


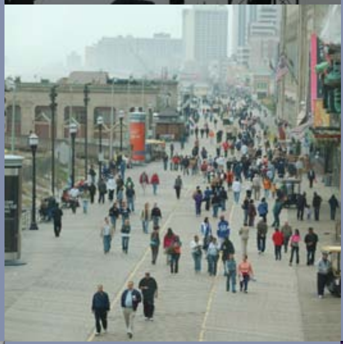

The Metro-Agro-Plex As A Geographical Unit Of Analysis For Regional And Global Environmental Change

A Report of the Aspen Global Change Institute
Elements of Change Series

Susan Joy Hassol
John Katzenberger
Editors

The Metro-Agro-Plex as a Geographical Unit of Analysis for Regional and Global Environmental Change

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Acronyms

APAR: Absorbed Photosynthetically Active Radiation

AVHRR: Advanced Very High Resolution Radiometer

AVIRIS: Airborne Visible/Infrared Imaging Spectrometer

BRDF: Bidirectional Reflectance Distribution Function

BRF: Bidirectional Reflectance Factor

BATS: Biosphere Atmosphere Transfer Scheme

DAAC:Distributed Active Archive Center

EDC: EROS Data Center

EROS: Earth Resource Observation Satellite

FASIR: Fourier-adjusted, solar zenith angle corrected, interpolation and reconstruction

FIFE: First ISLSCP Field Experiment

GCM: General Circulation Model

GIS: Geographic Information System

HTF: Humid Tropical Forest

ISLSCP: International Satellite Land Surface Climatology Project

LAD: Leaf Angle Distribution

LAI: Leaf Area Index

Landsat: Land Remote Sensing Satellite

Lidar: Light Detection and Ranging

MODIS: Moderate-Resolution Imaging Spectrometer

MSS: Multi-Spectral Scanner

NDVI: Normalized Difference Vegetation Index

NIR: Near Infrared

PAR: Photosynthetically Active Radiation

SAIL: Scattering by Arbitrarily Inclined Leaves

SAR: Synthetic Aperture Radar

SiB: Simple Biosphere model

SPOT: System Pour l’Observation de la Terre

TM: Thematic Mapper

The Metro-Agro-Plex As A Geographical Unit of Analysis For Regional and Global Environmental Change

William L. Chameides, Rosamond L. Naylor, Douglas S. Way
Co-Chairs

Session Three Summary

Although the three Continental-Scale Metro-Agro-Plexes comprise only 23% of the Earth's land surface, they account for about 75% of the world's consumption of commercial energy and fertilizers and about 60% of the food crop production and food exports.

The unprecedented increase in humankind's standard of living since the Industrial Revolution can be attributed in large part to two factors: the development of high-input/high-yield agriculture capable of feeding an increasingly urban population, and an urban-industrial infrastructure, heavily dependent upon fossil fuels for the production and transport of manufactured goods. This interdependence between agriculture and fossil-fuel burning is most pronounced in three regions of the northern mid-latitudes (Figure i.1): (I) Eastern North America (25-50°N, 105-60°W) ; (ii) Europe (36-70°N, 10°W-90°E); and (iii) eastern China and Japan (25-45°N, 100-146°E). Within each of these regions, urban-industrial and agricultural activities tend to cluster together into a single large network or plexus of human-impacted land-use categories.

Chameides et al. (1994) have proposed the term Metro-Agro-Plex (or MAP) as a shorthand to describe this intermingling of agricultural and urban-industrial activities within a developed or developing geographical area. They have used the term Continental-Scale Metro-Agro-Plexes (or CS-MAPs) to specifically refer to the three large MAPs of the northern mid-latitudes. Collectively, the CS-MAPs represent a major force in the global economy and also

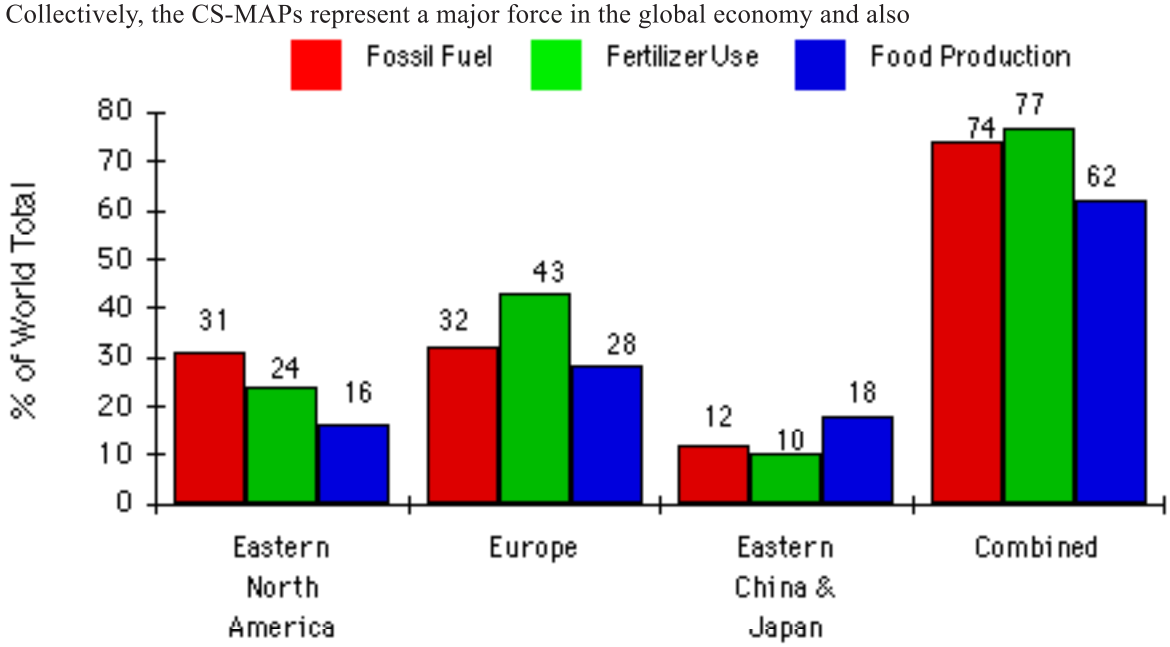


Figure i.1
A major fraction of the world's fossil fuel use, fertilizer use, and food production are concentrated in three geographic regions of the Northern Hemisphere.
(FAO, 1991; UN, 1992; OEC, 1993)

in environmental change. Although they comprise only 23% of the Earth's land surface, the three CS-MAPs account for about 75% of the world's consumption of commercial energy and fertilizers and about 60% of the food crop production and food exports. They are also major source regions for atmospheric pollutants such as carbon dioxide, the nitrogen oxides (NOx) and the sulfur oxides (SOx), which affect global and regional climate and air quality. It is this interplay between urbanization and high-input/high-output agriculture, the environmental changes that they cause, and the effects these environmental changes have, in turn, upon socially and economically important institutions within a MAP that formed the basis for the discussions of this Aspen Global Change Institute session.

The China Perspective

In order to provide a focus for our discussions, this AGCI session undertook a regional-scale case study of China as an evolving CS-MAP. The choice of China was based on its status as the most populous and most rapidly developing nation in the world, with a population estimated at 1.1 billion people and a Gross Domestic Product that is growing at an annual rate of about 13%. By the year 2000, China's population is projected to reach 1.25 billion and by the beginning of the 21st century its economy will likely surpass that of the United States in terms of purchasing power. China also plays an important role in the world food economy, accounting for roughly 20% of global production and consumption of the major staple crops wheat, rice, and maize (FAO, 1991).

The unprecedented combination of economic and population growth in China will bring about profound changes in the nation's landscape and demographics. Large tracts of land now in cultivation will be urbanized or converted to other uses (Streets et al., 1995). Enormous shifts in population will occur as well. About 80% of China's people now live in rural/agricultural areas. However, government plans for China's economic development call for a population of only 200 million in the agricultural sector (Zhou, 1995). To meet this goal, approximately 500 million people will be moved out of these rural areas. Rather than have them move to mega-cities, with their attendant infrastructural and cultural problems, however, the government plans to have them relocate to some 5000 different township and village enterprise zones or TVE's (Tao, 1995). Each TVE will be a small city, with a population of about 100,000 and will be interspersed in and among the agricultural areas of the nation. The resulting land use pattern will make China a patchwork of Metro-Agro-Plexes of unprecedented proportion and complexity. All of this contributed to the choice of China as a focus for the AGCI session on Metro-Agro-Plexes.

China's fertilizer use amounts to 20 Tg N per year, the most of any large economy, and this use is growing by 12% per year. Further, the N uptake efficiency is only 40%, resulting in growing N flux burdens on China's fresh water and atmosphere.

Key Issues

Several important issues emerged from the AGCI discussions of China as an evolving Metro-Agro-Plex . These are outlined below:

1 Environmental Change and Agriculture

In terms of CO2 emissions alone and their impact upon the climate, the global implications of China's impending economic and industrial explosion are serious. The likelihood that this economic explosion will be fueled by China's abundant coal reserves raise the level of concern. From China's point-of-view, however, the issues of sustainable development and food self-sufficiency are probably more pressing than those of global change. Moreover, given the likely impact on world food markets and the global economy if China should find it necessary to

import significant quantities of food, these other issues are also significant for the United States and the global community at large. China currently grows and harvests staple foods at a rate equivalent to about 2900 kcal/capita/day (FAO, 1991). While this rate is about a factor of 3 less than that of the United States, it is adequate, according to nutritional requirements set by the United Nations' FAO, to feed and nourish the Chinese peoples (see Figure i.2A). And, while the exact balance changes slightly from year to year, on the whole, China has been essentially food self-sufficient in the recent past.

