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Climate Change Impacts in the Asia-Pacific Region
- Outcomes from the AIM Model -

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Abstract: The paper introduces the Asian-Pacific Integrated Model (AIM) and demonstrates the possible impacts of SRES and Post-SRES scenarios. The results show that the global temperature increases under SRES scenarios would be 3.1±1.1ºC in 2100, creating serious climate change impacts in some sectors and countries. Wheat productivity would decrease 34% in India and population living in Malarial area would increase 18% in China. These impacts would be recovered considerably with the mitigation of greenhouse gas emissions.

1. Introduction

The Asian-Pacific Integrated Model (AIM) is a large-scale computer simulation model for scenario analyses of greenhouse gas (GHG) emissions and the impacts of global warming in the Asian-Pacific region. This model is being developed mainly to examine global warming response measures in the region, but it is linked to a world model so that it is possible to make global estimates (Kainuma *et al*., 2001).

Recently, in order to correspond with wide rage of disciplines related with global environmental problems, a group of models called Integrated Assessment Models (IAMs) have been developed. The AIM is one of the IAMs, and has several distinct characteristics. The model:

i. integrates emission, climate and impact models,
ii. prepares both country modules for detailed evaluation at the state and national level and global modules to ensure consistency across individual modules,
iii. integrates bottom-up approaches with top-down approaches,
iv. is designed to assess alternative policies,
v. contains a very detailed technology selection module to evaluate the effect

of introducing advanced technologies,

vi. uses information from a detailed geographic information system to evaluate and present the distribution of impacts at the local level, and

vii. focuses on the Asian-Pacific region and is based on a collaborative network of international research institutes.

The AIM model is used to estimate the greenhouse gas emissions, climate changes and their impacts. The IPCC SRES storylines are quantified and provide greenhouse gas emissions forecasts. Climate changes are projected based on these emissions forecasts. As examples of climate impact assessments, crop productivity change and population living in malarial epidemic area are examined. Several mitigation scenarios show the decrease of climate impacts and corresponding impacts on economy.

2. Long-term Emission Scenarios

Future environmental conditions depend on numerous driving forces including population growth, economic development, energy supply and use, land-use patterns and a host of other human activities. These main driving forces that determine the environmental trajectories in the scenarios often also provide input to assess possible policy strategies to mitigate environmental degradation.

The IPCC SRES (2000) examined various kinds of greenhouse gas emission scenarios and characterized several future paths for analyzing mitigation and adaptation strategies to avoid serious social and economic impacts of climate change. The future evolution is highly uncertain. Scenarios are alternative images of how the future might unfold and are an appropriate tool with which to analyze how driving forces may influence future emission outcomes and to assess the associated uncertainties.

Four qualitative storylines yield four sets of scenarios called families: A1, A2, B1, and B2. The A1 storyline and scenario family describe a future world of very rapid economic growth, global population that peaks in mid-century and declines thereafter, and the rapid introduction of new and more efficient technologies. Three scenarios in the A1 family, A1B, A1FI and A1T, are used to estimate climate impacts in the subsequent sections. A1FI is a fossil intensive scenario and A1T assumes rapid technological development. A1B is a balanced scenario among A1 family. The A2 storyline and scenario family describe a very heterogeneous world. The underlying theme is self-reliance and preservation of local identities. The B1 storyline and scenario family describe a convergent world. The emphasis is on global solutions to economic, social, and environmental sustainability, including improved equity, but without additional climate initiatives. The B2 storyline and scenario family describe a world in which the emphasis is on local solutions to economic, social, and environmental sustainability. Figure 1 shows the projections of CO_2 emissions under such storylines.

These four storylines and scenarios are the basis for Business-as-Usual (BaU) scenarios. The major results are: CO_2 emission is highest in A2 scenario and lowest in B1 sustainable development scenario among the four scenarios; Energy intensity improvement is highest in B1 scenario while carbon intensity reduction is highest in A1. Although energy intensity is not steep in A1 due to adoption of carbon-free technologies, the CO_2 emissions reduction is significant.

