APEIS

APEIS-IEM Web sites :
http://www-basin.nies.go.jp/english/project/iem/index.html

Independent Administrative Institution
National Institute for Environmental Studies

TECHNICAL SUMMARY

IEM

Integrated Environmental Monitoring

Asia
Pacific
Environmental
Innovation
Strategy project

APEIS

June 2005

APEIS-IEM Technical Summary

1. What is APEIS-IEM?

Rapid population growth and economic development in the Asia-Pacific region have resulted in serious local, national, and regional environmental problems such as floods; droughts; forest fires; dust storms; air, water and soil pollution; desertification; salinization; water resource depletion; and soil loss. Such problems are serious constraints to sustainable development in the region. In order to cope with these problems, a system of integrated environmental monitoring is indispensable.

Since 2001, the APEIS-IEM sub-project has developed a system of integrated environmental monitoring (IEM) that can be used to detect, monitor, and assess environmental disasters and degradation and their impacts in the Asia-Pacific region (Figure 1). By using IEM, we try to accurately describe the present conditions and trends of ecosystem services, as well as the pressures and impacts upon them, to contribute to policy making for sustainable development (SD).

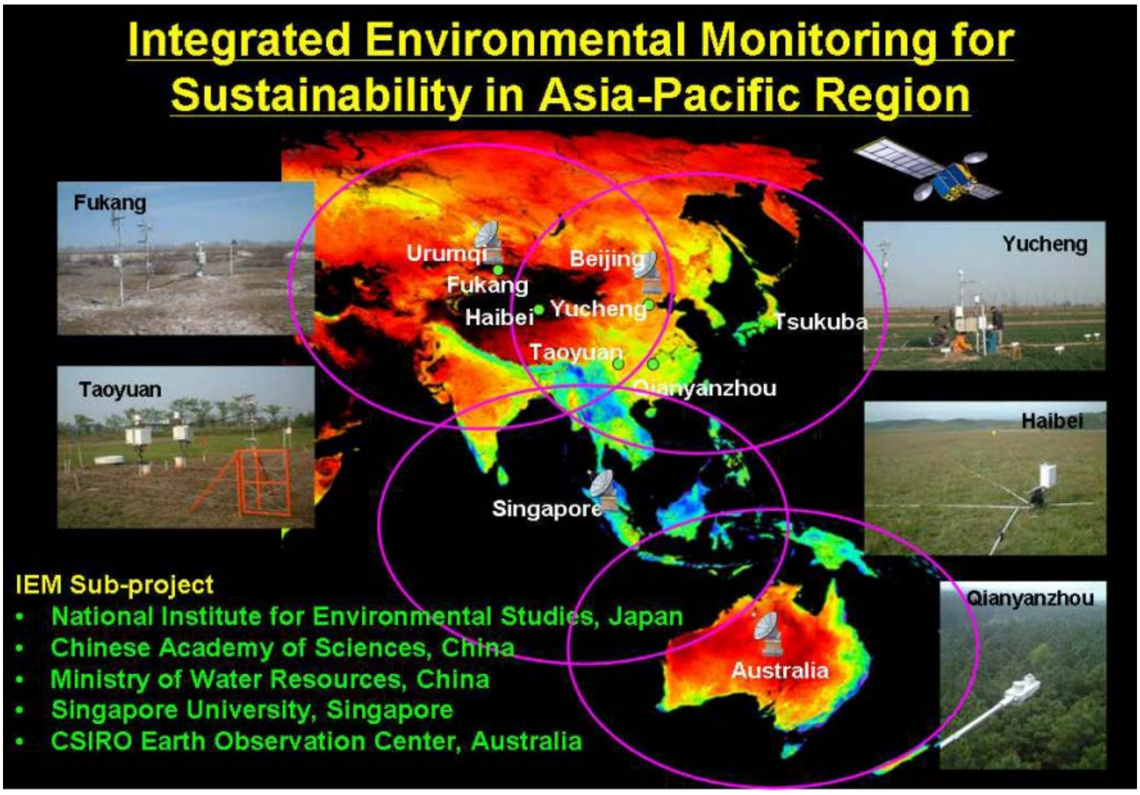

Figure 1 APEIS Integrated Environmental Monitoring (IEM) network in the Asia-Pacific Region

IEM provides ground-validated remote sensing data and images from MODIS (Moderate Resolution Imaging Spectrometer), and derived ecological indices such as water deficit index, dust storm index, land surface temperature, incidence of forest fires, and land productivity indices, as well as CO_2 sink areas. The APEIS-IEM sub-project has also developed an integrated model to assess the state of and changes in ecological goods and services, such as land use or cover changes, fresh water resources, carbon and nitrogen cycles, and food production. With this model, the trade-off between ecosystem services and the effectiveness of policies for sustainability can be demonstrated (Figure 2).

