Land Use Change and
the Terrestrial Carbon Cycle in Asia

[APN2000-02]

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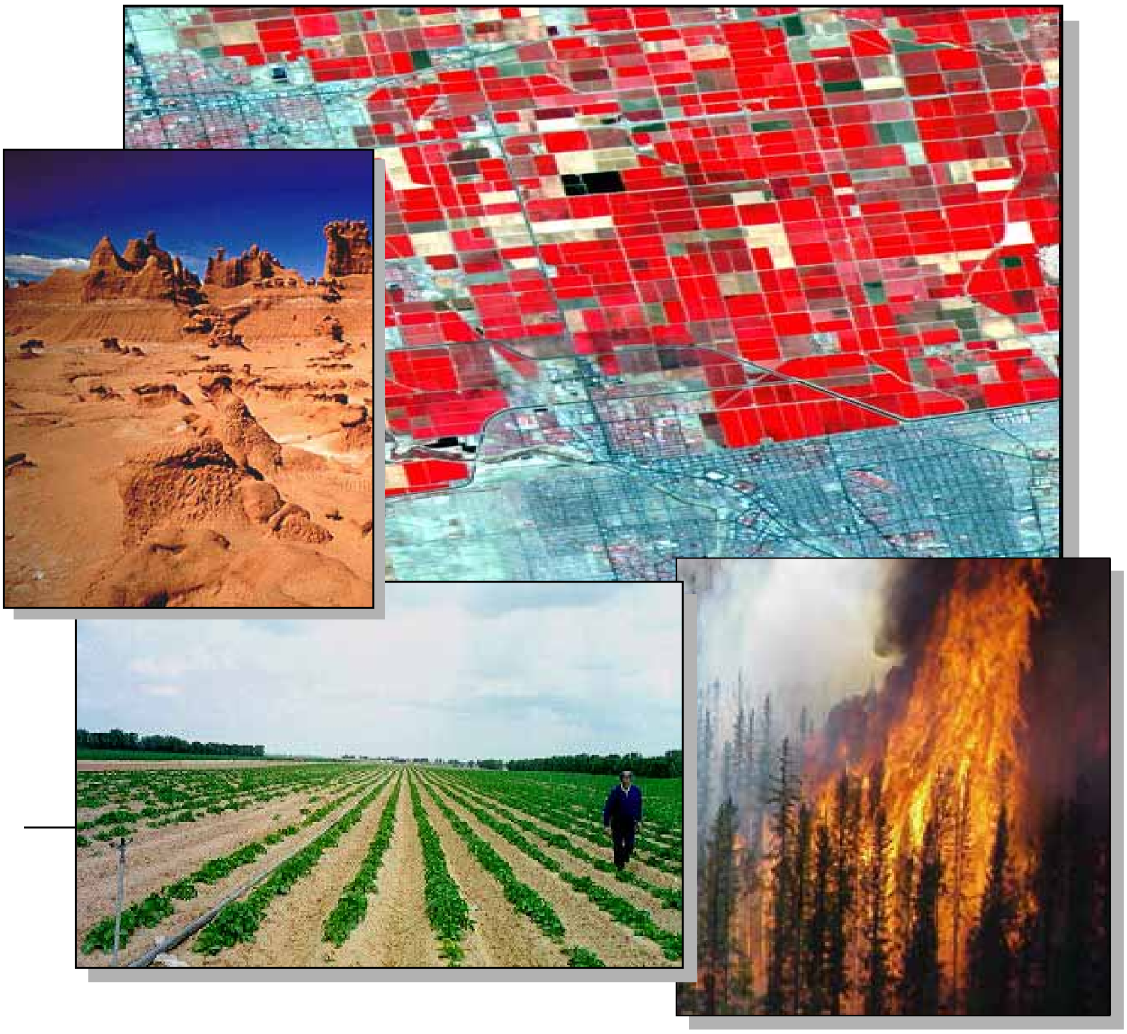

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Summary

"Land Use/Cover Change and the Terrestrial Carbon Cycle"

29th January – 1st February, 2001

Carbon dynamics along the IGBP-Northeast China Transect (NECT)

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Studies about greenhouse gas sources, sinks and their regional emission features have always been the hot-topic of global change study. The objective of the present research is to elucidate the daily variations of CO_2, N_2O and CH_4 fluxes from different land use types, and the seasonal and inter-annual variations of CO_2 fluxes from different land use types, and to investigate their relationships to environmental factors, and to evaluate the carbon balance of terrestrial ecosystems, in terms of the data from the field experiments and the long-term ecosystem research stations in the west NECT.

Material and Method

The field experiments were carried out around the Inner Mongolia Grassland Ecosystem Research Station (43°22'~44°08'N, 116°04'~117°05'E) of the Chinese Academy of Sciences, which is located in the west part of Northeast China Transect (NECT) of the International Geosphere-Biosphere Program (IGBP) and is one of the most sensitive regions to climate change. Measurement sites were selected along annual rainfall gradient variation from southeast to northwest (annual precipitation from southeast to northwest varies between 500 mm to 200 mm) with respect to representative grassland types and impact of human activities.

Daily greenhouse gas fluxes(CO_2, N_2O and CH_4) were measured with an enclosed chamber method from July 17-23,1998. Seasonal and inter-annual variations of CO_2 fluxes(soil respiration) were measured with the alkali absorption method. For fenced and grazing *Leymus chinensis* grassland, the experiments were done on 5^{th}, 15^{th} and 25^{th} from 31th May to September 25, 1998 and on 10^{th}, 20^{th} and 30^{th} from 30th May to October 15, 1999; and for fenced and grazing *Stipa grandis* grassland, the experiments were done on 5^{th}, 15^{th} and 25^{th} from 25th June to September 25, 1998. Each measurement will be repeated 9 times. The contents of the experiment measurement include soil respiration rate, aboveground biomass and belowground biomass which is divided into three levels: 0-10cm, 10-20cm and 20-30cm, litter, soil water and soil temperature in the depth of 0-10cm， 10-20cm and 20-30cm, air temperature.

Results and Discussions

Daily carbon dynamics

Daily carbon flux dynamics from *Leymus chinensis* grassland indicates that all of the measured grasslands emit CO_2 and N_2O while absorb CH_4.CO_2 and N_2O emissions have strong diurnal variation, while CH_4 absorption has weak diurnal variation. Higher emission appears during daytime and lower emission during nighttime for CO_2 and N_2O, while it is in reverse for CH_4. Maximum value appears around 12:00am, while the minimum around 3:00am for CO_2 and N_2O emissions and 1:00am for CH_4 absorption.

The fluxes of CO_2 and N_2O emissions and CH_4 uptake have a good linear correlation with air temperature. It suggests that temperature should be one of the most important controlling factors to daily dynamics of greenhouse gas fluxes from the grassland.

Seasonal carbon dynamics

Seasonal soil CO_2 flux dynamics from *Leymus chinensis* grassland shows that soil respiration has strong seasonal variation. Higher soil respiration appears during warmer seasons and lower soil emission during colder seasons. The maximum value of soil respiration appears around late-July.
Soil respiration also has a better correlation with air temperature and less relationship with soil water content. The combined effects of temperature (T) and soil water content(M) on soil respiration(Res) could be given as:

$$Ln(Res)=5.8596+0.0125M+0.0394T+0.0049MT \quad (R^2=0.7096, p<0.001)$$

Fluxes of carbon from different land use types

Mean daily fluxes of carbon from natural grassland types(*Leymus chinensis* grassland, *Stipa grandis* grassland, and dry steppe) along precipitation gradient indicates that all of the measured land use types emit CO_2 and N_2O while absorb CH_4.The fluxes of CO_2 and N_2O emissions and CH_4 uptake have a good linear correlation with precipitation.

Mean daily CO_2, CH_4 and N_2O fluxes from different land use types shows whether land use change may cause the increase of CO_2 and N_2O emission or not relies on the land use type. It suggests that the orderly human activities may be helpful to improve our life-supporting environment. All of land use changes cause the decrease of CH_4 uptake.

Seasonal soil respiration of fenced and grazing *Leymus chinensis* grasslands also shows that land use change may not cause a large increase of soil CO_2 emission.
The relationship between mean daily CO_2 flux from different land use types and environmental factors shows that soil organic matter (SOM) and total nitrogen in 0-20cm depth have significant effects on mean daily CO_2 flux from different land use types. Mean daily CO_2 flux from different land use types has a better relationship with the combined effect of SOM and total nitrogen, while mean daily CH_4 and N_2O fluxes from different land use types do not have a good relationship with SOM and total nitrogen. However, mean daily CO_2 fluxes have linear relationship with mean daily N_2O fluxes and hyperbolic relationship with mean daily CH_4 fluxes from different land use types.

Carbon balance evaluation of terrestrial ecosystems

The carbon budget of the *Stipa Grandis* steppe (fenced area: 400m×400m) in Xilin River Basin, Inner Mongolia was evaluated based on the observed data. The carbon flow for this fenced area is 45.1tC/a for plant photosynthesis, 18.0tC/a for plant respiration, 10.1tC/a for plant litter, and 14.1tC/a for soil and litter respiration. The carbon storage is 24.9tC in the atmosphere, 45.8tC for plant biomass, and 820.4tC for soil organic carbon. The carbon budget is 13.0tC/a for this ecosystems, and it indicates that *Stipa Grandis* steppe ecosystem is a carbon sink. However, the soil carbon budget is –4.0tC/a, thus the soil is a carbon resource.

Also, we estimated the carbon budget of *Larix* forest by CENTURY model. The net ecosystem productivity of *Larix* forest is 4.03tC.hm^{-2}.a^{-1}, soil respiration is about 1.91tC.hm^{-2}.a^{-1},. Thus, the *Larix* forest ecosystem is a carbon sink, and the carbon budget is 2.12tC.hm^{-2}.a^{-1}.

Changing annual CO_2 budget at the national scale of South Korea from 1990 to 1997

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Introduction

The annual economic growth-rate of South Korea is on average approximately 8.4% from 1981 through 1997. Primary energy was used at the rate of 45,717,000 TOE/yr in 1981 and 174,692,000 TOE/yr in 1997 (Korea Energy Economics Institute 1998), indicating that CO_2 emission of South Korea has increased rapidly.

Many people presume that forest is a major sink of CO_2 in Korea. Since approximately 65% of national land area is covered with forests and most of forests were destroyed during the Korean War in the early 1950s, those have been actively reforested since the 1960s. For example, forest woody biomass stock of South Korea is 60 million m^3 in 1964 and increased to 284 million m^3 in 1993. As planted trees are younger than 40 years in South Koran and still growing. forests may be removing a large amount of atmospheric CO_2.
Considering the increasing energy consumption and wood biomass, this study was aimed at estimating the major CO_2 fluxes at the national scale of South Korea and at addressing the contribution of landuse change and reforestation to the budget.

Methods

According to IPCC methodology, major sources of CO_2 were grouped into energy consumption, solvents/other product use, industrial processes, waste, agriculture, and landuse change/forest. Basically we focused on net emission of CO_2 into the air. Hence, we assumed that absorption and emission of CO_2 are balanced in agricultural areas, and considered the CO_2 net emissions from forests and soils.
The amount of CO_2 emitted by energy consumption was estimated by the equation as follows:
CO_2 emission by energy consumption
= Σ (annual consumption of i*th* fuel type * emission factor of i*th* fuel type
*combustion efficiency of i*th* fuel type * 44/12)

The amount of CO_2 emission by solvent/other product use was also estimated with IPCC methodology. The amount of solvent used was less than 1% of that of naphta and the fraction of carbon stored in asphalt is 100%. The following equation was employed for estimation of CO_2 emission from naphta.

CO_2 emission by naphta
= Domestic accumulation(Bbl) * (1-the fraction of carbon stored) * 158.988 (l/Bbl)
*Calorific value (kcal/l) * 10^{-7} (TOE/kcal)) * CO_2 emission factor (0.829) * 44/12
The following equation was used in estimation of CO2 emission from the use of limestone.
CO_2 emission from the use of limestone
= The amount of limestone * Degree of purity (85%)
(CO_2 molecular weight/$CaCO_3$ molecular weight)

Emission of CO_2 by waste combustion also was estimated with the IPCC methodology Althogh a large fraction of carbon (e.g., paper, food waste) is derived from biomass combustion, in general, it is are compenstated by plant regrowth and thus should not be considered net anthropogenic CO_2 emission once those are balanced, On the other hand, combustion of some materials, such as plastics and fossil fuel, releases net CO_2. into the atmosphere. When waste incineration is concerned, the desired approach is to separate carbon in the incinerated waste into biomass and fossil fuel based fractions.

•CO_2 emission from wastes (plastic materials)
= Combustion quantity * Caloric value * TOE conversion coefficient (10^{-7}TOE/kcal)
*CO_2 emission factor (0.829) * 44/12

Emission of CO_2 by landuse change/forest was based on changes in forest, other woody biomass stock and landuse (rice field, dry field, forest and so on), related to forest management, such as logging, fuelwood collection, etc.

Total C uptake increment
= annual biomass increment * C fraction of dry matter(0.5)
(considering a belowground biomass)
Forest and grassland conversion: from the burning and decay of biomass

Annual loss of biomass (esp. aboveground)
= area converted annually * Net change in biomass density * fraction left to decay * C fraction in aboveground biomass (biomass burning is forbidden in Korea by law)

Abandonment of managed lands is negliable due to high demant on land in Korea.
Emissions and removals from soil
= Soil C * (difference of land area during the 20 years)

Results

Estimted values of CO_2 in Korea are summarized in Table 1.

Table 1. National budget of atmospheric CO_2 (Gg CO_2 /yr) in Korea from 1990 to 1997.

year	Energy consumption	Solvent/other product use	Industrial processes	Waste combustion	Landuse change/forest	Net CO2 emission
90	233158.3	4598.2	18125.2	295.5	-25562.6	230614.6
91	254167.4	7048.1	22086.2	473.9	-17863.0	265912.6
92	275860.7	10359.7	24434.5	653.4	-27963.1	283345.2
93	302950.1	11315.2	28699.9	576.3	-19235.0	324306.5
94	328519.8	12584.7	30918.2	25.8	-20192.7	351855.8
95	357655.7	13401.9	32612.5	33.0	-22205.3	381497.9
96	393983.7	14746.6	32952.3	2061.4	-27962.7	415781.2
97	414058.2	19013.3	34513.9	1842.0	-30928.7	438498.8

Net CO_2 emission was 230,614.6 and 438498.8 Gg/yr in 1990 and 1997, respectively. Net CO_2 emission increased 2 times during the period of time. More than 90% of total CO_2 emission is derived from energy consumption in 1990 and 1997. The second largest part of CO_2 emission was released from industrial process, followed by the use of solvent and other products. Industrial and domestic wastes contributed less than 0.5% to total CO_2 budget. Effect of landuse change on CO_2 evolution was overwhelmed by accumulation of carbon into forest biomass. Forested area was 6.565 and 6.551 Mha in 1990 and 1996, respectively. Rice paddy and dry field were 1.270 and 0.886 Mha in 1990, and 1.267 and 0.837 Mha in and 1990 and1996, respectively. Woody biomass stock increased by 30% in forest, from 248,426,292 in 1990 to 323,780,332 m^3 1996. The forests absorbed 10% of the total amount of CO2 emitted in 1990 and 7% in 1997,and on average 5.5-10% of CO_2 emitted from 1990 through1997.

Discussion

Emission of CO_2 from industrial processes was overestimated, compated to that by IPCC guideline. Nevertheless net CO_2 emissions were similar in the two methods although the simplified method can requre less data. We found that net CO_2 emission was intimately related to GDP as Korean economics has relied on energy consumption and industrial activities, which are major sources of CO_2. Although forests contribueis to compensage for CO_2 release, energy-saving strageties will be more effective in controlling CO_2 emission in Korea, compared to any practice of forest management.

Topographic effect on soil respiration in a rugged montane forest of South Korea

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An integrative modeling system was developed to predict daily spatial patterns of meteorology, soil conditions, vegetation, and soil respiration in a topographically complex mixed-hardwood forest. The system is composed of several sub-models. The system needs input data of DEM and daily data of air temperature and precipitation from weather monitoring systems near the concerned area. As well, data from satellite remote sensing are required to run the seasonal LAI model. The spatial and temporal patterns of soil temperature and soil water content were successfully predicted. Predicted annual soil respiration showed two-fold spatial variation in the topographically complex forest. This indicates that topographic and microclimatic effects should be adjusted to use the plot-scale soil respiration as a surrogate of the landscape-scale soil respiration. Comparing distinct topographic effect on solar radiation and LAI, the effect diffused in soil respiration and soil temperature through complex interactions among the variables. The bottom-up modeling approach is necessary for the variable related with topography, such as solar radiation, to derive the coarse-scale prediction. Even in the variables weakly related with topography, such as soil respiration, the topoclimatic modeling is still advocated for the coarse -scale prediction. Although the modeling system has several empirical and technical limitations, the accuracy of the predictions can be enhanced further by improving the sub-models in future. The more detailed study on the additional scale-sensitivity by other factors besides topography is also expected in future. The modeling system is useful for intensive monitoring of topographically complex landscapes or to supply validation information for regional or global ecosystem models.

Effects of aspect and leaf litter on seasonal variation of soil respiration at a temperate hardwood forest

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Effect of leaf litter store on soil respiration, moisture, and temperature were compared between a south-facing and a north-facing slope in a temperature hardwood forest. For the whole year, leaf litter store was higher in the north-facing slope than the other. In spring and fall, soil respiration and temperature were higher at the south-facing slope than the other, In summer, soil respiration and moisture were higher in the north-facing slope than the other, but soil temperature was not comparable. Temperature effect of aspect on soil respiration became less in summer. To figure out a role of leaf litter in the seasonal pattern of soil respiration, a removal experiment of litter and organic layer was carried out in 2 x 2 factorial design at a north-facing slope, and soil temperature, respiration, and enzyme activities were monitored for a year. Soil temperature accounted for 84 % ($p<0.05$) of seasonal variation in soil respiration in control plots, but uncertainty increased as temperature increased. Complete removal of all floor litter resulted in less significant relation between soil respiration and temperature. Dehydrogenase and urease activities were highly correlated with seasonal patterns of soil respiration. Removal of the litter caused lower soil water content but increased soil temperature than control, indicating that leaf litter store buffers soil temperature during spring and fall and moisture during summer. However, it appeared that removal of leaf litter was compensated with alternative sources of substrate as far as soil microbial activities are concerned during a short period of time.

A Spatial Model of Daily Topographic Radiation (TopoRad) Based on Topography and Air Temperature

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Incoming solar radiation (insolation) drives many ecological and hydrological processes. In a landscape, topography determines spatial pattern of insolation. In this study, a new model named TopoRad was developed. TopoRad calculates and maps insolation based on daily maximum and minimum air temperature readings and a digital elevation model (DEM). Well-established, climatological relationships were used for total atmospheric transmittance and diffuse/direct partitioning in TopoRad. Two daily topographic modifiers were introduced to correct for effects of aspect, slope, and configuration of adjacent ridges and for effects of shadow during daytime on direct radiation. Diffuse radiation was modified using a sky view factor to account for only the unobstructed portion of the sky. In this study, isotropic diffuse radiation was assumed. TopoRad predicted distinctively different patterns between direct and diffuse radiation in a sample area. Direct radiation was predicted to contribute more to annual radiation than diffuse radiation. The predicted radiations were related nonlinearly with spatial resolutions. This indicates care should be taken when generalizing results across a gradient of spatial resolutions.

Estimating foliar biomass in a forested watershed based on remote sensing data

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The objective of this study was to describe spatial distribution of foliar biomass in a forested landscape of Korea, based on remotely sensed data from satellites. The area was classified into hardwood and coniferous patches by examining difference of two images of thematic mapper (TM) taken in early spring and mid-summer, and extracting reference points from the vegetation map. Leaf area index (LAI) was determined with LI-COR 2000 at the 40 points around the site in 1998 and 1999. The cell-based LAI of each forest patch was estimated by comparing the ground truths with normalized difference vegetation index (NDVI) or simple ratio (SR) calculated from the satellite imagery of TM. The Spatial distribution of LAI was determined at a watershed scale by statistical regression between the ground truths and NDVI or SR. The correlation coefficient of estimated and measured LAI was 0.6 for the hardwood patch. To estimate specific leaf area (SLA), leaves were collected and attached to a white paper. The material was scanned or taken a picture of with a digital camera. The area of leaf image was determined with a GIS-based procedure. After the leaves were oven-dried and weighed, specific leaf area (SLA) was calculated. Finally, foliar biomass was calculated by dividing LAI by SLA. Our methods indicate that the spatial distribution of foliar biomass at a specific time can be obtained economically. By calculating spatial autocorrelation index such as Moran's index and foliar biomass at the same altitude from the resultant grid, the spatial distribution of foliar biomass was prepared and interpreted easily.

Carbon Emissions and Sinks from and into Agricultural Systems

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Beside ruminant animal and its wastes, soil is an important agricultural factor in carbon cycling. The soil can be both a contribution to and a recipient of the impacts of climate change. In the past, land cultivation has generally resulted in considerable depletion of soil organic matter and the release into the atmosphere of such GHG.. The observation in the North-South Transect of Eastern China show that climate change will strongly impact all soil processes and GHG exchange between the soil and the atmosphere. Soil management can restore soil organic carbon in order to enhance soil structure and fertility and to help counter the atmospheric the greenhouse effect. The current National GHG Inventories in selected countries of Asia show that widely varying estimates of the soil's organic carbon content and of the potential for soil carbon sequestration point need to be enhanced.

Key words: agricultural carbon, GHG emissions and sinks, North-South Transect, National GHG inventories

Carbon emissions and sinks from and into agricultural systems mainly include CO_2 and CH_4 emission from cropland and grassland management, ruminant animal and its waste treatment, biomass burning and carbon sequestration caused by the lands management. It is now widely recognized that the soil constitutes the terrestrial environment's primary recycling and cleansing medium, for it is within the soil that the waste products of myriad plants and animals are decomposed and transmuted into nutrients that ensure the continual regeneration of life. Less widely appreciated is the soil's vital function in the larger-scale processes that govern the maintenance or modification of the earth's climate, hydrologic regime, and the cycling of elements.

Of particular interest and importance is the soil's role in the global carbon cycle affecting the composition of the atmosphere and climate change (see Fig.1).