After making BaU projections, various mitigation scenarios are developed with policies regarding energy conversion sector such as use of solar energy for electricity generation, biomass etc., energy efficient technologies in transportation sector, increase in plantation area, and so on. Different levels of stabilization of emissions such as 450 ppm, 550 ppm, 650 ppm were taken as constraints for mitigation policy scenarios

3. Climate Change Scenarios

Using the AIM model coupled with the GCM results obtained from 7 GCMs, climate responses under 6 IPCC/DRES emissions are calculated. Simulated 7 GCMs are GFDL R15a, CSIRO Mk2, HadCM3, HadCM2, ECHAM4/OPYC, CSM 1.0 and DOE PCM. 6 SRES scenarios are A1B, A1T, A1BI, A2, B1, and B2 scenarios. That is, there are 6 emission cases and 7 groups of climate parameters, 42 simulations were done and their results are shown in Figure 2. It presents the projected surface temperature change between 1990 and 2100 based on IPCC/SRES emission scenarios.

Research on climate change impact requires spatial data of future climate. To consider the spatial distribution of future climate, we use the outputs from the climate model, which were calculated using various GCMs. Since the spatial resolution of GCMs is not fine enough for direct use in impact studies, the output is interpolated spatially to generate values at a finer resolution.

Also, the AIM has a module to back-calculate suitable GHGs' emission paths, which realize prescribed atmospheric concentrations, temperature rises, sea level rises, or their changing velocities after a certain centuries (Matsuoka, 2000). The suitability of an emission path is measured by an index or several indices, such as the economic cost of emission control or the smoothness of the path, and most suitable path is found out with a mathematical optimization solver.

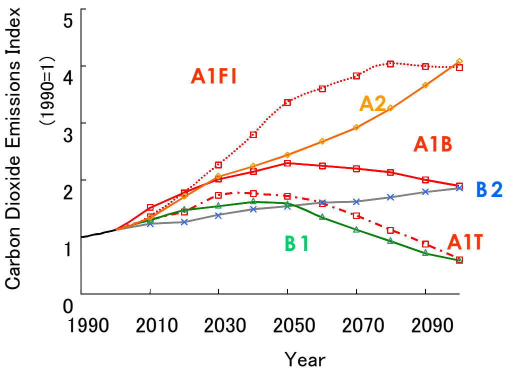

Figure 1 CO_2 emissions under IPCC/SRES scenarios.

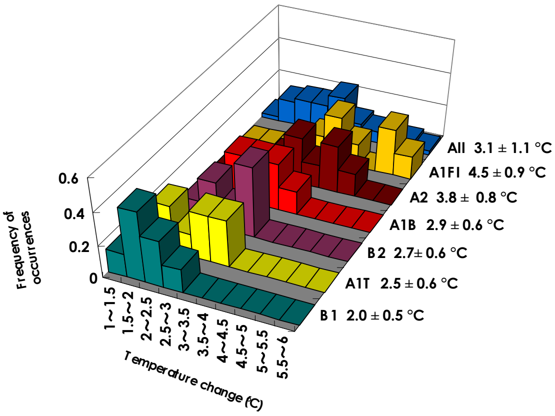

Figure 2 The earth's surface temperature change from 1990 to 2100 under IPCC/SRES scenarios.

4. Climate Change Impacts

Climate change has direct or potential impacts on water resources, agricultural production, natural ecosystems and human health, even if we do not consider the socio-economic interaction. In actual world, global trade, immigration, measures of adaptation modify direct impacts. In this way, there are two stages of impact study, i.e. direct and indirect stages (Takahashi *et al.*, 2001).

Figure 3 shows the histogram of changes of crop productivity under all emissions and climate sensitivity cases with fertilization effects. In Japan, 6.5% decrease is observed if we assume there is no CO_2 fertilization effect. The crop productivity change in India is the worst. The estimation shows the impacts would be minus 53% in India. Figure 4 shows the change of crop productivity where CO_2 fertilization is accounted. In this case the impacts could be mitigated. Even when we consider the CO_2 fertilization effect, the impact in India would be minus 34%.

Figure 5 shows the change of population ratio living in Malarial epidemic area from 1990 to 2100. In China, 18% increase is predicted. Although in China, wheat productivity would increase under the climate change, it will have a significant impact on malaria disease. In India where the impact on wheat productivity is very high, the change on malarial potential is not so high, although the impact itself is high.