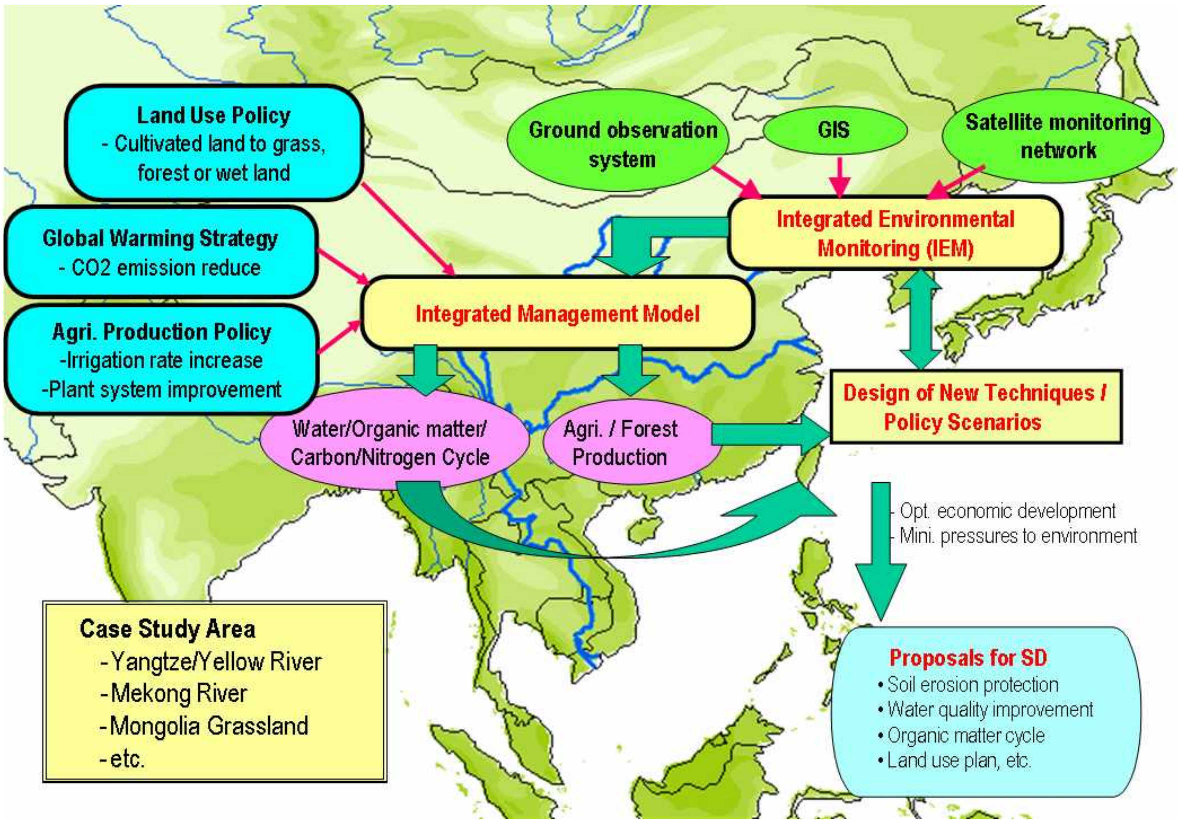

Figure 2 IEM tries to describe the present conditions and trends of ecosystem services and to demonstrate the trade-off between ecosystem services and the effectiveness of policies for sustainability

2. Current Progress and Contributions of APEIS-IEM

The integrated monitoring network system established by IEM covers most of the Asia-Pacific region, and continuously provided real-time remote-sensing and ground measurement data throughout 2004. The IEM network system is composed of two sub-systems: the APEIS-MODIS network and the APEIS-FLUX network. The APEIS-MODIS network includes four MODIS data receiving stations and MODIS data analyzing centers. Many environmental indices, such as MOD09 for land surface reflectance, MOD11 for land surface temperature, MOD12 for land cover, MOD13 for vegetation index, MOD15 for leaf area index, and MOD17 for net primary production, are continuously developed by the MODIS data-processing system. APEIS-FLUX, a real-time monitoring system covering five sites in different ecological systems in China, continues to provide real-time ground observation data, such as eddy-correlation flux measurements of sensible heat, latent heat, and CO_2 fluxes; micrometeorological measurements of air temperature, wind speed, and wind direction; measurements of total solar radiation, net radiation, and photosynthesis; and soil water content, underground water level, and salinity. The major task of APEIS-FLUX is to monitor water, heat, and carbon fluxes in different ecosystems. A secondary task is to develop a methodology to estimate regional water, heat, and carbon fluxes by using MODIS data. Another challenge is to understand the mechanisms and processes of the water, heat, and carbon cycles in terrestrial ecosystems, both in natural ecosystems, such as forest, grassland, and desert, and in managed agricultural ecosystems, such as irrigated agricultural fields and paddy fields, through the development and application of ecosystem models. The model has been developed to accurately simulate the natural processes of water, heat, and carbon cycles in terrestrial ecosystems and the effects of human disturbance. The data are released on the Internet to the world and are downloadable from the APEIS-IEM homepage at http://www-basin.nies.go.jp/english/project/iem/.

The data accumulated by the IEM network have been used to evaluate ecological goods and services, such as land use or cover changes, flood control function, carbon fixation, and ground water utilization for food production.

2.1 Accurate Land Cover Classification

A new approach to classifying land cover from MODIS time-series data has been to use a self-organizing feature map (SOM) neural network. The classification with the SOM neural network has been obviously improved compared with that of the commonly used maximum likelihood classification (MLC) method (Figure 3). Using this method in future to classify crops will greatly contribute to correct estimations of food production.