The prospects for China maintaining its food self-sufficiency in the future are problematic.

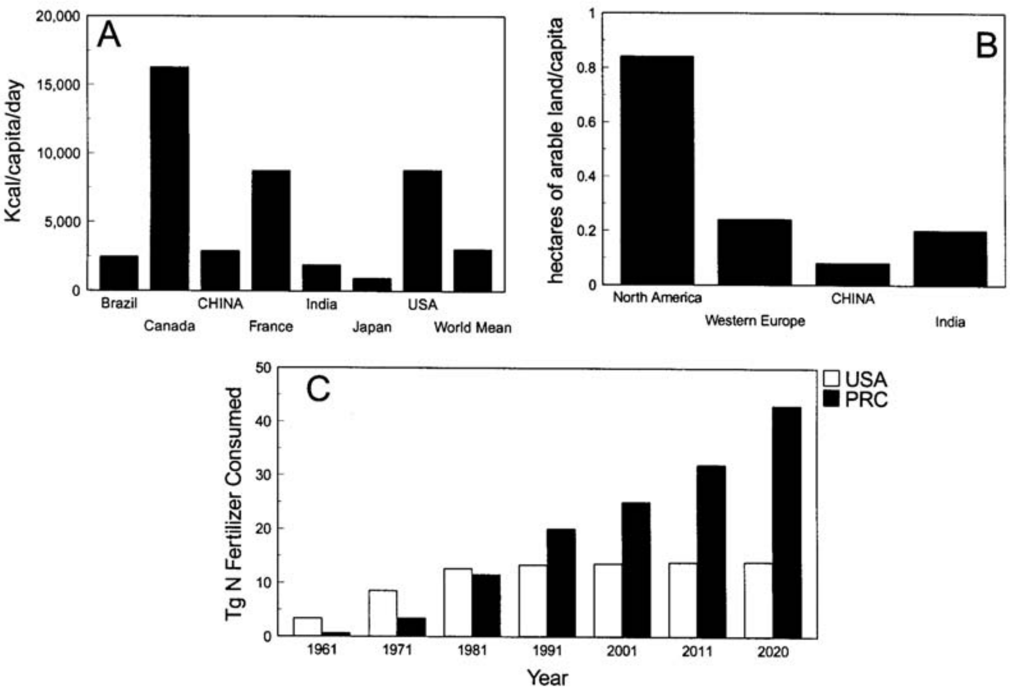


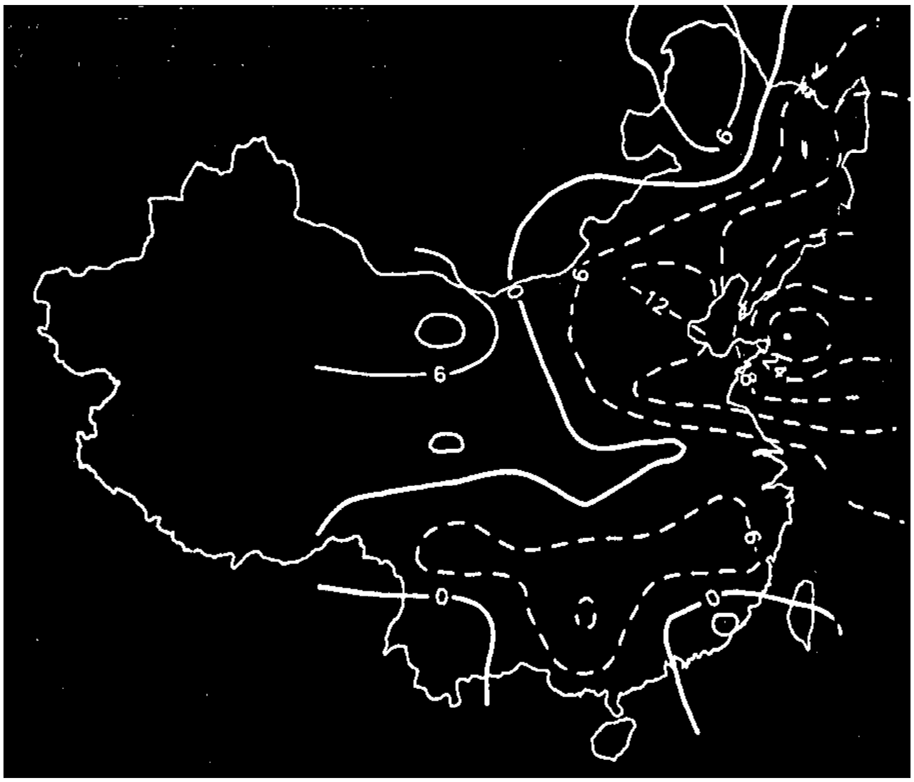
Figure i.2

Comparison of agricultural statistics for China and other developed and developing nations of the world. A. Staple food crop production in kcal per capita per day; B. Arable land in hectares per capita; C. Tg of N fertilizer consumed per year. Data sources: FAO, 1991; Galloway, et al., 1995; Tao, 1992.

However, China maintains this approximate level of food self-sufficiency at a significant price. As illustrated in Figure i.2B, China's arable land amounts to only about 0.08 hectares per capita, a factor of 10 less than that of the United States and a factor of three less than the global average (Tao, 1992). To compensate, China uses enormous amounts of fertilizer and irrigation. Its current rate of N fertilizer use amounts to about 20 Tg N/yr, the most of any large economy, and it is growing at an annual rate of ~12% (see Figure i.2C). Moreover, the uptake efficiency of the fertilizer in China is low, only about 40% (Smil, 1995). The resulting fluxes of fixed nitrogen into China's fresh waters, and N-containing gases, especially N_2O and NO_X, into the atmosphere are significant and present growing environmental burdens on regional and global scales (Tao, 1992; Galloway et al. 1995).

The prospects for China maintaining its food self-sufficiency in the future are problematic (Brown, 1995; Smil, 1993, 1995). The projected population increase of 100 million people by the year 2000 will be an additional burden on an agricultural system that is already stretched to meet current demand. At the same time, Chinese agriculture will have to cope with the loss of significant lands for cultivation as China's economic development forces the conversion of farmland to other uses (Streets et al., 1995).

A potentially serious complicating factor in China's equation for urbanization and food self-sufficiency is the environment. Although the impacts of future environmental stresses on Chinese agriculture remain largely unassessed, there is every reason to believe that they will be significant. For example, consider the potential effects of climate change. Observations in China indicate that the past few decades' global warming trend has coincided with a significant falloff in precipitation over some of China's most productive rice and wheat fields in the eastern half of the nation (see Figure i.3). Such a trend, if it continues, could have devastating effects on a national agricultural system that is highly dependent upon monsoonal rains for irrigation and where "...aridity is (already) a limiting factor threatening...agricultural production in China." (Tao, 1992).



Vast regions of southern and eastern China are susceptible to damage from acid deposition.

Figure i.3

Rain Trend in East China, Unit: 0.1mm/yr (1951-1990). Observed 40-year rain trend over China. Solid lines indicate positive trend and dashed lines indicate negative trend. (After Fu, 1995).

Moreover, regional and local pollution may already be taking their toll on China's harvests. Tao (1992) estimates that roughly 6.7 million hectares of Chinese farmlands have been impacted by "diverse sources of pollution," causing the loss of about 5% of the nation's annual production of grains. A more quantitative assessment of pollutant effects can be culled from the results of the recent RAINS-ASIA project. In this project, critical (i. e., harmful) loads from sulfur deposition for 14 distinct Asian ecosystems, including rice, other agricultural crops, forests, etc., were calculated (Hettelingh et al., 1991). These critical loads were then compared to model-estimated S deposition rates under present and a variety of future emissions scenarios. The results reveal vast regions of southern and eastern China with low critical loads and thus a susceptibility to damage from acid deposition. Moreover, estimates of sulfur deposition indicate that these regions are receiving deposition in excess of their critical load values (Arndt and Carmichael, 1995).

The projected rapid economic development of China over the next 20-30 years will likely further exacerbate the problem. For example, Galloway et al. (1995) estimate that China will surpass the United States as an emitter of photochemical smog-forming precursors such as nitrogen oxides in the next one to two decades and a recent global modeling study, Chameides et al. (1994), found that these emissions may result in significant increases in the surface ozone concentrations in China. They found that these increases would occur in regions of China that are currently used for agriculture, and concluded that this regional ozone pollution may significantly limit China's food-crop production in the coming decades.

Because topographical features and land use characteristics in China occur at scales which are considerably finer than today's global climate models, a regional-scale focus will be required to understand the sub-continent's climate and long-term response to regional and global-scale perturbations.

