Chapter 7

Climate Change Mitigation Options and Practices

Key Messages

Southeast Asia contributed 12% of the world's total greenhouse gas (GHG) emissions in 2000, an increase of 27% over 1990, twice as fast as the global average rate of increase.

Emissions from the land use change and forestry (LUCF) sector were 75% of the total, energy 15%, and agriculture 8%. Emissions rose fastest in the energy sector (83% during 1990–2000), while about 59% of total emissions came from Indonesia, largely from LUCF.

As the largest source of emissions, the region's forestry sector holds the key to the success of mitigation efforts, and has great potential to sequester carbon through reduced emissions from deforestation and degradation (REDD), afforestation and reforestation, and forest management.

Southeast Asia also has great potential for reducing GHG emissions in the energy sector, through energy efficiency improvements in buildings and industry; harnessing renewable energy resources, including biomass, solar, wind, hydro, and geothermal; and using more efficient and cleaner transport modes.

Southeast Asia has the highest technical mitigation potential to reduce GHG emissions from agriculture than any other region. Its vast area of croplands, through cropland management, could be an important area for sequestering carbon in soils. As a major world rice and livestock producer, the region could also contribute to a reduction of methane emissions while ensuring food security.

GHG mitigation has been high on Southeast Asia's climate change policy agenda. Given its high stake in preventing further global warming, the region should make greater effort on mitigation. There is a need for more action to support research and development; provide reliable information and high-quality data; allocate more financial resources; and strengthen international and regional cooperation for funding, technological transfer, and capacity building.

A. Introduction

It is widely agreed that there is a limit to what adaptation can achieve, and that mitigation measures must be undertaken in parallel to prevent GHG concentrations in the atmosphere from reaching a dangerous level. This chapter reviews mitigation measures that have already been implemented in Southeast Asian countries and those that could become feasible in the future.

GHG mitigation measures typically require large investment and financial resources. However, mitigation is a global public good. Once implemented, its benefits will be shared by the global population—those who fail to pay for it cannot be excluded from enjoying the benefits, and one person's or one country's enjoyment of the improved climate does not diminish the capacity of other persons or other countries to enjoy it. Markets do not automatically provide the right type and quantity of public goods, because in the absence of public policy there are limited or no returns to private investors for doing so. This, plus the global nature of the problem, means that addressing climate change needs public policy not only at the national level, but more importantly, at the global level. Further, climate change observable now is the result of past emissions, largely by developed countries, raising an important equity issue. These issues will be discussed in Chapter 9.

While the responses of the major current and future GHG-emitting economies under the United Nations Framework Convention on Climate Change (UNFCCC) hold the key to a successful global solution, Southeast Asian countries should also play an important part. This is because with the rapid pace of economic and population growth the region's GHG emissions are likely to grow further, and because a low-carbon growth path brings significant co-benefits. In the rest of this chapter, section B reports GHG emission levels and their sources in Indonesia, Philippines, Singapore, Thailand, and Viet Nam. Section C reviews the mitigation options and practices of the key sectors in these countries. Section D concludes.

B. Southeast Asia's GHG Emissions

Given the region's rapid economic growth, its GHG emissions have been rising twice as fast as the global average.

In 2000, Southeast Asia contributed 12% of global GHG emissions, amounting to 5,187.2 $MtCO_2$-eq, including emissions from LUCF (Table 7.1). The region's total emissions increased 27% during 1990–2000, faster than the global average. On a per capita basis, the region's emissions are considerably higher than the global average, but are still relatively low when compared to developed countries.

Table 7.1. Greenhouse Gas Emissions ($MtCO_2$-eq)

	1990	1995	2000	World (% share)	Per Capita Emissions (tons CO_2-eq)	% Increase over 1990–2000
Southeast Asia	4,091.2	4,944.9	5,187.2	12.0	10.2	27
Annex I countries	14,645.1	16,628.2	17,001.9	39.5	13.9	16
World	37,736.2	41,481.8	43,058.2	100.0	7.2	14

Note: Annex I countries (industrialized countries): Australia, Austria, Belarus, Belgium, Bulgaria, Canada, Croatia, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Japan, Latvia, Liechtenstein, Lithuania, Luxembourg, Monaco, Netherlands, New Zealand, Norway, Poland, Portugal, Romania, Russian Federation, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey, Ukraine, UnitedKingdom, United States of America (based on the United Nations Framework Convention on Climate Change grouping).
Source: CAIT Database (WRI 2008).

The land use and forestry sector has been the largest source of GHG emissions from the region, contributing 75% of the total in 2000.

The region in 2000 accounted for about half of global LUCF GHG emissions. Sources included the decrease in biomass stocks of forestland through deforestation, logging, fuel wood collection; and the conversion of forestland to other uses such as cropland, grassland or pasture, and settlements (Table 7.2). The energy sector is a key source in the region (15%). For agriculture (8%), emissions come chiefly from livestock production, rice cultivation, use of nitrogen fertilizer, and burning of agricultural residues.

Table 7.2. Global GHG Emissions by Sector in 2000 ($MtCO_2$-eq)

Sector	Southeast Asia	Annex I Countries	World
Energy	791.8	14,728.1	2,6980.4
Industrial process	50.8	628.6	1,369.4
Agriculture	407.0	1,445.8	5,729.3
Land use change and forestry	3,861.0	-274.0	7,618.6
Waste	76.6	473.4	1,360.5
Total	5,187.2	17,001.9	43,058.2

Source: CAIT Database (WRI 2008).

Southeast Asia's GHG emissions from the energy sector increased by 83% during 1990–2000, the highest among the major emission sources.

Greenhouse gas emissions from the energy sector have increased significantly since 1990 (Table 7.3), and are expected to continue increasing rapidly as demand for energy grows and as the region seeks to maintain high economic growth. Agriculture-related emissions increased by a more modest 21% during 1990–2000, while total emissions from the LUCF sector increased 19%.

Table 7.3. Trend of GHG Emissions in Southeast Asia ($MtCO_2$-eq)

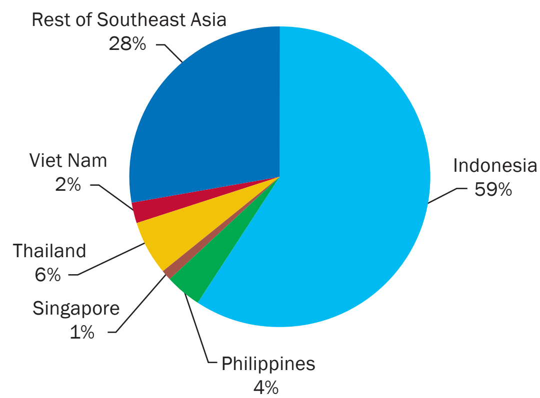
Sector	1990	1995	2000	% Increase over 1990–2000
Energy	432.6	635.5	971.8	83
Industrial process	25.4	46.4	50.8	100
Agriculture	336.7	369.3	407.0	21
Land use change and forestry	3,232.4	3,823.2	3,861.0	19
Waste	64.1	70.5	76.6	20
Total	4,091.2	4,944.9	5,187.2	27

Source: CAIT Database (WRI 2008).

About 59% of Southeast Asia's GHG emissions in 2000 came from Indonesia, mainly due to LUCF emissions.

Covering almost 42% of the region's land area and 40% of its population, Indonesia is the biggest contributor of GHG emissions (Figure 7.1) and is therefore a key player in the struggle against the adverse impacts of climate change.

Figure 7.1. GHG Emissions in Southeast Asia



Note: Total GHG emissions = 5,187 $MtCO_2$-eq.
Source: CAIT Database (WRI 2008).

C. Mitigation Options and Practices

Land Use Change and Forestry

Forests cover about 47% of Southeast Asia's total land area. The sector is recognized as an important resource base that creates environmental services, including biodiversity, as well as employment and livelihoods. From the perspective of climate change, the sector is a significant source of carbon stock. Options to reduce GHG emissions or to increase carbon storage in the sector are summarized in Table 7.4. According to Nabuurs et al. (2007), forestry mitigation options include:

- maintaining or increasing the forest area through reduced deforestation and degradation and through afforestation and reforestation;
- maintaining or increasing carbon density (tons of carbon per hectare) through forest management, forest conservation, longer forest rotations, and fire management; and
- increasing off-site carbon stocks in wood products and enhancing fuel substitution using forest-derived biomass.

Table 7.4. Mitigation Options for the LUCF Sector in Southeast Asia

Practice	Relative Mitigation Potential (unit of production)	Challenges/Barriers (policy, poverty, knowledge, extension)	Opportunities (feasibility, cost effectiveness, synergy with adaptation)	Co-benefits and Contribution to Sustainable Development
Reducing deforestation and degradation	Could store carbon of about 350–900 tCO_2/ha	Protecting forests could result in stable or increased forest carbon but may reduce wood and land supply to meet other societal needs	Depending on the cause of deforestation (e.g., timber or fuelwood extraction, conversion to cropland), cost effectiveness analysis can take into account the associated returns from non-forest land use, returns from alternative use of forests, and any incentives that may be given to change land use practices	Improve water and soil quality, enhance biodiversity and wildlife habitat, and improve the aesthetic/ amenity value of the area
Afforestation/ Reforestation	Depending on tree species and site, afforestation/ reforestation can sequester carbon in the range of 1–35 tCO_2/ha per year	High initial investment; long payback period	Costs of forest mitigation projects rise significantly when opportunity costs of land are taken into account	Reduce soil erosion, improve water and soil quality, enhance biodiversity and wildlife habitat, and improve the aesthetic/ amenity value of the area
Forest management	–	Retaining additional carbon on-site delays revenues from harvest; trade-off in carbon gain due to increased GHG emissions from fertilizer use and drainage	Alternative use of forest and incentives in maintaining forest growth	Reduce soil erosion, improve soil and water quality, and conserve biodiversity
Increasing off-site carbon stocks in wood products and enhancing product and fuel substitution	Using wooden instead of concrete frames can reduce lifecycle net carbon emissions by 110–470 kg CO_2/sqm floor area	In areas of limited supply of wood products, the cost will be restrictive. Also, durability of wood products (e.g., against termites) will pose a challenge	When used as bioenergy to replace fossil fuels, woodfuels can provide sustained carbon benefits; significant carbon sequestration from wood products that displace fossil fuel-intensive construction materials such as concrete, steel, plastic, etc.	Energy conservation through the use of bioenergy

Source: Nabuurs et al. (2007).

There is great potential to sequester carbon through reducing emissions from deforestation and degradation (REDD) and through afforestation and reforestation.

Increasing carbon storage (trees and soils) is highly applicable in the region. This is done by protecting these stocks from carbon losses through deforestation, forest and land degradation, urbanization, and other land management practices. Parties to the UNFCCC have recognized the significant emissions coming from deforestation and that, through REDD, a greater amount of carbon could be stored in the forests, with other environmental benefits (Box 7.1).