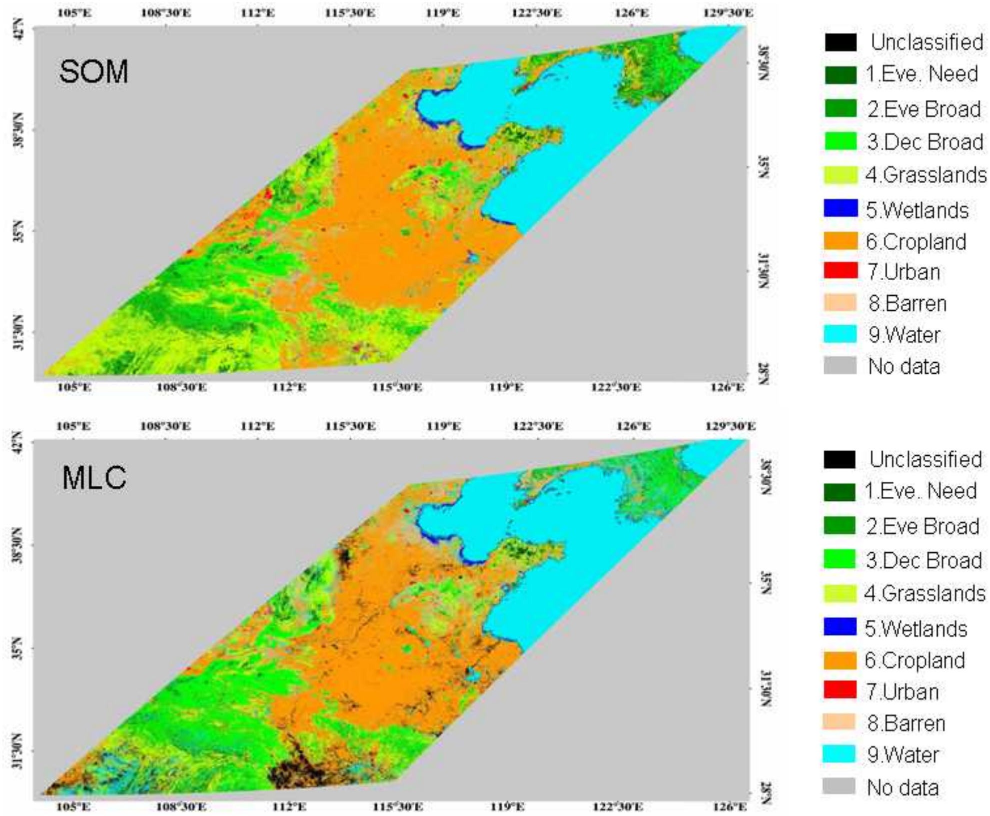

Figure 3 Land cover classification by the SOM neural network and the MLC method, both using MODIS time-series data

2.2 Assessment of Flood Control Functions and Flood Areas

The dynamic variation in surface water area and water storage in Dongting Lake, China, was estimated by using the IEM database. The estimated values for water level and storage were found to correspond well with the measured values. Furthermore, by coupling this information with elevation data and the MODIS vegetation coverage data into a watershed environmental management model, we could evaluate the loss of water and soil holding capacity of the terrestrial ecosystem and evaluate the shrinking of the buffering capacity of lakes. Finally, the areas of the Changjiang (Yangtze River) Basin where possible flooding could occur were mapped (Figure 4).

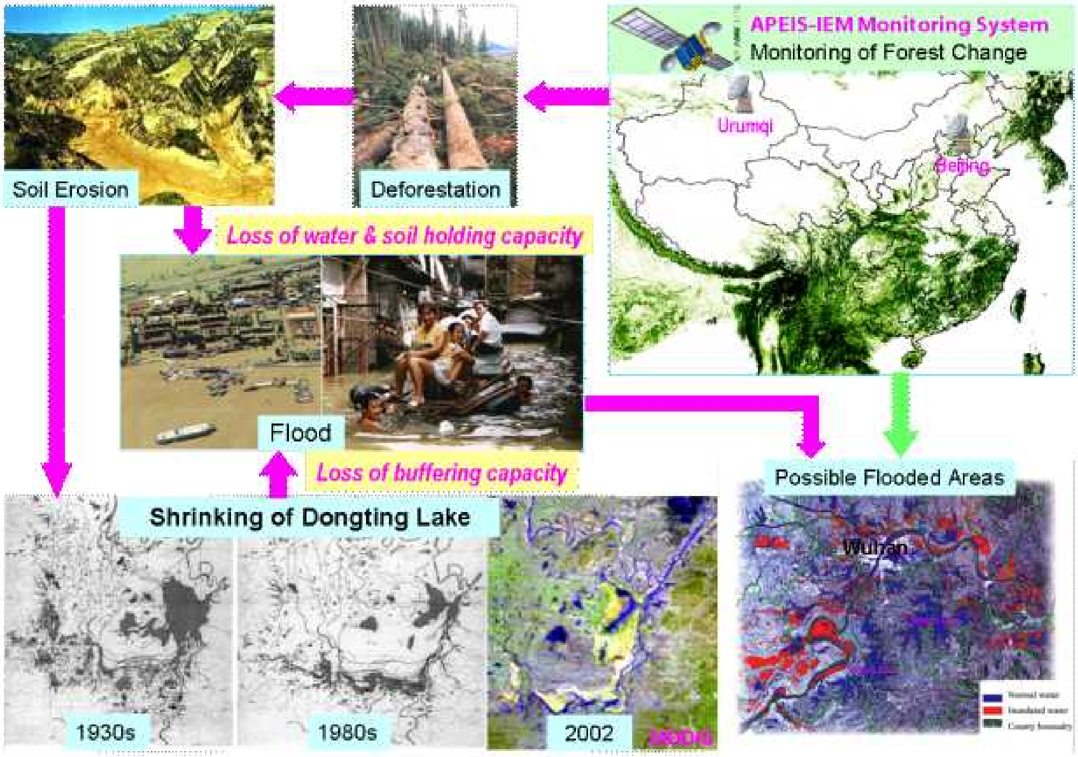

Figure 4 Evaluation of flood control capacity, such as the water storage and areas possibly prone to flooding by using the database of the APEIS-IEM network