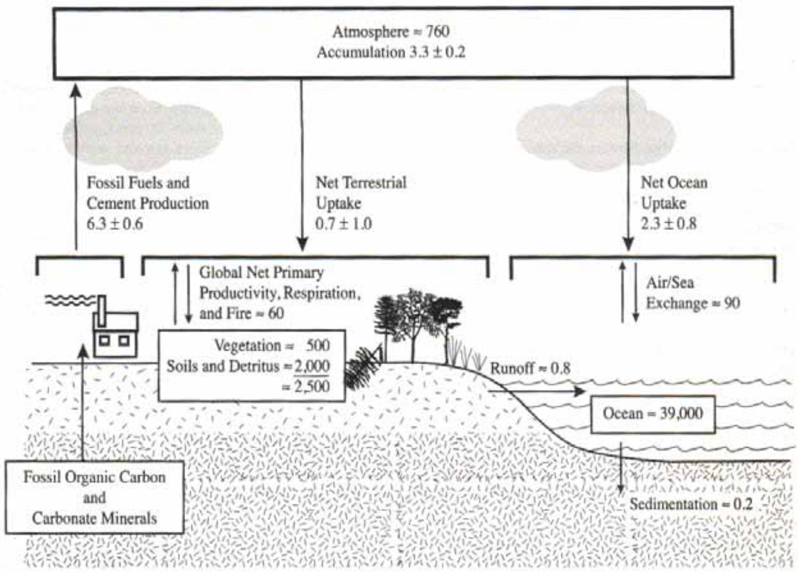
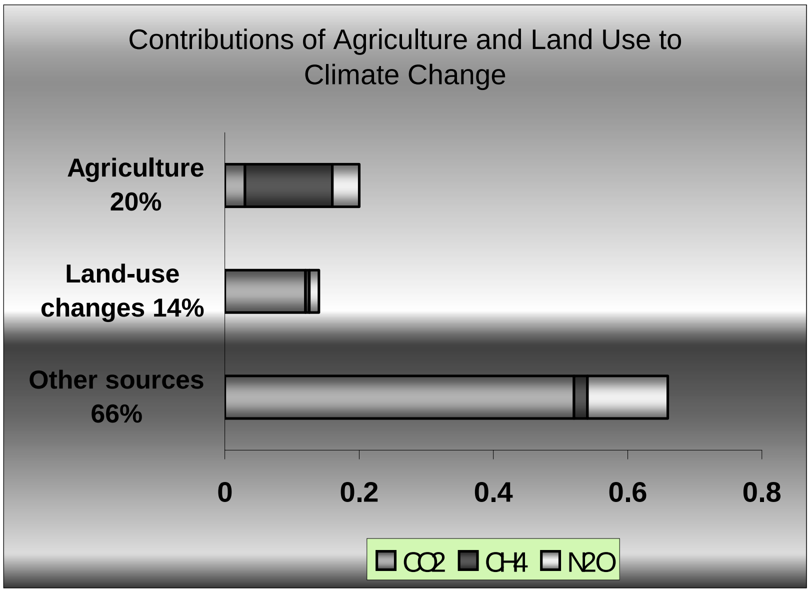


Figure 1-1: The global carbon cycle, showing the carbon stocks in reservoirs (in Gt C = 10^{15} g C) and carbon flows (in Gt C yr^{-1}) relevant to the anthropogenic perturbation as annual averages over the decade from 1989 to 1998 (Schimel *et al.*, 1996, Tables 2.1 and 2.2). Net ocean uptake of the anthropogenic perturbation equals the net air-sea input plus runoff minus sedimentation (discussed by Sarmiento and Sundquist, 1992).



In certain circumstances, the more labile fraction of soil carbon can be volatilized as either carbon dioxide or methane, depending on oxidation or reduction processes within the soil (methane is also released by ruminant animals). In other circumstances, however, the soil may absorb additional carbon from the atmosphere, thus helping to mitigate the greenhouse effect. Whether the soil serves as a source or sink of carbonaceous gases depends greatly on the manner and intensity of human management of the land. Nitrogen in the soil, which may cause the emission of nitrous oxide, another greenhouse gas, is similarly affect by human management. Altogether, agricultural sources are estimated to contribute about 20% of the total anthropogenic emissions of greenhouse gases (Fig.2)(IPCC,1996). Land use changes, often for agricultural development, accounts for an additional 14%. Conversion of land for agricultural purposes often involves such processes as land clearing, draining, sod breaking, cultivating, and establishing annual rather than perennial vegetation.

In order to understand the potential impacts of climate change on ecosystem patterns and reverse in China, an observation of GHG flow in the transect regarding to heat, North-South Transect of Eastern

China was carried out. The thermal gradient from south to north in eastern China shapes a special vegetation continuum belt in the world, which is incomparable in other continents. Along the transect scatter main agricultural ecosystems of the country, like grassland, maize, wheat-cotton, double-rice systems, which represent almost all main types of agricultural zonal ecosystems driven by summer south-east monsoon. From the observation a series of data on the rates of organic matter decomposition and gaseous carbon emission and absorption from and by the different agro-ecosystems have been got. The observation results show that the balance of C,N in the agricultural systems would be influenced by changed temperature, rain pattern and cultivation types. When land is first converted to agricultural use, the organic matter in the soil is gradually oxidized, much of the vegetative biomass originally present is converted to CO_2. Deforestation, biomass burning, drainage, plowing, cultivation, and overgrazing all promote the decomposition of organic matter and the release of carbon dioxide into the atmosphere. Soil degrading processes, such as erosion, crusting and compaction, acidification, and salinization, further exacerbate of soil carbon. As agricultural production continues over time, soil organic matter declines still further, resulting in more CO_2 releases until a steady state is reached or until the field is abandoned. Because the uptake of methane and more organic carbon in soils have been observed in the transect, we believe that the application of best-practice crop management, which may include conservation tillage, frequent use of cover crops in the rotation cycle, agro-forestry, appreciate use of fertilizers and organic amendments, site-specific management, soil water management that involves irrigation and drainage, and improved varieties with higher biomass production, can recover a substantial part of this loss over a period of several decades. In rice agriculture, careful water and fertilizer management can lead to increased carbon storage, but calculation of the net effect must consider simultaneous changes in CH_4 and N_2O emissions. In general, carbon-enhancing cropland management will increase the capacity of croplands to feed the world's growing population.

Based on their National Communications delivered to UNFCCC, Table 1 shows the inventory of GHG emissions from agricultural sector and absorption by land use changes and forestry in selected Asia counties:

Table 1. GHG emissions and removal from agriculture and by land use changes in selected Asia counties, 1994 (k tons)

Country	Proportion of GDP(agro/total)	CH_4	N_2O	CO	CO_2 By LUCF
Indonisia	17.4%	3244	53	331	156
Japan	(13.7%)	849	9	172	-83
Jordan	4.5%	27	0.01		-1455
Kazakstan	14.9%	827			-6627
Malaysia	11.5%	329	0.054		-67
Philippines	21.7%	990	40	435	-126
R. of Korea	6.4%	595	1		-26235
Uzbekistan	34.5%	377	481		

The above emission sources mainly include enteric fermentation and rice cultivation (CH_4), manure management and biomass burning of agricultural residues and grassland (CH_4, N_2O), nitrogen fertilizer (N_2O); the CO_2 removal sinks mainly include land use changes and agricultural soil. The larger difference and changes in national inventories of all countries delivered to UNFCCC have resulted that widely varying estimates of the soil's organic carbon content and of the potential for soil carbon sequestration point need to be enhanced.

The literature now contains many estimates of potential C gains from the adoption of improved practices in various regions of the world. Some of these estimates are summarized in IPCC special report on Land Use, Land Use Changes and Forestry. Using its factors, China's potential and relations with other GHG's emissions are listed in table 2, clearly illustrate the approximate size and range of potential C gains. Because of the larger uncertainties, the values were derived using a wide range of approaches and initial assumptions.

Table 2. Carbon Sequester Potential of Agricultural Activities in China

Activity	Area(Mha)	Feasibility (% of area)	Rate (t C/ha/y)	Duration (year)	C gain Potential (Mt C/y)	Other GHG's	Confidence
Cropland management							
Boreal	20.60	30	0.3-0.6	40	*1.81-3.61*	$+N_2O$	M
Temp. Dry	24.39	30	0.1-0.3	30	*0.73-2.19*	$+N_2O$	H
Temp. Wet	25.89	30	0.2-0.6	25	*1.55-4.66*	$+N_2O$	H
Tropical wet	15.20	30	0.2-0.8	15	*0.91-3.65*	$+N_2O$	M
Sub-total	**86.08**				**5.00-14.11 (9.26)**		
Rice paddy management	9.44	30	0.2-0.8 (0.5)	25	0.57-2.27 (1.42)	$+N_2O$ $++CH_4$	L
All Agroforestry							
Shelter-belt F	10.00	30	0.1-2.5	50	0.3-7.5	$+N_2O$	M
Economic F.	11.28	30	0.1-1.3	8	0.34-8.46	$+N_2O$	M
Sub-total	**21.28**				**0.64-15.96 (8.3)**		
Grassland management							
Tempt. Wet	35.56	15	0.4-2.0	50	0-30	$-N_2O-CH_4$	M
Tempt. Dry	257.78	15	0-0.3	50	0-11.6	$-N_2O-CH_4$	M
Tropical Wet	66.67	15	0.3-3.0	40	3-30	$-N_2O-CH_4$	M
Sub-Total	**360.01**				**5.13-52.27 (27.2)**		
Total					**46.22**		

Global Analysis of LAI Sensitivity to Precipitation and Surface Air Temperature Variations

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Introduction

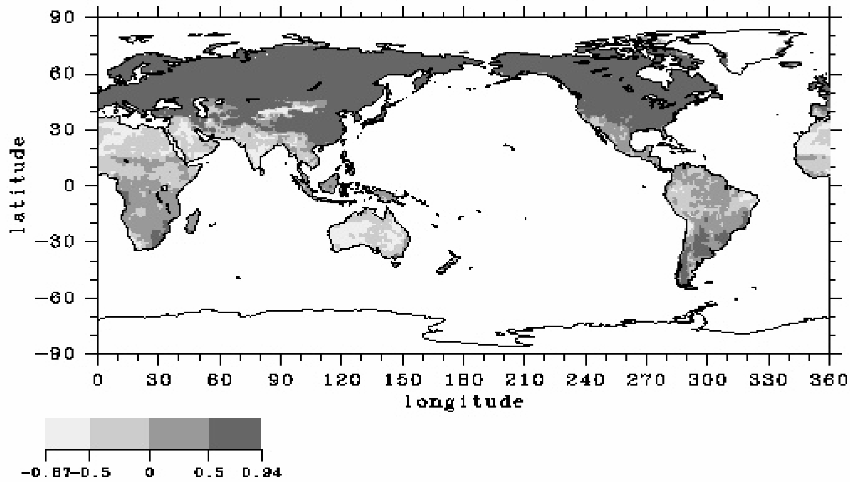
Leaf Area Index (LAI) is an important biogeochemical variable that impacts the land-surface process by influencing the surface roughness, albedo, transpiration rate, rainfall interception and carbon exchange, and also can be acted as significant proxy of terrestrial ecosystem biomass. However, recent studies show the sensitivity of LAI to climatic change is difficult to be determined. In that case, to study the relationship between LAI and climatic indexes (e.g., rainfall, temperature) is essential. In this study, statistical correlation analyses are adopted to examine the relationship of LAI to both precipitation and surface air temperature during 1982-1990 in global region.

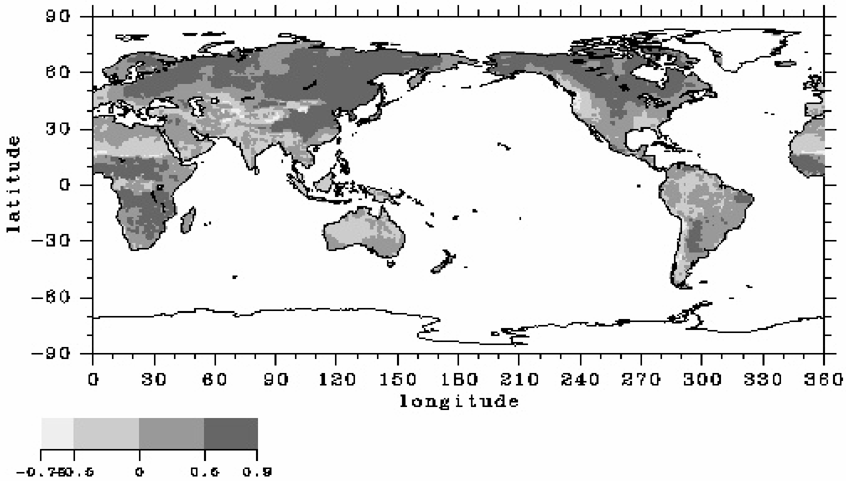
Data and methods

We used the newly released LAI dataset with a monthly, global scale, 1^{o} latitude by 1^{o} longitude grid. The temperature and precipitation datasets were produced by ECMWF and CMAP respectively, and were interpolated in space and time to monthly 1^{o} latitude by 1^{o} longitude resolution. Correlations of the 9-year monthly time series of LAI with those of temperature and precipitation were calculated separately using statistical linear correlations. Both monthly total (seasonal cycle included) and monthly anomaly (seasonal cycle removed) correlations were calculated. The monthly anomalies are computed as departures from the 1982-1990 base period monthly means.

Results

Figure 1 shows the LAI versus temperature total correlation. The high correlation between the annual cycles of temperature and LAI in the Northern Hemisphere middle and high latitudes are seen as is expected since plant growth is significantly reduced in the winter months, due to decreased temperatures and shorter daytimes. Lower LAI-temperature correlation exists in sub-tropics and tropics, partly because temperature is higher than the minimum temperature for vegetative growth for a greater portion of the year. Negative correlations between LAI and temperature occur in far eastern Brazil, the Sahara region, southwestern South Africa, India, and parts of southeastern Asia, and Australia. A partial reason is high temperature in the summer may act to inhibit the plant growth over these regions.





The LAI-temperature anomaly correlations (not shown) are lower than the total correlations. The largest anomaly correlations, approximately 0.4 to 0.6, tend to occur in the tropics. The other relatively large values occur in Tibetan plateau, Siberia, other extreme northern regions, and northwestern U.S., where vegetation growth is limited to some extent by cold temperature.

Figure 2 presents the LAI-precipitation total correlation. The largest extratropical LAI- precipitation correlations (>0.78) occur in eastern Asia, the interior of northern North America, and Sahel region, where the annual cycles of LAI and precipitation peak in the summer. The strongest negative correlations occur over some regions of middle and high latitudes, e.g., northwestern U.S., middle Asia, and Chile, where the precipitation maximum tends to occur in the winter, while the LAI maximum occurs in the summer. The most significant feature of LAI-precipitation anomaly correlations is the negative anomaly correlations in Siberia, northern Asia, and northwestern North America. The cause is somewhat uncertain; one is that a decrease in incident solar radiation owing to the effect of clouds accompanying rainfall may inhibit the growth of plant.

The Joint Carbon Cycle Research Project

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Three Global Environmental Change (GEC) Programmes have for the first time ever, agreed to collaborate on a Joint Project towards an understanding of the global carbon cycle. The International Geosphere Biosphere Programme (IGBP), the International Human Dimensions Programme (IHDP) and the World Climate Research Programme (WCRP) have determined that to integrate the biological, ecological, social, and physical climate communities would enable an integrated understanding of the Earth's global carbon system. While the three GEC's are not funding agencies, they provide the coordination and leadership to guide the science of their respective communities. This joint science project will provide a platform to address the needs of the assessment, or the International Panel on Climate Change (IPCC), the Integrated Global Observing Strategy (IGOS), and the scientific research communities. The aim is to address the necessary science needs while keeping in mind the policy relevance for carbon management strategies (e.g. Kyoto Protocol). This will be the first time that the pieces of the globally fractured science of carbon cycle research will be coordinated across disciplines and across international boundaries.

The first goal of the Joint Carbon Project is to develop a Framework document that outlines the crucial questions needed to understand the global carbon cycle. The necessary tools to address these questions include integrating process studies, manipulative experiments, observations, process or diagnostic models as well as future, or prognostic modelling technologies and methodologies. Implementation strategies include integration activities across disciplines (e.g. social/natural sciences; marine/terrestrial/atmospheric sciences) as well as focused activities within a discipline. In addition, the political implications with regard to short term treaties and long term carbon management strategies must be addressed.

The carbon system can be thought of as an evolution from 'normal' mode of operation during glacial/interglacial periods up until significant human activities, or around the early -to-mid 1900's. At this time, fossil fuel burning and land use practices were affecting the carbon cycle, however, human perceptions of a problem did not exist. It is not until the very recent contemporary period that a perception to human welfare was recognized and changes in human management of the carbon cycle were initiated (e.g. through Kyoto protocols and altered land use practices). Currently, there is a widespread activity among the science and policy communities to manage terrestrial carbon fluxes through sequestration strategies and other human-mitigated policies.

At this time, it is necessary to recognize the need for an integrated, international carbon cycle research programme. To glue the carbon puzzle in an intelligent and coherent fashion, interdisciplinary synthesis workshops, models and data must be co-evaluated and global observing systems must be supported. It is hoped that increased international pressure will result in increased national funding for carbon cycle research.

GHG Inventories for the Asian Region

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Greenhouse gas inventories are vital for quantifying the release of greenhouse gases into the atmosphere and for assessing the impacts of increasing greenhouse gases in the changing patterns of climate change. Emissions inventories are also critical in evaluating the cost-effectiveness and feasibility of mitigation strategies and emission reduction technologies.

Fully aware of the importance of GHG inventories in the Asia-Pacific region, the Environment Agency of Japan together with the Institute for Global Environmental Strategies (IGES) and the National Institute for Environmental Studies (NIES) sponsored and hosted, respectively, the IGES/NIES workshop on GHG inventories for Asia-Pacific Region on 9-10 March 2000. With participation of about 40 experts and scientists in the region, the workshop focused on three main sectors (Agriculture; Land Use Change and Forestry; and Waste) and discussed with the following objectives:

- To improve the national GHG inventory compilation for the Asia-Pacific region;
- To present the current state of knowledge on GHG inventories in the Asia-Pacific region;
- To initiate the development of a database for GHG inventories in the Asia-Pacific region;
- To identify data gaps and problems in GHG inventories for the Asia-Pacific region;
- To evaluate the current methods used in compilation of inventories in the Asia-Pacific and, where possible, improve the methods;
- To form a network of GHG inventory experts in the Asia-Pacific region with a view towards designing future collaborative work and information/data sharing;
- To contribute to the work of the IPCC National Greenhouse Gas Inventories Programme.

As for the land use and forestry (LUCF) sector, the workshop participants agreed on the following points.

Firstly, the poor state of accuracy of GHG inventory in this sector in the region was highlighted. It is not easy to resolve the uncertainties in the GHG inventory of LUCF sector. There are very few available data in the region and in some cases, the data are very old.

Secondly, the data gaps or areas to be prioritised in the future research were identified with a view to improvement of quality of the emissions/removals estimates in this sector in the region. Those are:

- Forest typology
- Growth rate per forest type
- Area of forest cleared by forest type
- Wood harvests
- Biomass density of each forest type
-

Among these factors, the “forest typology” was regarded quite important. Ideally, the forest classification should be linked to entities:

- that can be distinguished by remote sensing;
- that reflect the actual biomass density;
- that are functional from a land use perspective.
-

But actually, there are so many different typologies being used by these different countries. Some use functional classifications based on the official forest function while others follow ecological grouping. (Later, this issue of forest classification was also raised in the UNFCCC regional workshop of the Consultative Group of Experts on national communications from non-Annex I Parties of the Asian region, Bangkok, Thailand from 16 to 20 October 2000.) Harmonization efforts or further consideration will be needed based on the current naming of the forest types.

Thirdly, a strong need was identified for exchange of information and data and collaboration among GHG inventory experts and scientists in the region. The highlight of the workshop is the formation of a network of GHG inventory experts in the Asian region that will focus on improving GHG inventories.
It was suggested that the network may be established in two stages. In Stage 1, IGES may serve as the focus of a private network, comprising of individual experts from the region. In Stage 2, the network should firmly establish its role in supporting the work of the IPCC-NGGIP-TSU, and link with the UNFCCC National Focal Points of each country. Now, this network is being developed as NAPIID (Network for Asia Pacific to Improve (GHG) Inventories Database). This attempt has just been initiated. We would be most grateful for your interest in collaboration with us in the near future.

Please visit the NAPIID website, http://www.iges.or.jp/cc/napiid/NAPIID.htm)

Carbon Storage and Accumulation in Forests of China

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Abstract

In this study, we estimated the carbon storage for forest vegetation of China based on plot-level forest inventory data, national-level inventory statistics and the data from site studies specified for estimating biomass in different tree parts and understory. The mean biomass densities for the main forest types and age classes were estimated and then used to calculate the national totals. We also used results from a study on forest soil carbon and forest floor carbon to complete a carbon estimate of forest ecosystems in China. We found forest ecosystems in China (108 Mha) to contain 21.37 Pg of C. Of this total, 6.62 Pg of C (31%) is in live trees, 0.26 Pg (1.2%) in understory, 0.82 Pg (3.8%) on forest floor and 13.68 (64%) in forest soils. The uncertainty analysis revealed the importance of separating age groups in estimation and the effect of biased distribution of sample sites on the accuracy of estimation.

Introduction

Forest inventories represent a critical first step in quantifying forest carbon storage. Because regional inventories are based on statistical samples designed to represent the broad range of forest conditions actually present, estimates of carbon storage in forest trees are representative of the true average values (Birdsey, 1992). Recent research has pointed out the particular importance of understanding terrestrial carbon exchange in the Northern Hemisphere (Shimel. 1995). China is a large landmass in the Northern Hemisphere, and it is important to gain reliable carbon estimates for Chinese forests and provide useful information for the scientific community and policy makers.

Data and methods

Data from forest inventories and field studies

Forest inventories in China are designed to estimate the volume of growing stock for all trees, but do not include an estimate of biomass. In order to estimate the carbon storage in trees, it is necessary to convert inventory information to estimates of total tree biomass. Three types of data were used in this study. (1) Plot-level inventory data were collected across the country and covered the main forest types. The data came from 4970 plots and included information about locations, coordinates, species, forest types, age, dbh, height, numbers of trees, stocking, and other variables. (2) 1285 biomass equations (for calculating stem, branches, foliage and root biomass based on the tree DBH and height) were collected from the literature and field studies. These equations were grouped into 333 sets for 98 species and forest types. (3) National level inventory statistics included areas of forest types at different age classes and in different provinces.

Estimation of forest tree biomass and understory biomass

Estimates of forest tree biomass involved two processes. First, we estimated a mean biomass density for each forest type and age class. Plot measurements of tree DBH and height at sample plots were converted to total tree biomass by using allometric equations for calculating biomass of tree stem, branch, foliage and root. Plot biomass was calculated respectively for different forest types, age groups, and regions using the equations specified for the region. If there was more than one set of equations for the same tree species, the biomass was calculated using each set of equations and then averaged. The biomass density was calculated by dividing the biomass by the plot area. A mean biomass density of each forest type was estimated by averaging the plot values. The second step involved applying the mean estimates to national-level inventory statistics. The national inventory estimates include areas of forest types at different age classes in different provinces. Total biomass of each forest type was calculated by multiplying the mean biomass density by the area for each age class and province and then aggregating to the country level.

Understory vegetation biomass was estimated based on the data of field studies derived from the literature. It was impossible to directly calculate the understory biomass for those inventory plots because of a lack of measurements. The ratios of tree biomass to understory shrubs (including seedlings) and grasses were calculated. In general, the ratios ranged from 0.44%-6.1% for shrubs and from 0.25 to 2.64% for grasses in those main forest types of China.

