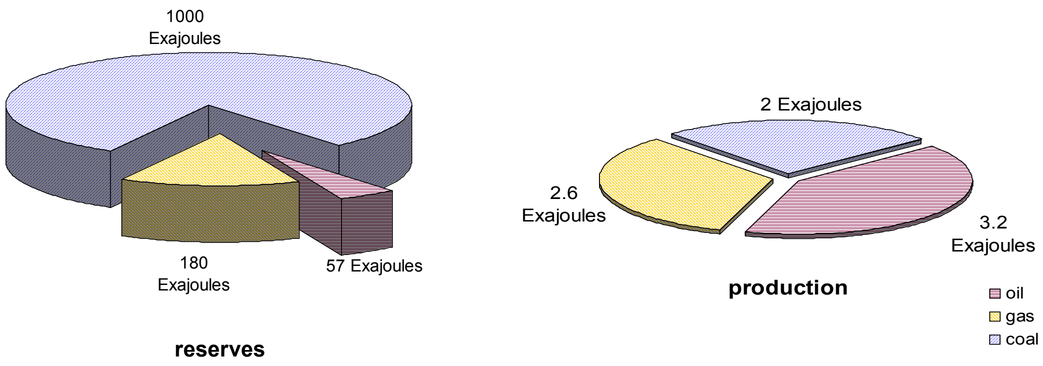


Source: EUSAI (2001)

Figure 1a. Fossil fuel reserves and production of oil, coal, and gas in 2000

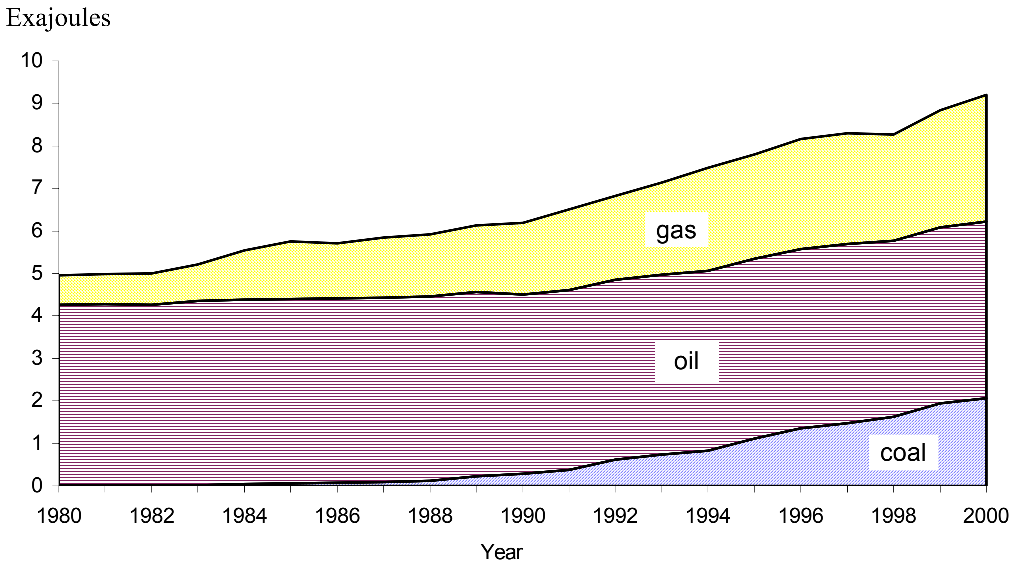
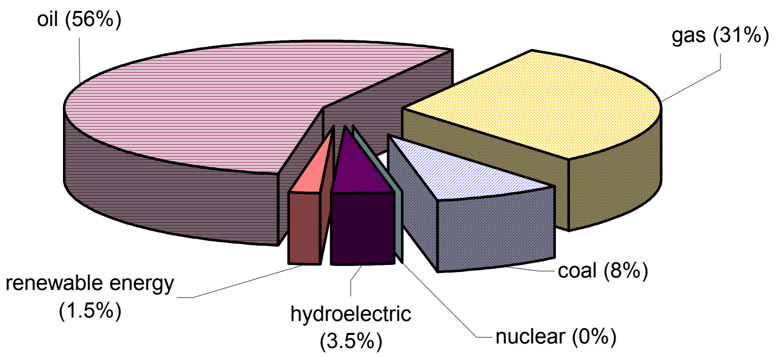
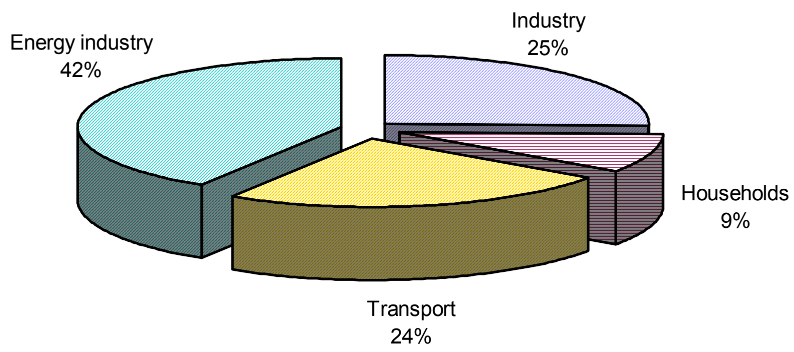