2.3 Evaluation of Groundwater Used by Agricultural Production

Sustainable water use is in crisis in the North China Plain, owing to rapid groundwater drawdown. Estimating the water requirements for agriculture, the biggest user of groundwater, is helpful in understanding groundwater decline and the sustainable use of water resources. In 2004, the APEIS-IEM sub-project aimed to study the trends between change in groundwater levels and simulated agricultural water use in the North China Plain. The Decision Support System for Agro-technology Transfer (DSSAT) model was used to estimate groundwater use for crops. The results for Gaocheng City, the site selected for a point-level study, showed that groundwater decline was sensitive to simulated crop water requirements and irrigation requirements. There were obvious relationships between groundwater depletion and agricultural water use on a monthly, seasonal, and yearly level (Figure 5). According to regression analysis, a 100-mm water requirement by cultivated land (mainly wheat and maize) resulted in an approximately 640-mm decline in groundwater. This relationship might be useful in controlling the groundwater decline through controlling crop water use or through using water saving technologies.

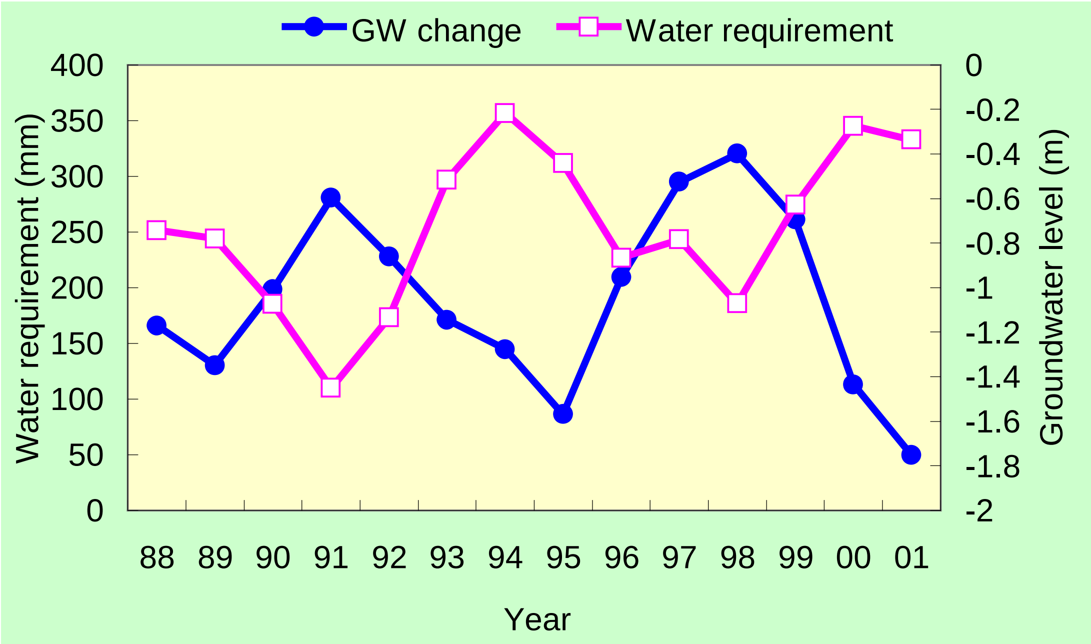

Figure 5 Changes in groundwater level in relation to simulated agricultural water requirements by winter wheat in March–June in 1988–2001. An inverse trend between the two factors is clear and significant.

Since 1987, the annual average decline in groundwater level has been 620 mm/yr. Considering that there is still a considerable amount of upstream groundwater recharge, much larger than the amount of water deficit, sustainable water use is still possible in the region if water-saving technologies are applied widely. Moreover, our study shows that through scientific irrigation management, approximately 76 mm of evapotranspiration water, which is sufficient to result in a 420 mm drawdown of groundwater, can be saved through irrigation planning without much reduction in the yield of winter wheat.

2.4 Evaluation of Land Surface Evapotranspiration and Water Deficit Index

Evaluation of evapotranspiration from the land surface and the water deficit index is essential in order to fully understand climate dynamics and ecosystem productivity, because they are closely related to energy transfer and material recycling processes between the Earth's surface and the atmosphere. The water deficit index is also widely used in water resource management, drought monitoring, catchment management, and wildfire assessment. The APEIS-IEM sub-project has developed a method using MODIS remote sensing datasets to estimate both the evapotranspiration and water deficit index of winter wheat fields in the North China Plain (Figure 6). The estimated values showed a relatively good consistency with the on-ground observations after some biophysical and meteorological parameters were adjusted.