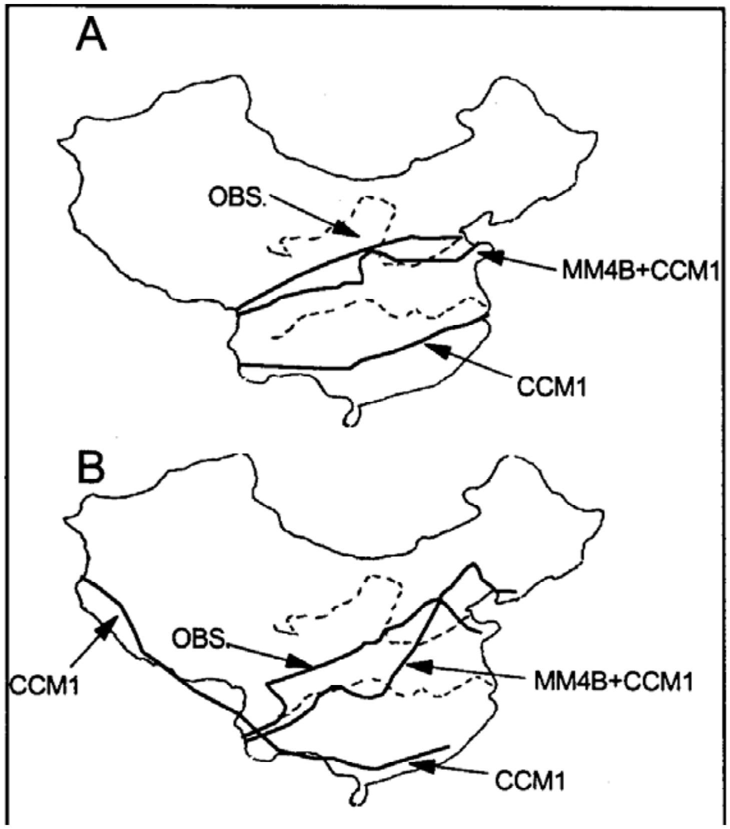


Figure i.4
Illustrative comparisons of monthly mean surface temperatures over China based on obser vations from 1956-1990 (OBS.), simulations using a general circulation model (CCMI), and simulations using a mesoscale model nested in a global circulation model (MM4B+CCMI). A. Lines illustrate the respective January mean 0°C isopleths. B. Lines illustrate the respective July mean 24°C isopleths. Results illustrate the systematic tendency of the global model to underpredict temperatures over China, while the nested mesoscale model appears to do a reasonable job of representing the observed temperature distribution.
(Figure produced from Zhou Xiuji, 1995)

Thus the picture of China one or two decades hence filled with burgeoning TVEs, interspersed among the nation's farmlands and fueled by energy derived from burning cheap, high-sulfur coal is a China with enormous air pollution problems that seem bound to impact agriculture negatively. How large will this impact be and what can be done to avert it? On the other hand, what will the role of agriculture be in driving environmental change? These are complex and difficult questions, but nevertheless questions of critical importance that require the attention of the scientific communities.

2 Understanding Climate Change in China

Because of the critical role meteorology plays in agriculture, any assessment of the viability of China's agriculture must also address the issue of regional climate change. This in turn requires an ability to simulate with reasonable accuracy China's present climatic conditions, in terms of the magnitude, temporal variability, and spatial distribution of key variables such as temperature and precipitation.

Although numerous assessments of regional climate change and its impact upon agriculture have been addressed using global climate models, simulations indicate that, at least for China, these global models do a poor job of replicating basic climatic features in China. For example, consider Figure i.4, adopted from a preliminary study by Zhou Xiuji (1995). Comparison of observed and model-calculated temperature isopleths over China clearly indicate a tendency for a global climate model (in this case NCAR's Community Climate Model or CCM) to underpredict temperature. On the other hand, a simulation using a mesoscale model (in this case a version of Mesoscale Meteorological Model or MM4) nested within the CCM shows much better agreement with observations. These results suggest that because topographical features and land use characteristics in China occur at scales which are considerably finer than today's global climate models, a regional-scale focus will be required to understand the sub-continent's climate and long-term response to regional and global-scale perturbations.

Another indication of our lack of a comprehensive understanding of climate trends in China comes from an analysis of surface temperature data spanning the 1980s from 160 meteorological stations situated throughout the country (Figure i.5A). The analysis indicates a striking north/south asymmetry, with a warming trend in the north and a cooling trend over the southeastern portion of the country.

The largest negative temperature anomalies are found over the Sichuan basin (T ~ -0.4°C) and in the western portion of the Yangtze Delta region (T ~ -0.2°C). Interestingly, the region of cooling in southeastern China closely corresponds to the area in China observed to have the most acidic precipitation (Wang and Wang, 1995). The correspondence of these areas suggests that the cooling has been caused by sulfate aerosols produced as a direct result of S emissions from the area.

On the other hand, model simulations give a very different picture. Sulfate loadings over China predicted by both global and regional Chemical Transport Models generally predict maxima running in a north-south direction along the eastern coast of China rather than over southeastern China. (In other words, there is no indication of a north-south asymmetry.) Typical are the sulfate loadings illustrated in Figure i.5B from the simulations of Kasibhatla et al. (1995a). Calculations of the (direct) radiative forcing from sulfate aerosol similarly give no indication of a preponderance of cooling in the southeastern portion of China (see Figure i.5C). Moreover, calculations of the combined radiative forcings from greenhouse gases and sulfate aerosols since the Industrial Revolution yield a positive forcing in southeastern China and only a tiny area in northern China with a negative forcing (see for example Figure i.4.5 in IPCC, 1995). Finally, global climate simulations that calculate the temperature changes caused by the forcing from greenhouse gases and sulfate aerosols generally predict a net warming in southeastern China with a band of cooling in the north, in direct contradiction with the data illustrated in Figure i.5 (see for example, Santeret al., 1995).

Global climate simulations that calculate the temperature changes caused by the forcing from greenhouse gases and sulfate aerosols generally predict a net warming in southeastern China with a band of cooling in the north, in direct contradiction with the data illustrated in Figure i.5.

The Yangtze Delta is very densely populated, leads China in both grain production and industrial output, and is growing economically by leaps and bounds.

Figure i.5
Comparison of observed and simulated aspects of the coupled climate/sulfur system over China.
A The observed distribution of temperature anomalies in the 1980s in China. The heavy lines indicate positive anomalies and the light lines, negative anomalies (in °C). The area of negative anomalies (i. e., cooling) in southeastern China corresponds to the area of low pH precipitation, suggesting that the cooling can be attributed to sulfate aerosol.
(After Li et al., 1995).
B The average distribution of sulfate aerosol column loading (in mg SO 4 = m-2) during the months of June, July, and August as calculated by the GFDL Global Chemical Transport Model (Kasibhatla et al., 1995a). Note that similar distributions have been obtained with a regional model simulation (RADM) carried out by the Chinese Academy of Meteorological Sciences (Luo Chao, personal communication, 1995).
C Predicted negative radiative forcing rates due to sulfate aerosol over China in 1990 (Carmichael, personal communication, 1995).

3 The Yangtze Delta

China is a huge country of diverse physical, chemical, and ecological characteristics. From the point-of-view of evolving Metro-Agro-Plexes, the Yangtze Delta is one of the more interesting regions of this nation. Extending from the mouth of the Yangtze River and the city of Shanghai in the east to the city of Chuzhou in the west, the Yangtze Delta comprises Jiangsu and Zhejiang provinces as well as the eastern half of Anhui Province (see Figure i.6). The region contains approximately 85 cities and townships, in addition to its one mega-city, Shanghai. With a population approaching 200 million, the region hosts approximately 530 people per km2, making it the most densely populated area in all of eastern Asia (Leman, 1995). Moreover, its major province, Jiangsu Province, has the distinction of having led China in both grain production and industrial output (Streets et al., 1995). Thus we can think of the Yangtze Delta region as one of the most productive Metro-Agro-Plexes in Asia, if not the world.

The Yangtze Delta is growing economically by leaps and bounds. It has been responsible for fully 25% of China's increased Gross Domestic Product since 1990 and has become a prime target for foreign investment (Leman, 1995). The government plans to create a modern highway system in the region that will link its cities, townships, and rural areas together (and no doubt create the same regional photochemical smog episodes that plague the U.S.). The projected rapid growth of the Yangtze Delta presents a unique target of opportunity to the scientific community to document, analyze, and better understand the dynamic interactions between economic development, rapid population growth, high-input/high-yield agriculture, and regional and global environmental change.

Recommendation: Implement Interdisciplinary, Regionally-Focused Study

The participants of the AGCI session agreed that much benefit could be gained from the implementation of an interdisciplinary research project aimed at documenting and analyzing the changes occurring in China in general, and the Yangtze Delta in particular, and assessing the likely impact of these changes on critical ecosystems in the region. It was also recommended that this research be closely aligned with the political and industrial organizations active in the region, in order to maximize the translation of the project findings into new technologies and economic and social policies that foster a sustainable economy and environment.

Much benefit could be gained from an interdisciplinary research project aimed at documenting and analyzing the changes occurring in China in general, and the Yangtze Delta in particular, and assessing the likely impact of these changes on critical ecosystems in the region.

Figure i.6
The Yangtze Delta region of China extends from the mouth of the Yangtze River and the city of Shanghai in the east to the city of Chuzhou in the west, and comprises the Jiangsu and Zhejiang Provinces as well as the eastern half of the Anhui Province. It is also one of the most rapidly developing regions in the world.

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Experimental Assessment of Expanding Energy Use on the Asian Environment

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Three quarters of all new electric power plants planned globally for the 1990s are being built in Asia. China currently accounts for 65% of Asia's SO_2 emissions and projections for a business-as-usual scenario show China's output tripling, India's rising by a factor of four, and Pakistan's by a factor of ten.

Carmichael discussed an integrated assessment of expanding energy use in Asia on the environment. The first phase of this project, funded by the World Bank and the Asian Development Bank, is now complete. The model was developed by a team that included energy experts, atmospheric modelers, environmental assessors, policy analysts, and others concerned about impacts of the 5-15% growth in energy consumption in Asian countries. Three quarters of all new electric power plants planned globally for the 1990s are being built in Asia.