Box 7.1. Reducing Emissions from Deforestation and Degradation (REDD) in Developing Countries

What is REDD?

REDD was first introduced in the agenda of the Conference of the Parties of the United Nations Framework Convention on Climate Change (UNFCCC) at its 11th session in Montreal (December 2005). Under the UN-sponsored REDD, developed world governments and investors would pay developing countries and their forest stakeholders not to cut down forest. REDD would offer an alternative revenue stream to those relying on forests for their livelihood. This proposal received wide support, with agreement on its importance in the context of climate change, particularly of the developing countries' large contribution to global GHG emissions from this activity.

Why is REDD important to global mitigation efforts?

The Food and Agriculture Organization (FAO 2005) reports that deforestation—that is, the conversion of forest to other uses such as cropland or grassland—continued at an alarming rate of about 13 million hectares per year from 1990 to 2005. Southeast Asia alone converted 41 million hectares of forest in that period. Forest degradation, on the other hand—unsustainable harvesting and land-use practices such as selective logging, fuelwood gathering, forest fires and other anthropogenic disturbances—have also contributed to a substantial reduction in forest carbon. Deforestation and forest degradation have resulted in the immediate release of carbon from the burning of biomass and decay of organic matter in biomass and soils. IPCC (2007) estimated that deforestation from developing countries alone released about 5.8 $GtCO_2$ per year in the 1990s.

Among mitigation options in the forestry sector, REDD has the largest potential in sequestering carbon (IPCC 2007). In the short term, the carbon mitigation benefits from reduced deforestation are far greater than the benefits that could be attained with afforestation. REDD is already getting attention as a low-cost mitigation option with significant positive side-effects (Stern 2007).

REDD Status and Future

The UNFCCC Subsidiary Body for Scientific and Technological Advice has been working on REDD issues related to (i) scientific, socio-economic, technical and methodological issues; and (ii) policy approaches and positive incentives. Its work program will depend on guidance from the Ad Hoc Working Group on Long-term Cooperative Action under the UNFCCC.

Some REDD initiatives in Southeast Asia

Regional:

- The Southeast Asia Indigenous Peoples Regional Consultation on REDD, 9–11 November 2008, Baguio City, Philippines was convened[1] to provide an opportunity for indigenous people (IP) from Myanmar, Cambodia, Indonesia Malaysia, Philippines, Thailand and Viet Nam to discuss the possible impacts and opportunities from these developments, and to develop an IPs REDD strategy for the region. The meeting came up with the following elements to become part of REDD strategy: (i) consider REDD under the framework of human rights; (ii) recognize land tenure and resource rights for IPs, and develop democratic forest governance structures; (iii) empower IPs to participate effectively in REDD by raising awareness, capacity building, consultation, and information sharing.

1 By the United Nations University - Institute of Advanced Studies (UNU-IAS) and Tebtebba - Indigenous Peoples' International Centre for Policy Research and Education, with the assistance of the David and Lucile Packard Foundation.

Source: http://UNFCCC.int

continued.

Box 7.1 *continued*.

- The United Nations Reduced Emissions from Deforestation and Forest Degradation Programme (UN-REDD) was launched in September 2008 to be carried out by UN agencies with the Government of Norway financing the $35 million initial phase. Nine countries including Indonesia and Viet Nam have expressed interest. The UN-REDD will support these countries as part of an international move to include REDD in new and more comprehensive UN climate change arrangements to begin after 2012.

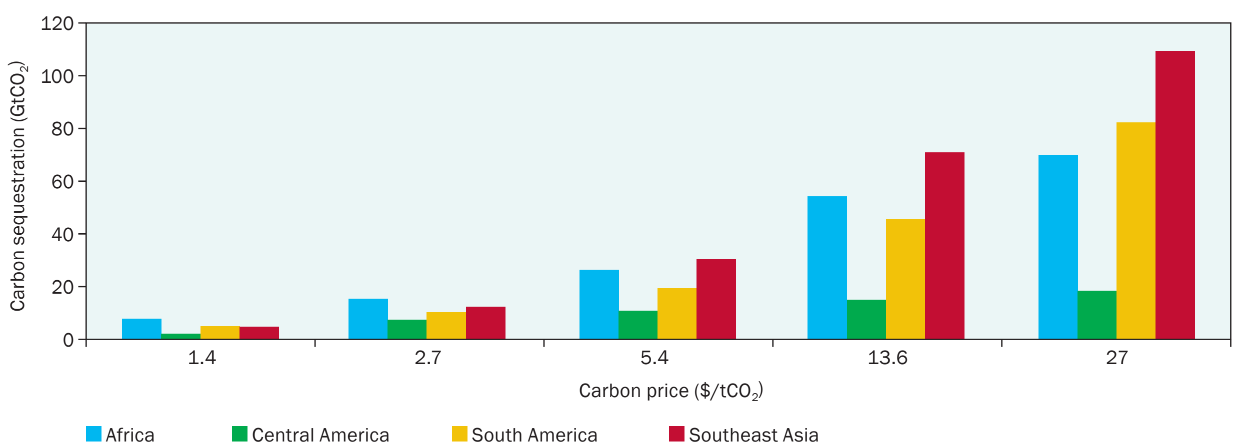
National:

- In March 2009, Indonesia applied to join the World Bank's Forest Carbon Partnership Facility, which has raised $350 million to support REDD projects and to protect its forest. Indonesia already has more than 20 REDD projects under development, mostly in Kalimantan, Papua, and Sumatra.

Sohngen and Sedjo (2006) as cited by the Intergovernmental Panel on Climate Change (IPCC 2007), estimated the potential of Southeast Asia to sequester carbon through avoided deforestation. The relative competitiveness of different regions as a source of carbon sequestration varies with the carbon price (Figure 7.2). A carbon price above $5.4/tCO_2$ would make Southeast Asia the most competitive source of carbon store in all the regions considered, an advantage that grows as the carbon price increases. A carbon price of $27/tCO_2$ is sufficiently high to make it financially attractive to halt deforestation in the region. Over 50 years, this would mean a net cumulative sequestration of 278 $GtCO_2$ relative to the baseline and an additional 422 million ha of forests.

Grieg-Gran (2009) studied eight tropical countries that collectively are responsible for 70% of LUCF emissions today, including Indonesia, and found the average opportunity costs of avoided deforestation to be in the range of about $1.2 to 6.7/tCO_2-eq depending on the scenario under consideration.

Figure 7.2. Projected Cumulative Carbon Sequestered through Avoided Deforestation by 2050 under a Reference Case, by Tropical Region under Various Carbon Price Scenarios



Source: Sohngen and Sedjo (2006).

In the case of mitigation through afforestation and reforestation, a review of the existing studies by IPCC (2007) indicates that, for a carbon price up to \$20/tCO_2, Southeast Asia is likely to have the potential to mitigate about 300 MtCO_2 per year by 2040, rising to 875 MtCO_2 when the carbon price increases to \$100/tCO_2.

Southeast Asian countries have already implemented significant measures to sequester carbon in forests.

Many programs have been implemented in the region primarily to protect forests against further degradation and to prevent further loss of biodiversity and wildlife. These also enhance the storage of carbon.

- Indonesia has reduced pressure on its forests by introducing permanent agriculture systems to farmers practicing shift cultivation. It has implemented several land and forest rehabilitation programs such as the afforestation of private community lands, reforestation in highly degraded state forest lands, and introduction of industrial forest plantations in unproductive forests.

- Indonesia has also sought to reforest its degraded mangrove forests. Between 1980 and 2000, the rate of mangrove reforestation was about 2,286 ha per year (Secretariat General of Ministry of Forestry and Estate Crops, as cited in Rosalina et al. 2003). In 2003, the government launched a program known as National Movement for the Rehabilitation of Forests and Lands, aiming to rehabilitate about 5 million ha of forestland by 2009. There were also a number of planting movements conducted by the community, local governments, and the private sector, which by May 2008 had planted about 100 million trees.

- The Philippines' Master Plan for Forestry Development serves as the government's blueprint for managing forest and woodland resources, including the establishment of forest plantations.

- Thailand is also implementing forest protection and reforestation measures for GHG reduction and enhancement of carbon sequestration. Almost every local administration has tree-growing projects for combating climate change. The Bangkok Municipal Authority's signing of a memorandum of understanding in 2007 to cooperate with 35 national agencies to combat climate change is a high-profile example.

- In 1998, the Viet Nam National Assembly adopted an ambitious 5 Million Hectare Reforestation Program (5MHRP) that aims to establish and restore 2 million ha of protected forests and 3 million ha of production forests, and to increase the total forest cover to 43% of the country by 2010, while ensuring environmental protection requirements are met. As of 2003, the 5MHRP had achieved the restoration of about 2 million ha, largely protected and special use forests.

These mitigation measures, however, require large investments. The land allocated for this type of mitigation activity will depend mainly on the price of carbon as compared to the financial returns from existing or other land use alternatives. On the other hand, the co-benefits from implementing this type of mitigation are very substantial. Afforestation and reforestation will improve the quality of the environment, reduce soil erosion and degradation, and enhance water quality and availability.

With about 200 million ha of forests (about 5% of the world total) Southeast Asia could contribute significantly to CO_2 emissions reduction through forest management.

This mitigation measure can be achieved through introducing forest harvesting systems that maintain partial forest cover, minimize losses of dead organic matter (litter and dead wood), minimize losses of soil carbon by reducing soil erosion, and prevent high-emission activities such as slash and burn farming.

According to the existing studies reviewed by IPCC (2007), for a large part of Asia (including Southeast Asia but excluding non-Annex I countries in East Asia), the mitigation potential of forest management could reach 960 $MtCO_2$ per annum by 2030 at a carbon price up to \$100/tCO_2.

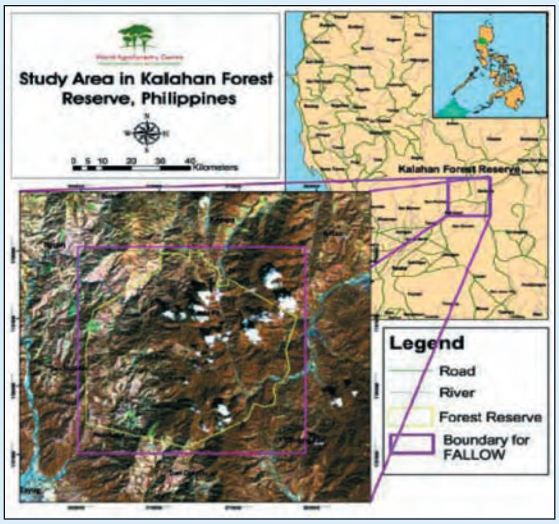
Boer et al. (1999) reported that forest protection in Indonesia, if properly applied, has the potential to sequester carbon in the range of 202–807 tCO_2 per ha while reduced logging can store carbon at 180 tCO_2 per ha and enrichment planting at 267 tCO_2 per ha.