Figure 1b. Energy production of Indonesia



Source: IEA, International Energy Agency (2000)

Figure 2. Energy consumption of commercial energy sources (oil, gas, coal, hydro + nuclear)



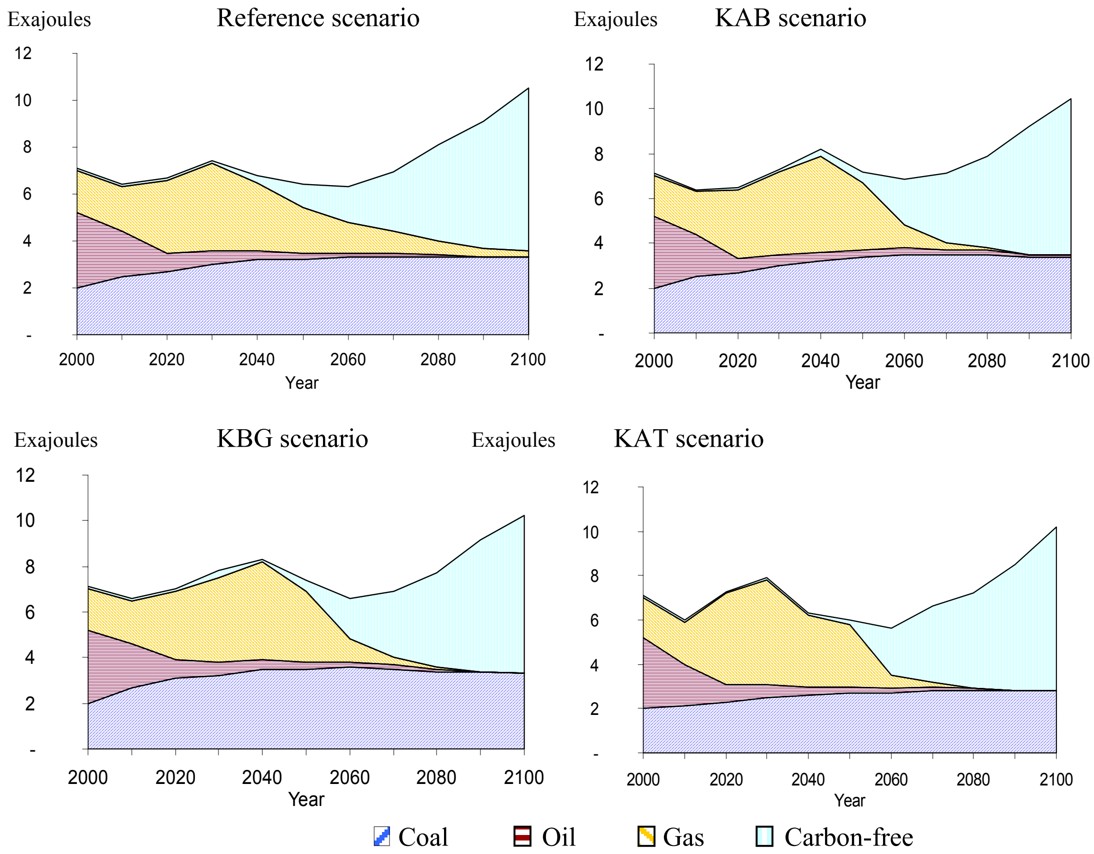
Source: SME-ROI (1999b)