Results and Discussion

Mean biomass densities estimated from the inventory plots differed greatly among the age classes and forest types. Mean biomass densities of forest types (based on mature stands) ranged from 100 (*Populus-Betula*) to 436 Mg/ha (tropical forests) for broadleaf forests; from 96 (Chinese pine, temperate coniferous forests) to 334 Mg/ha (Masson's pine, subtropical coniferous forests) for coniferous forests. Within a type, mean biomass densities of different age groups increased significantly as ages increased. For example, the biomass density of Masson's pine was 81 Mg/ha in young stands and ranged from 337 to 426 Mg/ha for more mature stands, which were about 4-5 times higher in biomass. This indicates the importance in estimating forest biomass by separating age groups.

The total area of forest in China is 108.63×10^6 ha (11.31 % of the country's land area). The total live tree biomass is 13.25 Pg, total forest vegetation biomass is 13.78 Pg, and total area-weighted mean biomass density is 126 Mg/ha. The area-weighted mean biomass density seems higher if compared with the estimate in some countries because woodland and shrublands that have low biomass densities were not included in the estimate. If 0.5 is used as the carbon conversion factor, the total forest vegetation carbon in China is 6.89 Pg C.

The carbon storage in forest soils and on forest floor, estimated by Wang (1999), is 13.68 PgC and 0.82 PgC, respectively. Including to the carbon stored in live vegetation, total carbon storage in China forests is 21.37 PgC. Of this total, 31% is in live trees, 1.2% is in understory vegetation, 3.8% is on forest floor and 64% is in the soil.

The total carbon storage in China forest ecosystem is about 1.86% of all carbon stored in the world's forests while forest area is about 1.83% of the forest area. Forest carbon storage in China represents only a small proportion of the global forest carbon pools. However, the area of the young and middle-aged forests in China is about 71.31% of total forestlands. These relatively young forests may have a great potential for storing additional carbon in the system.

Uncertainty in the estimates due to biased distribution of study sites may exist. Whether or not the inventory plots we used in calculating mean biomass densities represented the broad range of forest conditions and the true average value could affect the estimates of total biomass because we did not use growing-stock volume as the basis for estimating carbon storage in forest trees. Two critical issues affect the accuracy in estimating forest carbon storage, data and methods. Our current estimates are still preliminary and require further improvement and reduction in uncertainty. For example, the estimate for forest soil carbon only considered soil types and did not account for the effects of forest types, age structure, disturbance and land-use history on soil carbon storage. Applying a volume-based estimate, improving the soil carbon estimate, and evaluating reforestation and land-use effects on carbon accumulation in Chinese forests are the issues we need to consider in our future study.

The impact of conversion of grassland to agriculture on carbon cycle

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Introduction

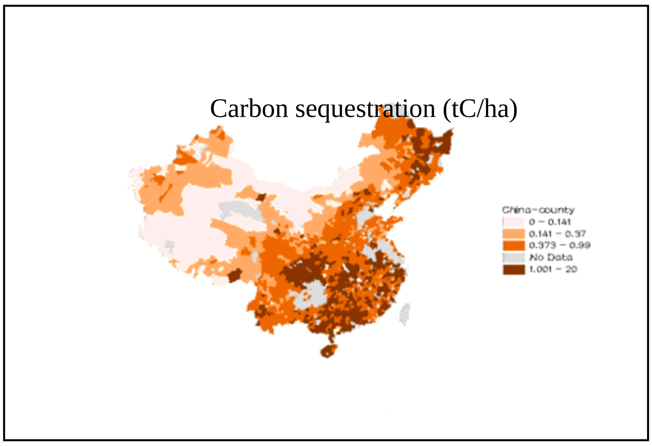
The steppe of China occupies the east part of Eurasian steppe region. But on the Eurasian continent, the steppe extends approximately from west to east swinging between 45 degrees and 55 degrees N latitude. In China, the steppe extends from northeast to southwest, and from 51 to 28 degrees N latitude. Within this vast range, the elevation gradually ascends as the latitude dips southwest, from 120-200meters in Songnei Plain, 400-500m in west Liao River Plain, 1100-1200m on the Inner Mongolia Plateau, 1400-1500m on the Ordos Plateau, more than 2000-3000m in the west part of Loess Plateau, getting to Qinghai-Tibet Plateau, generally more than 4500-5000.

The total area of natural grassland in China is 392.8 million ha, which represents for 41.4% of the total land area of China, and it is 4 time of the farmland (Liao GF & Jia YL, 1996). It is well known that 7 percent of the world farmland feeds 22 per cent of world population in China. In order to increase the area of farmland, the native ecosystems were reclaimed during past few decades, especially the natural grassland. The area of reclaimed grassland were 8 million ha in China before the mid of 1970s. Based on the statistics of National Committee of Planning, the applicable grassland area in 1980s in Inner NMongolia, Xingjiang Weiwu'er Municipality, Qinghai and Sichuan were decreased 4.6%, 4.8%, 5.7, and 5.5%, respectively. The total applicable grassland area decreased 11.55 million ha in these four provinces. In addition, the degraded grassland area was above one third of total grassland area in China.

Little information exists on C cycle of grassland and other non-CO_2 greenhouse gas emissions or uptake. The information of the impact of grassland conversion to farmland on CO_2 emission and CH_4 uptake in China is even little. So the objective of this paper are (1) estimate the CO_2 absorption by grassland in China; (2) assess the impact of the conversion of grassland to farmland on CO_2, N_2O emissions from grassland soil and CH_4 uptake by the soil.

CO_2 absorption by grassland in China

Based on the grassland area, grass yield, the total grass production and carbon sequestrated by natural grassland in China were calculated (Fig 1). Total carbon sequestration by natural grassland in China were estimated to be 134~153 Mt C/year.



The impact of land use change on CO_2 emission

The conversion of grassland to corn field can increase the CO_2 emission from soil. In 1998, the average emission rate of CO_2 from natural grassland was 11.9 kg CO_2-C $ha^{-1}d^{-1}$ during the whole growing season of the natural grass, while the average CO_2 emission rate was 20.0 kg CO_2-C $ha^{-1}d^{-1}$ during the corn growing period. The similar results were obtained from the experiment in 1999. The average CO_2 emission rates from natural grassland and corn field were 9.4 and 14.3 kg CO_2-C $ha^{-1}d^{-1}$, respectively. The emission rate increased 52%-68% after the natural grassland converted to farmland. These data indicate that disturbing the natural grassland increased CO_2 emission.

The impact on CO_2 absorption

The conversion of grassland to irrigated corn field can increase the production of aboveground and belowground biomass production. The carbon sequestrated by grassland was estimated to be 754.6 kg C ha^{-1} based on the grass production and belowground biomass measurement. While the carbon sequestrated by corn was 9612 kg C ha^{-1}, More than 10 times higher than natural grassland after the conversion (Table 1).

Table 1: The impact of land use change on overall GHG effects

	Natural grassland	Corn field
A: Aboveground biomass (kg dm/ha)	764.3	13350
B: Aboveground biomass (kg dm/ha)	912.5	1335
C: Carbon sequestration (kg C/ha)	754.6	9612.0
D: CO_2 emission from soil (kg C/ha)	1728.2	2568.6
E: CH_4 uptake (kg C/ha)	5.1	2.3
F: N_2O emission (kg C/ha)	62.4	140.5
G: Net GHG effect (kg C/ha)	1031.0	-6905.3

The impact on CH_4 uptake

The natural grassland, farmlands converted from natural grassland served as a sink for atmospheric methane. The methane uptake rates were decreased when the natural grassland converted to maize in almost of the measurements. The average methane uptake rates of natural grassland and maize field were 3.32 and 1.95 g CH_4 $ha^{-1}d^{-1}$, respectively, during the growing period in 1998. The CH_4 uptake rate decreased from 4.89 g CH_4 $ha^{-1}d^{-1}$ to 2.25 g CH_4 $ha^{-1}d^{-1}$ after the conversion. The methane uptake rates by maize in 1998 and 1999 were decreased by 41% and 54% compared with that by natural grassland, respectively, during the growing seasons. The methane uptake by farmland decreased 41% compared with that by natural grassland.

The impact on N_2O emission

The natural grassland, farmlands converted from natural grassland are sources of N_2O of emission. N_2O emission rates were increased after the conversion of natural grassland to farmland because of the fertilization. The emission rate from natural grassland and maize field were measured to be 4.1 and 9.2 g N_2O-N $ha^{-1}d^{-1}$, respectively, during the growing season in 1999.

The impact on overall GHG effects

Table 1 gives impact of conversion of natural grassland on overall GHG effects in 1999. The natural grassland are the source of GHG emissions. While the irrigated corn field, which was converted from natural grassland was sink of GHG. He calculation of net GHG effect in Table 1 is as following:

$$\text{Net GHG effects (G)} = D + F - (A+B)*0.45 - E$$

Conclusion

- The carbon sequestration by natural grassland in China was 134-153 Mt C.
- The conversion of grassland to corn field can increase the CO_2 and N_2O emissions and decrease the CH_4 uptake from the soil.
- The conversion of grassland to irrigated corn field can benefit to decrease the overall GHG effect.

Land Use and Land Cover for South East Asia

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Introduction

The rapid rate of deforestation has inundated the SEA region for the past few decades where the countries; $B!G; (J land resources has decreased due to activities that deplete biodiversity and caused degradation to soil and environment with declining productivities. As third world countries in SEA, further deforestation is expected with the pressures from the socio-economic factors and government policies to increase the rate of development and in their attempts to bring their nations out of the poverty levels.

Activities such as slash and burn agriculture; logging, mining, and plantations are causing the destruction of the local environment. The rapid rate of conversion of forests to agriculture, settlement and industrial estates due to the socio-economic pressures such as the increase in the rate of population and in population density, through the rise in infrastructure activities such as buildings, houses, factories, industrial areas, roads, transportation etc. put a high demand on the land requirement. Conversion to permanent cropland or settlements may cause a reduction in soil organic matter, depletion of nutrients and soil erosion. The land use changes may alter the rates of trace gas emissions and on the long term impact, ultimately affect the regional and world climate.

Tropical deforestation is a major component of the Carbon cycle. Atmospheric carbon dioxide and trace gases emitted from deforestation and deliberate fire activities performed during the clearing of land from forests to agriculture increases the net flux of carbon to the atmosphere, since the concentration of carbon in forests is larger than in cropland (Skole and Tucker, 1997).

The SARCS (Southeast Asian Regional Committee for START) Land Use Land Cover Changes Project was initiated to study, monitor and model the land use and land cover changes within the region by applying remote sensing and GIS that include the socio-economic aspects to explain the drivers of the land use changes. Regional understanding of the processes in landuse and landcover changes, which include the driving forces and impacts to the global environment are also the main objectives of the project. The initial group comprises of 4 countries: Malaysia, Thailand, Philippines and Indonesia. The project was partly funded by NASA and START.

The First Phase of the project initiated in 1994 was successfully completed with all its objectives fulfilled. For the Second Phase of the LUCC project, implemented in 1998, new member countries were included which consist of Laos, Cambodia and Vietnam. As latecomers to the SEA team, they were trained to assimilate the members with the capability of elevating them to the level of the expertise of the earlier teams. An APN funding was obtained to integrate the new members with current LUCC methodologies with support facilities that encompass hardwares, softwares and expert advices.

Investigation on the annual rate of deforestation and a comparison with the decadal mean rate of deforestation and deforestation dynamics are amongst the objectives of the Second Phase Project. The differential rates of deforestation and abandonment will be modelled (Sharifah Mastura et. al, 2000a). Diagnostic modelling of the LUCC and the relationship between the greenhouse impact, carbon stocks and forest cover in the region will be investigated (LULCC in SEA, 2000).

The changes in land use and land change that have taken place for the period of 10 years (1981-1995) were investigated in the 1st phase of the LUCC project. Each member country had selected specific study areas of their choice (Table 1). Amongst the criteria chosen was an area that has a size of greater than 3500 square kilometers and a watershed area that should be considered a critical site for each country (Sharifah Mastura, et al, 2000b), whether threatened by future deforestation with encroaching development or illegal logging.

Modelling Activities

Some modelling was performed to simulate land use land changes that have occurred in the South East Asian region. Results from the four countries are presented here. Table 2 shows the regression analysis pertaining to each country.

A logistic model was also performed to investigate the impact of road access on deforestation or land use change, particularly in terms of the hike in land price due to the improved road accessibility. The Malaysian watershed case study showed that transport access, land class, population density, agricultural employment, government enforcement on landuse change significantly affect the probability of forest clearing (Nor Ghani et. al, 2000).

Land Transformation Model (LTM) was also applied to investigate the influence of land use changes on ecosystem integrity and sustainability of large regions (Pijanowski et. al, 1995). The relative land transitions (using artificial neural networks) are based on spatial interaction of drivers such as population growth, agriculture sustainability, transportation, farmland policies etc. LTM can generate spatial and temporal aspects and test and predict scenarios of policies. The Kuala Lumpur watershed case study showed that 73% of the observed changes of land use and land cover over a 10 year period were predicted by the model.

Carbon modelling will be the next step implemented for the LUCC SEA Phase II Project (Table 3). Table 4 shows the land use categories that will be used in the carbon modelling. Emission inventory that considers the effects of human disturbances will be considered for the LUCC SEA carbon modelling. The emphasis will be on the land cover change rather than on the land use changes. Uncertainties in C include those due to spatial LUCC, biomass, response after disturbance, regrowth, abandonment etc. (Skole, 2000).

Simple and emphirical response curves will be used to estimate the response of forest disturbances (in terms of C flux), though this method is not able to account for the changes in the ecosystem metabolism (Skole, 2000). Vegetation maps with assigned values will be used to treat biomass, and the land use cover changes will be overlayed to find the changes. The fluxes of C will be obtained by running the model using the appropriate response curves of the changes of C per hectare of land per unit time.

Table 1: Project Areas Chosen by Participating Countries for Phase I Study

Malaysia	**Klang-Langat Watershed** 415,409 hectares
Philippines	Magat Watershed 16π 05′ –17π 01′ N, 120π 51′E –121π 27′E 177398 hectares
Indonesia	Upper Citarum Watershed in West Java 107π 15′E – 107π 60′E, 6π 40 S-7π 15′S
Thailand	Mae Chaem, Mae Khan and Mae Klang sub-watersheds

	669242 hectares

Table 2: Socio-Economic Results – Driving Forces and Changes Model : Phase I

Country	Model	Results
Malaysia	Stepwise regression	Socio-economic and government policies dictate the LUCC in the Klang valley area. Drivers: labourers in agriculture industry, road density and population growth. Population growth driven by government policies allowing conversion of forests, agriculture lands → housing, urban & industrial areas.
Philippines	Stepwise regression	Conversion of forests to other types of LU attributed to deforestation activities. Drivers : Agriculture, logging and population density.
Indonesia	Step wise regression	Industrial activities increase, decline in agriculture lands. Increase in need for settlement. LUCC of forest and agriculture not significantly related to socio-economic variables, but other LUCC variables. (Forest → Agriculture→-Grass→-Open→-Settlement→-Industry).
Thailand	Multiple regression	Human forces are drivers to LUCC. LUCC varied significantly to population density.

Table 3: Research Activities for LCLUC Phase II Project *(Sharifah Mastura et. al, 2000)*

Activity Tasks
Satellite data analysis
Regional analysis of annual change
Socio-economic and demographic assessment
Application of models **1. Land transformation model** **2. Carbon model**

Table 4: Land Use Categories for Carbon Emission Model ***(Sharifah Mastura et. al, 2000)***

Category	Land use type
1	**Build up areas/ openland/ grassland**
2	**Non-tree agriculture**
3	**Forest**
4	**Secondary forest / tree plantation**
5	**Water bodies**

Land-use Change and Terrestrial Carbon Stocks in Southeast Asia

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Abstract

Measurements of land-use change and the corresponding terrestrial carbon stocks and greenhouse gas emissions have been extensively conducted in Southeast Asia using national, bilateral and multilateral resources since at least five years ago. Global change scientists in the region have also been networked through various regional and international initiatives such as START, APN, IGBP/GCTE and GEF. The works are eventually beyond the IPCC agenda, widely known as Land Use Change and Forestry (LUCF) sector, and then later called Land-use, Land-use Change and Forestry (LULUCF). They consider broad forest agenda and the necessity of promoting sustainability issues of the systems they are working with.

To this end the general perception is that the figures of net carbon emission rates and growth are not the primary concerns. The figures are not strictly related to the global climate system, rather to find out the justification of the 'best bet' alternatives of land-use that provide promising trade-off in terms of environmental and economic benefits. In a situation where land-use decisions are made by several different players removal of carbon stock will be justified by a number of reasons, such as job created, the amount of food and fibre produced etc. Global environmental agenda has not been institutionalised at national and regional levels by which externalities of land-use change may be internalised in assessing the cost and benefit of the decisions.

The capacity in assessing terrestrial carbon stocks and emissions are more or less established but there is a substantial lack of integration mainly because the protocol used are not standardised. Above ground C-stocks are relatively easier to obtain provided that substantial labour is available since the method is usually laborious. The use of remote sensing techniques becomes more popular and fancy. Multi-date observations are also possible but in many cases the method is not cost-effective. Below ground C-stocks, however, offer much more challenges although in many tropical ecosystems carbon is stored more in the above ground storage.

Even the rates and quantity of soil emissions are not significant compared with the amount of carbon removed from or by above ground biomass, the fluxes are important part of the process in biogeochemical cycles. Quantifying such fluxes always provide useful information to determine sustainability criteria. In more practical term it may be related to land management and cares.

There is a serious missing middle when one has to share data for integration purposes, mainly because the scales in both temporal and spatial terms are not unified. Fluxes and stocks of carbon from a few plots measured directly in the field when extrapolated had never met with interpolated data obtained using remote sensing techniques. Direct measurement for the entire biome, ecosystems, or even landscape will no longer be cost effective. Temporal scale is often forgotten when comparisons are made for emissions from soils which usually use hourly rate. Meanwhile, flux rates due to biomass removal can only be derived when the second measurement is far apart from the previous one. Time-average from several cycle is proposed for the carbon stocks in the biomass to help moderating abrupt fluctuation. This is usually associated with land-use practices where fallow period is introduced as part of land management.

Developing a robust database is necessary. This will enable users from both scientific and policy communities in utilising and improving the data itself. A unified format should be introduced and followed. Access to the database should be as easy as possible, *e.g* using website platform.

Terrestrial carbon stocks are facing tremendous threat from both man-made and natural disturbances. One of them is fire, which to some extent used as tool in land management practices. The rates and magnitude of carbon lost by fire may be substantial that one can anticipate. The 1997/1998 fire

episode, for example, gave enough evidence the importance of fire control and risk analysis in any kind of forest carbon projects. Rapid assessment using combined remote sensing and GIS techniques are proposed.

From the review there is a number of emerging research agenda that may be linked to policy questions. Among others are, why in Kyoto regime forest carbon is a contentious issue, how policy-makers can benefit from a cost-effective research results, what parameters are needed to develop sustainable criteria, how to quantify trade-off for land-use change.

Intergrated Analysis of Land Use on Carbon Dynamics in East Asia

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The impact of land use and climate change on various managed and less managed ecosystems (such as croplands, grasslands, and forests) affects physical, ecological and socio-economic processes. Changes in these processes affects the soil fertility, soil moisture, and soil organic matter resulting in further regional land use and climate changes. These changes in land use and climate at the regional scale are often quite different from national or continental scale changes, so that regional differences are expected with in land use management decisions relative to climate change. Integrated assessments (IA) are needed to more completely model whole human-environment systems. IA efforts are under way that provide spatial and sectoral detail necessary to achieve reliable estimates of land use and ecological changes at county to regional scales.

The objectives here are: (1) to explore the development of an information linkage between terrestrial ecosystems and human activities affecting land use; (2) to describe the analytical framework to assess the importance of the critical human and environmental factors controlling land use decisions at local and regional scales which affect carbon and other critical biogeochemical processes. This presentation provides insight to the interactions of climate, ecosystem, economic and socio-cultural interactions controlling land use change at local to regional scales. The ability to analyze the integrated effects of the factors controlling ecosystem and socio-economic integrity relative to changes in climate and land use management of the these ecosystems is a complicated task. A framework to simplify the complex interactions within and between various subsystems is provided using a modelling approach that includes all the major components and links them together in an integrated fashion. Development of this framework for assessing changes and incorporation of information to integrate factors controlling ecosystem and social-economic dynamics.

Technological advances in remote sensing (RS), geographic information systems (GIS) and ecological simulation modeling have increased our ability to link information across a broad array of disciplines. This ability has allowed us to begin to answer a variety of complex issues related to changing patterns of environmental and socio-political drivers in the Temperate East Asia. Since land use change is a dynamic process, the integration of GIS with simulation techniques provides a way to examine their spatial and temporal characteristics and identify forces contributing to land use change. The utility and information content of GIS and RS data depends on our knowledge of the socio-political, economic, and ecosystem structure and function. Thus, a way to increase the utility of RS and GIS data for interpreting land use-ecosystem process has been to combine RS and GIS with socio-economic and ecosystem modeling technologies.

Introduction

The growing concern over the impact of changes in land use and land cover on environmental conditions and the increasing human impact on the natural resources in the East Asian region has captured the attention of the political and scientific community world-wide.

The region of East Asia has long been recognized for its wealth of natural and human resources. However recently, concern related to the changing environmental conditions in the region due to increasing human pressures degrading the environment have captured the attention of the scientific and political communities. The role of land use and land cover change in maintaining and in some cases leading to the degradation of the environmental health and sustainability of human welfare is a critical to the future of the region. The increasing dependance and utilization of the land and water resources in this region will further tax the limits of the ecological systems and increase the risk of environmental degradation. In addition, the need to produce food and clean water for the growing number of people in the region will further focus attention on the changes in land use and land cover in the region.

Growing from this concern to better understand the factors determining land use and land cover changes in the region and evaluate the potential impact these changes will have on the human condition and future global environmental change, the Temperate East Asian Committee of START (TEACOM) sponsored a working group to develop a science plan for land use and cover change studies in this region.

Land use/cover changes in the EA region has been a major factor in ecosystem changes for a long period of time. Agricultural and livestock developments have been recorded for millennia in this region. Currently the region is one of the most densely populated regions of the world. Due to a long history of environmental exploitation and recent population increases, the region is prone to environmental stresses such as salinization, desertification, deforestation, soil erosion, water pollution and air pollution. The impact of human activities on ecosystem dynamics and biogeochemical exchanges with the atmosphere have resulted in dramatic changes in the fluxes of C, N, and other atmospheric constituents in the region.

Research in the region on various aspects of land use and land cover change is well developed. Research conducted by scientists from around the world are currently engaged in investigations ranging from changes in population affecting land use and natural resources, to impact of intensification of agriculture practices on atmospheric pollution. The development of the LUTEA network provides a mechanism for greater exchange of information useful for the scientific and the policy communities alike. The network provides a vehicle for development of common databases that are needed by many of the LUTEA research groups.

This region covers all of East-Central Asia and South-East Asia north of the Philippines and south of the Arctic Circle. The climate is generally humid to semiarid and determined chiefly by the monsoonal circulation. A strong north to south rainfall and temperature gradient exists. Vegetation and land use practices change systematically across this north to south gradient with cool temperate forest and grasslands in the north where pastoral and forestry land use dominate. Toward the south more arable land is found in regions with mixed broad leaf forest, croplands, and ricefields.