The impacts of mitigation scenarios are also estimated. Figure 6 shows the global averaged temperature changes between 1990 and 2100 under mitigation scenarios where the CO_2 emissions are designed so that the CO_2 concentration approaches to some

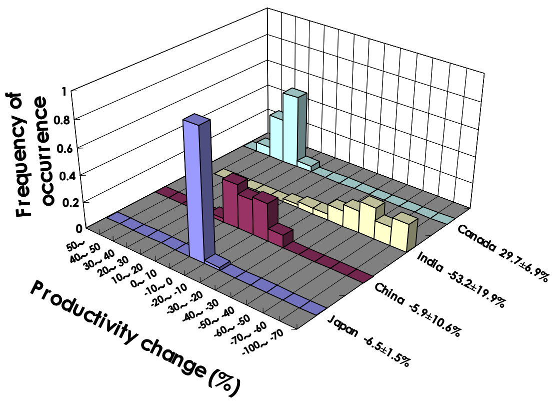

Figure 3 Wheat productivity change from 1990 to 2100 under IPCC/SRES scenarios without CO_2 fertilization effect.

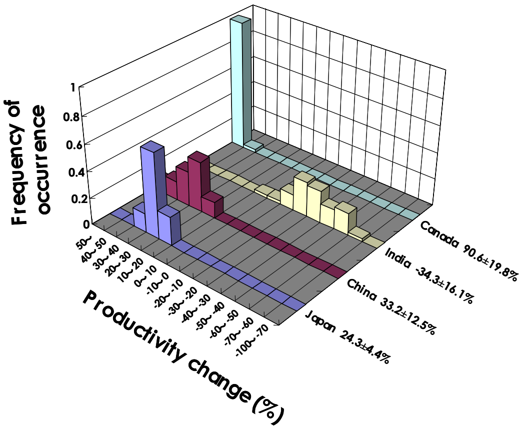

Figure 4 Wheat productivity change from 1990 to 2100 under IPCC/SRES scenarios with CO_2 fertilization effect.

prescribed concentration after the year 2150. Non-CO_2 gases emission caused by anthropogenic activities are assumed to decrease proportionally with the CO_2 emissions. For example, in the case of 450 ppm target, the mean temperature change becomes 1.7 ºC, in contrast with 3.1 ºC for all SRES cases. For 750 ppm case, three sets of scenarios: A1b, B2 and A1T has little impacts on the GDP loss, while for 450 ppm and A1FI case, the impact is the largest and it would be 4.1%.

Potential wheat productivity change in India under these constrained emission scenarios are shown in Figure 7. 34% decrease in case of no restriction of CO_2 emission

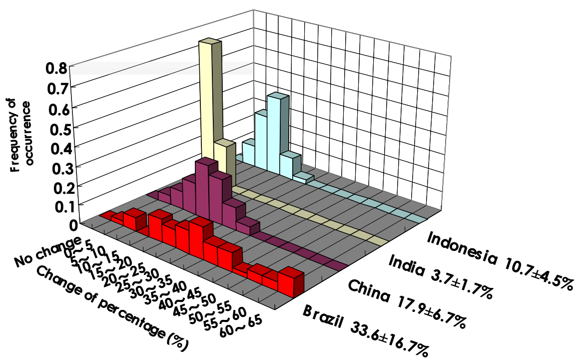

Figure 5 Change of country population ratio living in Malarial epidemic areas from 1990 to 2100 under IPCC/SRES scenarios.

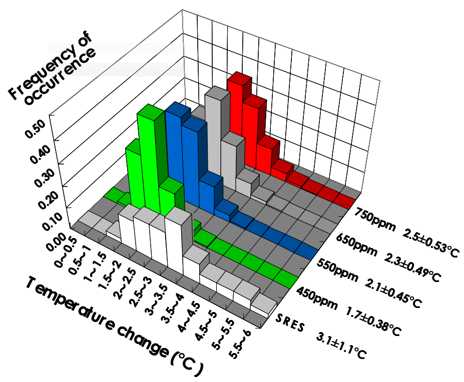

Figure 6 The earth's temperature change in India from 1990 to 2100 under mitigation scenarios.

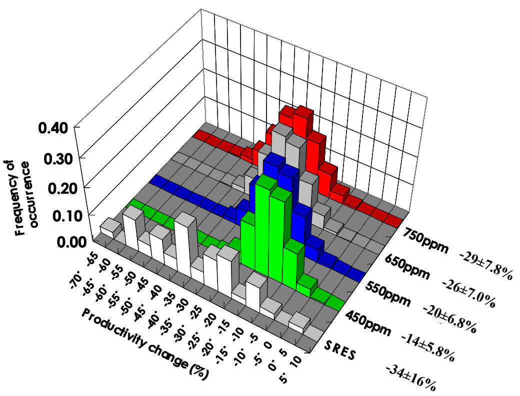

Figure 7 Wheat productivity change in India with CO_2 fertilization effect from 1990 to 2100 under mitigation scenarios.