This assessment was restricted to sulfur emissions and includes the effects of sulfate aerosols on climate, impacts of sulfur deposition on ecosystems, including agriculture, and the human health effects of sulfur dioxide emissions. The region studied stretched from Pakistan to Japan and from Mongolia to Indonesia. The preliminary integrated assessment follows from three major areas: 1) energy supply and demand scenarios which generate emissions at 1 degree resolution, 2) a long range transport model to calculate sulfur deposition and ambient levels of sulfur dioxide and sulfate, and 3) an ecosystem assessment using sensitivities and "critical loads" concepts as developed in Europe for the acid rain conventions and protocols.

Base year emissions were estimated for 1990 and forecasts were made over a 30 year time horizon for 2000, 2010, and 2020. The model provides a framework for large databases in a PC-based environment that makes this data available to everyone in the region to use in their own studies. This sharing of data is a strong component of the project. For each of the three areas (energy, atmospheric transport and deposition, and ecosystem analysis) there were western investigators and focal centers set up in various locations in Asia. Scientists from each Asian country participated and provided feedback throughout the process, making it an interactive one. A peer evaluation of the preliminary results was completed in May 1995.

For the purposes of this model, Asia was divided into 94 regions, and 20 megacities were identified and studied. Energy and technology implementation scenarios were run in each region and megacity independently. Asia is such a dynamic region that a platform for dynamic analysis was necessary. This model provides such a platform.

The base year inventory for China is estimated at 22 terragrams of SO_2 emission in China for 1990. From this base year, a number of scenarios were run from business-as-usual through best available technology implementation. China currently accounts for 65% of Asia's emissions and projections for a business-as-usual scenario show China's output tripling, India's rising by a factor of four, and Pakistan's by a factor of ten. Control technologies at various levels of implementation can also be brought into the mix.

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Four hundred large point sources are placed in the model. These include existing stacks plus those planned for the next 20 years. The model can be run to bring more or fewer of these on line depending on various policy decisions, and can also be used to evaluate alternative sites for plants. Volcanic emissions account for about 3 Tg per year and these are included in the model. Ship emissions are also included and account for about 0.25 Tg of sulfur. While this appears to be a small amount in the aggregate, in certain areas such as the Malocan Straits, this accounts for 20% of total.

Once the energy scenarios have generated the 1° by 1° emissions, the atmospheric transport part of the model comes into play, helping to determine where the emissions go and how much sulfur is deposited in what locations.

The long range transport model used is a 3-layer trajectory model. Sulfur deposition patterns closely reflect the spatial variability in the emissions patterns and the prevailing meteorology. Elevated levels of sulfur deposition occur in the central regions of India, Thailand, eastern China, Korea, and parts of Malaysia and Indonesia. The highest levels (about 10g S.m-2.yr-1) occur in the Sichuan-Chong Qing region of China. The model also tracks each source individually so that source-receptor information can be assessed. In east Asia, the winds are predominantly westerly, so that pollutants are transported off the continent into the Pacific Ocean (see Liu). How much of the deposition in Korea and Japan is from long range transport is an open question. If it is found, for example, that Japan would be heavily impacted by sulfur from Chinese coal burning, this could encourage Japan to invest in Chinese energy technology.

Once the transport model has determined the amount and location of deposition, the final element of the model is used to examine ecosystem response. This large mapping project takes into account vegetation sensitivity to sulfur and more importantly, how soil chemistry responds to sulfur deposition. The concept, borrowed from European acid rain work, is called "critical loads," and is a method of estimating ecosystem sensitivity to sulfur deposition. It is essentially a threshold sustainability index of ecosystems to sulfur deposition and is estimated for various soil and vegetation types and land uses.

The concept behind critical loads is that some soils can sustain much higher levels of deposition than others. Because of this differential sensitivity, different ecosystems are placed at risk of damage at differing levels of deposition. For example, the high pH soils in Northern China have a large capacity for sustaining sulfur deposition. By overlaying a sulfur deposition map with a critical loads map, we can see the areas at risk. For 1990, this project showed large exceedances in southeastern and coastal regions in northern China, Thailand, Malocan Straits, and a few other locations. This process identifies "red flag" areas that should be studied more closely.

The concept behind critical loads is that some soils can sustain much higher levels of deposition than others. Because of this differential sensitivity, different ecosystems are placed at risk of damage at differing levels of deposition.

In the analysis described above, "risk" is defined as changes in soil chemistry and toxicity to vegetation that might result from the mobilization of aluminum and other chemicals in the soil. It is important to point out that there are very large uncertainties in applying these concepts. The concept of critical loads is still debatable and controversial, but provides a valuable framework for evaluating environmental impacts.

Another use of the model is to look at human health and agricultural impacts by zooming in with higher resolution. Around and downwind of Beijing, for example, it was found that there were large regions where the average concentration exceeded 80 micrograms of SO_2 per cubic meter and short term average concentrations of 350 µg .m-3. These numbers can be compared

with the World Health Organization's annual exposure standard of 50 µg.m-3and 24-hour exposure standard of 125 µg .m-3. In addition, vegetation can be adversely affected at levels of 25 µg m-3.

In sum, the benefit of this model is that it is a framework that organizes large datasets in a PC environment that allows for dynamic, policy-relevant studies of the region. For example, if a power plant was moved to a different location, what might happen to the sulfur deposition pattern? The usefulness of these types of maps is that they reveal the gradients. They provide a scoping type of evaluation that indicates where to look first for problems.

There is also a great deal of value in scoping future scenarios for SO2 in Asia. Figure 1.1 shows the effects of four scenarios in the future. As the graph demonstrates, a business-as-usual scenario with no further control technologies used results in emissions rising by a factor of 3. Use of basic technology (characterized by low capital investment and multiple benefits) results in emissions rising by a factor of 2. Immediately applying the best available technology on a large scale basis could perhaps stabilize emissions at 1990 levels. For China, the costs of this last scenario are estimated to require an annual investment of $100 billion a year in power generation, home heating, and largest of all, industrial processes.

The benefit of this model is that it is a framework that organizes large datasets in a PC environment that allows for dynamic, policy-relevant studies of the region.

Phase two of this assessment project is expected to be funded by the World Bank and will involve a great deal of ground truthing and case studies. It is also hoped that a variety of users will work with and modify the model for a number of different uses.

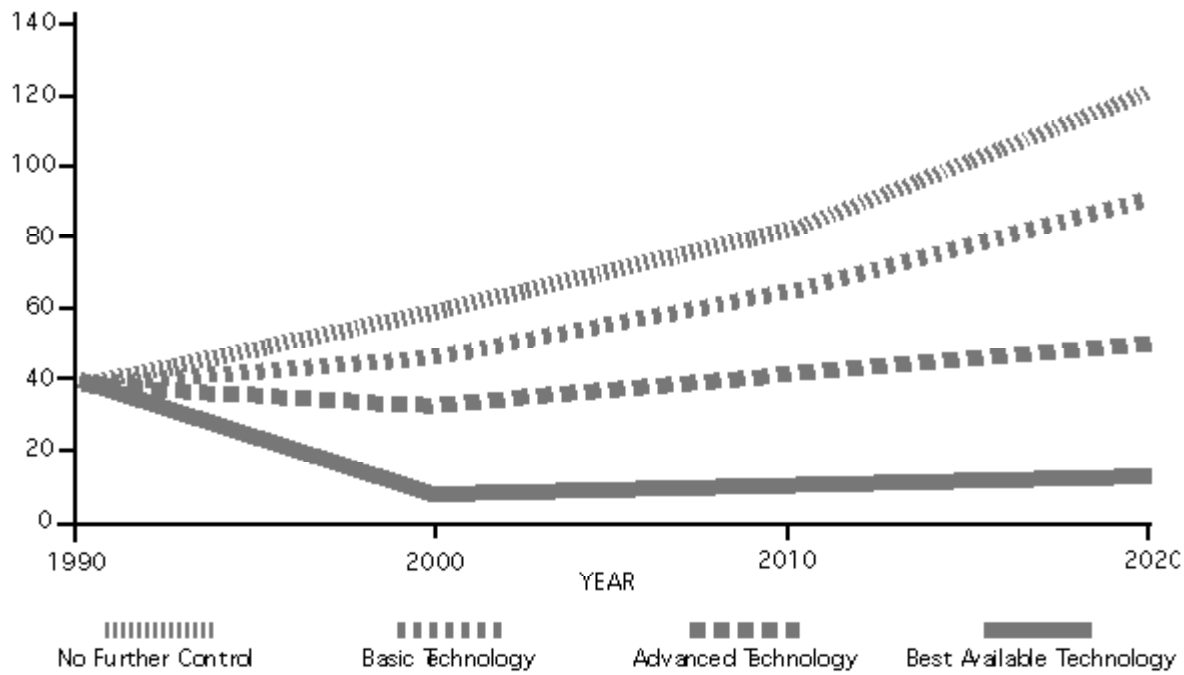

Figure 1.1
SO_2 Emissions in Asia (million tons)

Geographical Information Systems and Spatial Analysis

David Cunningham

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Cunningham maintained that communication is critical in interdisciplinary research because different disciplines often look at the world in different ways. The problems we face do not have instruction books so we must communicate effectively to solve them.

A Geographic Information System (GIS) is a group of elements or subsystems which are used to gain knowledge about the Earth, its features, and their distribution. The major components of a GIS are: hardware, software, digital data, procedures, and people. The major subsystems of a GIS are: data input, data storage and retrieval, data manipulation and analysis (that is what really sets GIS apart from other spatial information systems), and data reporting (output).