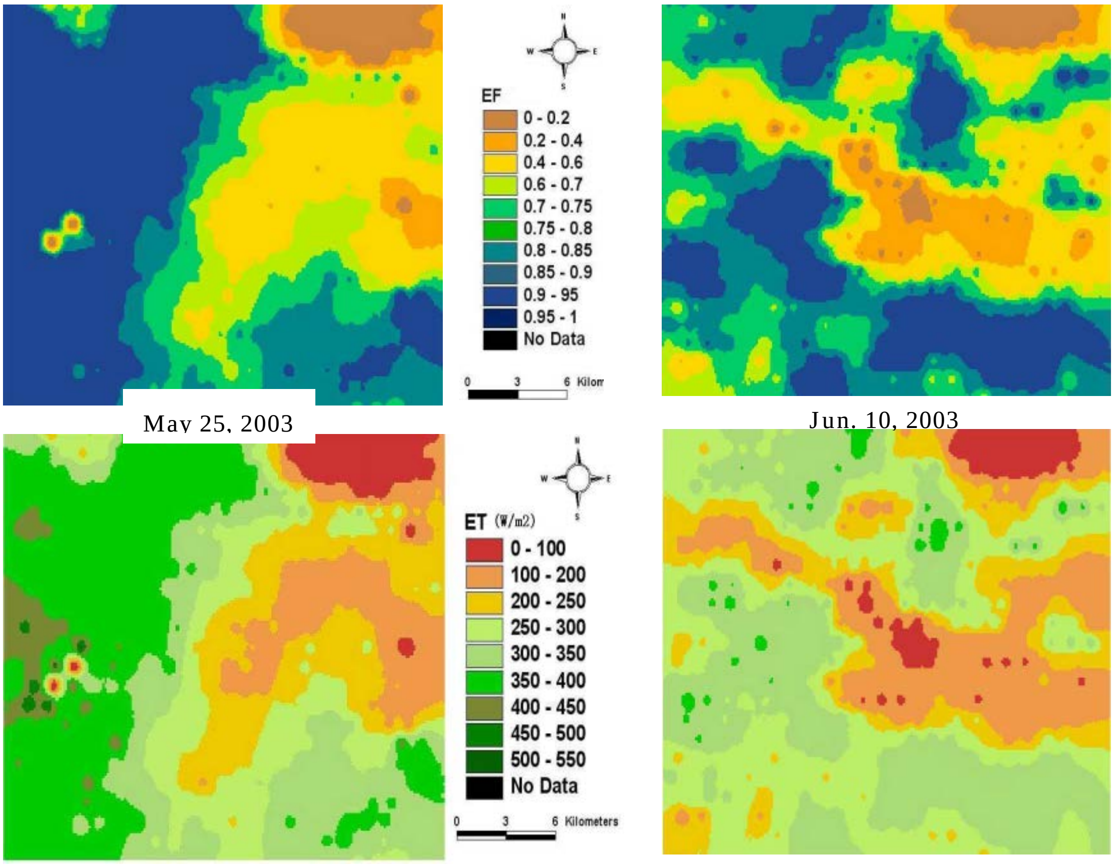

Figure 6 Water deficit index (EF) and evapotranspiration (ET) of winter wheat fields in the North China Plain estimated with MODIS remote sensing datasets

2.5 Monitoring of Plant Growing Process

The leaf area index (LAI) is the best index to monitor the growth of plants. With the help of the Global Positioning System (GPS) and geographical information systems (GIS), the temporal dynamics of MODIS-generated LAI can be compared across different ecosystems. We improved the MODIS LAI product using field-sampled data collected at APEIS-FLUX sites in China, and the improved spatial distribution of LAI in China, with a 1-km resolution, was produced (Figure 7). As the maps show, the lowest LAI occurred in January and the highest was in August, which suggests that the MODIS LAI product is reasonable throughout the phenological cycle of plants. Such datasets are very useful for assessment of land productivity, carbon sinks and sources, and agricultural and forestry production.

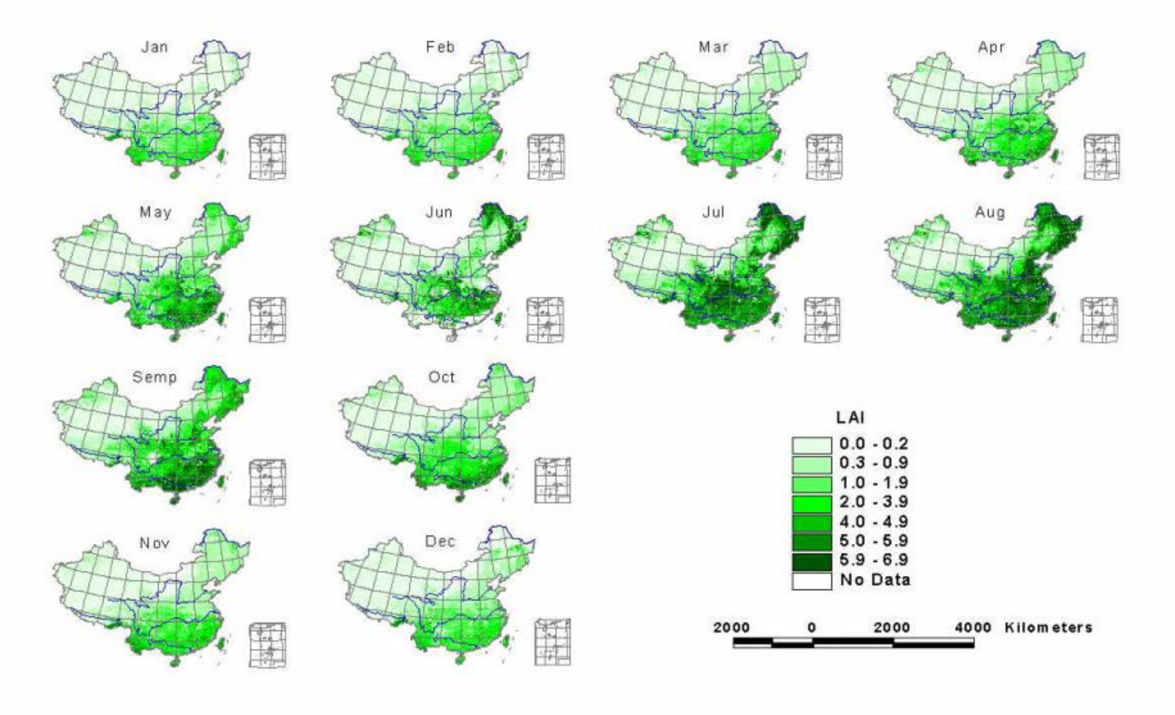

Figure 7 Monitoring of plant growth by leaf area index (2002)