Figure 3. Sources of emissions from the energy sector in Indonesia, year 2000

Table 1

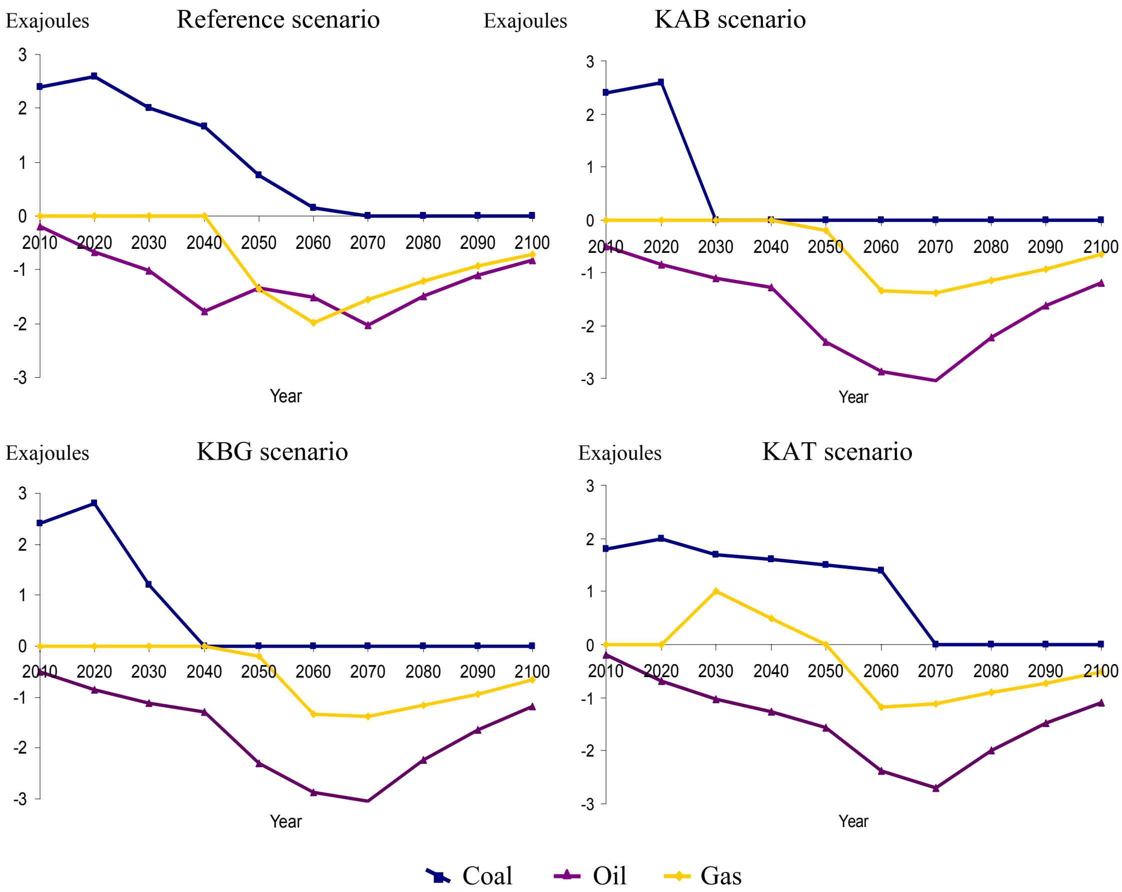
Different scenarios of the impact of the international climate policy on Indonesia

Scenario	*Emission reduction*	*Start date*	*Emissions trade*
Reference (REF)	No	–	No
Kyoto Annex B (KAB)	Annex B countries (exception of the USA)	2010	No
Kyoto Annex B with global trade (KBG)	Annex B countries (exception of the USA)	2010	All countries
Kyoto all countries with trade (KAT)	Annex B countries China, India, Mexico+OPEC Indonesia ROW (Rest of the World)	2010 2030 2050 2070	All participating countries



KAB – Kyoto Annex B scenario;   KBG – Kyoto Annex B with Global trade scenario;
KAT – Kyoto All countries with Trade scenario