Many countries in the region have been implementing some of these measures to protect their forestlands from further degradation. In the Philippines, for instance, the Master Plan for Forestry Development support a number of forest management activities that promote GHG mitigation, including the RUPES Kalahan Project (Box 7.2). This project promotes soil and watershed conservation and forest protection, and enhances community-based forestry activities. The drawback is in the delay in forest revenues due to partial harvesting, which are necessary to provide a form of payment to forest workers for maintaining the forest and to compensate them for their forgone harvest revenue.

Box 7.2. Forest Management as Carbon Mitigation Option: The RUPES Kalahan, Philippines Case Study

Long before the concept of Kyoto Protocol and terms like "carbon sequestration" were popularised in the Philippines, the Ikalahans (literally, "people of the broadleaf forest") practiced conservation measures. The Ikalahans are the indigenous people in the province of Nueva Vizcaya in the northeast of the Philippines belonging to the Kalanguya-Ikalahan tribe, which inhabits the Ikalahan ancestral domain. The domain includes the Kalahan Forest Reserve covering about 38,000 ha in Nueva Vizcaya and about 10,000 ha in Nueva Ecija. For generations, the Ikalahan's indigenous knowledge and environmentally sustainable practices have been key in the preservation of the Kalahan Forest Domain and have protected it from deforestation and further land conversion.

Box Figure 7.2.1. Study Area in Kalahan Forest Reserve, Philippines



In 1973, Ikalahan tribal elders organised the Kalahan Educational Foundation Inc. (KEF) to protect communities from possible eviction by land grabbers. Since then, KEF has pioneered and stood as legal representative during the Community-Based Forest Management Agreement with the Philippine government. They promoted Forest Improvement Technology to expedite the growth rate of indigenous trees within the forest to improve carbon sequestration. In 2003, Kalahan was chosen to be the first pilot site in the Philippines for the development of a carbon sequestration payment mechanism. KEF, together with the World Agroforestry Centre developed and implemented the Rewarding Upland Poor for Environmental Services (RUPES) Program aimed to enhance the livelihood and reduce the poverty of the upland poor, while supporting environmental conservation, biodiversity protection, watershed management, and carbon sequestration.

RUPES built on working models of best forest practices of the Ikalahan. The program helped to continue the carbon sequestration study set up by KEF in 1994 and assisted the foundation in examining the rate and extent of the carbon sequestration potential of the Kalahan Forest Reserve. Through RUPES, the local capacity to assess and understand the tools used to measure possible market-based rewards for environmental services were developed and strengthened. Potential buyers were sought within the Kyoto Protocol market after the Philippines ratified the treaty and got the national approval processes working. RUPES Kalahan has also pursued the voluntary market where the rules for generating carbon credits are more negotiable.

In 2002, KEF estimated around 38,383 tons of carbon dioxide were recycled by the Kalahan forests. To date, the KEF is analyzing 1994–2004 data using improved formulas to quantify carbon stocks. Also, forest inventories are being carried out in an area of about 10,000 ha. It is a huge task, but the Ikalahans are confident that by the time they finish the project they will be able to compare the growth rates of three forest types (dipterocarp, pine and oak forests) and the carbon sequestration rates of 15 indigenous tree species.

Five Key Strategies of RUPES Kalahan

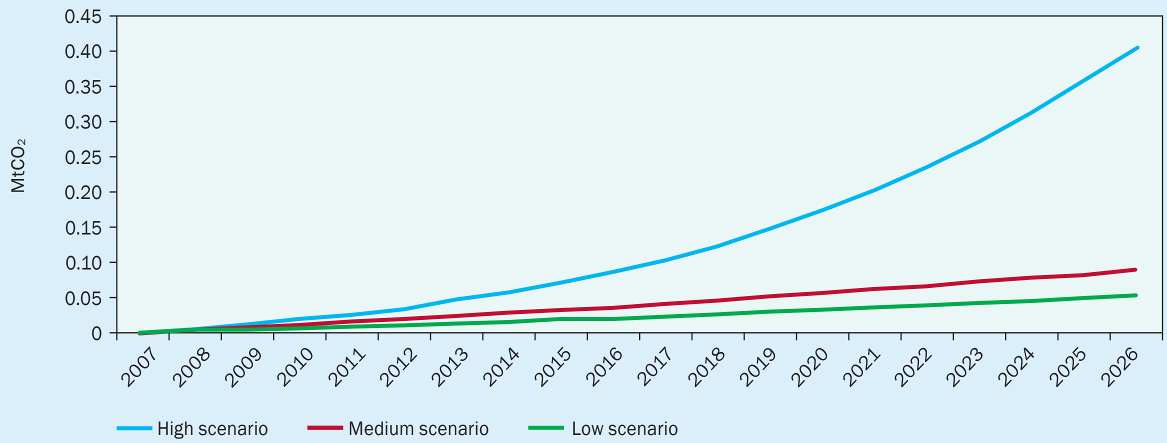
- Quantifying environmental services
- Developing environmental service agreements
- Supporting an enabling policy environment
- Raising awareness of the value of environmental services
- Forming effective partnerships

continued.

Box 7.2 *continued*.

In the meantime, the RUPES Kalahan team is preparing the CDM Project Design Document for the Kyoto market. The Kalahan forestry team, with technical assistance from The International Centre for Research in Agroforestry (ICRAF), also prepared the "Forestry Project Idea Note (PIN) on Sequestration Project in the Ancestral Domain of Ikalahan". The PIN proposes a carbon sequestration project on the 900 ha grassland portion of the domain. Among the activities conducted was the field measurement of carbon stocks in the grassland areas, which was carried out by the Kalahan forestry team. The grassland areas to be reforested have been covered with grasses at least since 1990, and without the project activity they are expected to remain so. Thus, the project sites are expected to regenerate as they have for decades, at a level considered insignificant under the CDM. For cropland areas, a similar baseline situation applies. These areas have been under cultivation with annual crops for decades and are expected to be planted with annual crops. Carbon sequestration to be provided by the project has been estimated under three growth scenarios (Box Figure 7.2.2).

Box Figure 7.2.2. Estimated Net Cumulative CO_2 Removals by the Kalahan Reforestation Project



Projections were based on the tree growth rates using the Philippine derived values (Lasco et al. 2004). The main purpose of the exercise was to assist the Kalahan indigenous people in obtaining funding for the carbon sequestration services they could provide. For this purpose the estimated carbon sequestration rates will suffice since the objective is to show potential buyers the expected range of benefits. In 2004, the KEF established two nurseries producing seedlings of various tree species for reforestation within the Kalahan Reserve and the adjacent communities covered by the ancestral domain. A total of 89,702 assorted, mostly indigenous forest trees were planted on approximately 40 ha within the ancestral domain, and enrichment plantings were done in many other portions of the forest. The Kalahan Forestry team initiated reforestation and rehabilitation activities in the grasslands, brushlands and open areas.

The Ikalahans initiated all the project activities described for their aspiration of sustainable development of forests on mountainous terrain. They are working hard to achieve rewards from this environmental service. The next step is to begin dialogue with the beneficiaries of the forest services to convince them to pay for the services rendered. Although monetary payments are not yet realized, KEF's hard work is nevertheless well recognized. With the RUPES project, it builds the capacity of indigenous communities to begin negotiations. It will also increase awareness and participation in carbon sequestration and other related issues in and around ancestral domain communities through public education programs.

Source: Villamayor and Lasco (2006).

Southeast Asia can also reduce GHG emissions from forests by increasing off-site carbon stocks and by enhancing fuel substitution.

This is achievable through harvesting practices that allow the maintenance or increase of forest carbon stocks while meeting the need for fiber, timber, and energy from forest harvesting. In some instances, biomass in the form of wood products can be used in place of fossil fuels, as well as fossil fuel-intensive construction materials such as concrete, steel, aluminum, and plastic. Within the region, the potential benefits from bioenergy technology are considerable, although fairly limited in practice at present. In Indonesia, for example, the use of biomass for generating electricity (bioelectricity) is still in its infancy, but some private sector firms (such as PT. Ajiubaya, a plywood manufacturer in Sumatra) use small (4–6 MW) biomass energy plants. Smaller power plants called bioner, with individual capacities of around 18 kW, have been installed in a number of rural areas in Kalimantan, Sumatra, and North Sulawesi Province (Martono 1998, Ridlo et al. 1998).

The Energy Sector

Although Southeast Asian countries together contributed about 3% of global energy-related CO_2 emissions in 2000, this share is expected to rise, given their relatively higher pace of economic and population growth compared to the rest of the world. The implementation of mitigation measures in the energy sectors in these countries could therefore contribute to global CO_2 stabilization efforts in the coming decades. Many options also bring significant co-benefits such as improved local environmental quality and energy security.

Mitigation strategies are available in both the energy supply and demand sectors. On the supply side, major options include efficiency improvements in power generation, fuel switching from coal to natural gas, and the use of renewable energy including biomass, solar, wind, hydro and geothermal resources. On the demand side, the key sources of GHG emissions are the residential and commercial building, industry, and transport sectors, with several key options.

- *Residential and commercial building sector*: Use of more efficient lighting and electrical appliances, energy efficiency standards and rating programs, improved insulation, and behavioral change.

- *Industry sector*: Use of more efficient boilers, motors, and furnaces, improved management practices such as energy auditing and benchmarking, heat and power recovery, fuel switching, and material recycling and substitution, particularly in energy-intensive sectors, such as iron and steel, cement, paper and pulp, and chemicals.

- *Transport sector*: Switching to cleaner fuels, use of fuel-efficient vehicles, use of hybrid/electric options in road transport, better traffic management, modal shifts from road transport to rail and public transport systems, promotion of non-motorized transport, and land use and transport planning.

Southeast Asia has great potential for reducing GHG emissions through greater energy efficiency.

IPCC (2007) identified a list of key mitigation technologies and practices for improving energy efficiency that are currently commercially available and could be adopted in the region, as well as those projected to be commercialized before 2030 (Table 7.5). Some of those currently available are already being practiced:

- In the power generation sector in Indonesia more efficient technologies such as circulating fluidized bed combustion and coal integrated gasification combined cycle have already been introduced. Similarly, increased energy efficiency has been obtained in oil refineries through revamping and reduced gas flaring. Nonetheless, there are opportunities for obtaining more energy efficiency savings in both industrial and residential uses.