2.6 Evaluation of Land Productivity and Carbon Fixation

Many ecosystem models have been developed for simulating water and carbon exchanges between the atmosphere and terrestrial ecosystems. One, the BIOME-BGC model, simulates the storage and fluxes of water, carbon, and nitrogen within the vegetation, litter, and soil components of a terrestrial ecosystem. The model permits sophisticated simulations of natural ecosystems such as forests, grasslands, and shrublands. However, it has rarely been applied to agricultural ecosystems. We modified the model by using APEIS-FLUX data, and then computed the carbon fixation in the Asia-Pacific region through a scaling-up approach using remote sensing data (Figure 8). Finally, we developed high-resolution maps of carbon fixation by vegetation from 2001 to 2003 in the Asia-Pacific region (Figures 9 and 10).

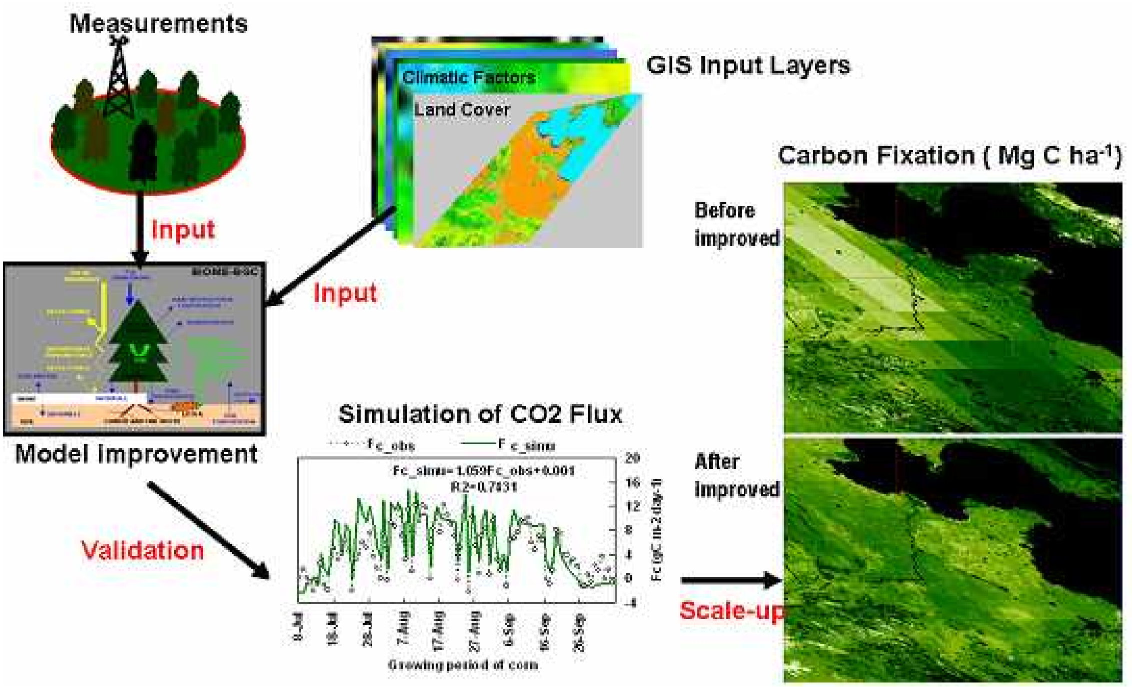

Figure 8 Evaluation of carbon fixation through a scaling-up approach using remote sensing data, field measurements, and the integrated ecosystem model