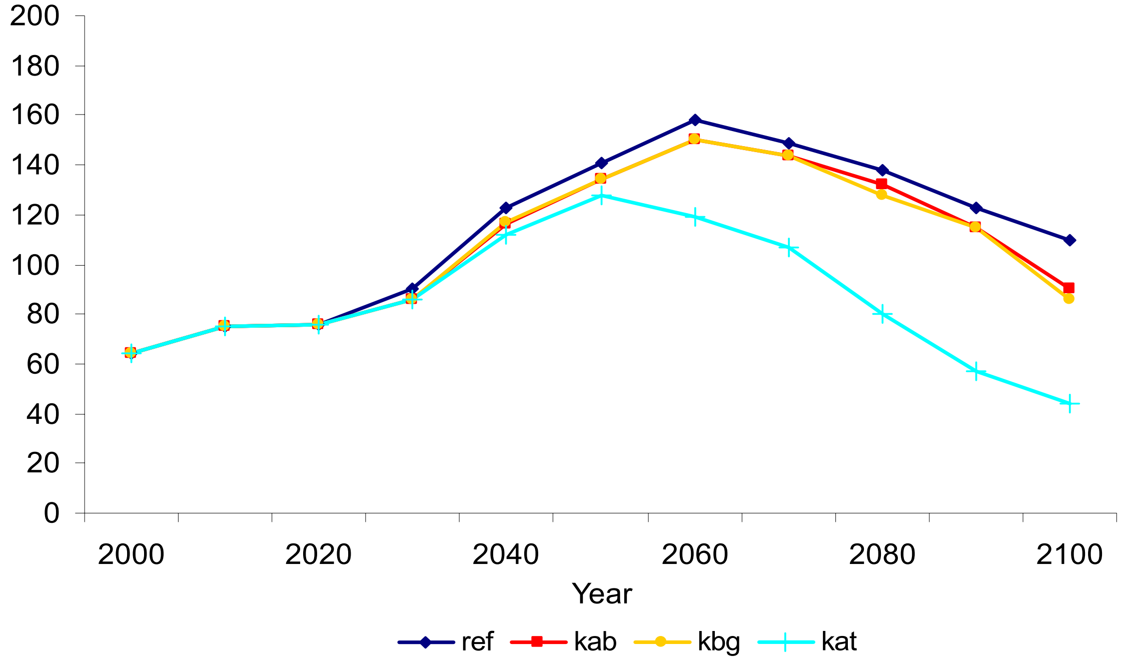
Figure 4. Primary energy production of Indonesia



KAB – Kyoto Annex B scenario; KBG – Kyoto Annex B with Trade scenario;
KAT – Kyoto All countries with Trade scenario