- In the Philippines, the Department of Energy has taken the lead in implementing mitigation-related initiatives. The Power Patrol was launched nationwide in January 1994 through radio, television, and print, aiming to promote efficient and sensible use of electricity by targeting a reduction of at least 10% in power demand in the household, commercial, and industry sectors. Through its Fuels and Appliance Testing Laboratory, the Department has implemented energy standards and labeling, and undertaken energy performance testing and certification of specific household appliances and electrical equipment.

- In Singapore, the Energy Efficiency Singapore Program is a key strategy in mitigating GHG emissions and addressing climate change for the various end-use sectors. The program emphasizes on supporting research and development, raising awareness, promoting the adoption of energy efficient technologies and measures, as well as building capabilities and expertise in this area. Various programs supporting research and development for energy efficiency include the Innovation for Environmental Sustainability (IES) Fund and

Table 7.5. Key Energy-efficient Mitigation Technologies and Practices

Subsector	Currently Commercially Available	Projected to be Commercialized before 2030
Buildings	• Efficient lighting and use of daylight • More efficient electrical appliances and heating and cooling devices • Improved cooking stoves • Improved insulation • Passive and active solar design for heating and cooling • Alternative refrigeration fluids and recovery and recycling of fluorinated gases	• Integrated design of commercial buildings including technologies such as intelligent meters that provide feedback and control • Solar photovoltaic integrated in buildings
Industry	• More efficient end-use electrical equipment • Heat and power recovery • Material recycling and substitution • Control of non-CO_2 gas emissions • A wide array of process-specific technologies	• Advanced energy efficiency • Carbon capture and storage for cement, ammonia, and iron manufacture; inert electrodes for aluminium manufacture

Source: IPCC (2007).

the Ministry of National Development (MND) Research Fund. To reduce the amount of energy used by air-conditioning, the Building and Construction Authority and the National Environment Agency have implemented measures to further improve energy efficiency in buildings. For example, the Building and Construction Authority has stipulated that air-conditioned non-residential buildings must be designed with a high-performance building envelope that meets the prescribed Envelope Thermal Transfer Value (ETTV), currently set at 50W per square meter. A study with the National University of Singapore had been done to review ETTV standards and explore the possibility of extending ETTV regulations to residential buildings. Findings from the study subsequently led to the inclusion of the Residential Envelope Transmittance Value (RETV) to the Code on Envelope Thermal Performance for Buildings (2008). The minimum Green Mark standards for both non-residential and residential buildings took effect in early 2008 (Box 7.3)

- In Thailand, financial incentives for promoting improvements in energy efficiency are being undertaken through a subsidy program for energy efficiency investments, based on concessionary loans and tax incentives. The government promotes energy efficiency-related information services such as handbooks, e-learning programs in energy conservation, energy clinics, and energy display centers. The Thailand Greenhouse Gas Management Organization initiated "eco-labeling", which gives carbon labels to industrial products.

- In Viet Nam, the government is giving priority to efficiency improvements in coal-fired industrial boilers. There are currently 485 of such boilers registered throughout the country, more than 90% of which have a burn capacity of 10 ton/hour or less. The efficiency of coal-fired industrial boilers is in the range of 50–75%. It is estimated that around 52% of existing boilers will need to be replaced and 10% rehabilitated.

Southeast Asia has considerable potential to harness renewable energy resources, including biomass, solar, wind, hydro, and geothermal; and to use emerging technologies on oceanic energy resources, such as tidal power.

IPCC (2007) has also identified key mitigation technologies and practices on renewable and cleaner energy that are now commercially available and could be adopted in the region (Table 7.6). Some have already been adopted.

- The use of renewable energy in Indonesia is still limited. While the country has been using biomass for electricity, its use remains limited. Presidential Decree No. 5 (2006) has set the goal of increasing the share of renewable energy (biomass, geothermal, wind, solar energy, and others) and new or clean energy such as nuclear power or hydrogen to 15% of the primary energy mix by 2025. As part of this initiative the Ministry of Energy and Mineral Resources Decree 1122/2002 for small-scale energy generating installations and Decree 02/2006 for medium-scale energy generating installations mandate Indonesia's national public utilities to purchase renewable energy generated from small- and medium-scale installations.

- In the Philippines, under the Philippine Energy Plan (PEP), new and renewable energy sources are seen contributing significantly to the country's electricity supply. Backing up the PEP are policies and laws such as the Philippine Clean Air Act of 1999, Biofuels Act of 2006, and the Renewable Energy (RE) Act of 2008. Through incentives, the RE Act encourages local entrepreneurs to go into the development

Box 7.3. Green Mark Ratings

The BCA Green Mark Scheme was launched in January 2005 as an initiative to move Singapore's construction industry toward more environment-friendly buildings. It is intended to promote sustainability in the built environment and raise environmental awareness among developers, designers and builders when they start project conceptualisation and design, as well as during construction.

Criteria and Scoring System

BCA Green Mark is a green building rating system to evaluate a building for its environmental impact and performance. It is endorsed and supported by the National Environment Agency. It provides a comprehensive framework for assessing building performance and environmental friendliness. Buildings are awarded the BCA Green Mark based on five key criteria:

- Energy efficiency
- Water efficiency
- Site/project development & management (building management & operation for existing buildings)
- Good indoor environmental quality & environmental protection
- Innovation

Under the Green Mark assessment system, points are awarded for incorporating environment-friendly features which are better than normal practice. The assessment identifies designs where specific targets are met. Meeting one or more indicates that the building is likely to be more environment-friendly than buildings where the issues have not been addressed. The total number of points obtained provides an indication of the environmental friendliness of the building design.

Green Mark Award Rating for New Buildings

Green Mark Points	Green Mark Rating
90 and above	Green Mark Platinum
85 to <90	Green Mark Gold PLUS
75 to <85	Green Mark Gold
50 to <75	Green Mark Certified

The assessment process consists of an initial assessment leading to the award of the Green Mark. Subsequently, buildings are required to have triennial assessment. This is to ensure that the Green Mark building continues to be well-maintained. Buildings are awarded Platinum, GoldPLUS, Gold or Certified rating depending on the points scored. Apart from achieving the minimum points in each rating scale, the project has to meet all prerequisites, and score a minimum of 50% of the points in each category, except the Innovation category.

New buildings assessed under the Green Mark will require triennial assessment to maintain their Green Mark status. They will be assessed under the existing buildings criteria during the triennial assessment. The same criteria apply to existing buildings, unless they are undergoing a major refurbishment program.

Source: Building and Construction Authority (2009).

Table 7.6. Key Mitigation Technologies and Practices on Renewable and Cleaner Energies

Subsector	Currently Commercially Available	Projected to be Commercialized before 2030
Energy supply	• Fuel switching from coal to gas • Biofuels • Nuclear power • Renewable heat and power (hydropower, solar, wind, geothermal and bioenergy) • Combined heat and power • Early applications of CCS (e.g., storage of removed CO_2 from natural gas).	• CCS for gas, biomass, and coal-fired electricity-generating facilities • Second generation biofuels • Advanced nuclear power • Advanced renewable energy, including tidal and wave energy, concentrating solar, and solar photovoltaic

Source: IPCC (2007).

of alternative energy resources and help decrease dependence on imported fuel. The RE Act directs the Department of Energy, National Power Corporation, and other government agencies to develop and institute a framework for propagating renewable energy, and seamlessly interconnecting these sources into the national power grid. In the short term, new and renewable energy sources such as solar, wind, mini-hydro, and biomass are expected to reach a capacity of 92.3 million barrels of oil equivalent in 2009 (as compared with 71.2 million in 2000).

- Singapore has shifted toward the use of less carbon-intensive fuels, principally natural gas. Efforts are under way for Singapore's first liquid natural gas terminal to be ready by 2012. Efforts in promoting renewable energy such as biomass and solar energy are focused on research and development, while the government is reviewing how electricity generation using renewable energy sources can be increased, and at the same time ensuring that this does not cause disruption to the network. Singapore is also one of the few countries in the world that incinerates almost all of its solid waste. As such, landfills generate negligible methane (CH_4). At present, five such waste-to-energy plants are in operation and electricity from the incineration plants contributes 2–3% of Singapore's energy supply.

- Thailand has developed the Alternative Energy Development Plan, which covers a wide range of power generation and heat from renewable energy sources, including biofuels. The government target

Table 7.7. Targets for Renewable Energy and Alternative Fuels in Thailand

	Power Generation		Process Heat	Alternative Fuels	
	(MW)	(ktoe)	(ktoe)	(million liter/day)	(ktoe)
Targets in 2011	3,276	1,047	4,035	5.4	1,606
Solar	45	4	5	–	–
Wind	115	13	–	–	–
Hydropower	156	17	–	–	–
Biomass	2,800	941	3,660	–	–
Municipal solid waste	100	45	–	–	–
Biogas	60	27	370	–	–
Ethanol	–	–	–	2.4	653
Biodiesel	–	–	–	3.0	953
Existing in 2006	1,621	530	2,424	0.5	–

– = data not available.
Source: Ministry of Energy (2008).

is to increase the share of renewable energy to 8% by 2011. There is an active biofuel program and a target for biomass energy of 2800 MW by 2011. Table 7.7 provides details of targets for all renewables and alternative fuels in Thailand. There are currently nine operating ethanol plants with a production capacity of 1.25 million liters/day and the government has approved the construction of an additional 45 ethanol plants (20 sugar mills and 25 cassava mills) with a total capacity of 12 million liters/day. Community-based biodiesel production commenced in 2005.

- In Viet Nam, the Energy Law of 2005 aims to improve energy efficiency and promote the development of renewable sources, including solar and wind power. As yet there has been little development of renewables, despite the huge potential for renewable energy (estimates range between 1,100 to 1,900 MW). The development of small, localized hydropower units to replace the present reliance on generation from coal-fired power plants is now being considered.

Southeast Asia has considerable potential to reduce CO_2 emissions by using more efficient transport and traffic management systems.

IPCC (2007) identified key mitigation technologies and practices for transport systems and road traffic management that are currently commercially available and could be adopted in the region (Table 7.8). Some are already being implemented.

- Indonesia considers the development of mass rapid transportation (a dedicated bus line and mono rail) an important measure to reduce CO_2 emissions in urban areas. The Blue Sky Programme was designed to improve air quality in Indonesia's five largest cities through, among other means, increasing the capacity and quality of public transportation. Indonesia has also introduced plans for the use of alternative fuels (liquefied natural gas and liquefied petroleum gas for public transport and taxis), inspection and maintenance programs, and stronger vehicle emission standards. The government has developed the Strategic Plan for the Transportation Sector in response to climate change, which aims to ensure that climatic considerations are incorporated in planning for the sector.