Intergration Activities

The ability to analyze the integrated effects of the factors controlling ecosystem and socio-economic integrity relative to changes in socio-economic, climate and land use management factors of these temperate ecosystems is a complicated task. A framework to simplify the complex interactions within and between various subsystems needs to be developed to organize fieldwork, modeling, and other related activities. Development of the framework for assessing changes and incorporation of information to integrate factors controlling ecosystem and socio-economic dynamics in the East Asian region is the focus of this research plan.

Our ability to predict changes in the human-ecological system relative to climate or land use changes is dependent on the development of analytical tools to integrate our current understanding of how these ecosystems behave relative to human and environmental factors. A framework to simplify the complex interactions within and between various subsystems is provided using a modelling approach that includes all the major components and links them together in a spatially integrated fashion. At the core of this approach is an ecological process model that incorporates the changes in external forcing factors, including climate and management on net primary productivity and carbon.

Development of critical databases on physical, ecological and social-economic factors

Database compilation of climate, topography, soils, and vegetation will be needed in order to evaluate land use and climate interactions for various land management practices implemented in the region. The use point or station data interpolated across the region will be made when possible. Remote sensing data for land cover will be incorporated in the analysis of current land cover and land use for the region. A number of research groups are actively working on a set of land cover data bases for this region.

Information on various levels of social institutions needs to be evaluated to identify the manner in which decisions are made that determine land-use systems under political units in the region. The analysis of this information will need to incorporate the critical factors of the physical environment, including climate and soil factors, but also include the human factors. Predictions of long-term agricultural and ecological sustainability in relationship to variations in livestock abundance, cropping types, and other land uses are needed to assess the full range of ecological impacts of agricultural development. These predictions require a synthesis of the long-term effects of livestock on forage plant production and survival; the effects of human wood use on woody plant populations; the direct and indirect effects of livestock on soil structure and fertility; and agricultural use of water, soil, other resources, and technologies. The importance of past and current climate and land use cannot be overlooked in assessing the how these ecosystems has developed over the centuries and changes in the future relative to new policies, technological advances, economic conditions, and environmental constraints.

Development of analytical procedures

Scaling of information between ecological and physical data and social-economic data needs special attention due to the difference in the factors defining boundaries defining ecological and social-economic systems. Physical data can often be spatially defined by topographic boundaries such as watershed, mountain ranges, river basins, etc. However, social-economic data are often organized by geopolitical boundaries, with little connection between the physical and social-economic scales. Time scale differences between the two systems are also quite distinct. Physical data can often range from continuous to point data, whereas, social-economic data are snapshots in time, ranging from annual to decadal in nature (e.g., taxation data, census data, birth rate, etc.). These differences between the physical, ecological, and social-economic systems create a number of problems for integration of data across these systems, however, a number of methods are being developed to integrate across these systems and evaluation of these techniques need to be applied for the situations found in this region.

Strategy for modeling activities

Models need to be able to evaluate land uses and ecological integrity along a gradient of environmental factors. With these models, we will be able to evaluate various scenarios of land use and climatic changes. The models employed are capable of simulating ecosystem responses to changes in climate and to various land use practices at the landscape to regional scale, and include processes such as, plant production, soil fertility, water availability, and agroecosystem dynamics. These models are used at various spatial and temporal scales. Models that integrate information on policy, economic, social, and cultural factors within a given environmental setting and provide information on land use practices need to be formulated.

The integrated model needs to incorporate the extensive information that exists on current land use practices. This framework needs to link the ecological, social, and economical sectors within an integrated structure. Information needed include records of weather and plant productivity, land use history, and socio-economic trends. Many factors and decisions bear directly on land use, including what land units are available for grazing or cropping, the severity of the climate, price of various input and output commodities, cultural and political constraints to the type of cropping system, or livestock system. The use of linked social-economic and ecosystem models is an integral component to the assessment at both the regional and local scale of ecological and socio-economical integrity. Technological advances in remote sensing (RS), geographic information systems (GIS) and ecological simulation modeling have increased our ability to link information across a broad array of disciplines. This ability has allowed us to begin to answer a variety of complex issues related to changing patterns of environmental and socio-political drivers in the Central US. Both in the US and in temperate east Asia we are using remote sensing data to establish patterns of land cover. The temperate east Asian land cover has been classified in collaboration with the EROS Data Center and Asian scientists resulting in the Temperate East Asian Landcover (TEAL) database (Ojima et al 1997). Since land use change is a dynamic process, the integration of GIS with simulation techniques provides a way to examine their spatial and temporal characteristics and identify forces contributing to land use change. The utility and information content of GIS and RS data depends on our knowledge of the socio-political, economic, and ecosystem structure and function. Thus, a way to increase the utility of RS and GIS data for interpreting land use-ecosystem process has been to combine RS and GIS with socio-economic and ecosystem modeling technologies.studies at various levels have been useful to investigate the specific interfaces between ecological and socio-economic and political sectors. These studies address issues related to climate change's impacts; to grazing impacts at the landscape scale; integration of multiple land uses; nomadic movements relative to ecological - climatic factors; and land use decision making and nomadic movements relative to social, political, economic, and demographic factors.

A regional model framework to integrate the effects of multiple land use practices that impact ecological integrity of the agroecosystems of the US has been developed that links agroecosystem in a spatially explicit manner. The agroecosystems of the southcentral US has a mixture of land use practices ranging from intensive agriculture (i.e., irrigated and fertilized croplands) to extensive use (i.e., grazing) of rangelands and woodlands. The spatial and temporal use of various landscape units for these different land use practices affects ecological integrity relative to soil fertility, plant production, water availability, and economic integrity relative to net economic gains integrated over the entire landscape and across the diverse land use practices. We plan to implement this scheme to the temperate Asian region.

Predictions of long-term agricultural and ecological sustainability in relationship to variations in livestock abundance, cropping types, and other land uses are needed to assess the full range of ecological impacts of agricultural development. These predictions require a synthesis of the long-term effects of livestock on forage plant production and survival; the effects of human wood use on woody plant populations; the direct and indirect effects of livestock on soil structure and fertility; and agricultural use of water, soil, other resources, and technologies.

Implementation of a spatial modeling and remote sensing scheme over larger areas will require a larger network of information flow (Figure 2). This scheme provides a methodology to integrate physical and social-cultural-economic data into land use/cover change studies. Monitoring over larger regions can be achieved through a hierarchically organized system where information flows upwards from local studies to provide assessments over larger spatial areas.   In addition, it is important to be able to understand the social context of land use decisions. Spatial variations in landscape properties must be integrated with ecosystem processes to understand or predict the dynamics of the agroecosystems.

Sponsors of LUTEA research are: START, APN, NASA, NSF, DOE-NIGEC

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Carbon Budgets of Forest Ecosystems in Southeast Asia Following Disturbance and Restoration

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Introduction

There is considerable interest on the role of terrestrial ecosystems in the global carbon cycle. Land use change and forestry (LUCF) activities, mainly tropical deforestation, are significant net sources of CO^2, accounting for 1.6 Gt/yr out of the total anthropogenic emissions of 6.3 Gt/yr (Scnimell *et al*., 1996; Watson *et al*., 2000). However, tropical forests have the largest potential to mitigate climate change amongst the world's forests (Brown *et al*., 2000; Brown *et al*., 1996). In tropical Asia, it is estimated that forestation, agroforestry, regeneration and avoided deforestation activities have the potential to sequester 7.50, 2.03, 3.8-7.7, and 3.3-5.8 Gt C between 1995-2050 (Brown *et al*., 1996).

In the last few years, research on C stocks and dynamics in forest ecosystems in Southeast Asia have been intensified and new data have been generated (e.g. Murdiyarso, 2000; Lasco and Pulhin 2000) This paper attempts to review the available information on carbon budgets of forest ecosystems in the region as a result of land use change and management activities such as harvesting and reforestation.

Effect of Logging Operations on Forest Carbon Budget

Logging activities are expected to reduce the C in the forest ecosystem as a result of wood extraction and the decay of dead materials. In the Philippines, we studied the carbon density of logged-over forest plots with varying ages after logging (Lasco *et al*., 2000). Right after logging, C density decline by about 50% of the undisturbed forest (198 MgC/ha). Forest blocks that will be logged again has recovered about 70% of the undisturbed forest C. This suggests that the cutting cycle may not be enough to recover the C lost through logging operations. The potential effect is a progressive decline in forest yield, which is in fact already being felt in the second cutting cycle (Weidelt and Banaag, 1982). In Indonesia, estimates of C density of logged-over forests range from 38-75% of the original forest.

The adoption of reduced impact logging (RIL) practices can significantly minimize C losses due to harvesting. In Sabah, Malaysia, the C density of RIL plots were 88MgC/ha higher than conventional logging (Pinard and Putz, 1996;1997). In addition, there were 86 MgC/ha less necromass in RIL plots.

Carbon Budgets Following Forest Conversion to Plantations

Conversion of natural forests to tree plantations and perennial crops is becoming a common land-use change in the tropics. In general, total C stocks decline with forest conversion to plantations. An APN-supported study in Indonesia and the Philippines showed that C stocks of plantations were 7-51% lower than the natural forest (Sitompul and Hairiah, 2000; Soekisman& Mawardi, 2000; Lasco *et al*., 2000). Various plantation cover in Indonesia have less than 63% of the C of natural forests (Table 1).

Table 1: C density of various land cover in Indonesia

Land cover	C density	% of Natural Forest*	Source of data
Rubber jungle	35.5	14	Praetyo et al., 2000
Home gardens	70-80	20**	Sitompul and Hairiah, 2000

Oil palm (30 yrs)	40.3	16	Tjitrosemito and Mawardi, 2000
Cinnamon	77	30	Gintings, 2000
	87	34	Gintings, 2000
A. mangium	159	63	Siregar et al., 1998
Natural forest	254		Noordwijk et al., 2000

* Natural forest assumed to contain 254 MgC/ha based on Noordwijk et al., 2000
** Calculated by Sitompul and Hairiah, 2000.

Effect of Reforestation/Afforestation on Carbon Budgets

The rapid loss of forest cover in many Southeast Asian countries have left millions of ha of degraded lands. In response, massive reforestation/afforestation projects have been launched in the region. The rate of C sequestration after planting varies with the conditions of the site and the species planted. Under severely degraded conditions in the Philippines, MAI of C was only 0.30-3.73 MgC/ha/yr (Table 2). While in a relatively better condition in Indonesia, the C MAI was 4.99-6.92 MgC/ha/yr.

Table 2: Biomass and C density and MAI in Nueva Ecija, Philippines

Species	Age (yr)	Ave dbh (cm)	Biomass Mg/ha	MAI Mg/ha/yr	C density Mg/ha	MAI Mg/ha/yr
Acacia auriculiformis	9	8.71	32.00	3.56	14.40	1.60
Tectona grandis 1	13	5.50	8.70	0.67	3.92	0.30
T. grandis 2	13	7.36	22.30	1.72	10.04	0.77
Gmelina arborea 1	6	7.33	17.22	2.87	7.75	1.29
G. arborea 2	6	6.80	7.71	1.29	3.47	0.58
Pinus kesiya	13	12.53	107.83	8.29	48.52	3.73
P. kesiya + broadleaf spp.	13	10.10	83.24	6.40	37.46	2.88

Note: age and dbh data from Sakurai *et al*., 1994; biomass computed using the equation Biomass/tree in kg= 21.297-6.953*dbh+0.74dbh^2 for broadleaf species and Biomass/tree= EXP-1.17+ 2.119*LN(dbh) for conifers (from Brown, 1997); %C in biomass= 45% (based on Lasco and Pulhin, 2000)

Conclusions

While there are still limited studies on C budgets as a result of LUCF activities in Southeast Asia, the following emerge from recent studies in the region:

- Logging activities significantly reduce forest C density in the above ground biomass (up to 50-60%). However, the logged-over forest sequesters C over time.
- Reduced impact logging (RIL) can minimize C loss due to logging
- Tree plantations and perennial crops have lower C density than natural forests they replace (ca. 10-60% lower)
- Reforestation/afforestation activities result to C sequestration at varying rates depending on the species and site conditions

In the future, research on C budgets of LUCF activities need to be intensified to get a better understanding of their impacts to the global C budget.

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Clean Development Mechanism under the Kyoto Protocol:
An Avenue for Forest Rehabilitation in Indonesi?

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The recent failure of the Sixth Conference of the Parties to the Climate Convention (COP6) in The Hague shows that the role of forest and forestry has become even more relevant in the debate on climate change. While the apparent failure was reportedly due to the disagreement between the UnitedStates and the European Union on the use of domestic carbon sinks (Articles3.3 and 3.4 of the Protocol) to meet their Kyoto commitments, the inclusionof carbon sinks in the Clean Development Mechanism (Article 12) was far from resolved.

My talk will address the potential institutional arrangements and capacity to undertake Clean Development Mechanism projects in Indonesia. The talk will also address the current state of the Indonesian forestry and its relevance with climate change and the Clean Development Mechanism. The talk will provide possible arrangements and capacity building requirements to undertake CDM projects in the forestry sector. A proposal for the establishment of a CDM Clearinghouse will be advanced.

1. Introduction

Research on the carbon cycle has become central to the political discourse over the last few years, as negotiations to stabilize atmospheric CO_2 concentrations are progressing under the Framework Conventions for Climate Change and its associated Kyoto Protocol. Carbon dioxide has been, and is projected to be, the most important greenhouse gas.

The Land Use Change and Forestry (LUCF) sector has become the more problematic throughout the negotiations as they are responsible for a large portion of the current terrestrial sinks, particularly in temperate regions, and for large carbon sources, particularly in tropical regions (e.g., SE Asia alone accounts for about 50% of the global carbon emissions from land use change.

Annual emissions of carbon dioxide from land use change and forestry are about 25% of the total global carbon emissions. However, they are especially important in non-Annex 1 Parties, and particularly tropical countries, where the major emissions of carbon are from changes in land use (largely deforestation for agriculture). See figures 1 and 2.

The emissions of carbon from land use change are also important because the role of terrestrial ecosystems in the global carbon balance is still somehow uncertain. Despite emissions from tropical deforestation, terrestrial ecosystems, globally, seem to be a carbon sink in the order of 0.5-3.0 Pg C yr^{-1} depending on the year, although the location and the mechanisms that drive this sink are still highly controversial (Canadell et al. 2000). Some analyses infer a major sink in northern mid-latitudes while others suggest a more uniform distribution in tropical as well as temperate zone regions (Ciais et al. 2000, Rayner et al. 1999). The latest analyses, however, are pointing towards a Northern Hemisphere sink (IPCC-TAR 2001) and a neutral tropical regions (between 30N and 30S) which suggests a biological sink of about 1.6 Pg C yr^{-1} in the tropics to balance out the relatively well constrained emissions of about 1.6 Pg C yr^{-1} due to deforestation.

Changes in land use and cover are associated with large biogeochemical changes, and particular in the aboveground and soil carbon content. The changes, although largely associated with carbon emissions due to deforestation, are also associated with increasing carbon sequestration due to agricultural abandonment or new agricultural management practises (e.g., no tilling approach) and forestry techniques.

This APN proposal aimed to increase the dialogue between groups working in Asia on land use change research and those groups measuring carbon stocks and fluxes. Several exercises were undertaken in order to develop a common framework and land use change typologies that could allow improved linkages between these two groups of disciplinary research.

2. Workshop Agenda

Land Use Change and the Terrestrial Carbon Cycle in Asia
Kobe, Japan
29th January 2001 – 1st February 2001

Workshop Agenda as per 25th January 2001
[Talks are 20-25 minutes with 5-10 minutes for questions = total 30 minutes]

Monday, 29th January 2001

Opening and Introduction

09:30 – 10.00 Welcome, Objectives, and Logistics.

- Opening and Welcome - Ryutaro Yatsu, APN Director
- Relevance to Kyoto Protocol - Ian Noble
- Networking and Integration - Dennis Ojima
- Purpose, Structure, and Products - Pep Canadell

10.00 – 10.30 Global Carbon Sources and Sinks – Pep Canadell

10.30 – 11.00 *Coffee Break*

Land Use Change

11.00 – 11.30 Land Cover of the Whole Asia – Ryutaro Tateishi

11.30 – 12.00 Land Use Change in Southeast Asia - Mastura Mahmud

12.00 – 12.30 Spatial Modeling and Land Use Change in the Asian Pacific Region – K.S.Rajan

12.30 – 13.00 Land Use Change and Carbon Cycle in Arid and Semi-Arid Lands of East and Central Asia - Togtohyn Chuluun

13.00 – 14.30 *Lunch Break*

Carbon Sources and Sinks

14.30 – 15.00 Land Use/Management Change and Trace Gas Emissions from East Asia - Zucong Cai

15.00 – 15.30 Carbon Emissions from Fire – Haruo Tsuruta

15.30 – 16.00 Land-Use Change and Terrestrial Carbon Stocks in Southeast Asia – Daniel Murdiyarso

16.00 – 16.15 *Coffee Break*

16.15 – 16.45 Carbon Budgets of Forest Ecosystems in Southeast Asia Following Disturbance and Restoration – Rodel Lasco

16.45 – 17.15 The Carbon Balance in the North East China Transect (NECT-IGBP Transect) - Guangshen Zhou

18.30 – 21.00 *Reception-Dinner at the Harborland New Otani Hotel*

Tuesday, 30th January 2001

09.00 – 09.30	GHG Inventories for the Asia-Pacific Region - Kiyoto Tanabe
09.30 – 10.00	Importance of Riverine C-fluxes for the C-cycle in Asian Countries – M. M. Sarin
10.00 – 10.30	Posters
10.30 – 11.00	*Coffee Break (posters continue)*
11.00 – 11.30	Posters
11.30 – 12.00	Spatial Distribution of Soil Respiration in a Korean forest and C Budget at the National Scale of Korea - Dowon Lee
12.00 – 12.30	Carbon Storage and Accumulation in Forests of China - Yude Pan
12.30 – 13.00	Institutional Dimensions of Carbon Management - Agus Sari
13.00 – 14.30	*Lunch Break*

Integration

14.30 – 15.00	Carbon Balance: Global Joint IGBP-IHDP-WCRP Carbon Cycle Research Program – Kathy Hibbard [IGBP - International Geosphere-Biosphere Program; IHDP – International Human Dimensions Program; WCRP – World Climate Research Program]
15.00 – 15.30	Carbon Balance: Regional Integration and Modeling Approaches - Dennis Ojima
15.30 – 16.00	Carbon Balance: The Kyoto Perspective. What we need to know and which datasets and measurements are needed – Ian Noble
16.00 – 16.30	*Coffee Break*
16.30 – 18.00	Discussion on Integration

Wednesday, 31st January 2001

Break-Out Sessions

09:00 – 09.30 Plenary to prepare Break-out session:

Questions for break-out groups:

- What are the factors influencing the carbon dynamics of the region?
- What are the major trends (human influence, climate change and variability, economic trends, etc.) of those factors?

- What are the key measurements and geographical information we need to assess the carbon sources and sinks of the region?
    - What information is available?
    - Where are the information gaps?
    - What do we need to put together the national and regional carbon balances?

Working groups:

- land use/cover detection and change
- forests
- agricultural systems
- grasslands

09.30 – 10.00 Break-out groups

10.00 – 10.30 Break-out groups

10.30 – 11.00 *Coffee Break (break-out groups continue the discussions)*

11.00 – 11.30 Plenary: Break-out groups report

11.30 – 13.00 Funding Opportunities – Various presentations (APN, GEF, Millennium Assessment, others related to carbon sequestration projects, etc.)

13.00 – 14.30 *Lunch Break*

14.30 – 15.00 Plenary to prepare next break-out session.

Questions for break-out groups:

- Which type of new research projects are necessary to reduce uncertainties in regional carbon balances?
- Discuss specific possible new projects linked to funding opportunities
- Which type of coordination of existing projects is necessary to reduce uncertainties in regional carbon balances?

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Working groups:

- 2-3 workings groups with a balanced mixture of expertise from the four previous working groups (land use change, forest, grassland, agriculture).

15.00 – 15.30 Break-out groups

15.30 – 16.00 Break-out groups

16.00 – 16.30 *Coffee Break*

16.30 – 17.00 Break-out groups

17.00 – 17.30 Break-out groups

17.30 – 18.00 Plenary: Break-out groups report

Thursday, 1st February 2001

09.00 – 09.30	Proposal for New Research Projects
09.30 – 10.30	Discussion
10.30 – 11.00	*Coffee Break*
11.00 – 11.30	Break-out groups working in writing specific proposals
11.30 – 12.00	Break-out groups working in writing specific proposals
12.00 – 12.30	Products from the meeting (special issue; homepage, research proposals, framework for coordination, directory of researches)
12.30 – 13.00	Concluding Remarks
13.00 – 14.30	*Lunch*

3. List of Participants

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4. Summary Contributions to the Workshop

The project has developed around four main activities: (i) one workshop, (ii) two commissioned studies, (iii) the development of a database of scientists working on the topic and associated website, and (iv) the development of two research proposals to be submitted for funding in the near future.

The workshop was held during 29th January to the 1st of February of 2001 in Kobe, Japan. Twenty-eight participants from Australia, China, Indonesia, Japan, Korea, Malaysia, Mongolia, Philippines, Russia, Thailand, and USA contributed to the meeting along with eight observers from Japan.

The objectives of the workshop were to review the variety of ongoing projects on land use change and terrestrial carbon in Asia and to foster linkages between land use change scientists (both remote sensing and land use change causation modelers) with ecologists measuring carbon fluxes and pools. The group identified areas to foster integration such as the development of new land use change typologies better linked to biogeochemistry studies with a focus on relevant management practices to increase carbon sink strength and reduce carbon emissions.

The main outcome of the workshop was an increased collaboration between land use change groups and ecologists who measure carbon pools and fluxes in forests, grasslands, and agroecosystems. This was achieved and two research proposals resulted:

- Land use change and carbon sequestration in Southeast Asia
- Potential adaptation strategies under global warming and land use change in Mongolia.

Other products of the workshop were the following commissioned studies:

- Land Use Change and Carbon Cycle in Arid and Semi-Arid Lands of East and Central Asia
- Carbon Budgets of Forest Ecosystems in Southeast Asia Following Disturbance and Restoration
- Database of scientists and reports (available in the web) on land use change and the terrestrial carbon cycle in Asia. The website also makes available the summary contributions, commissioned studies, and meeting presentations including power point shows, stemming from this APN project. The site will be used to further foster interaction among the various groups and as a central location to find topical information and funding opportunities. The homepage is still under development and currently can be found at: http://gcte.org/Kobe-Meeting-Index.htm].

Various scientists were also identified as contributors to the new IGBP-IHDP-WCRP Carbon Cycle Research Project.

Finally, a number of action items have been identified as follow ups of this APN proposal:

1. Two new commissioned studies have been undertaken to support the development and provide the background information for the two research proposals that will be fully developed at completion of the commissioned studies. The proposals will be submitted independently or cross-referenced to GEF-IPCC [Impacts and Adaptation] and APN**.**
2. Various groups in the region will be working over the next 5 months on papers that will contribute to the special journal edition that will be published as a result of the workshop in Kobe. Two synthesis papers will be written by a multi disciplinary group of scientists to identify future research and integration strategies.