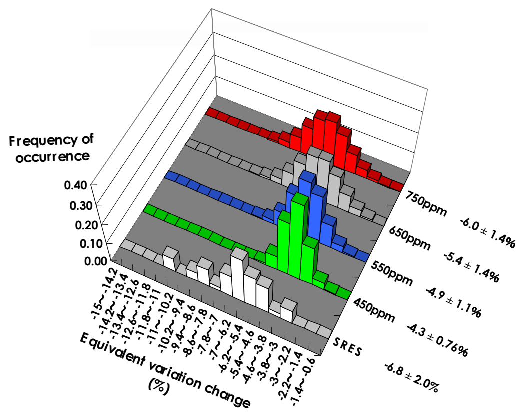

Figure 8 Recovery of economic welfare decrease in India from 1990 to 2100 by crop productivity change under mitigation scenarios.

becomes 14% decrease in case of 450ppm target case, and 20% decrease in case of 550ppm case.

Coupling with theses direct impact modules with economic adjustment mechanism, which reflects domestic and world market systems, we can estimate the change of economic indices caused by these climate impact. Figure 8 shows an index of economic welfare change. Equivalent variation change is calculated under the constrained CO_2 emission scenarios. In India's case, 6.8% decrease without no mitigation, and 4.3 % decreases with 450ppm target.

5. The AIM Approach and Its Policy Needs

In the previous sections, we introduced the AIM model and some examples of the outputs. The model has been developed in order to comprehend and assess the relationship between human society and the natural environment especially in the field of climate change. Recently, such kind of models, called Integrated Assessment Model (IAM), is developed intensively. The need of integrated assessment on climate change issues is requires on many occasions. Some needs are quite clear, while others are not so obvious. However, these needs increase quickly. Three major needs were identified and the AIM has been designed with a unique structure so that it can be used to meet these needs:

5.1 To identify incentives for policy measures of climate change

Many of the countries in the region need concrete estimates of climate change damage, short-term co-benefits and small economic impacts of policies in order to increase the incentives for policy adoption. To meet his need, they requires integration of emission and impact studies, global warming and local environmental studies, and emission and economic studies. Some topics belong to this category are:

- To compare costs and benefits of introducing global warming abatement policies,
- To identify vulnerable regions and sectors to climate change, and
- To identify and estimate secondary effects of global warming abatement policies on regional and local environments.

5.2 Systematic assessment of climate change mitigation policy

Systematic and consistent assessment of policy options is essential for policy makers to be able to make sound decision. Assessment needs to be made on the technical feasibility for GHG reduction, the combined effects of various policies, the consistency of policy combinations and approaches to GHG reductions. To meet these needs requires integration of technology and economic models, top-down and bottom-up models, energy and land-use models and CO_2 emission and other GHG emission models. Some topics belong to this category are:

- To asses technological and economical feasibility for GHG reduction considering costs and markets,
- To assess consistency of mitigation policies, such as increasing biomass use and land availability, and
- To assess comprehensive approaches for GHG reduction including energy saving, introduction of renewable energy, reforestation, methane emission reduction and CO_2 disposal.

5.3 Long-term policy option assessment

Consistent method to discuss on the atmospheric stabilization target is needed. Compatible short and long-term policies are required, and their feedback loops and interactions among energy use changes and the social and economic systems must be assessed. Some topics belong to this category are:

- To prepare a common platform to discuss on long-term targets of atmospheric stabilization.
- To compare short-term mitigations with long-term adaptation policies.
- To assess the long-term interaction among mitigation policies, natural and socio-economical impacts of climate change, and other global issues, such as

economic development, food problem and so on.

6. Concluding Remarks

Several anthropogenic GHG emission projections based on business-as-usual scenarios and mitigation scenarios were examined by AIM model. It is an urgent task to take actions to climate change, as it is an irreversible process and once it happens, the probability is very high that it will bring a positive feedback to enlarge its impacts. It is necessary to consider the many uncertainties of human activities such as population growth, economic development, and technological innovation as well as the uncertainties of natural processes to estimate future CO_2 emissions and to make plans for climate stabilization. Scenario approach is a practical one to analyze the policy options under such uncertainties. Further studies are required to reduce uncertainties to estimate environmental impacts of climate change and effects of mitigation and adaptation strategies.

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