- A Road Transport Patrol Program was launched in April 1998 in the Philippines, through Executive Order No. 472—Institutionalizing the

Table 7.8. Key Mitigation Technologies and Practices for the Transport System and Road Traffic Management

Subsector	Currently Commercially Available	Projected to be Commercialized before 2030
Transport	• More fuel-efficient vehicles • Hybrid vehicles • Cleaner diesel vehicles • Modal shifts from road transport to rail and public transport systems • Non-motorized transport (cycling, walking) • Land use and transport planning	• Higher efficiency aircraft • Advanced electric and hybrid vehicles with more powerful and reliable batteries

Source: IPCC (2007).

Committee on Fuel Conservation and Efficiency in Road Transport. The program promotes efficient use of fuel through a media campaign on fuel conservation for drivers, vehicle operators, and fleet owners. The Philippine Clean Air Act of 1999 mandates the Philippine Atmospheric, Geophysical and Astronomical Services Administration to regularly monitor meteorological factors affecting environmental conditions, including CO_2 emissions. Executive Orders 396 and 397 of 2004 provide for import duty reductions for hybrid and compressed natural gas vehicles.

- Singapore is improving the energy efficiency of its transport sector by managing vehicle usage and traffic congestion, improving and promoting the use of public transport, improving fuel economy, and promoting green vehicles. The transportation sector accounts for around 20% of CO_2 emissions, and the government plans to achieve a modal split of 70% in the use of public transport during peak hours by 2020, from 63% in 2004. A vehicle quota system and electronic road pricing are already used to reduce traffic congestion. A “green vehicle” rebate scheme to encourage the use of hybrid and compressed natural gas vehicles has been in operation since 2001. The rebate for such vehicles was increased from 20% to 40% of their open market value in 2006. Likewise, a fuel economy labeling scheme for vehicles, launched as a voluntary program in 2003, became mandatory for all passenger cars from April 2009.

- Policies in Thailand to mitigate CO_2 from transport include the development of a master plan in large cities, promotion of the mass transit system in Bangkok, encouragement of car pools, use of economic incentives to encourage mode switching, retrofitting and improvement of engine efficiency, and promotion of the use of natural gas in vehicles.

- In Viet Nam, the government plans to improve fuel efficiency in transport through the wider use of cars with “lean burn” engines. The aim is to substitute existing small gasoline cars (less than 1,500 cc) with cars of the lean burn type. This new engine improves fuel efficiency by about 20% and also emits less air pollutants per kilometer.

Costs associated with mitigation options vary greatly, but there remains low-cost potential that Southeast Asia should exploit.

IPCC (2007) reviewed the existing studies on the potential and costs of various energy sector mitigation options, focusing mostly on those with an abatement cost below $100/$tCO_2$. The results show that abatement cost estimates vary greatly depending on underlying assumptions regarding emission scenarios, time horizons, cost parameters, and technology specifications, among others. In the case of fuel switching from coal to gas power plants, for instance, the abatement cost is estimated to range from zero to $11/$tCO_2$ by 2030 for developing countries. Some mitigation options have much higher abatement costs. For example, it can go up to $50–100 or even higher per tCO_2 in the case of solar power plants and carbon capture and storage (CCS) technologies.

There are, however, win-win mitigation options, that is, CO_2 emissions reduction could be achieved at a negative cost. According to IPCC (2007), developing countries by 2020 could mitigate a total of 1.5 $GtCO_2$ from the residential and commercial building sector and, by 2030, depending on the projected oil prices, 88 to 146 $MtCO_2$ from automobiles on an annual basis at a negative cost. According to McKinsey (2007), a total of about 5 $GtCO_2$ emissions could be mitigated by 2030 on an annual basis at a negative net cost globally through measures including building insulation; use of high-efficiency appliances (e.g. air conditioners and water heaters) and lighting in the residential sector, fuel efficiency in vehicles, and biofuels; and reduction of industrial non-CO_2 emissions.

A number of studies have reported mitigation potential with a negative net cost in the Southeast Asian energy sector.

- On the energy supply side, efficiency improvements in system loss reduction in power plants have the potential to mitigate about 227 $MtCO_2$ in the Philippines during 2000–2020 (ADB 1998a). Switching from oil to gas power plants is projected to have the potential to mitigate about 4 $MtCO_2$ in Viet Nam by 2010 (MONRE 2004).

- On the energy demand side, Thailand has the potential to mitigate 31 $MtCO_2$ emissions from the residential and commercial building sector from 1997–2020 (ADB 1998). The same study reports that the Philippines and Thailand could reduce a total of 18 $MtCO_2$ and 89 $MtCO_2$, respectively, in the period up to 2020, through the use of efficient boilers and motors in the industry sector. The Philippines has the potential to mitigate about 40 $MtCO_2$ through the use of high-efficiency transport systems during the period 2000–2020, and Thailand could mitigate about 30 $MtCO_2$ during the period 1997–2020 through improvement of fuel efficiency in vehicles.

The Agriculture Sector

Agriculture remains a major economic sector in the region, with its share in GDP, albeit declining, still high. Most of the region's poorest people, living in rural areas, still rely on agriculture for their livelihoods and as a safety net. A variety of options exist for mitigation of GHG emissions in the agriculture sector. These include: (i) reducing fertilizer-related emissions; (ii) reducing CH_4 emissions from rice paddies; (iii) reducing emissions from land use change; (iv) sequestering carbon in agro-ecosystems; and (v) producing fossil fuel substitutes. Table 7.9 summarizes these agriculture-related mitigation options.

IPCC (2007) classified the mitigation potential for agriculture into technical and economic potential. Technical potential refers to the possible amount of GHG mitigation by implementing a technology or practice (such as the efficient use of nitrogen fertilizer) that has already been demonstrated successfully. This considers only practical constraints with no reference to cost. Economic potential, on the other hand, considers the costs.

Table 7.9. Mitigation Options in Agriculture in Southeast Asia

Practice	Relative Mitigation Potential (unit of production)	Challenges/Barriers (policy, poverty, knowledge, extension)	Opportunities (feasibility, cost effectiveness, synergy with adaptation)	Co-benefits and Contribution to Sustainable Development
Cropland management • agronomy • nutrient management • tillage/residue management • water management	Potential to sequester soil carbon by 0.55–1.14 tCO_2/ha/ year Potential to reduce N_2O emissions by 0.02–0.07 tCO_2-eq/ha per year.	This option could be costly to implement and would need considerable effort to transfer, diffuse, and deploy. Also, some measures may challenge existing traditional practices.	Use of improved varieties with reduced reliance on fertilizers and other inputs provides opportunity for better economic returns. Reduced tillage will reduce the use of fossil fuel thus lower CO_2 emissions from energy use.	Increases productivity (food security); improves soil, water, and air quality; promotes water and energy conservation; and supports biodiversity and wildlife habitat.
Rice management	In continuously flooded rice fields, potential to reduce CH_4 emission by 7–63% (with organic amendment) and 9–80% (with no organic amendment).	The benefit may be offset by the increase of N_2O emissions and the practice may be constrained by water supply.	More effective rice straw management to reduce CH_4 emissions (e.g., as a biofuel).	Promotes productivity (food security) and conservation of other biomes. Also enhances water quality.
Agroforestry, set-aside, land use change	Potential to sequester carbon by 0.70–3.04 tCO_2/ha per year; reduce CH_4 emission by 0.02 tCO_2-eq/ha per year; and reduce N_2O emission by 0.02–2.30 tCO_2-eq/ha per year.	Cropland conversion reduces areas intended for food production. Also, the fate of harvested wood products would need to be accounted for.	Harvest from trees (fuelwood) could be used for bioenergy; additional returns to farmers. Set-aside is usually an option only on surplus agricultural land or on croplands of marginal productivity.	This practice promotes biodiversity and wildlife habitats; energy conservation; and, in some cases, poverty reduction. Improves the quality of soil, water, and air; promotes water and energy conservation; supports biodiversity, wildlife habitats, and conservation of other biomes.
Grassland management • grazing management • fertilization • fire	Potential to sequester carbon by 0.11–1.50 tCO_2/ha per year.	Nutrient management and irrigation might increase the use of energy; introduction of species might have an ecological impact.	Improves productivity.	This measure increases productivity (food security); improves soil quality, promotes biodiversity and wildlife habitats; and enhances aesthetic/amenity value.
Peatland management and restoration of organic soils	Potential to sequester carbon by 7.33–139.33 tCO_2/ha per year; and reduce N_2O emission by 0.05–0.28 tCO_2-eq/ha per year.	Need better knowledge of the processes involved to avoid double counting.	Avoiding row crops and tubers; avoiding deep ploughing; and maintaining a shallower table are strategies to be explored.	Improves soil quality and aesthetic/amenity value; promotes biodiversity, wildlife habitats, and energy conservation.
Restoration of degraded lands	Potential to sequester carbon by 3.45 tCO_2/ha per year.	Where this practice involves higher nitrogen application, the benefit of carbon sequestration may be partly offset by higher N_2O emissions.		Increases productivity (food security); improves soil and water quality and aesthetic and amenity value; and supports biodiversity, wildlife habitats, and conservation of other biomes.

Table 7.9 *continued.*

Practice	Relative Mitigation Potential (unit of production)	Challenges/Barriers (policy, poverty, knowledge, extension)	Opportunities (feasibility, cost effectiveness, synergy with adaptation)	Co-benefits and Contribution to Sustainable Development
Bioenergy (soils only)	Potential to sequester carbon by 0.70 tCO_2/ha per year; and reduce N_2O emission by 0.02 tCO_2-eq/ha per year.	Competition for other land uses and impact on agro-ecosystem services such as food production, biodiversity, and soil moisture conservation.	Technical potential for biomass; technological developments in converting biomass to energy.	Promotes energy conservation.
Livestock management feeding practices	Improved feeding can reduce CH_4 emissions from enteric fermentation by 1–22% for dairy cattle; 1–14% for beef cattle; 4–10% for dairy buffalo, and 2–5% for nondairy buffalo.	The effect varies depending on management of animals, i.e., whether confined animals or grazing animals.	The measure depends on soil and climatic conditions, especially when dealing with grazing animals.	Reduced pressure on natural resources (such as soils, vegetation, and water) allow a higher level of sustainability.
Manure management	Up to 90% of CH_4 emitted can be captured and combusted, 10–35% of CH_4 can be reduced by composting, and 2–50% of N_2O emission can be reduced through improved soil application.	Lack of incentives for the broad application of this measure would be a challenge.	Applicable to all waste management systems particularly swine production.	Fewer odors and less environmental pollution.

Source: Smith et al. (2007).