A key ability of a GIS is to take implicit information in a map and make it explicit (land form and slope from contours; distance to/from a feature). Cunningham quoted Ron Abler as saying that "GIS technology is to geographical analysis what the microscope, the telescope, and computers have been to other sciences."

Maps form the basis of any GIS. The basic elements of a map are scale, projection/coordinate systems, and symbolization. The fundamental problem of cartography is that there is a round Earth and a flat map. A map projection is the systematic representation of all or part of the surface of a round body on a plane. Because map projections represent a 3-D surface in only 2 dimensions, all map projections have some type of distortion. Map projections are usually based upon one of three types of developable surfaces: cylinder, cone or plane.

Many map projections exist to capture specific characteristics with the least distortion possible. No single projection can correct all errors; there is no "best" projection. Map projections generally address four types of distortion: area, shape, scale, and direction. The most common projections used are conformal; shape, angle and scale are generally correct, though scale is generally enlarged. Map projections are based upon datum. Horizontal datums are base on an ellipsoid and vertical datums are based on a geoid. Global Positioning Systems (GPS) is an Earth-centered coordinate system.

Cartographic primitives represent data on maps. They are either points, lines or polygons. These are discrete features. However, many natural phenomena are continuous. Discrete data is well represented by points, lines and polygons; these are called vector systems. Continuous data is best represented by a more regularly sampled array or surface; these are called raster systems. There are advantages and disadvantages of both which can be summed up in the quip: "Raster is faster, but vector seems more corrector."

The power of the GIS is in creating derivative data. It combines traditional land use maps with land cover characteristics from satellites, making data more valuable by combining it with other data.

GIS begins with building a digital spatial database. Creating this database is the most expensive aspect of any GIS project, taking from 50-90% of the total time invested. Methods of entering data include: manual encoding (typing in the data; slow, tedious, prone to error), manual digitization (tracing a map using a digitizing tablet), scanning or semi-automated processing (not a panacea, still requires lots of editing time), or direct digital transfer (transfer data from existing digital sources; faster, but still requires editing time, translating, checking).

Critical issues with regard to data input:

* build the data base with a vision of what you will be doing with it
* scale, resolution, accuracy of the data
* data needs assessment (what data are needed)
* how will the data be obtained and maintained
* documentation and metadata (data about the data)

A GIS could create a model of ecological corridors or predict where development will occur based on the elements development generally follows. Combining several GIS models could predict where the most pristine areas are likely to be developed, with obvious policy implications.

The ability to manipulate and analyze spatial data is what most clearly distinguishes GIS from other spatially referenced systems such as automated mapping and computer aided design. Beginning with a digital dataset, GIS provides the ability to interact with spatial data, to redefine, reassign and recombine spatial data, and to construct cartographic models, or a set of procedures to solve a problem. Three major types of spatial analysis are location, neighborhood, and zone.

Locations combine spatially discrete data, traditional overlay analysis, and local operators (any mathematical operation can be performed between layers or themes, for example, dividing the number of people by the number of households to get people per household). Neighborhood analyses analyze data within a prescribed distance. One type of neighborhood analysis is the proximity analysis which, for example, could identify all residences within five miles of a particular hazard. “Scan” or “focal” operations can determine minimum, maximum, density, average, diversity, etc., for example, determining the area with the greatest diversity of vegetation. Zone analyses analyze data within a prescribed boundary. Zonal operations might include summarizing conditions within a political unit, such as the percentage of agricultural land in a country.

Cartographic modeling is the combination of several layers of data through a prescribed set of procedures to create information. For example, it might be used to find the best place to site a landfill based on geology, hydrology, land acquisition costs, proximity to existing roadways and residential areas, etc. It is important to recognize however, that there are limitations to the technology. It does not always yield the right answer, and answers are only as good as the quality of the data going in. GIS is really two dimensional, so it has problems with 3-D and even more trouble dealing with time. There are also problems with how to deal with multiple scale and multiple resolution data.

Cunningham discussed several applications of GIS that he has worked on. One involved integrating GIS with an environmental simulation model for the Big Darby Creek Research Project in Ohio. The situation was that poor agricultural practices such as over-tilling had caused a great deal of soil erosion and siltation of Big Darby Creek. Using GIS to map the area revealed that over 90% of the land in the watershed is in active agriculture. The GIS also identified slope, soil information, 107 threatened and endangered species, and in creasing urbanization. Once baseline information was established, the GIS was used to predict sediment levels based on four scenarios: historic baseline, current conditions, adding a forest buffer strip

along the stream to filter nitrogen and sediment, and a management policy that implemented the conservation reserve program. Four scenarios for nitrogen fertilizer application were also tested out in the GIS.

In another example, GIS was used in the service of the Cincinnati Hillside Trust, a project aimed at protecting the hillsides of Cincinnati. The GIS was used to simultaneously look at soil associations, land slopes, orientation, etc. The power of the GIS is in creating derivative data. It combines traditional land use maps with land cover characteristics from satellites, making data more valuable by combining it with other data. The GIS could also be used to study landslide patterns and provide predictions, by combining data on slope and geology and existing landslides; a landslide map could be created. Similarly, a GIS could create a model of ecological corridors or predict where development will occur based on the elements development generally follows. Combining several GIS models could predict where the most pristine areas are likely to be developed, with obvious policy implications. A policy matrix could be created based on this information.

In the development of GIS, there is a goal of technology transfer from government to private industry. One such example is the use of GPS in construction and mining operations. By placing a GPS on a bulldozer, the operator can be directed to avoid hazardous conditions and can properly position a building with respect to orientation. Tests have found such devices to be within 5 cm accuracy for real time positioning of x, y, and z coordinates. GPS is critical to GIS because it gives the spatial reference necessary.

Another allied technology is called "terrestrial photogrammetry" which records digital pictures from a van as it drives along. This technology reveals features of the land in great detail, collecting features for a county in one third the time usually needed to collect far less accurate data. Its greater accuracy and detail for less time and money is beginning to bring this technology into use in local mapping projects.

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Land Resources Assessment: Modeling Food and Agriculture Systems

Günther Fischer

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The results of these simulations suggest that food production on the global scale is not likely to be significantly affected by climate change during the next sixty years. However, the distribution of climate impacts may be fairly uneven and the differences between developed and developing countries seemed quite large.

The International Institute for Applied Systems Analysis (IIASA) in Austria is involved in about a dozen projects studying and evaluating various causes and implications of global change. Project themes include land resources and land-use changes, sustainable use of forest resources, water resources, transboundary air pollution, and energy systems. Many of these projects involve complex modeling including representations of economic, social and physical systems. Günther Fischer presented results from IIASA's earlier Food and Agriculture project and described the issues and methods being studied by the current project on Modeling Land-Use and Land-Cover Changes in Europe and Northern Asia (LUC) which is focused on gaining a better understanding of land-use change and its effects in Europe and Northern Asia, and on developing improved methodologies and databases for projecting future scenarios of land-use and land-cover changes under a range of assumptions on future demographic, economic, technological and geobiophysical conditions.

Fischer gave a brief overview of the global general equilibrium model system developed by IIASA's Food and Agriculture Program (FAP), termed the Basic Linked System of National Agricultural Policy Models (BLS). It consists of 34 national and/or regional models: 18 national models, 2 models for regions with close economic cooperation (European Union and Eastern Europe + former USSR), and 14 aggregate models of country groupings. The individual models are linked together by means of a world market module. The outcome in terms of "real" variables is neutral with respect to monetary changes. The system is recursively dynamic, working in annual steps, the outcome of each step being affected by the outcomes of earlier ones. Each model covers the whole economy, for the purpose of international linkage aggregated to nine agricultural sectors and one non-agricultural sector. All accounts are closed and mutually consistent the production, consumption and financial accounts at the national level, and the trade and financial flows at the global level.

The concept of economic agents who decide on production and disappearance is the basis on which the BLS is built. Producers maximize returns to primary factors, i. e., capital, labor and land. Consumers are assumed to maximize utility. And governments follow prescribed objectives in their policy setting within the constraints of balancing expenditures with the revenues generated through taxes, tariffs or other means and international transfers.

The BLS has been used for several studies including an examination of the potential effects of climate change on world food supply, demand and trade. Using historical climate data and outputs from several General Circulation Models (GCMs), physiological crop models were used to track the effects of climate change on the yield of major crops, simulated at a number of sites representing a wide range of agro-ecological production conditions. These changes were then

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used to modify the yield functions used in the agriculture sector models of the BLS in order to examine the implications of climate change for the world food system.

A number of different scenarios were analyzed including current and doubled carbon dioxide (CO_2) climate scenarios and several different adaptation strategies that ranged from basic and simple adaptive changes to expensive and intensive changes in agricultural techniques. The results of these simulations suggest that food production on the global scale is not likely to be significantly affected by climate change during the next sixty years. However, the distribution of climate impacts may be fairly uneven and the differences between developed and developing countries seemed quite large. In general, mid and high latitude (mostly developed) countries experienced an increase in agricultural productivity while in tropical (mostly developing) countries, productivity generally decreased. For China (being the geographic focus of this Aspen Global Change Institute summer science session), all the simulations led to slightly positive changes in productivity.

If results of crop simulations, based on physiology but without economic feedbacks on production, are compared to dynamic simulations of crop and economic changes (including market forces that act upon changes in productivity), the addition of economic factors acts to reduce global scale changes in productivity, i. e., acts as an additional adaptive mechanism. But again, there are opposite effects in developed and developing countries. In developed countries, inclusion of economic factors in the simulations actually increases the benefits from climate change and in developing countries, the economic feedbacks exacerbate the reductions in yields due to climate change.