5. Discussion Points

Defining the information across human and biogeochemical systems.

- What are the critical pieces of information? E.g. land use type systems, in agro-eco zones, or systems?
- A system may contain several layers of information, a hierarchical organization.
- What are the cross-scale information, or key variables, or axes?
- Need local level process information: e.g. nitrogen management, water management; underlying social/cultural practices;

Land use typologies relevant to biogeochemistry:

What are the management information that is needed for agricultural systems?
Crop, animal residue management, the harvest practice, what's the cropping type? Annuals or perennials: consequences to belowground carbon; tillage (plough or no), fire management, grazing management (type of animals - grazers, browsers, seasonally, year-round, outside amendments)

What are the management information that is needed for forests?
Logging style (clearcut vs. selective harvest), reforestation (timing, species), revegetation (shrubs vs. grasslands), agroforestry, rotation rates, industry vs. community management conversion to other (urbanization, abandonment, pastures), inter-harvest management (thinning, branch removal), grazing (intensity, types of animals), age structure and planting strategies, slash management (burned, removed, left)

Two working groups developed a case study each as possible templates for land use change/biogeochemistry integration type of studies:

Case Study 1
Developing a land use/biogeochemistry, environmental typologies

Semiarid grassland/ transition zone in North Eastern China

The rationale:

Land intensification in northern china has increased either through erosion, removal of forest, or losses in organic matter through oxidation: through agriculture, forestry, grazing.

- Three major river systems
- This region is approximately 30% each forested/grazed (grassland)/ agriculture with about 5% urban, 5% other.

Forest Issues in Northeastern China:

Primarily a timber harvest/reforestation region –
Reforestation:

1. Species/functional composition: in the northern area, larch and conifer/boreal moving south is a mixed broadleaf/conifer
2. Some reforestation by natural reseeding (in the mixed forests), primarily by seedling replanting in the softwoods; e.g. cedar, some plantations
3. Actively reforesting areas as windbreaks towards dune stabilization
4. Harvest techniques in softwood areas (larch/pine) selective harvest, generally clear cutting in mixed forests maybe need some more information
5. No harvesting in windbreak areas; some trimming
6. Post-harvest activities: In southern region, slash may be collected for fuelwood, there is a high demand for fuelwood - in general in the south, unsure of exact locations; slash burning depends on risk of fires:

- Road Building Activities
- Disturbance Frequencies: fire, insects; Intervals and Intensities
- A simple breakdown into whether a forest is managed at all, or whether it's left alone, and the history. Very little pristine, most is secondary growth.
- A suggested harvest rotation for soft (north): 40 years for *Larix* plantations, 40-60 years mixed forests
- The environmental factors: boreal to temperate climatologies as well as the seasonality of the precipitation/snowfall. Are the soils boggy, free draining; generally loess type soils well drained with a good potential to store soil carbon. Potential for erosion in steep slopes (mountainous areas).
- What are some feasible mitigation strategies:
- Lengthen rotation - a potential for leakage, however
- Reduce slash removal for fuel or not to burn, potential to induce harm in nearby communities (through fuelwood buildup)
- Strip cutting in steep topography and other areas (reduce wind/water erosion)

Grassland Issues in Northeast China:

- Grazing Grasslands: primarily in the western area of our region
- Desert steppe, typical, meadow steppe (important for winter pastures and hay), improved pasture and wetland grasslands: primarily perennials
- Environmental: desert ppt ~ 150 to 350 mm
- Dung use: historically as a fuel by farmers; however contemporary coal mines have removed the need for dung use. The extent of coal vs. dung for fuel is questionable: also rice straw is used as a fuel in those systems.
- Grazing Management
- Livestock mixtures and/or stocking rates
- Desert steppe: goat, sheep; typical steppe: sheep, cattle; meadow: sheep and cattle (beef and dairy); also some improved pastures for hay and dairy (uncommon)
- Free and fenced grazing systems occur in all grassland types, however, in typical grassland is generally free grazing: rotation grazing in meadow steppe (harvest and free grazing)
- Mitigation Strategies:
- Reduction of grazing intensities; however this may be offset by other activities, e.g. conversion rates from grazing to agricultural systems have increased;
- Increased number of conservation areas: from agricultural to protected
- What is the resilience of these systems - time/ability to return to a 'stable state'
- Replanting denuded grasslands (an actual ongoing project joint Japan, Korea, china?)

Future

- There exists a strong conservation policy in China today towards replanting of trees, protected forests and grasslands: this conservation policy is one mechanism for conserving carbon.

- However, increasing protected sites such as upland areas has consequences for decreasing the rotation rates and intensive management on fertile sites (in the US). Is this envisioned in China?

- Planting brush in the desert: called Saving Water.

- There is little potential to expand northeastern forests (e.g. converting croplands back to forests: There is a limit on forest mitigation for newly reforested lands in arid areas

Case Study 2.

Developing a land use/biogeochemistry, environmental typologies

Carbon Sources and Sinks in Southeast Asia

Background:

- Major pools and fluxes in terrestrial carbon systems
- 1990 as a base year:

The land systems typology:

- Forest vs. non-forest (sub categories)
- C stocks/density
- Area
- Data quality
- Confidence intervals on estimates
- Classification per country
- Age structure: vs. C density
- BG vs. AG carbon stocks and fluxes
- Estimates of emissions now and over time?

The Projections:

1. Land development scenarios:
   - BAU (historical baseline, governmental master plans, intermediate/trade-off/compromises.
   - Which variables to consider: Population, infrastructure development, decentralization/community-based/civil societies, incentives (different land uses), "off-farm/off-forest" opportunities, credit/macro-economic policies, international regimes.
2. Modelling:
   - Age structure of forests (c density?) vs. disturbance regimes, stage
   - Major land in land types across categories
   - Typology of sub regional transitions
   - Tree plantations/palms
   - Transitions?

10 year time frame: too short?
What are the critical pools and fluxes e.g. Below Ground and peatlands
First cut: using existing datasets (forest vs. non-forest)
Peatlands were identified as the least understood w/huge potential towards emissions.
Assessment of stocks and stock changes is a do-able activity

Emerging land use change issues?

The time scale is very important. The assigned time frame was very short. What were the potential mitigation strategies? Are there any activities that can change substantially/significantly the directional vector of existing carbon stocks? Peat systems were identified as a big unknown. Also ENSO a big factor. But social system changes (demographic changes) such as migration. Used 1990 - 2000 to calibrate. Then, are there any big changes from 2000-2012? e.g. land development vs. decentralization in Indonesia; transitions of peatlands to others.
Are the land use intensities, and other activities relatively well-characterized? IGES activities by APN.

Transitions : conversion of forest to agriculture as a huge impact on carbon stocks→ looked at the bigger picture rather than the details. Capturing the BIG events are important.

Some hypothetical questions:

1. What are the forest types most likely subject to change (vulnerability) and where might they be?
2. What/Where are the (vulnerable) transition zones? E.g. tree/crop, marginal forest/forest encroachment/changes in cropping systems/urbanization. Alternatively, it may be possible to develop a topology by elevation.
3. What influences the management decisions - from the SE Asian group
4. Can we build a better IMAGE model for this region?
5. What are some of the proxies available to the social sciences to help quantify the unquantifiable?

6. Products

- Commissioned Study 1: Carbon Budgets of Forest Ecosystems in Southeast Asia following Disturbance and Restoration (see section 7)

- Commissioned Study 2: Land Use Change and Carbon Cycle in Arid and Semi-Arid Lands of East and Central Asia (see section 8)

- Special journal edition on “Land use/cover change and the terrestrial carbon cycle in Asia” (to be assembled and edited over the next 12 months).

- Drafts for research proposals and support background papers

- Recommendations to further link land use/cover change projects to the effects on the terrestrial carbon cycle.

- Linkages to the new Carbon Cycle Research Program of IGBP, IHDP, WCRP.

7. Follow ups

Introduction

There are three major follow ups stemming from the workshop in Kobe and the commissioned studies that will take place over the next 12 months:

- To write the support background papers in order to develop two research proposals that will be submitted to the GEF-IPCC Impacts and Adaptations program and the Asian Pacific Network.

    1. *Land-use change and carbon sequestration in Southeast Asia.*
    2. *Potential adaptation strategies under global warming and land use change in Mongolia*

- To involve key scientists of Asia in the development and activities of the new Carbon Research Cycle Project (IGBP-IHDP-WCRP).

- To assemble and edit a special journal edition with invited papers from the workshop and commissioned studies.

Research Proposal 1 - Draft #01
Land-use change and carbon sequestration in Southeast Asia
Rodel Lasco – leader
Philippines, Indonesia, Thailand

Background

A major study and capacity building project, partially supported by APN, on *Land-use Change and Terrestrial Carbon Stocks* has recently been completed under the leadership of IC-SEA. This project explored the applicability of a range of methods for estimating carbon stocks via the plot, landscape and modelling approaches. The project engaged stakeholders at various stages including as assessment of the opportunities and issues relating to possible inclusion of "sinks' in the CDM of the Kyoto Protocol. The project has produced a number of scientific reports that provide clear pointers to feasible methodologies.
Recommendations from the project give emphasis to the continuing need:

- to explore adequate methodologies for estimating carbon in terrestrial ecosystems,
- for integrated work on land-use change,
- for national guidelines on CDM projects, and
- for research to incorporate sustainable development guidelines in assess the impacts of projects.

Options

There appears to be opportunities to build upon this work on two fronts.

The first would extend some of the pilot studies to additional sites and after further experience to regional wide coverage. An example of this would be the extension of the study of land-use change and its impact on carbon stocks in the Batanghari watershed in Jambi, Sumatra (Murdiyarso, Suyamto & Widodo 2000). An empirical model of the social and biophysical drivers of land-cover change was developed for one time period and successfully tested over a later period. This model could be tested in other locations and it could be simplified by attempting to reduce the number of parameters used (currently 8). If the model were to be applied across more regions this exercise would provide inputs into developing a more process oriented model of the drivers of land-use change. This study used a relatively simplistic approach to changes in carbon stocks by applying average carbon stock values to existing and predicted vegetation types. Applying some of the models used in the capacity building workshops could improve the projections. Such a project would provide better estimates of possible changes in land-use patterns and carbon stocks over the next decade or so. It is likely that further work on the links between ENSO events and other sources of climate variability, fires and deliberate land-use change will be needed.

The second opportunity is to explore the best opportunities for carbon sequestration projects under the CDM. This would involve further refining the estimates of changes in carbon stocks described above and extending the range of options to other land-use changes. These estimates would act as a guide to policy staff as to which options to foster or avoid. Additional research and monitoring of each proposed CDM project would remain the responsibility of the proponents of the project. A critical component of such a project would be establishing indicators of sustainability and finding practical measures to apply them. The indices should take into account obligations associated other international conventions such as the CBD and RMSAR.

Next Steps

Commission a paper that brings together the materials in the reports and scientific publications from recent (1995-2000) programs in Southeast Asia. Initially this should be an information gathering exercise possibly carried out by one or two scientists. It could be developed into a short review paper that documents the current state of knowledge. This document could be used to help prepare bids for other supporting agencies.

Another task is to design a feasible extension of the first project listed above to provide complete regional coverages. This task should consider the magnitude of the land-use changes and carbon stock changes in the region, continuing applicability of the models of land-use change and carbon stock change, and the availability of the necessary data sets.

Research Proposal 2 - Draft #01
Potential adaptation strategies under global warming and land use change in Mongolia

Enviromental Impact Assessment Center, MNE
Institute of Meteorology
Computer Information Center
Mongolian Academy of Sciences (IG, IB)
IISNC

Background

- One of the highest global warming signal is coming from this area. Frequency and scale of extreme climatic events is increasing.
- Dust and snow storm frequency is increased 2-3 times since 1960.
- Mongolia lost 2.5 mln of livestock from the *zud* (severe winter condition) in 1999-2000 and 0.5 mln of livestock by January of 2001 because of drought summer and *zud* conditions. Some scientists are estimating that this year's *zud* is much more severe than last year's. This leads to poverty increase among the Mongolian herders.
- Livestock number has increased from 24 mln in 1990 to 33mln in 1999. A number of goats doubled since privatization of livestock early 1990s. People say that increase of goat numbers intensifies pasture degradation leading to desertification.
- Extensive overgrazing is happening in western and central parts of Mongolia.

In the semiarid regions of the Mongolian steppe, nomadic pastoralism has been the dominant agronomic activity for many centuries. Recently changes in cultural, political and economic factors have caused changes in how the pastoral systems operate within the region. Currently, a range of pastoral systems are operating in the region of Mongolia. These systems encompass a range of grazing patterns (i.e., frequency, intensity of grazing and the types of animals). These systems have incorporated new breeding stocks that are potentially not suitable to certain climate regimes (e.g., drought conditions of the Gobi desert, cold hardiness against severe winter storms in the Mongolian steppe region). These changes in pastoral management have altered the nomadic patterns of the region.

Pastoral systems, where humans depend on livestock, exist largely in arid or semi-arid ecosystems where climate is highly variable. Thus in many ways pastoral livestock systems are intimately adapted to climatic variability. In general, there is a direct relationship between climate variability and the spatial scale of pastoral exploitation. Extensive nomadic systems are found in the most variable regions; less extensive, more intensive modes of livestock management occur in less variable grazing lands. Climate change in drylands can thus be expected to have important implications for the dynamics and viability of pastoral people, their exploitation patterns and through these exploitation patterns, on land cover and land cover change.

We also recognize the pervasive role of demographic, political and economic driving forces on pastoral exploitation. The general trend involves greater intensification of resource exploitation at the expense of traditional patterns of extensive range utilization. This set of drivers is orthogonal to the above described climate drivers. Thus we expect climate-land use-land cover relationships to be crucially modified by the socio-economic forces mentioned above. Nevertheless, the fundamental relationship between climate variability and pastoral exploitation patterns will still form the environmental framework for overall patterns of land use-land cover change.

In addition, recent political and economic changes (i.e., in the past 50 years) in land use management have resulted in a more sedentary livestock management system. These changes have led to more intensive stocking rates in localized areas and change in the breeds of animals used. More recent changes in the social-economic setting have forced new changes in pastoral management due to relaxation of central government controls and the implementation of a more "free-enterprise" system. What will result from these recent changes is unclear, and the effect on the human and natural resources of these arid and semi-arid regions need to be determined.

Rationale

Critical Issues / Key questions

What is the relationship to land use patterns determined by climate variability or land use or economic policies?

Mongolia currently experiences high levels of climate variability in precipitation and it is likely that climate variability in terms of drought and “zud” (severe winter condition for pastoral systems) frequency and intensity due to climate change will be increased in temperate grasslands of Asia. Areas of high coefficients of variation (CV) are found in the western portion of Mongolia near the Gobi Desert and areas of relatively lower CV’s are found in the eastern portion of Mongolia. Changes in land use patterns are changing due to economic and political driving forces, becoming more sedentary and the success of these are associated with changes in climate variability, overall, and more specifically to changes in variability from the historical normals.

Are land use systems developed in areas of high historical CV’s better pre-conditioned to withstand further increase in variability? (Are these systems more resilient?)   Or Will these system be pushed beyond a critical threshold with increasing land use intensification? Under what conditions will changes in these climate patterns make these adapted systems less effective as a sustainable land use system? What will be the situation in less variable climates? Are the land use systems from one region transferrable to another region? What are the constraints in this transfer?

Strategies for coping with climate variability has changed over the past 100 years in Mongolia due to the political and economic changes. The traditional patterns were greatly modified during the collective period (i.e, 1950 to 1990). Though these systems were more dependent on a more technologically-based system of hay production and trucking of animals, these systems provided a buffer against extreme climate events. Today the change in economic and political policy has undermined these coping mechanisms and have resulted in a more vulnerable situation. Analysis of the land productivity and livestock dynamics will be compared in the period preceding and following the change in government/economic situation in 1990. Pastoral systems which lost traditional resilience mechanisms to cope with extreme climate variability will be the most vulnerable to climate change. A research on socio-economic, political and demographic factors contributing to the change in traditional land use, informal institutions and culture is important for rural sustainable development policy.

How is the recent changes in land use intensification affecting pastoral institutions? Rangeland ecosystem structure and function?

Land use intensity increased in central parts of Mongolia. However, there isn’t focused study how it is affected pastoral institutions. *Hot ail* (several households who share their resources) structure re-emerged after privatization in many parts of Mongolia. An impact of recent changes on *neg golynhan* (people from the same river valley) - next level of informal traditional institution is unclear. It appears that we need to provide a rural development policy to strengthen these informal institutions in order to develop sustainable rural community conserving cultural and ecological integrity.

Where are thresholds of land cover / use changes across the gradient of rainfall variability? How the relative variability of rainfall changing and affecting changes in grazing intensity?

Climate change trend and land use intensity are two main interacting factors influencing on dynamics of the thresholds of land cover. A boundary area between Gobi desert and dry steppe is likely impacting greatly by both of these factors as our sociological and remote sensing studies showed. However, we are not taking any mitigation policy against it. It means that we are enhancing climate change impact on these vulnerable ecosystems by continuous land use practices.

Objectives

Identification of vulnerable pastoral systems and ecosystems to climate change and land use intensification in Mongolia;

Develop potential adaptation strategies for mitigation of climate change impact on pastoral systems and rangeland ecosystems for each land use type region.

Land use type regions

Agriculture/cropland region (north central region)
Eastern steppe
Central mountain region
Gobi mountain region
Gobi steppe region

Research needs to be targeted

Identification of vulnerable regions in terms of water resources, food security, human health, socio-economic well being, safety network, drought and *zud* management capacity, ecosystem productivity and carbon stock.

Assessment Methodology

- Trends of NDVI/PPT can be used as an integrated indicator of climate and land use change impact on ecosystem at larger scales. Another indicator could be trend of plant onset derived from RS database;
- Then socio-economic survey in critical regions will help to assess biophysical and socio-economic impact at landscape level and evaluate adaption options for particular regions or areas;
- Different adaptation strategies in terms of ecosystem productivity and carbon stock can be evaluated with CENTURY model.

Potential Adaptation options:

- Maintaining traditional land use practices;
- Strengthening traditional pastoral institutions (resilience networks) such as hot ail (several households), *neg golynhon* (from the same river area), *neg nutgiinhan* (from the same living area). Advertise prime-example sustainable traditional communities;
- Re-storing degraded pastures planting N-fixing *Caragana* etc.
- Adding water points in unused pastures;
- Enhancing hay production where-ever it is possible;
- Increasing security of pastoral communities;

- Facilitate local productive (adapted) livestock breed distribution.

Describe increase of disturbances at the beginning

- Carbon emission per capita;
- Fire frequency and size;
- Microtus Brandtii impact

8. Commissioned Studies

CARBON BUDGETS OF FOREST ECOSYSTEMS IN SOUTHEAST ASIA FOLLOWING DISTURBANCE AND RESTORATION[1]

Rodel D. Lasco[2]

Introduction

There is considerable interest on the role of terrestrial ecosystems in the global carbon cycle. It is estimated that about 60 Gt C is exchanged between terrestrial ecosystems and the atmosphere every year, with a net terrestrial uptake of 0.7 ±1.0 Pg[3] C (Schimell *et* al., 1996). The world's tropical forests which cover 17.6 M km^2 contain 428 Pg C in vegetation and soils. On the other hand, land use change and forestry (LUCF) activities, mainly tropical deforestation, are significant net sources of CO^2, accounting for 1.6 Pg/yr out of the total anthropogenic emissions of 6.3 Pg/yr (Houghton *et al*., 1996; Watson *et al*., 2000). However, tropical forests have the largest potential to mitigate climate change amongst the world's forests through conservation of existing carbon (C) pools (e.g. reduced impact logging), expansion of C sinks (e.g. reforestation, agroforestry), and substitution of wood products for fossil fuels (Brown *et al*., 2000; Brown *et al*., 1996). In tropical Asia, it is estimated that forestation, agroforestry, regeneration and avoided deforestation activities have the potential to sequester 7.50, 2.03, 3.8-7.7, and 3.3-5.8 Pg C between 1995-2050 (Brown *et al*., 1996).

In spite of their importance to the carbon cycle, there is little information on the effects of land use change and management activities on the carbon budgets of forest ecosystems in the tropics. For example, one of the major research needs identified in the Second Assessment Report of the IPCC is how different silvicultural and other management practices would affect the C dynamics in forests (Brown *et al*., 1996). In the last few years, research on C stocks and dynamics in forest ecosystems in Southeast Asia have intensified and new data have been generated (e.g. Murdiyarso, 2000; Lasco and Pulhin 2000) This paper attempts to review the available information on carbon budgets of forest ecosystems in Southeast Asia in response to land use change and management activities such as harvesting and reforestation.

Forest Land Use Change In Southeast Asia And The C Cycle

Rate Of Deforestation And Landuse/Cover Change In Southeast Asia

The last few decades have seen massive deforestation and landuse/cover change in the tropics and Southeast Asia was no exception. In fact, tropical deforestation is the dominant change in land use in the tropics (Lugo and Brown, 1992). Deforestation rates in tropical Asia were estimated to be 2.0 M ha in 1980 and 3.9 M ha in 1981-1990 (Brown, 1993). In Southeast Asia, the 1990 annual deforestation rate is estimated at about 2.6 M ha/yr (Table 1).

Table 1:1990 Annual deforestation estimates for countries in Southeast Asia (from Trexler and Haugen, 1994)

Country	Deforestation (ha)
Indonesia	800,000
Laos	200,000
Malaysia	275,000
Myanmar	600,000
Philippines	200,000
Thailand	300,000

[1] Review paper prepared for the GCTE-APN project "Land Use Change and the Terrestrial Carbon Cycle in Asia".

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[3] 1 Pg= 10^{15}g; 1 Tg= 10^{12}g; 1 Mg= 10^6g

Vietnam	200,000
Total	2,575,000

There exist varying estimates of the rates of deforestation for each country, partly because of different time frames and sources of data. This is illustrated in the case of the Philippines where deforestation rates have fluctuated in the last 100 years with an average of about 148,000 ha/yr (**Table 2**).

Table 2: Deforestation rates in the Philippines in the 20th century

Period	Years	Loss of forest area (Ha)	Rate (ha/yr)
1900-1934	35	4,000,000	114286
1935-1988	54	9,700,000	179630
1989-1996	8	1,200,000	150000
Mean			147972

Forest loss data adapted from Lasco and Pulhin (2000)

The forest area in Thailand declined from 28.03M ha to 13.35 Mha between 1961 to 1993 (Boonpragob, 1998), an average loss of 445,000 ha/yr, much higher than the estimate in Table 1. However, a recent GHG study in the country, estimated deforestation rate at only 150,000 ha/yr in 1992-93 (ALGAS, 1998 as cited by Macandog, 2000a).

The initial National Communication of Indonesia estimated the rate of forest conversion at about 800,000 ha/yr (State Ministry for Environment, 1999); other estimates place it
1 M ha in the early 1990s and 721,000 ha in 1994 (Sorensen, 1993; MoF, 1996 as cited by Macandog, 2000a).