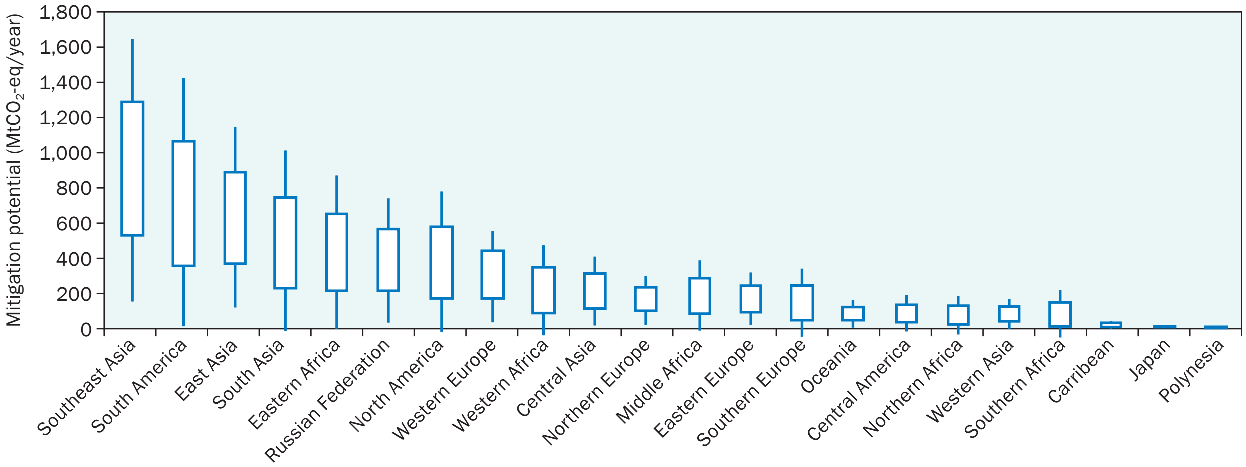
Estimates exist, though limited, on the range of economic mitigation potential of agricultural practices in Southeast Asia.

Empirical estimates of mitigation potential of the agriculture sector are limited. The United States Environmental Protection Agency (2006) estimates the economic potential for reducing net emissions of nitrous oxide (N_2O) and soil carbon from cropland in South and Southeast Asia at zero cost would be 2.1 $MtCO_2$-eq in 2010 and 2.3 $MtCO_2$-eq in 2020. Increasing the carbon cost to \$30/tCO_2-eq would increase the potential by 20% in 2010 and 35% in 2020. The study also estimates that the same regions' economic potential in reducing GHG emissions from rice fields at zero cost would be about 60.6 $MtCO_2$-eq in 2010 and 72 $MtCO_2$-eq in 2020. Increasing the carbon cost to \$30/tCO_2-eq would significantly increase the potential, by about 60% in both 2010 and 2020.

Southeast Asia has the highest technical mitigation potential to reduce GHG emissions from agriculture than any other region.

Smith et al. (2007) report that the technical potential for emissions reduction from using all technically feasible practices and covering all GHGs ranges from 550 to 1,300 $MtCO_2$-eq per year for Southeast Asia by 2030, the highest among regions in the world (Figure 7.3). The study also estimates that by 2030 the global economic potential for agricultural GHG reduction could

Figure 7.3. Total Technical Mitigation Potential in Agriculture (all practices, all GHGs) for Each Region (2030)



Source: IPCC (2007).

reach 28% of its total technical potential at a carbon price of up to \$20/tCO_2-eq and 46% at a carbon price of up to \$50/tCO_2-eq. Roughly applying these proportions to Southeast Asia implies that by 2030 the region's economic potential for GHG mitigation in the agriculture sector would be about 152 MtCO_2-eq per year at a carbon price of up to \$20/tCO_2-eq and about 414 MtCO_2-eq per year at a carbon price of up to \$50/tCO_2-eq. However, these estimates are derived from a strong assumption that the composition of Southeast Asia's mitigation practices approximates that at the global level, and should be taken to provide only very rough orders of magnitude.

Southeast Asia's vast area of croplands, through cropland management, could be an important channel to sequester carbon in soils.

Proper cropland management has the potential to sequester soil carbon by 0.55–1.14 tCO_2/ha per year and to reduce N_2O emissions by 0.02–0.07 tCO_2-eq/ha per year. This mitigation measure can be achieved through improved agronomic practices that enable crops to increase yield and generate higher inputs of carbon residue, resulting in higher carbon storage (Follet 2001). Examples of improved agronomic practices include use of improved crop varieties, extending crop rotations, particularly of perennial crops, and avoidance of cultivation of bare unplanted or fallow land (West and Post 2002, Smith 2004a and 2004b, Lal 2003 and 2004a, Freibauer et al. 2004).

The challenge in using improved crop varieties, with a view to increasing yield and biomass as carbon residue input, is in the management of nitrogen fertilizer requirements so as not to offset gains in soil carbon with the emission of N_2O from fertilizer application. However, this mitigation measure, if implemented, will contribute to increases in crop productivity and improved soil quality due to increased soil carbon storage.

Nutrient management also reduces GHG emissions from agriculture. Improving efficiency in nitrogen use can reduce the emissions of N_2O and indirectly reduce the emissions from nitrogen fertilizer (Schlesinger 1999).

This also reduces off-site N_2O emissions from leaching and volatilization. Practices that improve the use of nitrogen fertilizer include the use of slow- or controlled-release fertilizer, precision farming or applications based on precise estimation of crop needs, and precise application of fertilizer to the soil to make it more accessible to plant roots (Robertson 2004, Dalal et al. 2003, Paustian et al. 2004, Cole et al. 1997, Monteny et al. 2006).

A study in Indonesia, on the use of slow- or controlled-release nitrogen fertilizer in rice fields, showed that applying non-prilled urea, such as tablet urea, polymer-coated urea and nutralene, can result in a reduction of N_2O emissions (Setyanto 1997). Use of polymer-coated urea could reduce N_2O emissions by 4–16%, as compared with prilled urea, and can also increase yield significantly more, from 17–25% in some cases (Table 7.10).

Tillage and residue management in croplands could promote carbon gain since soil disturbance often results in carbon losses through decomposition and soil erosion (West and Post 2002, Ogle et al. 2005, Gregorich et al. 2005, Alvarez 2005). Water management could also reduce GHG emissions by using more effective irrigation measures that enhance soil carbon storage, crop yields, and residue return (Follett 2001, Lal 2004a).

Table 7.10. Effects of Different Types of Nitrogen Fertilizer on N_2O Emission in Rice Fields in Central Java, Indonesia (1997)

Treatment	N_2O Emissions (kg/ha)	Grain Yield (kg/ha)	Effect of Technology on N_2O Emissions (%)	Grain Yield Difference (%)	Benefit per kg Reduction of N_2O ('000 x Rupees)
Dry Season					
Prilled urea	225	3,953	–	–	–
Tablet urea	194	5,172	-13.8	30.8	58.9
Prilled urea + sulfur	182	3,908	-19.1	-1.1	1.5
Nutralene	215	4,154	-4.4	5.1	30
Certified Reference Material	165	4,634	-26.7	17.2	17
Wet Season					
Prilled urea	73	4,008	–	–	–
Tablet urea	73	4,698	0	17.2	0
Prilled urea + sulfur	47	4,114	-35.6	2.6	6
Nutralene	61	4,279	-16.4	6.8	33.8
Certified Reference Material	64	5,021	-12.3	25.3	168.8

Source: Setyano, (1997).

As a major world rice producer, Southeast Asia can contribute to a reduction of CH_4 emissions while ensuring food security.

In a continuously flooded rice field, rice management has the potential to reduce emissions of CH_4 by 7–63% (with organic amendment) and by 9–80% (with no organic amendment) (Table 7.11). This can be achieved by a combination of water management and management of organic and mineral fertilizer inputs.

- Intermittent irrigation techniques, which are known to reduce CH_4 emissions, are already being practiced by farmers in Indonesia, not for the specific purpose of reducing CH_4 emissions, but as part of normal management practices. Setyanto et al. (1997) found that intermittent irrigation reduced CH_4 emissions by 83% as compared to continuous flooding. The yield, however, was also reduced by 24%. Other potential mitigation options available to Indonesian farmers are the use of the direct seeding method as opposed to the transplanting method, and use of slow-release nitrogen fertilizer. Direct seeding in irrigated rice fields has been found to reduce CH_4 emissions by 8–32% as compared with the baseline technique of transplanting rice (Makarim and Setyanto 1995). With the same amount of inputs, yields increased by 21%.

- In the Philippines, Corton et al. (2000) found that the use of ammonium sulfate as nitrogen fertilizer in place of urea resulted in a 25–36% reduction in CH_4 emissions. The use of phosphogypsum when applied in combination with urea fertilizer reduced CH_4 emissions by 72%. Mid-season drainage, which is associated with the influx of oxygen into the soil, reduced CH_4 emissions by 43%. The practice of direct seeding rice instead of transplanting reduced CH_4 emissions by 16–54%. The addition of composted rice straw increased CH_4 emissions by only 23–30%, as compared to the 162–250% increase in CH_4 emissions that occurred with the use of fresh rice straw.

- Wassmann et al. (2000) found that CH_4 emission rates in rice fields vary over a very wide range from 5 to 634 kg CH_4/ha depending on the season and management practices. Field drying at mid-tillering can reduce CH_4 emissions by 15–80% compared to continuous flooding, without a significant effect on grain yield.

- Research institutions in Thailand have evaluated CH_4 emissions from deepwater rice fields. Chareonsilp et al. (2000) found that CH_4 emissions were highest with raw straw incorporation, followed by straw compost incorporation, then zero-tillage with straw mulching, and last with straw ash incorporation. Other mitigation options have been introduced slowly into practice, while others are still to be tested before farmers can be convinced that the benefits outweigh the costs.

- A study in the Dien Ban district of Viet Nam between 2002 and 2004 developed a model for reducing CH_4 emissions from paddy rice cultivation through an innovative water management regime. It found that a reduction in CH_4 emission of 40kg/ha per year could be obtained with an increase in rice yield of 0.3 ton/ha.

The challenge in using rice management as a mitigation measure is to ensure that the gains in reducing CH_4 emissions are not offset by the increase in N_2O emissions due to the application of nitrogen fertilizer. Residue management can also be a challenge to farmers, since the burning of rice straw, which is often seen as a preferred practice due to the ease of implementation, causes emissions of non-CO_2 gases. Composting rice straw, instead of burning, would be a better management strategy, but this would entail additional costs to farmers. Water management may also be a challenge since this will require efficient irrigation and drainage systems. However, implementing this measure could promote greater rice productivity (and thus contribute to food security) and could enhance water quality through efficient use of water resources and mineral inputs.