Fischer described a second example of agriculture sector modeling done at IIASA, related to land resources evaluation and agro-ecological analysis. To examine the effects of climate change at a national scale, a case study was done in Kenya. These simulations were performed using several layers of geographic data characterizing land resources and climate in a GIS environment. A major goal of this study was to examine the effects of climate change on land productivity considering a large number of different land utilization types. Using a number of climate sensitivity tests and GCM-derived climate scenarios, the simulations allowed the examination of the sensitivity of growing season length to factors such as temperature, soil moisture conditions and levels of atmospheric CO_2 concentrations. When examining the effects of temperature on productivity the results were highly spatially variable. Western, Nyanza and Central provinces (i. e., highland areas of central and western Kenya) generally showed increases in productivity with warming, while decreases resulted elsewhere (i. e., the low lying parts in Eastern, North-Eastern and Coast provinces). Interestingly, Kenya as a whole, when aggregating the results, did not show a major change in productivity. An important conclusion that emerges from this study is that in heterogeneous regions, there can be very diverse impacts of climate change on agriculture and this could be important for demographic, social and economic changes within countries even if there is little overall effect on national agricultural productivity.

In heterogeneous regions, there can be very diverse impacts of climate change on agriculture and this could be important for demographic, social and economic changes within countries even if there is little overall effect on national agricultural productivity.

Returning to the geographic focus of the AGCI session, Fischer explained that several meetings on integrated assessment, concentrating on East Asia, had been held at IIASA. A number of factors were identified that must be addressed in order to project the future economic, demographic and environmental conditions in China. These factors include demographic aspects such as population size, its geographic distribution, the effects of rapid aging of Chinese society, level of education, changing lifestyles, and effectiveness of population policies. It is also important to understand the major dynamics in the economy, including level of savings rates,

labor force, capital/labor ratios, technological development, distribution of economic sectors, and energy use. In addition to development issues, future environmental stability in China is a critical unknown factor and there are a number of problems that need to be examined including water supply and quality, land degradation, land transformation, air pollution, biogeochemical cycles, and potential climate change. Finally, political and institutional factors will need to be examined in order to make any predictions about future development.

Fischer also discussed work at IIASA currently in progress. IIASA has initiated a project on Modeling Land-Use and Land-Cover Changes in Europe and Northern Asia, to gain a better understanding of the critical social, technological and environmental factors and the constraints that have determined land-use change patterns. A better understanding of the sensitivity of land-use/cover change to different factors (e. g., technology, demographic and economic development, policy and changing environmental conditions) can then be applied to develop projections of regional land-use/cover change for a range of scenarios. To do this, IIASA is developing an integrated system of dynamic and geographically explicit models. The project is organized into several distinct research phases. The primary task of research activities at IIASA is to develop the continental-scale model system and databases. In parallel, a number of case studies are conducted to refine the questions that will be addressed at the continental scale. These case studies will also be used to strengthen the research methodology and to provide a historical analysis of what land-use and land-cover changes have taken place. In Russia, five case studies were initiated, each in a prototypical ecological and socioeconomic setting. In China, four case studies are underway representing both agricultural land use changes and the effects of urbanization on land use change.

The modeling methodology of this analysis of land-use change includes components dealing with demography, the economy, land use, land cover and environmental impacts and resource accumulation/degradation. The focus is on the feedbacks between economics, changing land use, and land productivity. This requires that production functions in the economic model consider both resource and environmental limitations, and consumer demand functions differentiate, at least, between urban and rural classes. A number of regional models will be combined at the national scale and will also be sensitive to international trade and policies.

The IIASA LUC project aims to provide an advanced and innovative methodology for the analysis of biophysical and human dimensions of land-use/cover change in the study region at different spatial scales, based on improved knowledge and data.

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Regional Effects of Global Warming in China

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Fu's research provides background for understanding the integrated effects of all Metro-Agro-Plex (MAP) units at the regional and global scale. In assessing potential impacts of global warming in China, uncertainties regarding how the climate will change regionally make impact assessments even more uncertain. Two approaches are to use General Circulation Model (GCM) outputs to drive statistical models and to look at historical analogs from long term records to see if there is a relationship between temperature change and other environmental elements.

China is becoming drier rainfall, river discharge and lake levels are all declining, and the amount of desertified land is increasing by 1,560 square kilometers per year.

As for the first approach, Fu has little confidence in using present GCM outputs to make regional assessments because the regional accuracy of GCMs is generally believed to be quite poor. GCM simulations indicate that under doubled carbon dioxide (CO2) concentrations, China will become 1 to 1.5°C warmer than at present with slightly higher precipitation and somewhat lower soil moisture. Model results also indicate that it will be drier in summer, with little change in precipitation in winter. Surface runoff is predicted to be less than at present, related to the drier conditions. The cropping system model of Zhao and Wang (1994) predicts that in the year 2050, under model-predicted climate conditions, there will be a 23.1% reduction in the amount of land in China that is single cropped and a 16.2% increase in the amount of land doubled cropped.

Using the second approach of examining historic records, we can look for relationships between changes in temperature and environmental conditions. The aridity (dryness) in China has had a strong influence on agriculture. Looking at the aridity index for eastern China from 100 stations, there has been an increase in aridity over the past century, with a significant jump in aridity in the 1920s that seems to be closely correlated with the temperature record. Statistics show that the rise in the aridity and temperature records were simultaneous in the 1920s.

Other evidence supporting the hypothesis that China is becoming drier includes recent data on rainfall in eastern China which indicates that rainfall is declining. A third corroboration comes from data on river discharge, which also indicates a decline. Data also indicate that the amount and length of the plum rains have decreased, by 22% and 37% respectively from the 1900s averages to the 1980s averages. Lake levels are falling too, and the amount of desertified land is increasing by 1,560 square kilometers per year.

Drier conditions in China is only part of the larger pattern which seems to follow the global warming scenario. Other parts of this pattern include the fact that there is increased rainfall in the tropics and less rainfall at mid-latitudes and in the subtropics, indicating an intensification of the Hadley circulation. Regarding the transition zone between the arid and moist areas,

paleoclimatic data indicates that this zone shifts southward during cooling periods and northward during warming periods. Such climatic changes related to the pattern of the monsoon can be used as historical analogs for climate warming.

Uncertainties for making assessments of the impacts of climate change are quite large. GCM outputs used for regional predictions are presently at a low level of confidence. For example, analysis of several GCMs simulated climatology of precipitation in China reveals similar results, matching the curve of precipitation decrease from the east coast to inland, and the general pattern of becoming drier in winter and wetter in summer. But comparing observations with GCM simulations of precipitation patterns, the spatial distribution of the rainfall pattern is quite different.

The high resolution regional model simulates the shifts of rainbelts, while the GCM does not. Simulating changes in rainfall patterns is the first step toward predicting harvests.

GCMs can not even simulate regional climatology, so how can we use their output to deal with regional agricultural questions? There is a need to improve cloud physics, boundary conditions and other elements of the models before we can begin to trust their regional predictions. GCMs are ineffective at simulating regional climate for a number of other reasons. Their resolution is too coarse and they cannot account for ecosystem effects well (that is why their spatial results are so poor). In response, high resolution regional models are being developed and may have more accurate results because they include mesoscale topography and land cover patterns, and vegetation/atmosphere interactions, which are particularly important in monsoon areas in which evapotranspiration and biogeochemical cycles are key.

To improve the regional climate system models, two major advances over GCMs in terms of regional predictive ability have been made recently. One is improved boundary parameterizations through the addition of a near surface layer so the flux between the boundary layer and the soil is transferred to the canopy and the surface layer. This offers better a simulation of the transfer of heat, moisture, etc. Secondly, links have been made between the physical and biological elements of the model, enabling vegetation to be linked directly to surface physical parameters.

Results of this regional model reveal that it captured not only the rainfall belts, as did the standard MM4, but also that it has the capacity to simulate the regional patterns of climate, which will be used as the inputs of impact models. In terms of temperature, the regional model performed better than the GCM regionally. Shifts of rainbelts due to advanced summer monsoons has not been captured in most GCMs, but this general pattern has been simulated by the regional model. Simulating changes in rainfall patterns is the first step toward predicting harvests, as rainfall remains a dominant factor in terms of impact on harvest.

The regional model can also be used to attempt to predict the impact of regional SO2 and SO4 distributions. Will these effects change the regional and global simulations under doubled CO2? Land use patterns can also be factored into the model to simulate regional forcing impacts of changing land cover types. Issues of Metro-Agro-Plexes may potentially be explored using these models.

The Nitrogen Cycle in China

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The global biogeochemical cycling of nitrogen (N) has been significantly impacted by anthropogenic activity. Perturbations to the global nitrogen cycle have implications that range from terrestrial ecology to atmospheric chemistry and global climate change. To understand these effects and predict future changes in the nitrogen cycle, it is important to examine the pre- and post-agroindustrial global nitrogen cycle as well as to estimate the potential effects of human activity in the future. To do this, Galloway has calculated the effect humans have and may have on the cycling of reactive nitrogen through the atmosphere and biosphere.

It is clear that human activity has dramatically altered the global biogeochemical cycling of nitrogen.