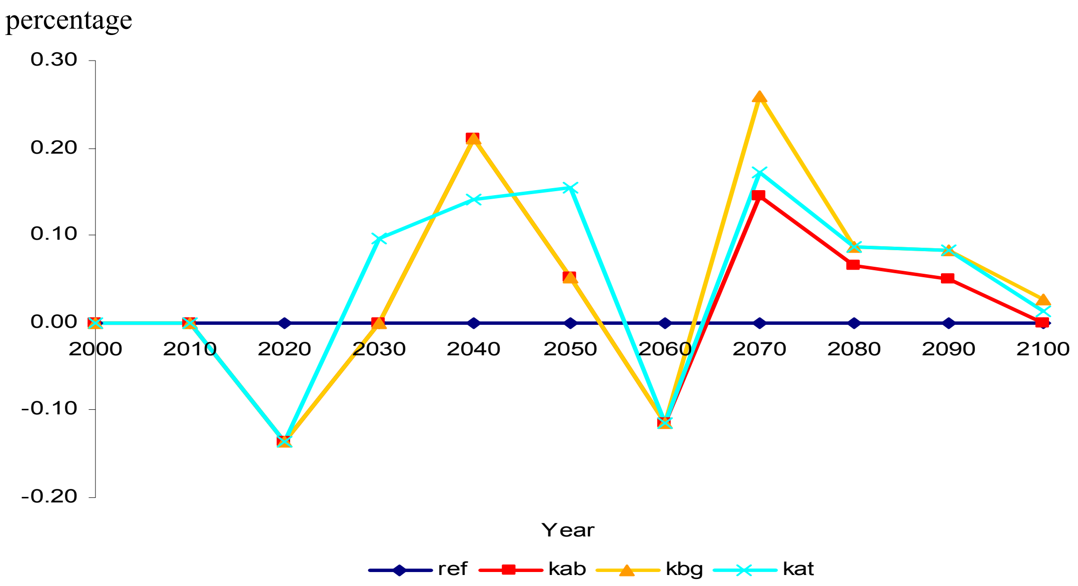
Figure 5. Net exports of Indonesia

million tonnes of C



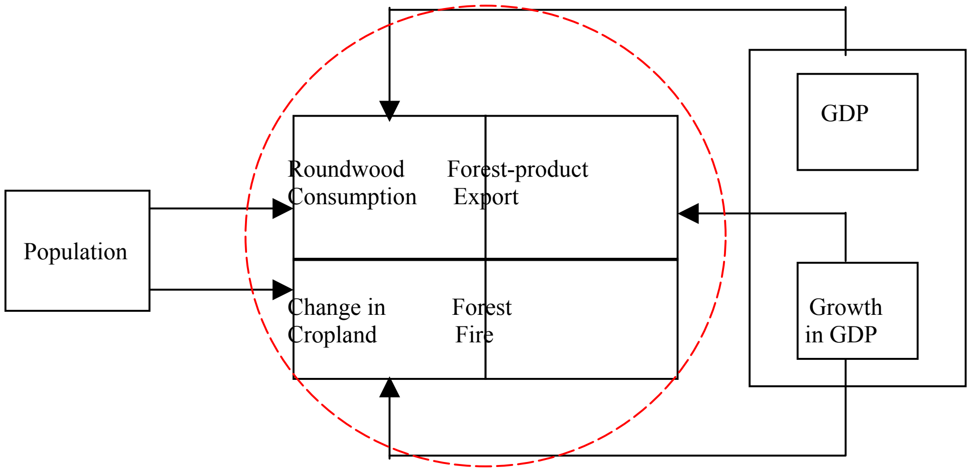
REF – Reference scenario; KAB – Kyoto Annex B scenario; KBG – Kyoto Annex B with Trade scenario; KAT – Kyoto All countries with Trade scenario

Figure 6. Total carbon emissions of Indonesia



REF – Reference scenario; KAB – Kyoto Annex B scenario; KBG – Kyoto Annex B with Trade scenario; KAT – Kyoto All countries with Trade scenario

Figure 7. GDP losses for mitigation scenarios relative to the Reference scenario



Note: Modified from Kant and Redantz' model

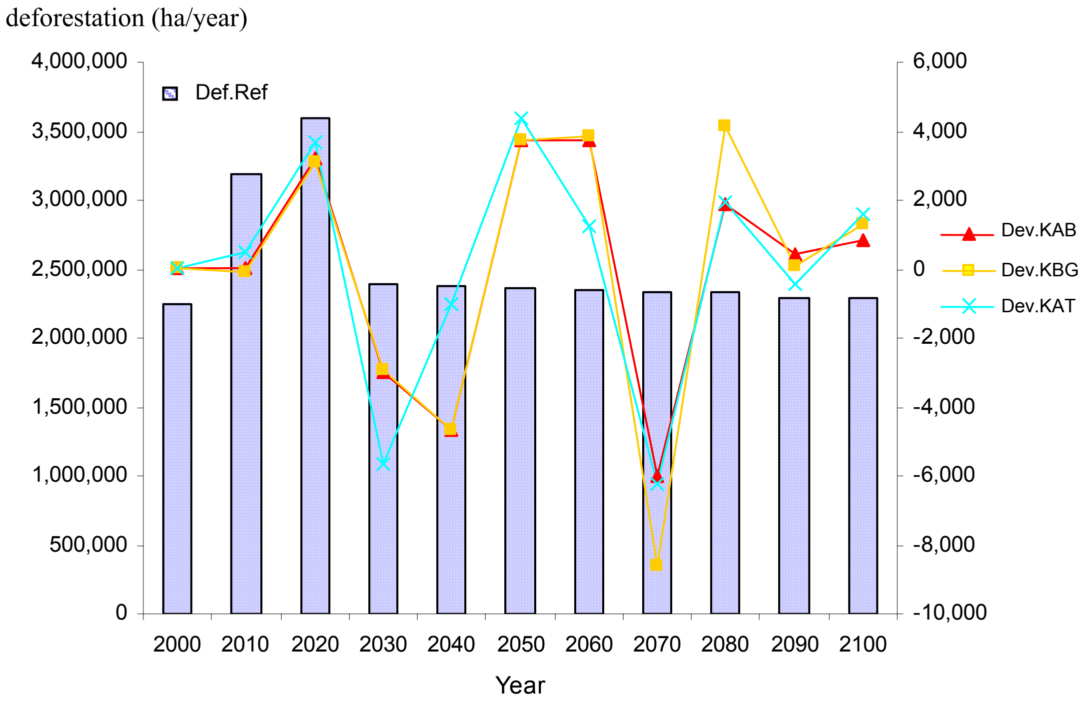
Figure 8. Interaction between deforestation, population and economic growth