Table 7.11. Potential Options for the Reduction of CH_4 Emissions in Rice Fields

Management Practice	Continuous Flooding, Organic Amendment	Mid-season Drainage, Organic Amendment	Continuous Flooding, No Organic Amendment
Water regime	Mid-season drainage (7–44%)		Mid-season drainage (15–80%)
	Alternate flooding/drying (59–61%)	Alternate flooding/drying (21–46%)	Alternate flooding/drying (22%)
		Early/dual drainage (7–46%)	
Organic amendments	Compost (58–63%)	Biogas Residues (10–16%)	
Mineral amendments	Phosphogypsum (27–37%)		Phosphogypsum (9–73%)
			Ammonium sulphate (10–67%)
			Table urea (10–39%)
Straw management		Fallow incorporation (11%)	
		Mulching (11%)	
Crop establishment	Direct wet seeding (16–22%)		

Note: Values in parentheses are reduction effects for each mitigation practice or modified crop management.
Source: Wassmann et al. (2000).

Other potential mitigation options could boost agricultural production, help reduce poverty, while at the same time help stabilize GHGs.

Agroforestry, Set-Aside[1], and Land Use Change

These mitigation measures have the potential to sequester carbon by 0.70–3.04 tCO_2/ha per year, reduce CH_4 emission by 0.02 tCO_2-eq/ha per year, and to reduce N_2O emissions by 0.02–2.30 tCO_2-eq/ha per year. Agroforestry can be achieved by growing food crops or producing livestock on land that also grows trees for timber, firewood, or other tree products. Set-aside and Agroforestry options include planting trees as shelterbelts, riparian zones, and buffer strips. Soil carbon is enhanced by planting trees and other woody species on cropland and grassland. These mitigation measures could entail high investment, but it promotes conservation of biodiversity and wildlife habitat, and improves the water holding capacity of the soil. Woody biomass from trees (fuelwood) can be used as bioenergy to replace fossil fuels that would have otherwise been used to generate power. Boer et al. (1999) found that in Indonesia, planting of fruit trees could sequester carbon in the range of 53–254 tC/ha and provide farmers with a high-value crop.

Grassland Management

Grassland management has the potential to sequester carbon by 0.11– 1.50 tCO_2/ha per year. This can be achieved by controlling grazing intensity through regulation of the animal stocking rate, by enhancing rotational grazing, and by limiting grazing time by season over the year. Increasing pasture productivity through increased above-ground biomass density could also increase carbon storage in grasslands. Nutrient management could be applied to reduce N_2O emissions from nutrient application while at the same time maintaining the productivity of grasslands. Fire management can also reduce emissions of

[1] Land left fallow.

non-CO_2 gases while increasing tree and shrub cover that can provide a CO_2 sink in soil and in biomass (Scholes and van der Merwe 1996).

The challenge with this option is putting in place proper regulations on grazing intensity to avoid overgrazing of grassland that could result in even more GHG emissions. With appropriate grazing management, soil quality will be enhanced by the increase in soil carbon, and desertification will be prevented. Co-benefits would include the reduction of soil erosion and degradation, which would help in rural poverty reduction. There will also be promotion of biodiversity and wildlife habitat, as well as the enhancement of aesthetic and amenity values of lands.

Peatland Management and Restoration of Organic Soils

These mitigation practices have the potential to sequester carbon by 7.33–139.33 tCO_2/ha per year and reduce N_2O emission by 0.05–0.28 tCO_2-eq/ha per year. The sequestration of carbon can be achieved by avoiding the drainage of organic or peaty soils that are known to contain high densities of carbon, or by re-establishing a high water table in the area (Freibauer et al. 2004). Furthermore, emission of GHGs from drained organic soils can be reduced by avoiding the planting of row crops and tubers, avoiding deep ploughing, and maintaining a shallower water table (IPCC 2007). Restoring peatland areas or organic soils can reduce the runoff from agricultural fields and settlements, which causes eutrophication, algal blooms, and hypoxic dead zones in lakes, estuaries, bays, and seas. It can also reduce flood damage; stabilize shorelines and river deltas; retard saltwater seepage; recharge aquifers; and improve wildlife, waterfowl, and fish habitat. Restoration of organic soils can also improve soil quality and aesthetic and amenity values, promote biodiversity and wildlife habitats, and support energy conservation.

Restoration of Degraded Lands

Restoration of degraded lands has the potential to sequester carbon by 3.45 tCO_2/ha per year. This can be achieved using practices that reclaim productivity, such as revegetation (that is, planting grasses); improving fertility through nutrient management; use of organic substrates such as manures, biosolids, and composts; tillage management; and retaining crop residues and water management (Bruce et al. 1999, Lal 2001, Lal 2004b, Olsson and Ardö 2002, Paustian et al. 2004). The challenge with this option is to ensure that the benefit of carbon sequestration is not offset by the additional N_2O emissions from the use of nitrogen inputs in the soil. This mitigation measure, if implemented, would increase soil productivity (thus improving food security); improve soil and water quality and aesthetic and amenity value; and support biodiversity, wildlife habitats, and the conservation of other biomes.

Bioenergy Use

This mitigation measure has the potential to sequester carbon by 0.70 tCO_2/ha per year, and reduce N_2O emission by 0.02 tCO_2-eq/ha per year. This can be achieved by using agricultural crops and residues that can be burned directly to produce energy or which can be processed to generate liquid fuels such as ethanol or diesel. Such fuels, when burned, release biogenic CO_2

(that is, CO_2 of recent atmospheric origin taken by plants via photosynthetic carbon uptake), which displaces CO_2 that otherwise would have come from fossil carbon. The challenge with this option is the competition between land use for dedicated energy crops against food crops. On the other hand, implementing this option will promote energy conservation.

- Bioelectricity is already being tested in Indonesia. According to Boer et al. (1999), bioelectricity—using biomass as a source fuel for generating electricity—has the potential to mitigate CO_2 emissions by 183–678 tCO_2/ha.

- In Thailand, with its strong agriculture sector, particularly in the production of cassava and sugarcane, early adoption of gasohol as a substitute for Benzene 95 has proved to be a good test case for the use of bioenergy.

Livestock Management and Manure Management

Livestock management through improved feeding practices can reduce CH_4 emissions from enteric fermentation by 1–22% for dairy cattle; 1–14% for beef cattle; 4–10% for dairy buffalo, and 2–5% for non-dairy buffalo. This can be achieved by providing animals with an enriched diet that would lower the enteric CH_4 emissions per output or input unit. Farmers can implement this measure by managing their grain supplementation, using higher quality forages, using forage from plants containing some natural methanogenic depressors, and using mineral supplements to overcome any possible nutrient deficiencies (DEFRA 2007, de Klein and Eckard 2008, and IPCC 2007). This measure, when implemented, will reduce pressure on natural resources and increase the profitability of livestock production systems.

Manure management can also be used to mitigate GHG from livestock. The measure can reduce emissions of CH_4 emitted through capture and combustion by up to 90%, reduce CH_4 through composting by 10–35%, and reduce N_2O emissions through improved soil application by 2–50%. Manure management can be achieved by enhancing CH_4 production in closed environments (such as biodigesters, covered manure piles, and lagoons) and then collecting and using it as biogas, applying aerobic treatments of manure such as composting, aerobic animal waste treatment systems, or applying manure to soil under aerobic conditions (Hao et al. 2008). The challenge with this option is the lack of financial incentives to support the investment needed by farmers for the broad implementation of this mitigation practice.

- Under its National Action Plan on Climate Change, the Government of the Philippines has proposed the use of tubular polyethylene biodigesters and urea-molasses mineral blocks as nutrient supplements in animal production.

- Manure management and improved feed are commonly practiced in Thailand. Waste-to-energy has been developed on a commercial scale, especially in providing energy for pig farms.

D. Conclusions

With an estimated 12% of total world GHG emissions in 2000 coming from Southeast Asia, mitigation has been high on the agenda of many countries in the region, particularly with regard to its key emission sources—land use change and forestry, energy, and agriculture. The region's total GHG emissions have grown at a faster rate than the global average because of its higher GDP growth and, if not managed, this is likely to continue. Recognizing the limitation of adaptation practices, the region will need to contribute to the global reduction of GHG emissions by pursuing mitigation options.

A number of studies have shown that Southeast Asia has considerable potential to sequester carbon through avoided deforestation, protection of existing forests, afforestation and reforestation, and forest management. Similarly, there is considerable potential for increasing off-site carbon stocks and enhancing fuel substitution and the use of bioenergy. The region has large areas devoted to agriculture and pasture where mitigation of GHGs can be achieved in a sustainable manner and with co-benefits and synergies with adaptation efforts. The increasing population and the growing demand for energy pose both a challenge and opportunity to reduce GHG emissions.

There are a number of mitigation practices that can already be applied in Southeast Asia. However, options would differ widely between countries, and while some of them will be country-specific, others could have broader application. There is an opportunity for the countries of the region to learn from each other and adapt national policies accordingly. There may also be a need for certain countries to provide more information publicly as to current efforts and results, so as to better benchmark the progress being made.

Currently, most mitigation efforts in the region have focused on improving energy efficiency, developing renewable sources of energy, promoting urban mass transit systems, rehabilitating forests, and restoring degraded land. There are several practices already implemented in crop and livestock management, which are known to reduce GHG emissions, although, originally, their introduction was not intended for mitigation purposes. Those that are already tested and validated need to be promoted throughout the region for broad implementation.

The challenges are many for mitigation measures to be effective, but the need is immediate. Meeting the challenge will require support for research and development, provision of reliable information and high-quality data, technology transfer, capacity building, as well as additional financial resources. In this regard, international and regional cooperation as well as the efforts of individual governments—from national to local levels—will play an important role in providing policy and economic incentives that will support the promotion and sharing of innovative and effective mitigation technologies in Southeast Asia.

References

ADB. 1998. Asia Least-cost Greenhouse Gas Abatement Strategy (ALGAS) Report. Asian Development Bank, Manila.

Alvarez, R. 2005. "A review of nitrogen fertilizer and conservative tillage effects on soil organic storage." *Soil Use and Management* 21: 38-52.

Boer, R., __ Khaimuddin, M.A. Ratag and B. Bey. 1999. Impact of Doubling CO_2 on Forest Productivity. Technical Report for the Initial National Communication. Ministry of Environment, Republic of Indonesia.

Bruce, J. P., M. Frome, E. Haites, H. Janzen, R. Lal, and K. Paustian. 1999. "Carbon Sequestration in Soils." *Journal of Soil and Water Conservation* 54:382–89.

Building and Construction Authority (Singapore). 2009. BCA Green Mark Scheme. Available: www.bca.gov.sg/GreenMark/green_mark_buildings.html. Accessed: 6 February.