In a world unimpacted by human activity, the fluxes of N between reactive and unreactive forms would be roughly balanced. In this environment, denitrification fluxes would probably be about equal to fluxes via biological N fixation (converted from N2 to a reactive form of N). The global atmospheric/terrestrial N budget would include approximately 110 Tg N per year in denitrification and N fixation, 3 Tg N per year of N2 would be converted to NO due to lightning, 4 Tg N per year would be emitted to the troposphere as nitrogen oxides from soils and 6 Tg N of NH3 would be emitted to the troposphere from vegetation and soils and about 3 Tg N of NH3 per year from animals.

When human activities are added to these numbers, the global fluxes of nitrogen change dramatically. The combustion of fossil fuels results in the conversion of about 20 Tg N per year from N2 to NOx (NO + NO2). But combustion is not the only human impact on the global N cycle. The use of commercial fertilizers has resulted in major global changes in N cycling. Use of fertilizers results in the conversion of roughly 80 Tg N of N2 to reactive N annually. An additional ~40 Tg N of N2 is fixed due to the cultivation of leguminous crops. Significant amounts of agricultural N are then lost to the atmosphere as NOx or NH3. When soil, vegetation and animal losses are combined, these fluxes may amount to ~60 Tg N per year. While there are large uncertainties in these flux estimates, it is clear that human activity has dramatically altered the global biogeochemical cycling of nitrogen.

Atmospheric emissions of NOx and NH3 are increasing. The increase in NOx emissions began in the early 1900s and is closely related to increases in the extent of biomass burning and combustion. NH3 emissions have not been increasing for as long but are increasing at a more rapid rate now as the result of increasing fertilizer use and generations of domestic animals. Generally, the highest rates of NHx (NH3 + NH4 + aerosol) deposition also occur in the areas with the highest agricultural activity but there is also substantial hemispheric dispersion of NH3 emissions.

On a global scale, about 140 Tg of N are fixed annually by human activity. Of the 140 Tg total, an estimated 40 Tg are injected into coastal regions by rivers, 18 Tg are deposited onto the oceans from the atmosphere, 3 Tg accumulate as atmospheric N2O. This leaves about 80 Tg N unaccounted for. The possible sinks of this 80 Tg of nitrogen are increases in N in biomass, N in ground water, and denitrification to N2. It is worth noting that biological and social consequences of these potential sinks are very different. If reactive nitrogen is converted back to non-reactive N2 by denitrification, this nitrogen will be removed from the reactive nitrogen cycle and will become benign. If however, the reactive nitrogen ends up in ground water or biomass, there will be significant implications for water quality and aquatic and terrestrial ecosystems.

Looking forward to 2020, U.S. emissions will likely increase only slightly while Chinese emissions (from NOx) are projected to increase to about 5 Tg N per year.

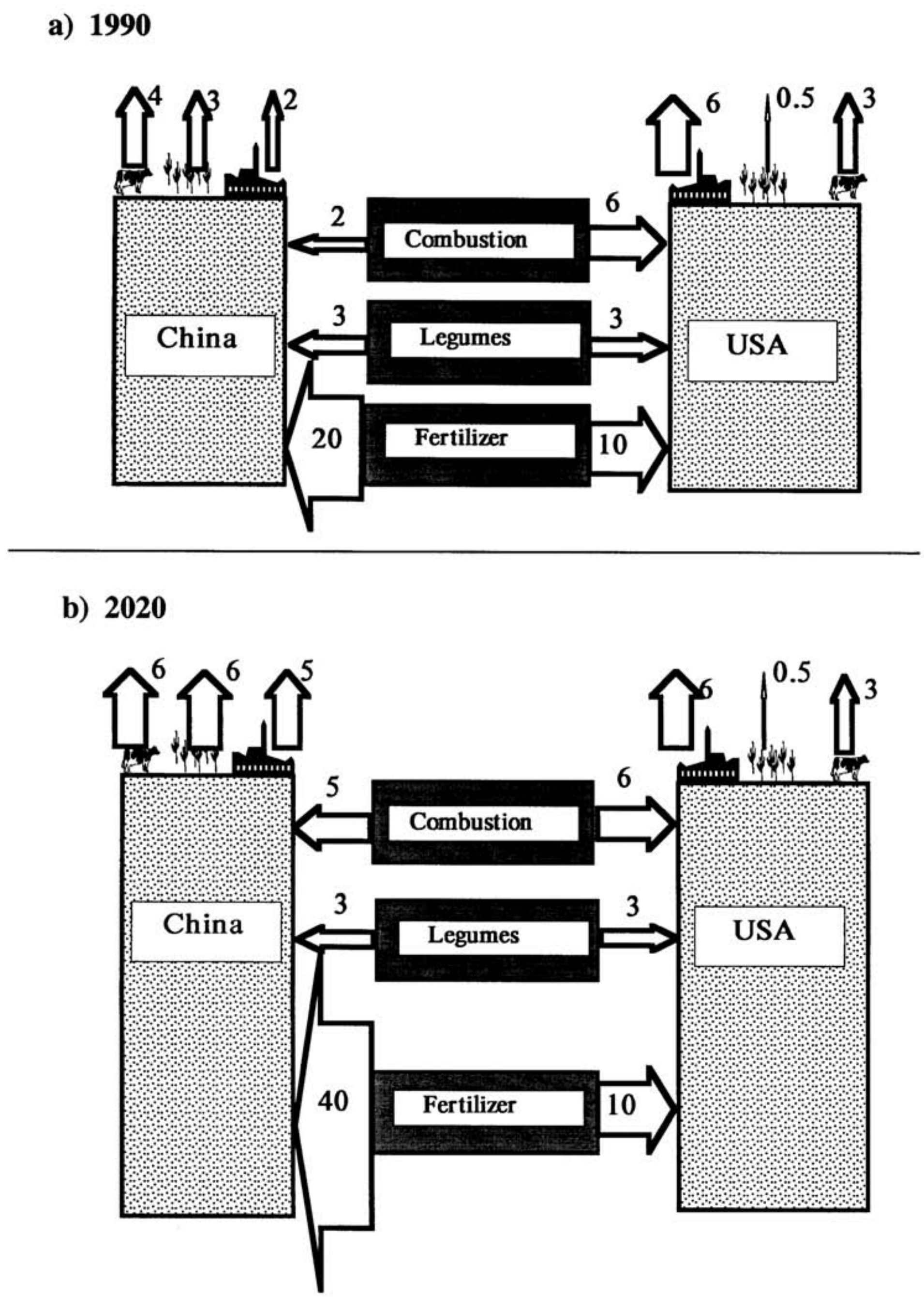
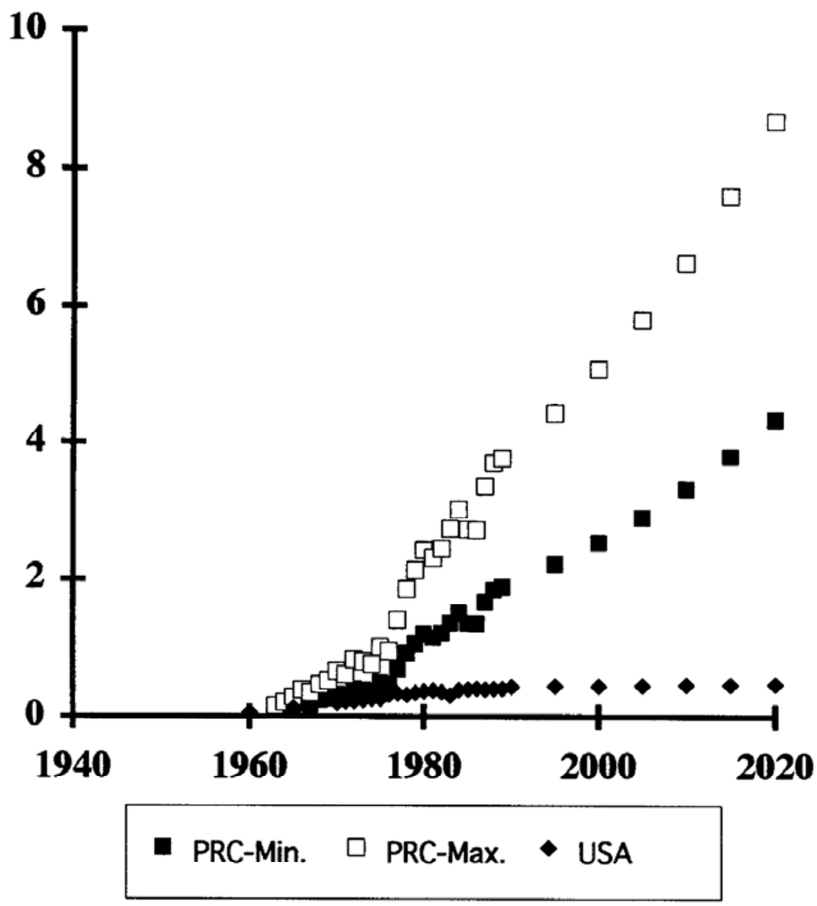


Figure 5.1
N Fixation and Atmospheric Emission - PRC and USA

Emissions of NOx and NH3 are currently high in Asia and are projected to rise dramatically in the future. To understand the potential for changes in the reactive N cycle in Asia, it is useful to compare China with the United States and examine both the present alterations of the N cycle in the two countries and the potential for future change (see figure 5.1). Current emissions of NOx due to energy use in the United States are relatively certain as both total energy use and NOx emission factors are known fairly well. Estimates for China are more problematic as both energy use patterns and emission factors are not as well documented. However, it is possible to make minimum and maximum estimates of NOx production using estimates for energy consumption and maximum and minimum NOx emission factors. Using this approach, current U.S. NOx emissions are about 6 Tg N per year while Chinese emissions are about 2 Tg N per year. Looking forward to 2020, U.S. emissions will likely increase only slightly while Chinese emissions (from NOx) are projected to increase to about 5 Tg N per year.