Table 2

Elasticities of deforestation for Indonesia

Variable	*Elasticity*		
	RWCONS	*FOPREXP*	*CHCROPL*
Population	0.06509	-	-
GDP growth	-	0.00668	0.06171

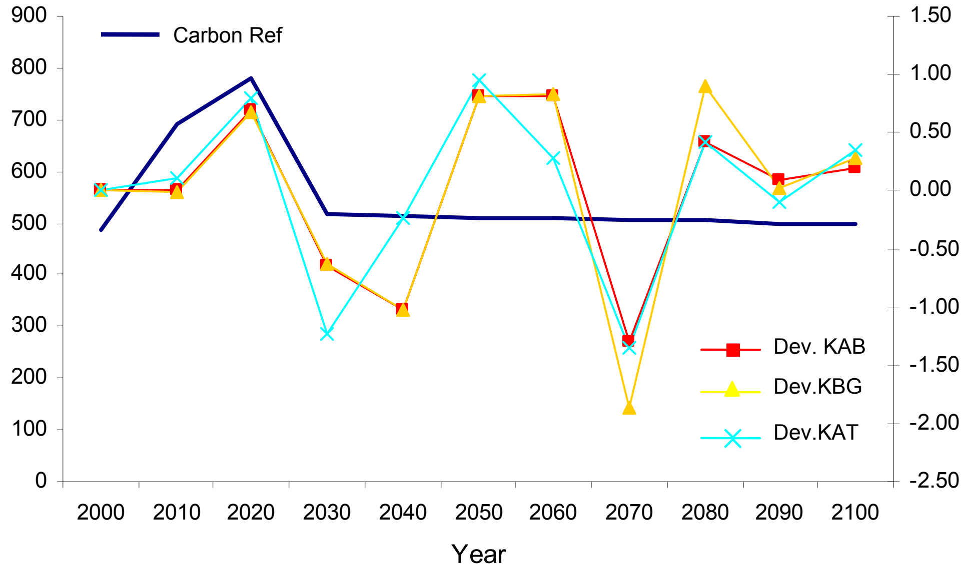
RWCONS: Annual roundwood consumption
FOPREXP: Forest-product exports
CHCROPL: Annual change in cropland



Def. Ref = Deforestation Reference scenario;
Dev. KAB = Deviation (Reference – Kyoto Annex B scenario)
Dev. KBG = Deviation (Reference – Kyoto Annex B with Global trade scenario)
Dev. KAT = Deviation (Reference - KAT – Kyoto All countries with Trade scenario)