CAIT Database. 2008. Climate Analysis Indicators Tool. World Resources Institute, Washington, D.C., USA. Available:http//cait.wri.org/

Chareonsilp, N. C., P. Buddhaboon, P. Promnart, R. Wassmann, and R. S. Lantin. 2000. "Methane Emission from Deepwater Rice Fields in Thailand." *Nutrient Cycling in Agroecosystems* 58:121–30.

Cole, C. V., J. Duxbury, J. Freney, O. Heinemeyer, K. Minami, A. Mosier, K. Paustian, N. Rosenberg, N. Sampson, D. Sauerbeck, and Q. Zhao. 1997. "Global Estimates of Potential Mitigation of Greenhouse Gas Emissions by Agriculture." *Nutrient Cycling in Agroecosystems* 49:221–28.

Corton, T. M., J. B. Bajita, F. S. Grospe, R. R. Pamplona, C. A. Asis, Jr., R. Wassmann, R. S. Lantin, and L. V. Buendia. 2000. "Methane Emission from Irrigated and Intensively Managed Rice Fields in Central Luzon (Philippines)." *Nutrient Cycling in Agroecosystems* 58:37–53.

Dalal, R. C., W. Wang, G. P. Robertson, and W. J. Parton. 2003. "Nitrous Oxide Emission from Australian Agricultural Lands and Mitigation Options: A Review." *Australian Journal of Soil Research* 41:165–95.

de Klein, C. A. M., and R. J. Eckard. 2008. "Targeted Technologies for Nitrous Oxide Abatement from Animal Agriculture." *Australian Journal of Experimental Agriculture* 48:14–20.

DEFRA. 2007. A Review of Research to Identify Best Practice for Reducing Greenhouse Gases from Agriculture and Land Management. Defra Project AC0206. London, United Kingdom.

Follett, R.F. 2001. "Organic Carbon Pools in Grazing Land Soils." In R. F. Follett, J. M. Kimble, and R. Lal, eds., *The Potential Of U.S. Grazing Lands To Sequester Carbon And Mitigate The Greenhouse Effect*. Lewis Publishers, Boca Raton, Florida.

Freibauer, A., M. Rounsevell, P. Smith, and A. Verhagen. 2004. "Carbon Sequestration in the Agricultural Soils of Europe." *Geoderma* 122:1–23.

Gregorich, E. G., P. Rochette, A. J. van den Bygaart, and D. A. Angers. 2005. „Greenhouse Gas Contributions of Agricultural Soils and Potential Mitigation Practices in Eastern Canada." *Soil and Tillage Research* 83:53–72.

Grieg-Gran, M. 2009. "The costs of avoided deforestation as a climate change mitigation option." In C. Palmer and S. Engel, eds., *Avoided Deforestation: Prospects for Mitigating Climate Change*. Oxford: Routledge.

Hao, X, T. A. McAllister, and K. Stanford K. 2008. Optimizing Feed and Manure Management to Reduce Methane and Nitrous Oxide Emissions from Livestock Manure Storage and Composting. Taller LEARN, Montevideo, 15-17 July.

IPCC. 2007. *Climate Change 2007: Mitigation of Climate Change*. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge, United Kingdom and New York, USA.

Lal, R. 2001. "Potential of Desertification Control to Sequester Carbon and Mitigate the Greenhouse Effect." *Climate Change* 15:35−72.

Lal, R. 2003. "Global Potential of Soil Carbon Sequestration to Mitigate the Greenhouse Effect." *Critical Reviews in Plant Sciences* 22:151−84.

Lal, R. 2004a. "Soil Carbon Sequestration Impacts on Global Climate Change and Food Security." *Science* 304:1623−27.

Lal, R. 2004b. "Soil Carbon Sequestration to Mitigate Climate Change." *Geoderma* 123:1−22.

Lasco, R.D., Pulhin, F.B. and Roy, S.S.N. July 2004. "Ecosystems in the Philippines Using GIS and Holdridge Life Zones", Environmental Forestry Programme. College of Forestry and Natural Resources, University of the Philippines Los Baños, Laguna, Philippines

Makarim A. K., and P. Setyanto. 1995. Methane Emission from Rice Field at Jakenan, Indonesia. Presentation for the Annual IRI-EFA-UNDP Planning Meeting of Methane Emission from Field. IRI-EFA-UNDP, Bangkok.

Makundi, W. R., and J. A. Sathaye. 2004. Mitigation Potential and Cost in Tropical Forestry —Relative Role for Agroforestry (January 1, 2004). Lawrence Berkeley National Laboratory. Paper LBNL-50984_Preprint.

Martono, R. W. 1998. Kajian keekonomian pembangkit listrik gasifikasi Bioner-1. In Konperensi Energi, Sumberdaya Alam dan Lingkungan. BPPT, Jakarta.

McKinsey and Company. 2007. "A Cost Curve for Greenhouse Gas Reduction." *The McKinsey Quarterly* 1:35–44.

Ministry of Energy (2008). *Alternative Energy*. Bangkok: Department of Alternative Energy Development and Efficiency. Retrieved on 2 January 2008 at http://www.dede.go.th

MONRE 2004. Viet Nam National Strategy Study on Clean Development Mechanism.

Monteny, G. J., A. Bannink, and D. Chadwick. 2006. "Greenhouse Gas Abatement Strategies for Animal Husbandry." *Agriculture, Ecosystems and Environment* 112:163−70.

Nabuurs, G. J., O. Masera, K. Andrasko, P. Benitez-Ponce, R. Boer, M. Dutschke, E. Elsiddig, J. Ford-Robertson, P. Frumhoff, T. Karjalainen, O. Krankina, W. A. Kurz, M. Matsumoto, W. Oyhantcabal, N. H. Ravindranath, M. J. Sanz Sanchez, and X. Zhang, 2007. "Forestry." In B. Metz, O. R. Davidson, P. R. Bosch, R. Dave, L.A. Meyer, eds., *Climate Change 2007: Mitigation*. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change Cambridge University Press, Cambridge, United Kingdom and New York, USA.

Ogle, S. M., F. J. Breidt, and K. Paustian. 2005. “Agricultural Management Impacts on Soil Organic Carbon Storage under Moist and Dry Climatic Conditions of Temperate and Tropical Regions.” *Biogeochemistry* 72:87–121.

Olsson, L., and J. Ardö. 2002. “Soil Carbon Sequestration in Degraded Semiarid Agro-ecosystems—Perils and Potentials.” *Ambio* 31:471–7.

Paustian, K., B. A. Babcock, J. Hatfield, R. Lal, B. A. McCarl, S. McLaughlin, A. Mosier, C. Rice, G. P. Robertson, N. J. Rosenberg, C. Rosenzweig, W. H. Schlesinger, and D. Zilberman. 2004. Agricultural Mitigation of Greenhouse Gases: Science and Policy Options. CAST (Council on Agricultural Science and Technology) Report, R141 2004, ISBN 1-887383-26-3.

Ridlo, R., and Sucahyo dan Shaffriadi. 1998. ioner-1, Gasifikasi gambut dan biomasa untuk listrik dan pompanisasi air. In Konperensi Energi, Sumberdaya Alam dan Lingkungan. BPPT, Jakarta.

Robertson, G.P. 2004: “Abatement of Nitrous Oxide, Methane and Other Non-CO_2 Greenhouse Gases: The Need for a Systems Approach.” In C. B. Field and M. R. Raupach, eds. *The Global Carbon Cycle: Integrating Humans, Climate, and the Natural World.* SCOPE 62, Island Press, Washington D.C.

Rosalina, U. D. Murdiyarso, R. Boer, K. L. Ginoga, L. Aukland, G. Kohn, B. Shield, S. Rahayu, B. D. Dasanto, Hendri, M. Ridwan., S. Ikhwan, P. Sinaga, Perdinan, and N. Satriani. 2003. CDM Eligible Lands, Portfolios and Potential CDM LULUCF Projects in Indonesia. In SME. National Strategy Study on CDM for Forest Component. Ministry of Environment and the World Bank, Jakarta.

Schlesinger, W. H. 1999. “Carbon Sequestration in Soils.” *Science* 284:2095.

Scholes, R. J. and M. R. van der Merwe. 1996. “Sequestration of Carbon in Savannas and Woodlands.” *The Environmental Professional* 18:96–103.

Setyanto P, __ Mulyadi, and Z. Zaini. 1997. “Emisi gas N_2O dari beberapa sumber pupuk nitrogen di lahan sawah tadah hujan.” *Journal Penelitian Pertanian Tanaman Pangan* 16: 14–8.

Smith, P. 2004a. “Carbon Sequestration in Croplands: The Potential in Europe and the Global Context.” *European Journal of Agronomy* 20:229–36.

Smith, P. 2004b. “Engineered Biological Sinks on Land. In C. B. Field and M. R. Raupach eds. *The Global Carbon Cycle: Integrating Humans, Climate, and the Natural World*. SCOPE 62, Island Press, Washington D.C.

Smith, P., D. Martino, Z. Cai, D. Gwary, H. H. Janzen, P. Kumar, B. McCarl, S. Ogle, F. O’Mara, C. Rice, R. J. Scholes, and O. Sirotenko. 2007. “Mitigation.” In B. Metz, O. R. Davidson, P. R. Bosch, R. Dave, and L. A. Meyer, eds., *Climate Change 2007.* Contribution of Working Group III to the Fourth Assessment Report of the Integrated Panel on Climate Change Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

Sohngen, B. and R. Sedjo. 2006. “Carbon Sequestration Costs in Global Forests.” *Energy Journal* Special Issue:109–26.

Stern, N. 2007. *The Economics of Climate Change: The Stern Review.* Cambridge: Cambridge University Press.

UNFCCC. 2009. REDD Web Platform. Available: //unfccc.int/methods_science/redd/

United States Environmental Protection Agency. 2006. Global Mitigation of Non-CO_2 Greenhouse Gases. United States Environmental Protection Agency, EPA 430-R-06-005, Washington, D.C. Available: www.epa.gov/nonco2/econ-inv/downloads/GlobalMitigationFullReport.pdf > accessed 26 March 2007.

Villamayor, G., and R. Lasco. 2006. The Ikalahan Ancestral Domain, the Philippines. In *Community Forest Management as a Carbon Mitigation Option: Case Studies*. Center for International Forestry Research, The World Forestry Centre, University of the Philippines Los Baños, Philippines.

Wassmann, R., R. S. Lantin, H. U. Neue, L. V. Buendia, T. M. Corton, and Y. Lu. 2000. “Characterization of Methane Emissions from Rice Fields in Asia. III. Mitigation Options and Future Research Needs.” *Nutrient Cycling Agroecosystems* 58:23–36.

West, T. O., and W. M. Post. 2002. “Soil Organic Carbon Sequestration Rates by Tillage and Crop Rotation: A Global Data Analysis.” *Soil Science Society of America Journal* 66:1930–46.