Forest land cover change dynamics in Southeast Asia[*]

Fig. 1 illustrates the general land-use change dynamics in the Philippines which is generally applicable also in other Southeast Asian countries. In the last century, commercial logging has been the main cause of conversion of old-growth (primary) forests to secondary forests. In addition, small-scale swidden farming are also deemed responsible for the formation of secondary forests (Kummer, 1992). Since 1900, the Philippines lost about 15 M ha of tropical forests. It can be presumed that these were first converted to secondary forests before being totally denuded.

Secondary forests could be converted to the following land uses: upland farms, pasture areas, brushlands and tree plantations. Conversion to upland farms is typically done by farmers who follow at the heels of loggers. Logged-over areas are easy to clear because the largest trees have been removed and logging roads provide easy access. Upland farms may revert back to secondary forests through fallow. Forest fallows are more often associated with indigenous peoples. Several indigenous fallow systems have been documented in the Philippines (Hanunos of Mindoro; Tagbanua of Palawan, etc). However, upland farms of migrant farmers hardly, if ever, revert back to forests as they are continuously cultivated until the soils are very degraded. Most grasslands in the Philippines are formed in this manner.

Clearing of secondary forest areas for pasture could also have happened in the past. However, it is more likely that pasture areas were former upland farms. When abandoned, pasture areas remain grasslands because of very poor soils and regular burning. If fire is controlled, studies and observations have shown that grasslands can return to secondary forests through natural succession (Friday *et al*., 1999).

[*] This section was adapted from Lasco *et al*., (2000b).

Secondary forests could become brushlands as a result of continuous cutting of trees, mostly illegal. Brushlands contain less than 20% forest cover. If further denuded, they could become grassland areas. However, if disturbance ceases, they revert back to secondary forests.

Finally, secondary forests could also be converted to tree plantations. This is not allowed anymore at present, but could have been significant in the past. Tree plantations rarely return back to natural forests.

The case of the Philippines is not unique. In many countries in the region, forest conversion starts with selective logging and ends with degraded pastures and grasslands (Detwiler and Hall, 1988).

C budgets of forest ecosystems and their potential for C sequestration

Tropical forests contain a significant amount of C in the biomass, necromass and in the soil. In tropical Asia, 41-54 Pg C and 43 Pg C are found in vegetation and soils, respectively (Dixon et al., 1994) Annual C flux from tropical Asian forests is estimated at -0.50 to –0.90 Pg/yr.

In terms of their potential to mitigate carbon from the atmosphere, the amount of C that could be sequestered in above ground biomass of the technically suitable present forest lands in Asia is estimated to be about 15 Pg; or an average of 88 MgC per ha (Iverson *et al*., 1993). Another study showed that Southeast Asian countries the potential to sequester 9.0 Pg to 21.0 Pg of C from 1995-2050 in 66 M ha through forest regeneration, farm forestry and plantation development (**Table 3**).

Table 3 Potential C sequestration of regeneration, farm forestry and plantation development activities in Southeast Asia from Trexler and Haugen, 1994)

Country	Regeneration (000ha)	Farm forestry (000ha)	Plantation (000ha)	Total (000ha)	C stored (Tg C)	
					Low	High
Indonesia	20,000	5,000	10,000	35,000	5,400	14,000
Laos	10,000	1,000	2,000	13,000	530	1,000
Malaysia	6,000	500	400	6,900	1,000	1900
Myanmar	13,000	1,000	500	14,500	390	950
Philippines	5,000	3,000	1,000	9,000	840	1,600
Thailand	4,000	4,000	1,000	9,000	170	630
Vietnam	8,000	0	4,000	12,000	620	1300
Total	66,000	14,500	18,900	99,400	8,950	21,380

More recently, there were attempts to estimate the C mitigation potential of some countries in Southeast Asia. For example, Indonesia is estimated that an additional 546 TgC will be conserved and sequestered from 2000-2012 under certain development and investment conditions (Boer, 2001). While in the Philippines, an additional 35TgC will be conserved and sequestered during the same period (Lasco and Pulhin, 2001).

Carbon Budgets Following Logging Operations In Natural Forests

Carbon Stocks of Natural Forests in Southeast Asia

Using GIS, Brown *et al*. (1993) estimated that in 1980 the average C density for tropical forests in Asia was 144 Mg/ha of actual biomass, and 148 Mg/ha in soils (up to 100cm) which corresponds to total estimates of 42 and 43 Pg, respectively, for the whole continent. It was noted that C densities and pools in vegetation and soil varied widely by ecofloristic zone and country. Actual biomass C densities range from less than 50 to more than 360 Mg/ha with most forests having 100-200

MgC/ha. The higher biomass is in Borneo and Irian Jaya (Indonesia) while there was lower biomass C in forests in India and Thailand. C densities in soils range from 60-160 Mg/ha.

A similar study by Iverson *et al*., (1993) reported an average maximum C stock in present forest lands in tropical Asia of 185 MgC/ha with a range of 25 to more than 300 MgC/ha. On the hand, Palm *et al*., 1986 as reported by Houghton (1991) found out that forests in tropical Asia has C density of 40-250 Mg/ha and 50-120 Mg/ha in vegetation and soils, respectively (**Table 4**). Brown *et al*., (1991) reported that Southeast Asian forests have a biomass range of 50-430 Mg/ha (25-215 MgC/ha) and >350-400 Mg/ha (175-200 MgC/ha) before human incursion. For national GHG inventories, the IPCC (Houghton et al. 1997) recommends a default value of only 275 Mg/ha (138 MgC/ha) for wet forests in Asia.

Table 4: Carbon in vegetation and soils of forest ecosystems in tropical Asia (from Palm et al., 1986 as cited by Houghton, 1991)

Carbon Pool	Tropical moist forest	Tropical seasonal forest	Tropical dry forest
Vegetation (MgC/ha)			
High biomass	250	150	60
Low biomas	135	90	40
Soils (MgC/ha)	120	80	50

There are limited data on carbon densities of natural forests in specific Southeast countries. Most of the recent studies have been reported for Indonesia and the Philippines. These studies are largely based on the use of allometric equations to estimate tree biomass (e.g. equations from Brown, 1997). Indonesian forests have C density ranging from 65-390 MgC/ha (**Table 5**).

Table 5: Biomass and C density of natural forests in Indonesia

Forest type	Biomass Density (Mg/ha)	C density (MgC/ha)	Source
Primary humid evergreen	600-650	300-325	Murdiyarso and Wasrin, 1996
Montane	450-700	225-350	Murdiyarso and Wasrin, 1996
Lower montane	505	253	Murdiyarso and Wasrin, 1996
Lowland dipterocarp	322	161	Murdiyarso and Wasrin, 1996
Swamp forest	500	250	Murdiyarso and Wasrin, 1996
Mangrove	130	65	Murdiyarso and Wasrin, 1996
Natural forest		254	Noordwijk et al.,, 2000
Undisturbed forest		390	Hairiah and Sitompul, 2000

On the other hand, recent studies report that Philippine natural forests contain 86-507 MgC per ha (**Table 6**). The IPCC Revised Guidelines (Houghton *et al*., 1997) estimates that old-growth forests in the Philippines contain 370-520 Mg/ha of above-ground biomass equivalent to about 185-260 MgC/ha at 50% C content.

Table 6: Biomass and C density of natural forests in the Philippines

Forest type	Biomass Density (Mg/ha)	C density (MgC/h a)	Source
Old growth forests	446	201	Lasco et al., 1999
Old growth forests	1126	507	Lasco et al., 2000a
Mossy forest	419	189	Lasco et al., 2000a
Mangrove forest	409	184	Lasco et al., 2000a
Pine forest	191	86	Lasco et al., 2000a

For Thailand, it is reported that the various forest types have a C density ranging from 72-182 MgC/ha (**Table 7**). A similar data set for Thailand is presented in **Table 8**. These C data are used in the national GHG inventory reports of the country.

Table 7: Above ground biomass and C density of various forest types in Thailand (Boopragob, 1998)

	EGF	MDF	DDF	PF	MF
C content, %	54	52	49	48	55
Above Ground Biomass (Mg/ha)	337	266	126	160	200
C density (Mg/ha)	182	138	62	77	110

(from various sources; C density calculated based on 50% C content)

EGF- tropical evergreen forest; MDF- mixed deciduous forest; DDF- dry Dipterocarp forest; PF- pine forest; MF- mangrove forest

Table 8: Biomass and C density of forests in Thailand (from Macandog, 2000b)

Forest type	AGB (Mg/ha)	C density (Mg/ha)	Source of AGB data
Tropical evergreen forest (EGF)	358	179	Ogawa *et al*., 1965
Mixed deciduous forest (MDF)	311	156	Ogawa *et al*., 1965
Dry Dipterocarp forest (DDF)	126	63	Ogawa *et al*., 1965
Pine forest (PF)	162	81	Sabhasri 1978
Mangrove forest (MF)	200	100	Aksornkoae *et al*., 1972

C density calculated based on 50% C density

Malaysian forests have C density ranging from 100-160 Mg/ha and 90-780 Mg/ha in vegetation and soils, respectively (**Table 9**). Cairns *et al*., (1997), citing various sources, reported that mature lowland forests in the country have above ground biomass and root density of 431 and 43 Mg/ha, respectively, equivalent to 216 and 22 Mg C/ha, respectively.

Table 9: Carbon density of various forest types in Malaysia (Abu Bakar, 2000)

Forest type	Area (M ha)	Carbon density (Mg/ha)			Total C (Mt)
		Vegetation	Soil	Total	
Dipterocarp					
Superior	0.831	260	100	360	299
Good	1.116	220	100	320	357
Moderate	1.466	190	100	190	425
Hill					
Partly exploited	1.268	160	100	260	330
Disturbed	1.714	130	100	230	390
Poor edaphic and upper hill	0.701	130	90	220	154
Swamp	0.815	100	780	880	717
Mangrove	0.150	130	320	450	68
Total	8.061				2,744

Carbon Budgets of Forest Ecosystems After Logging Operations

Natural forests in the Southeast Asian region have been one of the world's foremost source of tropical hardwoods. Logging activities are therefore a dominant activity in many countries. As discussed earlier logging operation is primarily responsible for the conversion of primary forests. Destructive logging and subsequent agricultural conversion has vastly depleted natural forests and left millions of ha of degraded lands in each country. Some countries, notably Thailand and the Philippines have banned logging operations in primary forests.

In general, logging leads to a reduction of C stocks in the forest as biomass is reduced by the extraction of wood. C is released upon the decomposition or burning of slash and litter. However, regenerating trees sequester C back to biomass over time. In general, the biomass and C of tropical forests in Asia decline by 22-67% after logging (**Table 10**).

Table 10: Biomass and C (in parenthesis) density of tropical forests in Asia (Brown and Lugo, 1984

	Closed- broadleaf	Closed-conifer	Open forest
Undisturbed-productive	196.3 (98.2)	144.9 (72.5)	79.0 (39.5)
Logged	93.2 (46.6)	112.5 (56.3)	26.32 (13.16)
% Decline	53	22	67

In the Philippines, we studied the carbon density of logged-over forest plots with varying ages after logging (Lasco *et al*., 2000c). Right after logging, C density decline by about 50% of the undisturbed forest (198 MgC/ha) (**Fig. 2**). Forest blocks after 21 years of logging have recovered about 70% of the undistrubed forest C. These blocks are the oldest blocks before the next cutting cycle begins (the Philippine cutting cycle is every 35 years). This suggests that 35 years may not be enough to recover the C lost in the forest through logging operations. The potential effect is a progressive decline in forest yield, which is in fact already being felt in the second cutting cycle (Weidelt and Banaag, 1984).

There is no similar study in other Southeast Asian countries which tracks the decline of C density after logging . However, C measurements have been taken on logged-over forests which could be compared to primary forests in those countries. In Indonesia, estimates of C density of logged-over forests range from 38-75% of the original forest (**Table 11**).

Table 11: Carbon density after logging of Indonesian forests

Source	Above ground C Density (Mg/ha)		% of Original C
	Undisturbed	Logged	
Hairiah and Sitompul, 2000	390	148.2	38
Noorwijk et al., 2000	254	150	59
Murdiyarso and Wasrin, 1996	325	245	75

As can be gleaned from above, logging is typically a very destructive practice. In Malaysia, extracting 8-15 trees (80 m^3; ca. 22 MgC/ha) damaged as many as 50% of the remaining trees (Putz and Pinard, 1993). Out of the initial 348 MgC/ha, 95 MgC/ha are transformed to necromass which eventually releases its C via decomposition. In the Philippines, for every tree cut greater than 75 cm dbh, 1.5 and 2.6 trees are damaged in favorable and unfavorable conditions, respectively (Weidelt and Banaag, 1982).

However, numerous studies have shown that logging damage can be significantly reduced by directional felling and well-planned skid trails (Putz and Pinard, 1993). These practices are collectively known as reduced impact logging (RIL). The effect of RIL on C conservation has been thoroughly investigated in a study conducted in Sabah, Malaysia as reported by Pinard and Putz (1997, 1996). The rest of this section is based on their papers.

The project started in 1992 with a power company providing funds to a timber concessionaire for training logging operators and implementing improved harvesting practices to conserve C. The researchers compared the C budget of Dipterocarp forests using conventional logging and reduced impact logging. The above-ground biomass was estimated using allometric equations developed by others workers . However, for trees <10 cm equations were developed from 40 trees harvested. A model was developed to track carbon stored in the forest biomass and necromass pools over time and is intended to simulate forest recovery following logging. It is scaled to 1 ha, uses annual time steps, and includes C pools for aboveground biomass and necromass.

The biomass and C density are very similar before logging operations (**Table 12**). About one year after logging, forest areas logged conventionally and under RIL contained 44% and 67% of their pre-logging biomass, respectively (**Table 13**). The C density of RIL was 88 MgC/ha higher than conventional logging. In terms of logging damage, in RIL ca. 27% of trees >10 cm dbh were damaged and ca 19% were dead within the first year after logging. In contrast, in conventional logging, ca. 54% were damaged and ca. 46% died. Expectedly, there were 86 MgC/ha less necromass in RIL compared to conventional logging (**Table 14**) which will translate to lower CO_2 emissions from decomposition.

After logging, biomass is predicted to decline in both areas for 2-6 years. Consequently, C stored will decline because of high mortality rates and decay of logging debris. Following stabilization of mortality rates, biomass accumulation will be greater in RIL areas. Indeed, it will become net sinks in fewer years than conventional logging. Modeling showed that during the 40-year project life span, about 90 MgC/ha will exist in forest biomass due to RIL. Of these, 55% will be present 10 years after logging due to less damage.

Table 12: Above- and below-ground biomass of Dipterocarp forest in Ulu Segama Forest Reserve, Sabah, Malaysia before logging (SD, number of plots or logging units) (Pinard and Putz, 1996)

	Conventional logging	**Reduced-impact logging**
Trees > 60 cm dbh	190 (35, 4)	190 (53, 4)
Trees 40-60 cm dbh	53 (20,4)	46 (6.5, 4)
Trees 20-40 cm dbh	46 (2.5, 4)	46 (6.3, 4)
Trees 10-20 cm dbh	21 (2.7, 4)	23 (2.8, 4)
Trees <10 cm dbh	13 (2.0, 4)	12 (2.0, 4)
Vine biomass	7.6 (3.8, 4)	7.6 (3.8, 4)
Understorey biomass	2.87 (1.50, 45)	2.94 (1.67, 45)
Butt root biomass	26.8 (6.2, 4)	24.5 (5.7, 4)
Coarse roots (alive)	35.9 (33.0, 40)	39.4 (38.7, 40)
Coarse roots (dead)	1.6 (2.6, 30)	1.8 (3.5, 26)
Fine root biomass	2.57 (1.30, 31)	2.74 (1.43, 18)
Total mean (SD) biomass before logging	399 (40)	394 (59)
C density	196*	194*

*C content= 49.2%

Table 13: Above- and below-ground biomass (and necromass) for the two logging treatment areas 8-12 mo after logging; for coarse roots, three mo after logging. Means (Mg/ha) presented with SD and N noted parenthetically. For trees, vines, and butt root mass, SD describes variation among logging units and does not incorporate errors in biomass equations (Pinard and Putz, 1996)

	Conventional Logging	**RIL**
Trees > 60 cm dbh	49 (15,4)	100 (16, 4)
Trees 40-60 cm dbh	37 (13,4)	41 (4.9, 4)
Trees 20-40 cm dbh	29 (5.0, 4)	42 (7.0, 4)
Trees 10-20 cm dbh	11 (2.7, 4)	16 (3.6, 4)
Trees <10 cm dbh	6.9 (1.2, 4)	9.8 (1.8, 4)

Vine	2.6 (1.1, 4)	0.99 (0.49, 4)
Understorey (skid trails)	0.30 (0.38, 40)	0.82 (0.97, 30)
Understorey (disturbed forest)	1.24 (1.02, 60)	1.17 (1.03, 45)
Butt root	11.53 (3.0, 4)	17.39 (2.73, 4)
Coarse roots (skid trails-alive)	2.80 (6.08, 20)	1.81 (3.75, 20)
Coarse roots (skid trails-dead)	2.58 (3.32, 20)	8.28 (15.0, 20)
Coarse roots (disturbed forest- alive)	28.1 (30.2, 20)	30.0 (36.8, 20)
Coarse roots (disturbed forest-dead)	0.98 (1.43, 20)	4.08 (14.8, 20)
Mean (SD) total biomass after logging	176 (34)	264 (40)
C density	86	130

Table 14: Mean (SD) Mg biomass per ha converted to necromass. SD described variation among four logging units and does not incorporate error in biomass equations (Pinard and Putz, 1996)

	Conventional logging units	RIL units
50% of extracted timber	32.22 (4,4)	25.50 (1.12)
Branches, stumps, and butt roots of extracted trees	67.14 (9.76)	45.93 (22.96)
Destroyed trees (uprooted and crushed)	67.49 (45.68)	14.28 (9.56)
Damaged trees dead within one year after logging	7.20 (6.90)	4.01 (5.00)
Lianas destroyed	5.05 (3.23)	6.61 (3.3)
Understorey plant death	1.74 (1.77)	1.78 (1.94)
Coarse root death (excluding butt roots)	10.8 (42.39)	10.4 (48.47)
Total necromass produced	192 (37)	108.5 (22.5)
Mean (SD) difference between two logging methods 86 (43) Mg necromass per ha		

Carbon Budgets Following Conversion From Forest To Non-Forest Cover

Impact of Deforestation to Carbon Budgets

As discussed earlier, deforestation is a major land-use change in Southeast Asia.
There are no studies that directly tracks the change in C budget through the deforestation process. However, there are studies that have quantified the C stocks in deforested lands, typically covered with grasslands or annual crops.

In Indonesia, various reports show that above-ground C density in grasslands and shifting cultivation areas is less than 40 MgC/ha (**Table 15**). While in the Philippines, grassland and crop lands contain 3.1 to 13.1 MgC/ha. In both countries, these are vastly lower than the C density in the natural forests they replaced.

Table 15: Above ground biomass density of grasslands and annual crops in Indonesia and the Philippines

Land cover	AGB Carbon density (Mg/ha)	Reference
Indonesia		
• *Chromolaena sp.*	4	Sitompul and Hairiah (2000)
• *Imperata* sp.	1.9	Gintings, 2000
• Cassava	1.7	
• Cassava/imperata sp.	74	Noordwijk et al., 2000
• Upland rice/bush fallow rotation	39	
• Cultivated agricultural lands	5	Murdiyarso and Wasrin, 1996
• Shifting cultivation	15-50	
• Grasslands	15-20	
• Grasslands	6.0	Prasetyo *et al.*, 2000

Philippines		
• *Imperata* sp.	8.5	Lasco et al., 1999
• *Sacharrum* sp.	13.1	
• *Rice*	3.1	
• Sugarcane	12.5	
• Banana	5.7	
• *Imperata* sp.	1.7	Biomass from Lachica-Lustica, 1997; converted to C

Soil organic carbon (SOC) may also be affected by the change in land use. However, no data is available for Southeast Asia. In general, many studies have shown that continuously cultivated systems have lower SOC than adjacent forests (Lugo and Brown, 1993). However, pasture areas can accumulate as much C in the soil as adjacent natural forests.

Conversion to Tree Plantations and Perennials Crops

Natural forest areas can be converted to plantations of forest tree or perennial crops, usually after commercial logging. This land-use change is expected to reduce C stocks. There are no studies that directly measure the change of C stocks as a result of this change through time. However, by comparing the C stocks of the resulting land use with the C stocks of a natural forest we can have an idea of the magnitude of change. This kind of comparison is of course preliminary as the C stocks vary with age of the plantation and the site characteristics.

In a multi-country study supported by the APN, tree and agricultural plantations, have C stocks that are 7-51% lower than natural forests (**Table 16**). Similarly, another study in Indonesia showed that agroforestry and plantation farms had C stocks that are 4-66% lower than an undisturbed forest (**Table 17**). These data also show how C stocks vary with the age of rubber plantation, with older rubber agroforests having almost seven times more C than a 5-year old plantation.

Table 16: Above-ground C density of tree and agricultural plantations in the Philippines and Indonesia

Category	Carbon density (ton/ha)	% of Natural forest	Source of data
Philippines			
• Mahogany	264	51	Lasco *et al*. (2000a)
• Legumes	240	46	
• Dipterocarp	221	43	
• *Acacia sp.*	81	16	
• Teak	35	7	
Natural forest	518		
Indonesia			
• Oil-palm (10yrs)	62	19	Sitompul and Hairiah (2000)
• Oil-palm (10 yrs)	31	10	
• Oil-palm (14 yrs)	101	31	Tjitrosemito & Mawardi (2000)
• Oil-palm (19 yrs)	96	30	
• Coffee	18	6	
Natural forest	325		

Table 17: C stocks of agroforestry and plantation farms in Jambi and Lampung, Indonesia (C density data from Hairiah and Sitompul, 2000)

Land use	C density (MgC/ha)	% of Undisturbed Forest
Undisturbed rainforest	390	
Opening for agriculture		
With burning	257.4	66
Without burning	81.9	21
Mature agroforest (rubber jungle)	104	27
5-yr old rubber	15.6	4
Oil palm plantation	62.4	16
Coffee mixed garden	18	5

In a lowland peneplein in Indonesia, rubber and oil palm plantations were estimated to contain 36-46% of the C of the natural forest (**Table 18**). While various land cover types in Indonesia are estimated to contain 14-63% of the C density of a natural forest (**Table 19**). These land cover types are briefly described below:

- Rubber jungle: rubber and secondary vegetation; Jambi province (Prasetyo et al., 2000)
- Home gardens: cultivation of annual and perennial crops on the same piece of land near the house (Sitompul and Hairiah, 2000). The data presented is from Malang.
- Oil palm: 19-year old plantation; soil organic C 48.3 Mg/ha (Tjitrosemito and Mawardi, 2000)
- Cinnamon: part of 10-ha demo plots in Sarolangun Bangko district; in vast area of degraded grasslands (recovery); 7-year old plantation (Gintings, 2000)
- *Acacia mangium*: 9-year old plantation (Siregar et al., 1998)

Table 18: Time-averaged C stocks for lowland peneplein in Indonesia(above ground biomass and top 30 cm soil) (Age and C data from Noordwijk *et al*., 2000)

Land use system	Maximum age (yr)	Time averaged C stock (Mg/ha)	% of Natural forest
Natural forest	120	254	
Rubber agroforests	40	116	46
Rubber agroforests with selected planting material	30	103	41
Rubber monoculture	25	97	38
Oil palm monoculture	20	91	36

Table 19: C density of various land cover in Indonesia

Land cover	C density	% of Natural Forest*	Souce of data
Rubber jungle	35.5	14	Praetyo et al., 2000
Home gardens	70-80	20**	Sitompul and Hairiah, 2000
Oil palm (30 yrs)	40.3	16	Tjitrosemito and Mawardi, 2000
Cinnamon	77	30	Gintings, 2000
	87	34	Gintings, 2000
A. mangium	159	63	Siregar et al., 1998
Natural forest	254		Noordwijk et al., 2000

* Natural forest assumed to contain 254 MgC/ha based on Noordwijk et al., 2000
** Calculated by Sitompul and Hairiah, 2000.