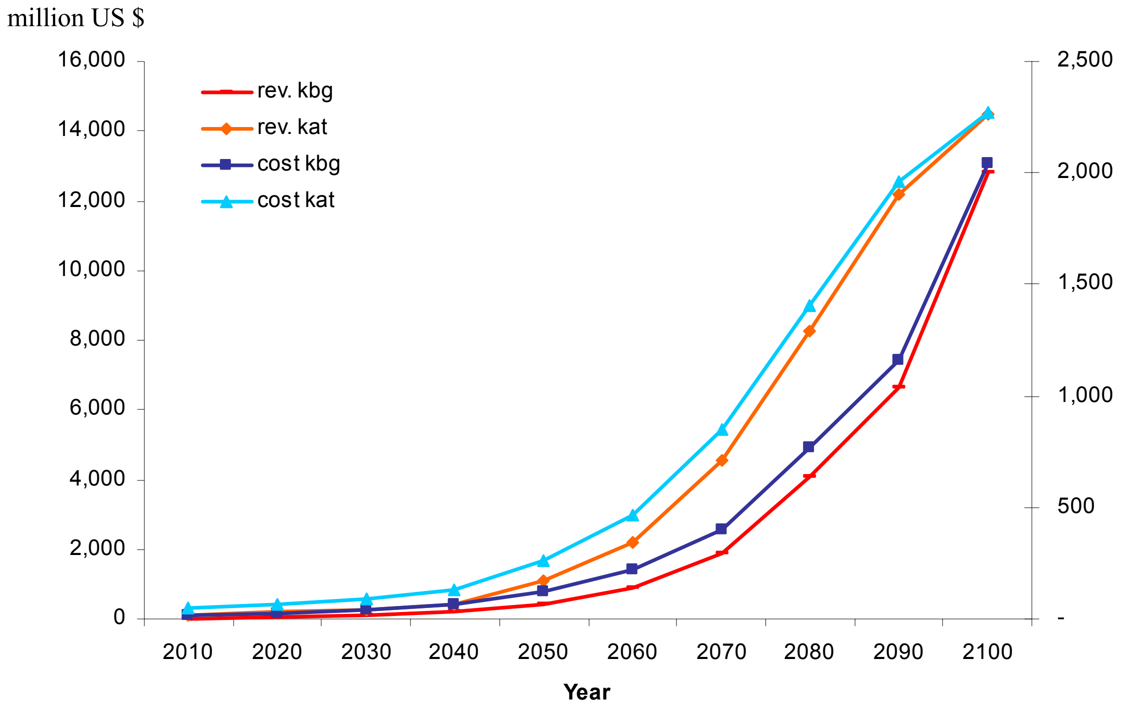
Figure 9. The effects of fossil fuel reduction on deforestation

million tonnes of C



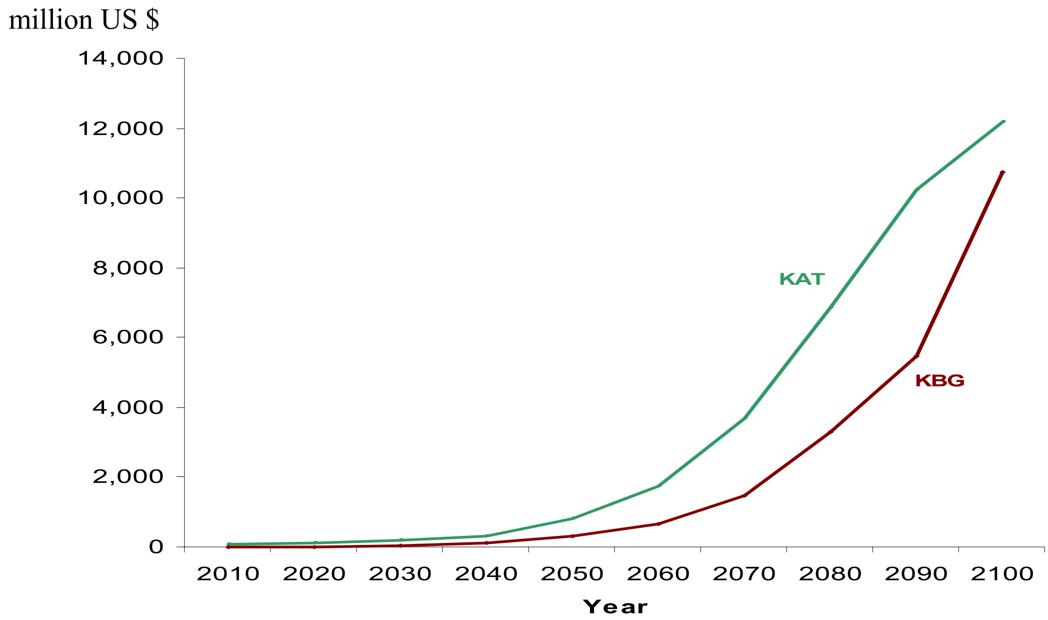
Carbon Ref = Carbon emission Reference scenario;
Dev. KAB = Deviation (Reference – Kyoto Annex B scenario)
Dev. KBG = Deviation (Reference – Kyoto Annex B with Global trade scenario)
Dev. KAT = Deviation (Reference - KAT – Kyoto All countries with Trade scenario)

Figure 10. Carbon emission from land use change and forestry



KBG – Kyoto Annex B with Global trade scenario;
KAT – Kyoto All countries with Trade scenario

Figure 11. The revenues and costs of slowing deforestation



KBG – Kyoto Annex B with Global trade scenario;
KAT – Kyoto All countries with Trade scenario

Figure 12. The profits of slowing deforestation

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