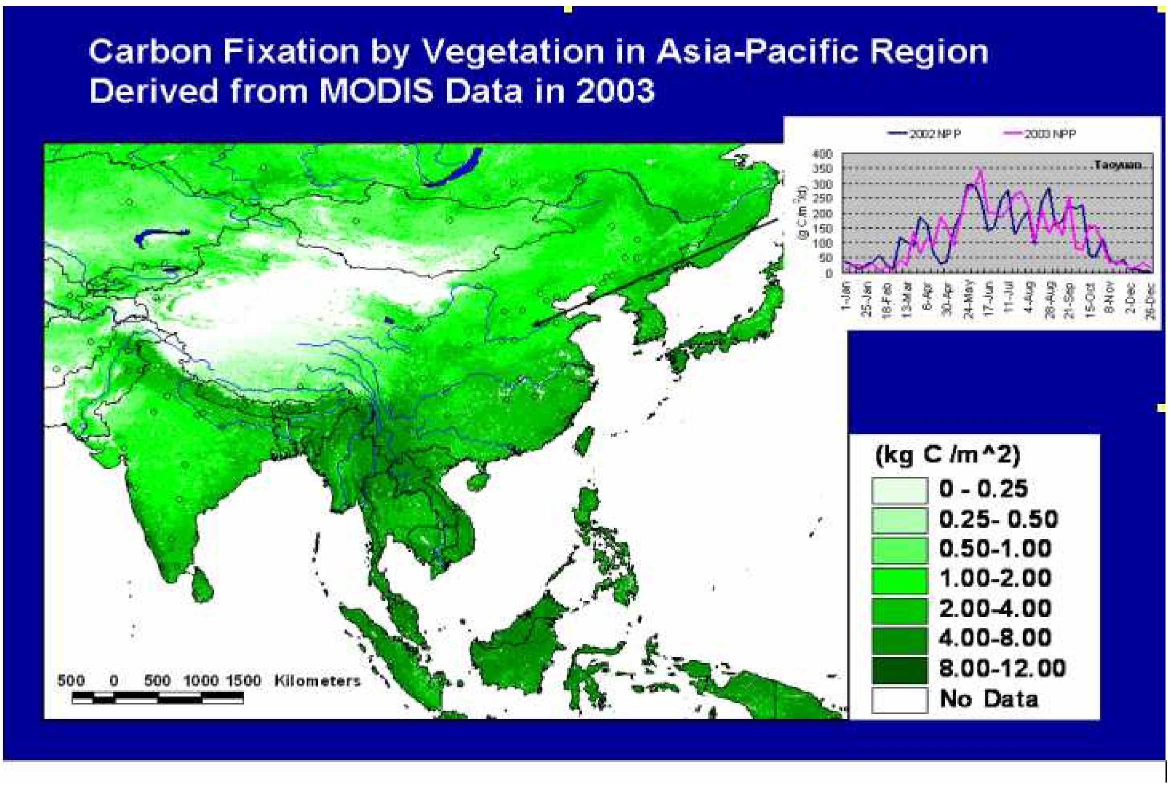

Figure 9 Carbon fixation by vegetation in the Asia-Pacific region as evaluated by the integrated ecosystem model using MODIS data

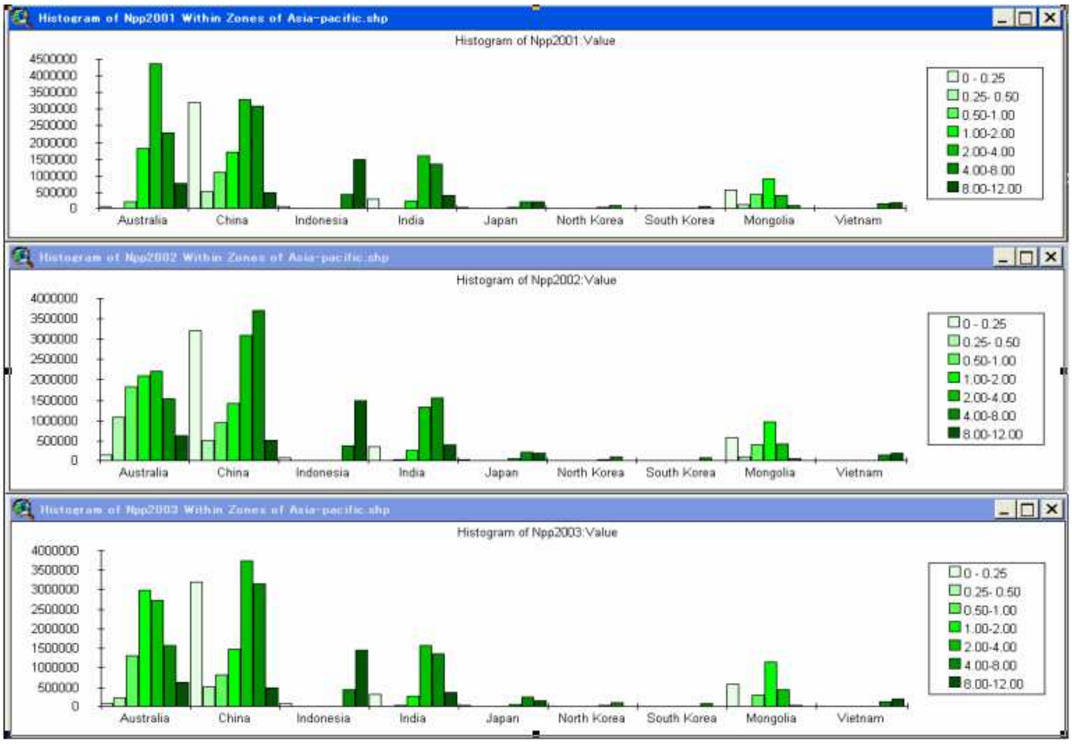

Figure 10 Carbon fixation by vegetation in each country of the Asia-Pacific region

3 Capacity Building and Contributions to Policy Making

The APEIS-IEM sub-project has contributed to the Millennium Ecosystem Assessment (MA), Eco-Asia, CSD12, and Water Forum. In addition, more than 30 peer-reviewed papers have been published in academic journals, and the APEIS-FLUX sites have become important training centers for the Chinese Ecological Research Network, and have been continuously visited by many local people, scientists, students, and policymakers in China. The activities of APEIS-IEM are closely linked with the MA through its participation in the China MA, one of the sub-global assessment projects of MA. The outcomes of APEIS-IEM have contributed to both the China MA report and the Synthesis Report of the MA sub-global assessment as a core scientific method for assessing conditions and trends of ecosystem services.

The third APEIS Capacity Building Workshop on Integrated Environmental Monitoring of the Asia-Pacific Region was held on December 9–11, 2004, in Singapore (Figure 11). Participants from Vietnam, Australia, Mongolia, China, Singapore, India, Russia, and Japan attended the workshop. The workshop presented the importance of capacity building in the MODIS Network and the APEIS-FLUX tower measurements, and included presentations on the regional integrated models and their applications to the Asia-Pacific region. Other presentations focused on cooperative studies of forest fires, the carbon cycle, and MODIS validation in different countries of the region.