In Mindanao, Philippines, tree plantations of fast growing species contain 3-45% of the C of a natural dipterocarp forest (**Table 20**). On the other hand, a mature coconut plantation in Leyte province contains 86 MgC/ha in above-ground biomass (Lasco *et al*., 1999) which is about 43% of a natural forest in the same area (259 MgC/ha; Lasco *et al*., 2001).

Table 20 C density of tree plantations in Mindanao, Philippines

Species	**Age (Yrs)**	**AGB Mg/ha**	**C density MgC/ha**	**% of Dipterocarp forest**
Albizzia falcataria 1	4	69.5	31.28	26
A. falcataria 2	5	75.6	34.02	28
A falcataria 3	7	96.4	43.38	36
	7	8.1	3.65	3
A. falcataria 4	9	108.2	48.69	41
	9	28.7	12.92	11
Gmelina arborea 1	7	85.7	38.57	32
G. arborea 2	9	87.4	39.33	33
G. arborea 3	9	120.7	54.32	45
Dipterocarp*		265.4	119.43	

* Harvested 20 years ago
Biomass data from Kawahara (1981); C content assumed to be 45% (Lasco and Pulhin, 2000)

Agroforestry systems have been widely promoted as an alternative technology to slash-and-burn farming. They involve planting of treee and perennials in conjunction with agricultural crops. Various forms of agroforestry exist in the Philippines (Lasco and Lasco, 1989). A *Leucaena lecuocephala* fallow field in Cebu, Philippines has a mean C density of 16 MgC/ha during its 6-year cycle (**Table 21**). This is very low compared to natural forests in the country. A coconut-based multisotrey system in Mt. Makiling has a C density in AGB of 39 MgC/ha (Zamora, 1999) which is only about 15% of the C of adjacent natural forests.

Table 21: C density and MAI of a *Leucaena leucocephala* fallow field in Cebu, Philippines (from Lasco and Suson, 1999)

Years under Fallow	**Mean Dry Wt. of above-ground biomass (t/ha)**	**% Leaves**	**C in Biomass (t/ha)**	**Annual rate of C accumulation (t/ha/yr)**
1	4.3 d	36.5	2.2	2.2
2	16.1 cd	13.8	8.1	5.9
3	17.6 cd	8.9	8.8	0.7
4	36.4 bc	7.4	18.2	9.4
5	53.8 ab	5.3	26.9	8.7
6	63.6 a	6.1	31.8	4.9
Mean	32		16	5.3

Means in a column with the same letter are not significantly different using DMRT at 0.05.

In conclusion, it appears that tree and perennial crop plantations typically have C stocks in above-ground biomass that are less than 50% of natural forests they replace.

In the process of converting natural forests to agricultural and tree plantations burning is often used for site preparation. In Indonesia, changes in C stocks during land clearing from old jungle rubber/secondary forest for replanting rubber varied depending on whether burning is used (Noorwijk et al., 2000). "Slash and burn" lost 66% C (from ca. 80 MgC/ha to 25 Mg/ha) while "slash and mulch" (no burning) lost only 20% C (ca 110 Mg/ha to 90 Mg/ha). In North Lampung, the biomass declined from 161 Mg/ha to 46 Mg/ha because of burning (Hairaih et al., 1999). This is equivalent to a loss of about 58 MgC/ha.

Once tree and perennial crop plantations have been established, they begin to accumulate C. Noordwijk *et al*., 2000 reported C accumulation rate of 2.5 MgC/ha/yr in natural fallows (secondary forests), agroforests and more intensive tree-crop production systems in Indonesia. An example of these is jungle rubber system (Hairiah and Sitompul, 2000).

Table 22 shows the rate of annual C accumulation by various forest plantations as used in the first Indonesian national communication to the UN Framework Convention on Climate Change (UNFCCC). It ranges from 0.50 to 12.50 Mg/ha/yr.

Table 22: Annual C accumulation rate of various forest plantations used in the national GHG inventory of Indonesia (State Ministry of Environment, 1999)

Land use type	Species/forest type	Annual growth rate (Mg/ha)	Annual C accumulation (MgC/ha/yr)
Forest plantation (Java)	Tectona grandis	3.90	1.95
	Pinus merkusii	6.93	3.47
	Swietenia spp.	7.97	3.99
	Paraserianthes falcataria	19.07	9.54
	Rimba	4.3	2.15
Timber estate (outside Java)	*Acacia* spp.	25.00	12.50
	Paraserianthes falcataria	19.07	9.54
	Dipterocarp	5.78	2.89
Reforestation	*Pinus merkusii*	6.93	3.47
	Tectona grandis	2.41	1.21
	Acacia spp.	25.00	12.50
	Eucalyptus spp.	14.00	7.00
	Others	6.82	3.41
Other forests	Production forest	1.61	0.81
	Conversion forest	2.11	1.06
	Protection + Conversion forest	2.78	1.39
	Others	2.22	1.11
Afforestation	*Pinus* spp.	6.93	3.47
	Acacia spp	25.00	12.50
	Aucalyptus spp.	14.00	7.00
	Paresiranthes falcataria	19.07	9.54
	Others	4.30	2.15
Estate	*Hevea braziliensis*	12.00	6.00
	Coconut	15.00	7.50
	Oil palm	10.00	5.00
	Others	1.00	0.50

A 7-yr old cinnamon plantation in Indonesia accumulates C at the rate of 4.49 to 7.10 kgC/tree (**Table 23**). In the Philippines, commercial tree plantations of fast growing species sequestered C at the rate of 0.50-7.82 MgC/ha/yr (**Table 24**). The next section (5.0) also presents estimates of C density and rate of sequestration of reforestation/afforestation species .

Table 23: Rate of biomass and C accumulation (in kg) of a 7-yr old cinnamon plantation in Indonesia (Gintings, 2000)

In Blui Tinggi						
Tree	Root	Biomass	Total	% R/S	C density	MAI
1	18.94	91.58	110.52	20.7	49.73	7.10
2	15.05	59.36	74.41	25.4	33.48	4.78
3	18.72	67.17	85.89	27.9	38.65	5.52
4	19.32	58.85	78.17	32.8	35.18	5.03
5	18.42	70.98	89.4	26.0	40.23	5.75
In Bukit Suban						
Tree	Root	Biomass	Total	R/S	C density	MAI
1	10.8	45.54	56.34	23.7	25.35	3.62
2	12.03	72.61	84.64	16.6	38.09	5.44
3	13.23	88.03	101.26	15.0	45.57	6.51
4	7.01	62.81	69.82	11.2	31.42	4.49
5	7.18	64.7	71.88	11.1	32.35	4.62

Table 24: MAI of biomass and carbon of tree plantations in Mindanao, Philippines

Species	Age (Yrs)	Biomass MAI Mg/ha/yr	C MAI MgC/ha/yr
Paraerianthes falcataria 1	4	20.20	7.82
P. falcataria 2	5	11.20	6.80
P. falcataria 3	7	8.40	6.20
	7	2.20	0.52
P. falcataria 4	9	5.30	5.41
	9	3.70	1.44
Gmelina arborea 1	7	11.30	5.51
G. arborea 2	9	10.50	4.37
G. arborea 3	9	9.60	6.04
Sweitenia macrophylla	16	19.60	7.33
Natural forest*	100	4.90	1.19

* Harvested 20 years ago; assumed to be 100 years old
Biomass data obtained by destructive sampling (Kawahara *et al*., 1981)

Soil organic matter/carbon (SOC) is also affected by the change in land use. C in the soil is a significant pool. It has the longest residence time among organic C pools in the forest (Lugo and Brown, 1993). However, the exact effect of land use change on SOC is largely unknown in tropical forests specially the rates and direction of change. Below, we present the available data in the Southeast Asian region, mainly from Indonesia and some from the Philippines.

In North Lampung, Indonesia, the total LUDOX fraction of SOC was reduced by 70-80% under degrading situations (burnt imperata; sugarcance with burning; forest plantation with bulldozer for land clearing) in the top soil (0-5cm), 8-10 years after converting forest without effort of maintaining SOM (Murdiyarso and Wasrin 1996). The methods of forest conversion also has big impact on SOM: slash-and-burn practices on forest plantation reduced total LUDOX fraction about 50% which may be due to washing away of the SOM during high intensity rainfall. On the other hand, clearing forest using bulldozer reduced LUDOX fraction by about 70%.

Planting fast growing species like P. *falcataria* increased LUDOX fraction at 0-5cm by about 5 times higher than forested area. However, a mixed plantation of P. *falcataria* and A. *magium* reduced total LUDOX fraction up to 50% compared to forest. In the Rantau Pandan site, a newly developed cinnamon plantation reduced SOM by 30% while cassava plots increased SOM. In the Sitiung site, imperata grass with regular burning after years of intensive cultivation, also had great reduction of SOM.

In another study, tree plantations in Indonesia also have lower SOC density than natural forests (**Table 25**).

In the Philippines, a coconut plantation was found to have about half the SOC density of a natural forest (111 MgC/ha vs 191 MgC/ha) (Lasco *et al*., 1999).

Table 25: SOC at various depth and land use (Siregar and Gintings, 2000)

Land use	**Organic C, %**	**C density ($Mg\ ha^{-1}$)**
Mineral soil, Dipterocarp forest, LOA		
0-10cm	2.6	26
10-20 cm	1.0	10
Mineral soil, Dipterocarp forest, buffer zone		
0-10 cm	7.0	70
10-20 cm	1.3	13
Mineral soil, *Shorea polyandra* 25 year old plantation		
0-10 cm	2.4	24
10-20 cm	1.2	12
Mineral soil Dipterocarp forest, seriously damaged		
0-10 cm	1.8	18
10-20 cm	1.1	11
Mineral soil, *Eucalyptus deglupta*, 2 year old plantation, sandy and acid soil		
0-10 cm	1.7	17
10-20 cm	1.0	10

Carbon Budgets Following Reforestation/Afforestation of Degraded and Denuded Lands

The rapid loss of forests in many Southeast Asian countries has left millions of ha of denuded and degraded land areas. For example, in the Philippines, at least 2 M ha of former forested lands are now grasslands (Lasco and Pulhin, 2000) while in Indonesia imperata grasslands cover 10.7 M ha (Boer, 2001). As discussed earlier, deforested lands have much lower C density than the forests they replace. More importantly for these countries, they have greatly impaired ecological functions and provide little economic benefits.

In response, countries in the region have launched massive reforestation/afforestation programs. The Philippines has reforested 42,368 ha in the 1998 (FMB, 1998) while Indonesia is reforesting/afforesting at the rate of 212,000 ha/yr (Boer, 2001). In addition, tree plantations are also being established at a faster rate, not only to rehabilitate degraded lands, but to meet the wood demand of the respective countries. The Philippines has about 500,000 ha of tree plantations, mostly of fast growing species (Lasco and Pulhin, 2000).

There are very limited reports in literature on C density of reforestation/afforestation areas. However, there is a large body of literature on the performance of species planted in reforestation/afforestation areas. Typically, dbh and height are the main variable measured and reported. Through the use of allometric equations, primarily from the FAO Handbook by Brown (1997), we attempted to estimate the biomass and C stocks and their rate of accumulation.

In the Philippines, a reforestation project in very degraded soil conditions using fast-growing exotic species have C stocks of 3.47-48.52 MgC/ha 6 to13 years after planting (**Table 26**). On the other hand, MAI (mean annual increment) of C was 0.30-3.73 MgC/ha/yr. These values are very low compared to other Philippine forests and tree plantations because of the poor site conditions in the area which is predominantly covered with *Imperata* and *Sacharum* spp. grasses (Sakurai *et al*., 1994)

Table 26: Biomass and C density and MAI in Nueva Ecija, Philippines

Species	Age (yr)	Ave dbh (cm)	Biomass Mg/ha	MAI Mg/ha/yr	C density Mg/ha	MAI Mg/ha/yr
Acacia auriculiformis 1	6	5.68	7.39	1.23	3.33	0.55
A. auriculiformis 2	6	6.46	9.97	1.66	4.49	0.75
A. auriculiformis 3	9	9.62	42.51	4.72	19.13	2.13
A. auriculiformis 4	9	8.71	32.00	3.56	14.40	1.60
A. auriculiformis 5	9	10.47	46.11	5.12	20.75	2.31
A. auriculiformis 6	9	8.73	39.73	4.41	17.88	1.99
Tectona grandis 1	13	5.50	8.70	0.67	3.92	0.30
T. grandis 2	13	7.36	22.30	1.72	10.04	0.77
Gmelina arborea 1	6	7.33	17.22	2.87	7.75	1.29
G. arborea 2	6	6.80	7.71	1.29	3.47	0.58
Pinus kesiya	13	12.53	107.83	8.29	48.52	3.73
P. kesiya + broadleaf spp.	13	10.10	83.24	6.40	37.46	2.88

Note: age and dbh data from Sakurai *et al*., 1994; biomass computed using the equation

Biomass/tree in kg= 21.297-6.953*dbh+0.74dbh^2 for broadeaf species and Biomass/tree= EXP-1.17+ 2.119*LN(dbh) for conifers (from Brown, 1997); %C in biomass= 45% (based on Lasco and Pulhin, 2000)

In another part of the Philippines with similar vegetative cover but higher rainfall, C MAI was 6.4-7.9 MgC/ha (**Table 27**). The C accumulation in this site was higher than the previous site most likely because of the more abundant water supply. This study is also unique in that the biomass was determined directly by destructive sampling (Buante, 1997). In the same island, three fast-growing species have a C density and MAI 8-88 MgC/ha and 0.7-8.0 MgC/ha/yr, respectively (**Table 28**).

Table 27: Biomass and C density and MAI in Leyte Philippines

Species	Biomass Mg/ha	MAI Biomass	C density	C MAI
Acacia mangium	56.90	14.23	25.61	6.40
Gmelina arborea	70.20	17.55	31.59	7.90
A. auriculiformis	63.5	15.88	28.58	7.14

Biomass data from Buante (1997); % C in biomass assumed to be 45%
Age of trees= 4 years

Table 28: Carbon density and MAI of reforestation species in Leyte, Philippines (Lasco et al., 1999)

Species	Biomass (Mg/ha)	MAI Biomass (Mg/ha/yr)	C density (MgC/ha)	C MAI (MgC/ha/yr)
S. macrophylla				
1	22.62	2.06	10.18	0.93
2	19.90	1.81	8.96	0.81
3	8.52	0.77	3.83	0.35
Mean	17.01	1.55	7.66	0.70
A. mangium				
1	220.93	20.08	99.42	9.04
2	162.93	14.81	73.32	6.67
3	203.64	18.51	91.64	8.33
Mean	195.84	17.80	88.13	8.01
G. arborea				
1	165.09	10.32	74.29	4.64
2	117.01	7.31	52.65	3.29
3	89.92	5.62	40.46	2.53
Mean	124.01	7.75	55.80	3.49

A planting trials of species not commonly growing in the Philippines but with potential for reforestation was conducted in Iloilo province again with similar grass cover as the above sites (Lachica-Lustica, 1997). After 4 years, C density ranged from 0.30-70.11 MgC/ha while C MAI was generally less than 10 MgC/ha/yr (**Table 29**). In contrast, adjacent grassland area has only 1.68 MgC/ha.

Table 29: Biomass and C density and MAI in Iloilo province, Philippines

Species	Mean dbh (cm)	Biomass Mg/ha	MAI Biomass	C density	C MAI
Acacia neriifolia	17.53	87.13	21.78	39.21	9.80
A. holosericea	11.92	34.40	8.60	15.48	3.87
A. crassicarpa	18.91	155.79	38.95	70.11	17.53
A. aulacocarpa	12.99	56.36	14.09	25.36	6.34
Leucaena diversifolia	3.28	0.66	0.16	0.30	0.07
Casuarina cuminghiana	3.76	3.21	0.80	1.44	0.36
C. equisitifolia	7.77	15.55	3.89	7.00	1.75
Eucalyptus citrodora	12.14	52.41	13.10	23.58	5.90
E. cloeziana	11.61	48.27	12.07	21.72	5.43
E. pellita	10.36	33.99	8.50	15.30	3.82
E. tereticornis	11.76	49.87	12.47	22.44	5.61

DBH data from Lachica-Lustica (1997); age of trees= 4 years; biomass computed using the equation Biomass/tree in kg= 21.297-6.953*dbh+0.74dbh^2 for broadeaf species and for conifers Biomass/tree= EXP-1.17+ 2.119*LN(dbh) (from Brown, 1997); %C in biomass= 45% (based on Lasco and Pulhin, 2000)

In terms of long term C sequestration after reforestation, mahogany and dipterocarp trees planted about 80 years ago is estimated to contain 126-286 MgC/ha with an MAI of 1.57-3.57 MgC/ha/yr (**Table 30**). These density and MAI are lower than the above results because mahogany and dipterocarp trees are relatively slow growing species.

Table 30: C density and MAI of reforestation areas 80 years after planting in Mt. Makiling, Philippines

			Biomass	Annual	C density	MAI
Species	Age (yrs)	Number		rate	Mg/ha	Mg/ha/yr
Sweitenia macrophylla 1	80	802	564.92	7.06	254.21	3.18
Sweitenia macrophylla 2	80	405	634.99	7.94	285.75	3.57
Parashorea malaanonan+ Anisoptera thurifera	80	569	536.12	6.70	241.25	3.02
Parashorea malaanonan+ Dipterocarpus grandiflorus	80	701	279.14	3.49	125.61	1.57

Note: age and dbh data from Sakurai *et al*., 1994; biomass computed using the equation Biomass/tree in kg= EXP{-2.134+(2.53*LNdbh)} (from Brown, 1997); %C in biomass= 45% (based on Lasco and Pulhin, 2000)

Silvicultural treatments, like fertilization, weeding and mycorrhizal inoculation, increase the growth of trees and thus enhances the rate of C sequestration. In degraded areas in Surigao del Sur, Philippines, the inoculation of mycorhizae increase C density by 32-237% compared to uninoculated treatments (**Table 31**). In another area of the country, mycorrhizal inoculation increased C density and MAI by 43-169% (**Table 32**).

Table 31: Effect of mycorhizal inoculation C density and MAI of tree plantations in Surigao del Sur, Phillippines

Species/ Treatment	Age (yrs)	Diameter (cm)	Biomass Mg/ha	MAI Biomass Mg/ha/yr	C density MgC/ha	C MAI MgC/ha/yr
Pinus caribaea						
Uninoc	2	6.11	15.97	7.98	7.18	3.59
Inoc	2	9.17	37.74	18.87	16.98	8.49
		% Difference	136			
Eucalyptus deglupta						
Uninoc	2	4.15	5.76	2.88	2.59	1.30
Inoc	2	6.3	7.63	3.81	3.43	1.72
		% Difference	32			
Eucalyptus deglupta						
Uninoc	3	9.435	23.96	7.99	10.78	3.59
Inoc	3	14.26	80.69	26.90	36.31	12.10
		% Difference	237			

Diameter data from dela Cruz (1999); No of trees= 1111/ha
Allometric equation for P. caribaea: Y (kg)= exp{-1.170+2.119*ln(D)}; for E. *deglupta*: Y (kg)= 21.297-6.953(D)+0.740(D^2) (Brown, 1997)

Table 32: Effect of mycorhizal inoculation C density and MAI of tree plantations in Tarlac, Phillippines

Species/ Treatment	Age (yr)	Diameter (cm)	Biomass Mg/ha	MAI Biomass	C density (MgC/ha)	C MAI MgC/ha/yr
Acacia auriculiformis						
Uninoc	2	6	6.91	3.45	3.11	1.55
Inoc	2	7	9.87	4.94	4.44	2.22
		% Difference	43			
Casuarina equisitifolia						
Uninoc	2	2.7	2.83	1.41	1.27	0.64
Inoc	2	4.3	7.58	3.79	3.41	1.71
		% Difference	169			

Allometric equation for C. equisitifolia: Y (kg)= exp{-1.170+2.119*ln(D)} (Brown, 1997)
Allometric equation for A, auriculiformis: Y (kg)= 21.297-6.953(D)+0.740(D^2) (Brown, 1997)

In Indonesia, a reforestation project in Sumatra produced C density of 39-76 MgC/ha and a C MAI of 4.9-6.9 MgC/ha/yr (**Table 33**). On the other hand, a reforestation project in Bogor produced a C density and MAI of 162-256 MgC/ha and 3.6-8.0 MgC/ha/yr (**Table 34**). These C densities are much higher than the site in Sumatra because the former is much older. However, the rate of C accumulation is comparable.

Table 33: C density and MAI of reforestation species in Sumatra, Indonesia

Species	**Age (yr)**	**Number Per ha**	**Biomass Mg/ha**	**Annual Rate Mg/ha/yr**	**C density MgC/ha**	**MAI MgC/ha/yr**
Sweitenia macrophylla	11	940	169.24	15.39	76.16	6.92
Acacia mangium	11	912	157.34	14.30	70.80	6.44
Peronema canescens	8	1016	87.49	10.94	39.37	4.92

Age, dbh and number per ha data from Sakurai *et al*., (1995)
Allometric equation used to estimate biomass: Biomass per tree (kg)= EXP{-2.134+(2.53*LN(dbh)} from Brown, 1997.

Table 34: C density and MAI of a reforestation species in Bogor, Indonesia

Species	Age (yr)	Number	Biomass	Annual rate	C density MgC/ha	MAI Mg/ha/yr
Sweitenia macrophylla	45	666	359.02	7.98	161.56	3.59
Dipterocarpus retusus	33	428	413.69	12.54	186.16	5.64
Shorea selanica	32	244	567.83	17.74	255.52	7.99

Age, dbh and number per ha data from Sakurai et al., (1995)
Allometric equation used to estimate biomass: Biomass per tree (kg)= EXP{-2.134+(2.53*LN(dbh)} from Brown, 1997.