Figure 11 The third APEIS-IEM capacity building workshop in Singapore

4 Contributions from the IEM Network

APEIS-IEM is an international cooperative project comprising many different institutes that frequently exchange information. Figures 12 to 14 are provided by member institutes of the IEM network.

Imaging date: 13 Jan 2003 Imaging date: 29 Dec 2004

Figure 12 Tsunami disaster in Aceh, Sumatra, Indonesia (Provided by Centre for Remote Imaging, Sensing and Processing, National University of Singapore)

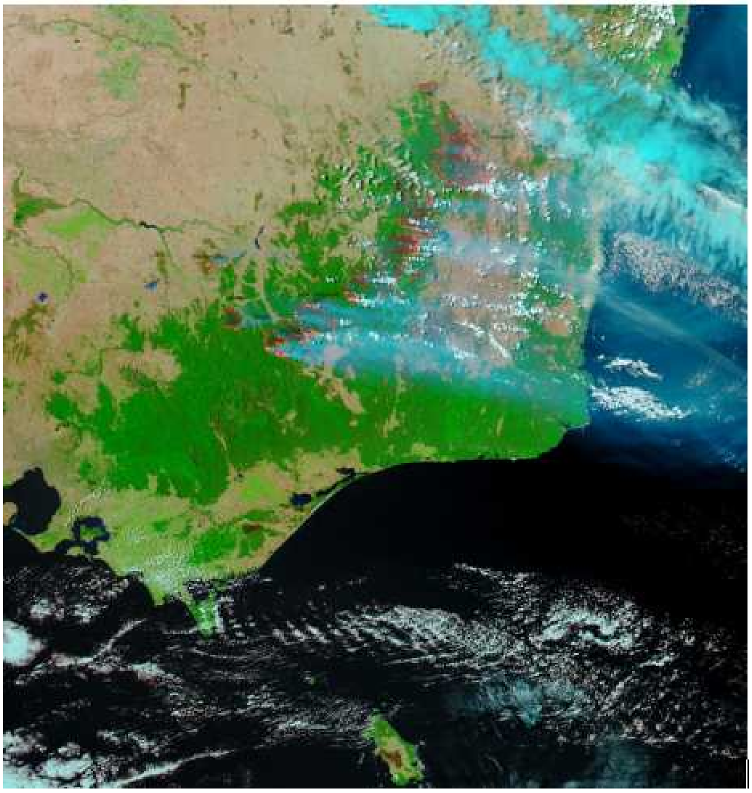

Figure 13 Forest fire in Australia (Provided by CSIRO Earth Observation Centre)

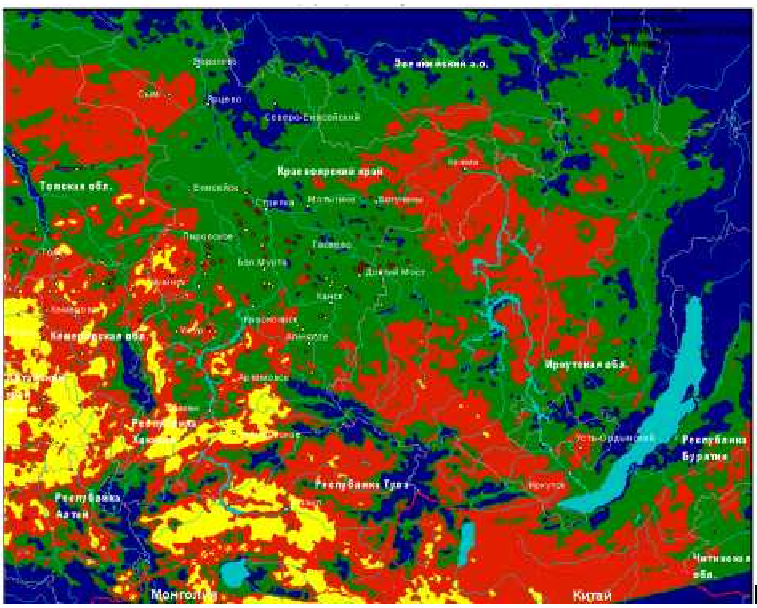

Figure 14 Typical Fire Danger Map based on MODIS information on May 28, 2004, in which yellow shows the most dangerous areas (Provided by Russian Academy of Sciences, V.N. Sukachev Institute of Forest, Krasnoyarsk, Russia)

Following are the Internet addresses of the member institutes of the APEIS-IEM network:

- Watershed Environments and Management Research Project, National Institute for Environmental Studies (NIES), Japan
  http://www-basin.nies.go.jp/english/
- Institute of Geographical Sciences and Natural Resources Research, Chinese Academy of Sciences (CAS), China
  http://www.igsnrr.ac.cn/
- Earth Observation Centre, Commonwealth Scientific and Industrial Research Organization (CSIRO), Australia
  http://www.eoc.csiro.au/
- Centre for Remote Imaging, Sensing and Processing, National University of Singapore, Singapore
  http://www.crisp.nus.edu.sg/
- Chinese Ecosystem Research Network, CAS, China
  http://www.cern.ac.cn/0index/
- Xinjiang Institute of Ecology and Geography, CAS, China
  http://www.xjb.ac.cn/
- Institute of Subtropical Agriculture (ISA), CAS, China
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