In Malaysia, afforestation projects have been conducted in two degraded soils: BRIS (162,000ha) and tin tailings (113,000ha) (Amir *et al*., 1994). BRIS soils ("beach ridges interspersed with swales") form an almost continuous belt in the east coast of peninsular Malaysia. While tin tailing soil is a waste product of tin mining. Soil composition is mainly sand, with low nutrient status, inferior water and nutrient-holding capacity, and poor structure. The growth rates are expected to be lower under such soils. Results of afforestation trials show that most species accumulate less than 4 MgC/ha/yr while C density ranged from 7-261 MgC/ha depending on the species and age (**Table 35**).

Table 35: estimated above ground biomass of afforestation sites in Malaysia

Species	Stand age	MAI dbh (cm)	dbh (cm)	Biomass (Mg/ha)	C density MgC/ha	Biomass MAI Mg/ha/yr	C MAI Mg/ha/yr
Tin Tailing							
1. Sandy							
Acacia aulocarpa	27	0.85	22.95	100.59	45.27	3.73	1.68
A. auriculiformis	32	0.78	24.96	123.51	55.58	3.86	1.74
A. mangium	4	2.87	11.48	15.60	7.02	3.90	1.76
Pinus caribaea	26	0.76	19.76	69.14	31.11	2.66	1.20
P. elliotii	33	0.59	19.47	67.00	30.15	2.03	0.91
Casuarina equisitifolia	30	0.78	23.4	98.92	44.52	3.30	1.48
2. Sandy slime							
A. auriculiformis	30	1.24	37.2	314.67	141.60	10.49	4.72
A. richii	28	1.02	28.56	170.53	76.74	6.09	2.74
P. merkusii	32	0.87	27.84	142.95	64.33	4.47	2.01
P. caribaea	30	1.22	36.6	255.24	114.86	8.51	3.83
3. Slime							
A. auriculiformis	32	0.99	31.68	217.48	97.87	6.80	3.06
Paraserianthes falcataria	30	1.63	48.9	580.32	261.14	19.34	8.70
Fagraea fragrans	30	0.47	14.1	28.15	12.67	0.94	0.42
BRIS soils							
A. mangium	8	2.6	20.8	78.73	35.43	9.84	4.43
Hopea odorata	6.5	0.72	4.68	1.99	0.89	0.31	0.14
Araucaria cunninghamii	29	0.65	18.85	62.56	28.15	2.16	0.97
P. caribaea	30	0.92	27.6	140.35	63.16	4.68	2.11
P. merkusii	24	0.92	22.08	87.47	39.36	3.64	\1.64
P. oocarpa	24	0.91	21.84	85.47	38.46	3.56	1.60
C. equisitifolia	8	2.74	21.92	86.13	38.76	10.77	4.85

Age and dbh MAI data from Amir *et al*., 1995
Spacing assumed to be 5 x 5 m (400 trees per ha)
Biomass C content= 45%
Allometric equation used to estimate biomass: Biomass per tree (kg)= EXP{-2.134+(2.53*LN(dbh)} from Brown, 1997.

Conclusions

On the basis of the above review of C budgets following disturbance and restoration of forest lands in Southeast Asia, the following conclusions emerge:

- C density in above-ground biomass declines by at least 50% after logging
- Deforested areas covered with grasses and annual crops have C density that are typically less than 40 MgC/ha, much lower than natural forests
- Conversion of natural forests to tree plantations and perennial crops reduce C density by at least 50% compared to natural forests
- Reforestation/afforestation activities in degraded areas increase C density compared to the original grassland cover; the rate of increase vary depending on the species planted and the site conditions
- Silvicultural treatments such as mycorrhizal inoculation can significantly increase the rate of C accumulation
- Most studies to estimate C density relied on allometric equation derived globally rather than from within the country
- SOC declines with deforestation and conversion of natural forests
- There is still limited data available on C dynamics and most of those available are on above-ground C; there is less data on SOC and below-ground biomass

In spite of the rise in available information in the last few years, there are clearly much more that needs to be done. It is noteworthy that many research results are found in “grey” literature. In addition, much of the biomass and C data are based on extrapolation rather primary data collection. The following research topics need to be further pursued:

- Generate country-specific allometric equation for biomass and C density
- Assessment of C dynamics associated with key land use/cover change
- Comprehensive C stocks assessment of LUCF activities including above and below ground biomass and soils
- Effects of silvicultural treatments and management practices on C budgets of forest ecosystems

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9. Database and Website Development

A database of scientists and reports on land use change and the terrestrial carbon cycle in Asia has been developed as part of this APN project. This documentation is only available via the web or on CD upon request to the GCTE IPO. The website also makes available the summary contributions, commissioned studies, and meeting presentations including power point shows. The site will be used to further foster interaction among the various groups and as a central location to find topical information and funding opportunities. The homepage will be further developed and currently can be found at:

http://gcte.org/Kobe-Meeting-Index.htm

10. Budget

Requested to APN

Travel and accommodation for participants from APN member countries	**$30,880**
Commissioned Studies	**$20,000**
Others	**$10,100**
TOTAL REQUESTED	**US$60,980**

Cost Sharing

GCTE – Cost of two participants from outside the APN region	**$ 4,000**
GCTE – Coordinating Cost (commissioned Studies, workshop, book)	**$ 4,000**
GCTE – Web Development	**$ 2,000**
IAI and ENRICH will be invited to participate on a self-funded basis	**$ 5,000**

11. Funding Opportunities

PROJECT TITLE: **Assessments of Impacts of and Adaptation to Climate Change in Multiple Regions and Sectors (AIACC)**

GEF IMPLEMENTING AGENCY: United Nations Environment Programme (UNEP**)**
EXECUTING AGENCIES: Global Change System for Analysis Research and Training (START), Third World Academy of Sciences, in collaboration with the Inter-governmental Panel on Climate Change
TRY OR REGION: Global
ELIGIBILITY: Only countries as eligible under paragraph 9(b) of the GEF Instrument.
GEF FOCAL AREAS: Climate Change
GEF PROGRAMMING FRAMEWORK: Enabling Activities

Summary

Assessment of climate change impacts and adaptation options for the most vulnerable regions and sectors in developing countries will be targeted through and open process based on scientific merit. Forty to fifty individual research activities are planned. The targeted regions and sectors represent gaps in the current assessments. This project will develop capacity to address these gaps through training, technology transfer, and interaction with international assessment teams.

Background

The Earth's climate is changing: the Earth is becoming warmer, with the last decade being the warmest in more than 600 years, and precipitation patterns are changing, with an apparent increase in the incidence of floods in recent decades. Observed climate changes cannot be explained by natural phenomena alone, and the weight of scientific evidence suggests that there is now a discernible human influence on climate. The question is not whether the Earth's climate will change in the future, but rather by how much, when, and where, i.e., magnitude, timing and regional patterns.

The projected changes in climate are predicted to have adverse consequences for many developing regions of the world, particularly for their water resources, agricultural productivity, natural marine and terrestrial ecological systems, coastal zones, human settlements, and human health. Developing countries, particularly the poor within them, are the most vulnerable, primarily because they lack the technical, financial, and institutional capacity to evaluate the impact of climate change and the ability to develop and implement cost-effective response and adaptation measures.

Recognizing concerns about global climate change, and the need to develop an international consensus on the state of understanding, the World Meteorological Organization (WMO) and the United Nations Environment Programme (UNEP) established the Intergovernmental Panel on Climate Change (IPCC) in 1988. The IPCC's role is to assess scientific, technical, and socio-economic information relevant to understanding the risk of human-induced climate change, based on published, peer-reviewed literature.

IPCC assessments have evaluated the potential changes in climate and the impacts of climate change on socio-economic sectors and ecological systems on a regional scale. There is a clear recognition of the relative dearth of detailed information for many developing countries concerning the impact of climate change on water resources, agricultural productivity, forestry, fisheries, human health, human settlements, and natural ecological systems. In addition, it is well recognised that many developing countries lack the observational and modelling capabilities to study these issues. Hence, there is an urgent need to enhance the scientific and technical capacities in many developing countries to assess the impacts of climate change, and to design cost-effective adaptation response measures, which are needed to formulate national policy options and prepare national communications.

In this proposal, we first review the state of knowledge drawn from the IPCC and Stage I national communications (Reference Documents 1 and 2) to identify research priorities for the project (Reference Document 3) and assess which methods will be used in the studies (see Reference Document 4 and 5). We then address how the program will be implemented, including the criteria that will be used to select countries and a management plan.

A list of selected UNFCCC decisions relating to Adaptation and capacity building are attached as an Annex. Climate Change Enabling Activities call for the assessment of adaptation to climate change. National activities to cope with current climate variations and national scientific effort towards sustainable development and ordinary donor support forms associated baseline activity but global assessment and science capacity development is incremental to this effort.

State of Knowledge on Vulnerability of Developing Countries to Climate Change

This brief summary of the state of knowledge on the vulnerability[4] of developing countries to climate change is based on the Draft Third Assessment Report of the IPCC.

Developing countries appear to be more vulnerable to climate change than developed countries. *This is because impacts on food production, water resources, and human health are potentially more adverse in the low latitudes than elsewhere, which is where many developing countries are located. Also, adaptive capacity is lower in developing countries than in developed countries as a consequence of fewer financial resources, poorer infrastructure, lower levels of education, and lesser access to technology. For example, adapting to the threat of sea level rise will be more challenging in developing countries. In addition, populations in developing countries face substantial and multiple stresses, including rapidly growing demands for food and water, large populations at risk to hunger and infectious diseases, degradation of land and water quality, and other sources that may amplify stresses from climate change, or be amplified themselves by climate change*.

Africa is generally considered to be highly vulnerable to climate change because it has a high exposure and sensitivity to climate change, a quite limited adaptive capacity (in its current state of development), and large portions of its population subject to other stresses that could interact with climate change to further detract from their well-being.

Asia spans low to high latitudes and quite different socioeconomic conditions, therefore, the relative vulnerability of countries in this continent to climate change varies considerably. The relatively high exposure of some of its countries and high population densities could leave many regions highly vulnerable.

Latin America is characterized by a high sensitivity to climate extremes such as the El Niño Southern Oscillation, and an increasing environmental deterioration resulting from the misuse of land. It also has widely disparate economic conditions across countries and within countries. Its high exposure and limited adaptive capacity make many regions and peoples vulnerable to climate change.

Small island states are highly vulnerable to climate change because of their small size (and low elevation in many cases), relative isolation, high population growth rates, and amounts of poverty, which limit their ability to adapt.

Considering the number of regions and sectors, 45 assessment activities are needed to create a critical mass for sustainability. It is noted that this number is very small compared to the experts from Annex I countries that are active in adaptation assessment. Reference Document 1 provides a more detailed discussion of the state of knowledge on vulnerability of developing countries to climate change and Reference Document 2 lists climate change impact sectors addressed in those national communications that have been submitted.

Rationale and Objectives

The project supports enabling activities by developing science capacity and assessment techniques and information targeted at the most vulnerable regions and sectors where capacity is needed. This proposed global project would fund a number of studies assessing the impacts of climate change on a range of socio-economic sectors and ecological systems at the regional and national scale and the development of a range of adaptation response options. Science capacity building is a primary aspect of the project.

This project will enhance the comprehensiveness of impact and adaptation assessments using a consistent methodological approach (Carter et al., 1994) by supporting regionally focussed research to be undertaken by developing country experts, often in partnership with

[4]. The IPCC defines vulnerability as, “the extent to which climate change may damage or harm a system; it depends not only on a system’s sensitivity, but also on its ability to adapt to new climatic conditions” (Watson et al., 1996).

developed country experts. This will enhance regional scientific capacity and provide expertise available to governments, the private sector, and other entities that are developing national and subnational, sectoral and multisectoral policies and adaptation plans. The results will include expanded socioeconomic and other data, training and methodologies adapted to developing country regions. These results will then serve as reference impact scenarios and model adaptation strategies in the United Nations Framework Convention on Climate Change (UNFCCC) national communications. Countries can further expand or differentiate nationally focussed impact and adaptation effort using these reference cases and the methodologies developed in further regional/national Stage II adaptation studies.

This proposed effort will also contribute to global assessment activities in collaboration with IPCC by enabling selected developing countries, chosen on the basis of several criteria discussed in Section 7, Selection Criteria, to develop technical capacity and apply it to the assessment of climate change impacts and options for adaptation.

Research Needs to be Targeted

The proposed multi-sectoral/multi-stress/multi-country research will cover a number of research priorities concerning vulnerability of key sectors affecting human development. It will also address key policy relevant questions, including:

- Where and to what extent are water resources at risk?
- How vulnerable is food security in developing countries?
- How much of a risk to human health does climate change pose in developing countries?
- How vulnerable are societies on small island states?
- What coastal areas are at substantial risk from sea level rise?
- How vulnerable are natural ecosystems?

The research will also address a number of cross-cutting factors that are important for assessing vulnerability, including:

a) *Changes in baseline socioeconomic conditions*. Changes in socioeconomic conditions, such as population, income, institutions, and technology can substantially affect vulnerability and need to be assessed.
b) *Integration of related impacts*. Studies need to integrate related sectors, such as water supplies and irrigated agriculture, where a change in one sector can substantially affect the related sector. In addition, studies need to be integrated across borders, e.g., international river basin studies should include all nations in the basin.
c) *Adaptive capacity*. Studies need to consider the potential for adaptation to offset adverse effects of climate change and take advantage of positive effects of climate change. Only when adaptive capacity is considered can vulnerability be determined.
d) *Assessment of effectiveness, feasibility, and costs of proactive adaptation*. Adaptations that address vulnerabilities to climate change through proactive (anticipatory) measures need to be assessed, and the capacity of developing countries to assess vulnerability needs to be enhanced. Capacity building should include providing training to enable country experts to undertake the assessment (e.g., data collection, climate modeling, impacts modeling) themselves. A key consideration is to provide training to those who will be in a position to continue research and participate in future assessments. (See Reference Document 3 for a more detailed discussion.)

Assessment Methodology

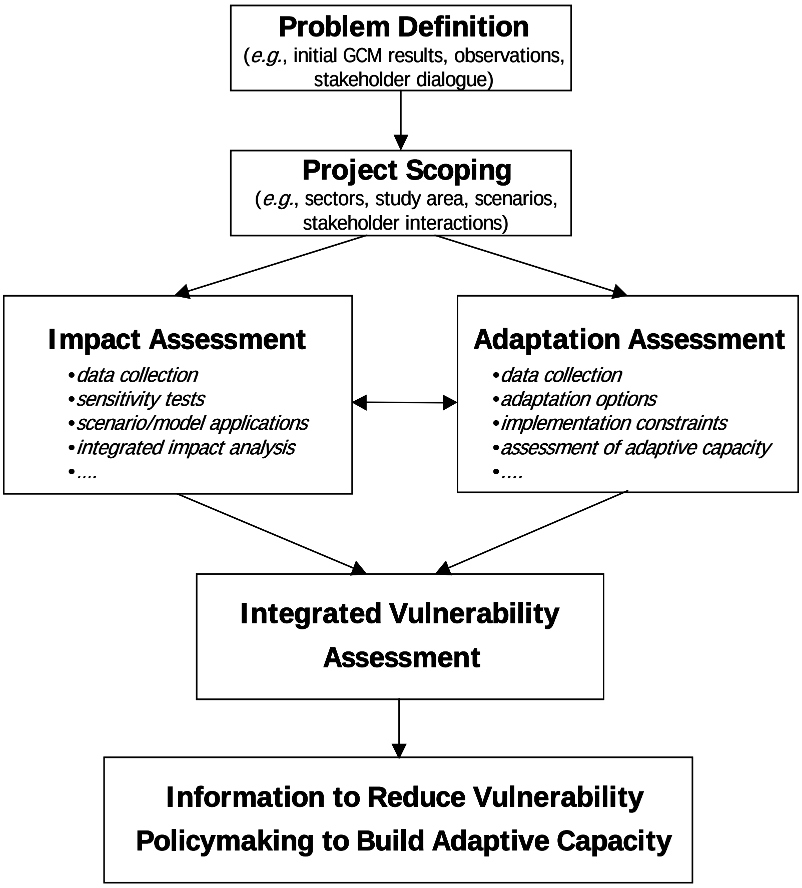
The emphasis will be on research approaches that result in building adaptation capacity to climate change impacts. Methods will build on the IPCC Technical Guidelines for Assessing Climate Impacts and Adaptations (Carter et al., 1994), which have been tested in a number of case studies; e.g., the US Country Studies Programme (Benioff et al., 1996) and the UNEP country studies (UNEP, 1998). They have been expanded on a sector-by-sector basis in the UNEP Handbook on Methods for Assessing Climate Change Impacts and Adaptations Strategies (Feenstra et al., 1998). Methods for developing and applying climate change scenarios are reported in the IPCC Task Group on Climate Impact Assessments (TGCIA)

Guidelines on the Use of Scenario Data for Climate Impact and Adaptation Assessment (http://ipcc-ddc.cru.uea.ac.uk/). Methods of adaptation assessment are discussed in detail in Chapter 18 (currently in draft) of the IPCC Third Assessment Report. (See Reference Document 4 and 5 for a more detailed discussion.)

Where feasible, outputs of various regional-scale climate model projections will be used to develop scenarios for impact and adaptation analyses. Where possible, a comparison of model simulations of past and present climate with meteorological data will be used to assess the ability of the models to simulate regional changes in climate. An array of scenarios, simulation tools, and methods will be identified for the project as a whole; these will help to encourage comparability, communication, and cohesion across the entire project. It should be emphasized, however, that specific methods will vary according to the countries and regions that will be targeted in the project. One of the first tasks will be to identify from the array of methods those that will be appropriate for each individual study. A Technical Committee made up primarily of project researchers and other climate change impacts and adaptation experts will provide advice on methods and training activities. Two or three preferred climate models may be recommended to develop more consistency in scenarios.

A general framework for conducting climate impact and adaptation assessments consists of seven main steps of analysis:

a) define problem (including the study area, its sectors, etc.);
b) select method of assessment most appropriate to the problems;
c) test methods and conduct sensitivity analyses;
d) select and apply baseline and climate change scenarios;
e) assess biophysical and socioeconomic impacts;
f) assess autonomous adjustments; and
g) evaluate adaptation strategies.



The field of climate change vulnerability and adaptation assessment is now evolving to realize that these steps may need to be addressed simultaneously, rather than sequentially. It is especially useful to assess the potential impacts of climate change and the relevant adaptation capacity in parallel throughout the project. Another emphasis will be on the integrative aspects across sectors, countries, and regions. A key element will be the involvement of all key stakeholders at the initiation of and throughout all stages of each study. Our proposed general research project framework is shown in the figure.

Expected results are:

a) Guidance on methodologies
b) Review and modification of methods as appropriate for each region/sector
c) Consistent methodologies for use in the activities
d) A more comprehensive global assessment of climate change impact and adaptation

Selection Criteria

Assessment activity awards will be determined under an objective process that evaluates each proposal against a set of criteria that contains both required and recommended elements. The proposed criteria are described below.

Required Elements:

Consistency with IPCC TAR needs and scientific merit. Proposals need to identify the linkages to the research needs identified in the TAR, either on a region or sector basis, and have sufficient scientific merit for consideration.

Focus and orientation of each study should be clear and well defined. Proposals must clearly describe the scope and objectives of the research and identify the key elements and issues for scientific investigation.

Integrated and comprehensive analyses. Proposers should ensure that the analyses consider key relevant linkages both across regions, sectors, and disciplines. For example, an assessment of agriculture might be incomplete without proper consideration and integration of changes in water supply and use. Studies should examine, where appropriate, changes in baseline socioeconomic conditions and the effect of autonomous adaptation.

Country endorsement. To receive awards, proposers must provide documentation that the study is approved and endorsed by the relevant national governments. *This is not, however, a requirement for proposal submission, and can be addressed following study initiation.*

Publications. Proposals must include efforts to publish and disseminate findings in peer-reviewed literature. Contributions to the peer-reviewed literature should be a stated objective of the research.

Capacity building. Strengthening the technical capacity within countries is a key element of this project. There are many ways to support capacity building, for example, training and education, creating shared databases and models, outreach and grassroots communication, and information and expertise exchange. Each proposal should identify how it contributes to capacity building and, if appropriate, describe how that capacity might be maintained over time.

Climate change and reference scenario development. Proposals should describe the approach used to develop and define relevant climate change and reference (baseline socioeconomic) scenarios. As relevant climate change data are readily available through the IPCC Data Distribution Centre, studies should aim to develop scenarios based on at least three of the available GCMs. In developing both reference and climate change scenarios, studies should consider using at a minimum, the A2 and B2 storylines from the IPCC's Special Report on Emissions Scenarios (SRES) report.

Recommended Elements

Co-funding potential. Proposals should identify if additional funding from other sources has been or could likely be obtained for the study.

Interdisciplinary and/or multi-country collaboration. Interdisciplinary and multi-country teams from developed and developing countries are encouraged. This lays the foundation for increasing the breadth and integration of the research and the exchange of technical information.

Stakeholder benefits and policy relevance. Proposers are encouraged to clearly identify stakeholder benefits which should lead to policy-relevant results, particularly where there is potential to identify and assess potential adaptation strategies and policies.

Contribute to national communications and future IPCC reports. Proposers are encouraged to identify linkages that can materially contribute to the national communications of one (or more) countries and to the Fourth Assessment Report of the IPCC.

Adaptation strategies and coping mechanisms. Proposers are urged to consider appropriate adaptations and coping mechanisms in their analyses.

Other Factors

Other factors that may be considered in deciding on study awards include:

a) the assessed likelihood of the study's success and quality of the research,
b) distribution of awards across targeted regions, and
c) how the studies complement one another and build scientific understanding either regionally or sectorally.

Link to Ongoing GEF, IPCC, and Other Activities

Links to other GEF funded projects will be accomplished through the steering committee. Regional and national studies will build on the science capacity and findings developed in this project to accomplish more comprehensive regional studies leading to national policy and planning for adaptation. This project proposal has been developed in close coordination with the UNDP project “Stage II Adaptation to Climate Change,” and the China project entitled “Targeted Research Related to Climate Change.” To ensure that regional GEF adaptation projects and national communications support are complementary, close communication will be maintained throughout project implementation so that course modifications can be made, if needed. To facilitate communication, the UNDP representative on the Steering Committee will review proposals submitted to this project so that duplication can be avoided and vice versa.

The success of the IPCC is dependent on the full participation of experts, and the availability of scientific, technical, and economic data, from all regions of the world. Due to lack of research support, the literature and knowledge base on climate change impacts in developing country regions is relatively rudimentary and the use of regionally specific climate models is still uncommon. This project will enhance the comprehensiveness of impact and adaptation assessments using a consistent methodological approach by supporting regionally focussed research to be undertaken by developing country experts.

All efforts will be made to publish the studies in the peer-reviewed literature. This will expand the peer-reviewed literature on climate impacts and adaptations assessment, particularly in areas where key uncertainties have been identified in the IPCC TAR. Researchers involved in the project will contribute to future IPCC assessment as lead authors, contributors, or reviewers and so improve the level of participation of developing country experts in IPCC assessments of climate change. They will also attend expert meetings and plenary meetings of the IPCC, as required. A comparable number of additional developing country experts, funded through this proposal, will also participate in the IPCC assessment process to further enhance capacity in developing countries.