The tremendous potential for NH3 loss due to fertilizer application in China is likely to play a dominant role in the Chinese N cycle in the future.

Figure 5.2
Emission of NH3 from fertilizer (U. S. and China)

Currently, Chinese fertilizer use is increasing at a rate of 2.7% annually. In contrast, U.S. fertilizer use is relatively constant and is projected to remain flat. To calculate losses of ammonia from fertilizer use again requires the use of an emission factor. Unfortunately, emission factors vary with the type of fertilizer used. Unlike the U.S., much of the fertilizer used in China is in the form of ammonium bicarbonate for which published emission factors are uncertain. Using urea emission factors for ammonium bicarbonate (probably an underestimate

of losses) it is possible to estimate NH3 losses from fertilizer use. Emissions of NH3 from fertilizer use in China currently are about 3 Tg N per year. These emissions are already higher than U.S. emissions of about 0.5 Tg N per year. In the future, China's emissions (from NH3) are projected to increase to about 6 Tg N per year by 2020 while U.S. emissions remain relatively flat. The tremendous potential for NH3 loss due to fertilizer application in China is likely to play a dominant role in the Chinese N cycle in the future. Atmospheric NH3 in China will also be significantly affected by emissions of NH3 due to animals. These emissions could reach as high as 6 Tg N per year with significant uncertainty (see figure 5.2).

The comparison of the U.S. versus China demonstrates that human effects on nitrogen cycling in the two countries occur with different combinations of agricultural and industrial pathways. While fertilizer use dominates the current and future N cycle in China, combustion and fertilizer use dominate in the U.S. These two types of human intrusions on the N cycle have very different pathways for mitigation. Emissions of NOx due to combustion can be reduced by reducing the amount of material combusted or by controlling the combustion characteristics. NH3 emissions from agricultural systems may be reduced through a variety of management techniques.

NH3 emissions from agricultural systems may be reduced through a variety of management techniques.

Biomass Burning and Atmospheric Chemistry

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The trace gases and particulate matter emitted during biomass burning play significant roles in tropospheric and stratospheric chemistry and significantly affect the Earth's radiative balance. The impact of biomass burning is particularly significant in the tropics where the extent of land burned annually is quite large. For these reasons, it is important to develop accurate estimates of the spatial and temporal distributions of the trace gases and particulate matter emitted during biomass burning. These estimates require the use of data that range from FAO statistics to satellite images and involve multiple levels of analysis.

Fires are used widely for land use practices in most tropical countries and involve the burning of several types of vegetation. The largest amount of biomass burned in the tropics, roughly half, is combusted during savanna fires, followed by shifting cultivation, and deforestation, according to estimates based on FAO survey data of forest resources and several other sources. The spatial distributions of biomass burning can be obtained from satellite images. However, it is significantly more difficult to estimate the size of the burned area, the amount of vegetation that is burned, and the trace gas emissions that result from burning.

The largest amount of biomass burned in the tropics, roughly half, is combusted during savanna fires.

Satellite images provide information on the patterns of biomass burning in a region. However, the calculation of the amount of vegetation burned in that area requires several additional steps. The first step is to determine the vegetation type in each pixel. Each of these vegetation types is characterized by different burning patterns. The areas that are burned include tropical rain forest, and wet and dry savanna. Dry savannas are burned very infrequently because there is insufficient vegetation to support the spread of fires; thus these areas do not contribute significantly to the annual biomass burning emissions. In the rain forest, some areas are burned during deforestation and during shifting cultivation. For the most part, however, burning activity is concentrated in the transition zone between rain forest and humid savanna.

For each of these regions, the amount of biomass available for burning must be estimated. For forested areas, these estimates are based on the amount of aboveground biomass (derived from FAO statistics). In order to calculate the amount of biomass available for burning in humid savannas, rainfall is used to estimate the aboveground biomass. For savannas, the frequency of burning is also used to calculate the annual exposure of biomass to fires. Using these techniques, the amount of biomass burning in a geographic region can be estimated.

Following determination of the amount of biomass burned in each pixel, it is necessary to estimate the emission factors for trace gases (amounts of trace gases emitted per unit weight of biomass burned). The emission factors vary considerably between the flaming and smoldering phases of burning and are different for different types of fuels. Consideration of these aspects

of biomass burning are important in estimating trace gas emissions. During the flaming phase, there is usually ample oxygen to oxidize the biomass but during the smoldering phases, oxygen diffusion to the site of combustion becomes limited. This can then influence the relationship between combustion efficiency and trace gas emission (the emission factor).

To calculate emission factors, field measurements are used in which combustion efficiencies are compared to measured or estimated emission factors for each trace gas and vegetation type. For methane emissions, there is generally a linear correlation between the combustion efficiency and the emission factor with a general pattern of decreased hydrocarbon emissions with increased fire efficiency (see Figure 6.1). Methane emissions can be used to estimate the emissions of other hydrocarbons such as the non-methane hydrocarbons (NMHCs) as there is usually a positive linear relationship between the NMHCs and methane.

Biomass burning contributes more carbon monoxide to the global budget than industrial emissions. And the amount of benzene emitted from biomass burning is about twice the amount emitted from industrial activities.

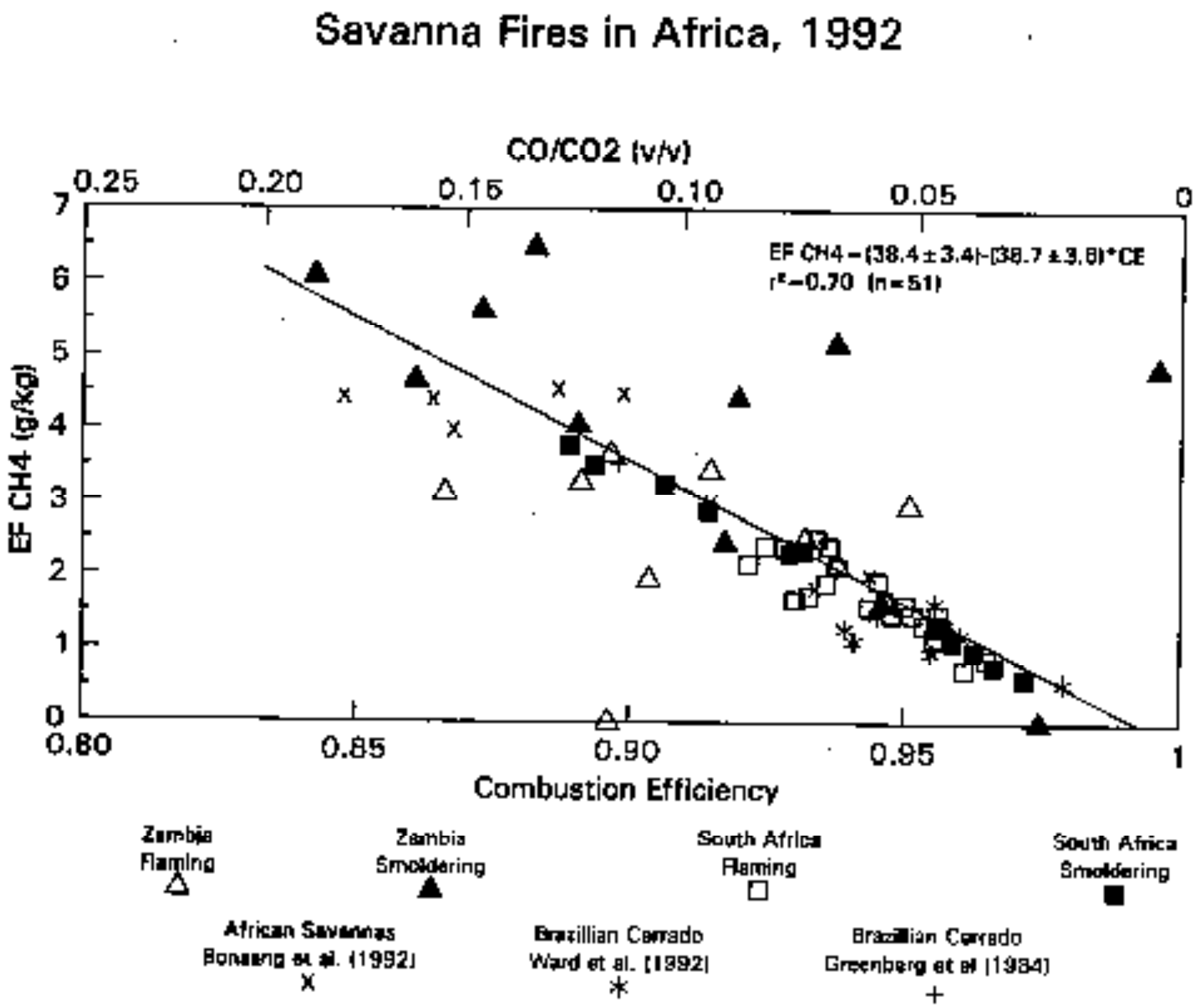

Figure 6.1
Savannah Fires in Africa, 1992

The global contribution of biomass burning to trace gas budgets is significant. For carbon monoxide (CO), biomass burning contributes more to the global budget than industrial emissions. In determining global budgets, it is important to consider, however, that all biomass burning is not equivalent and the relative contribution of different types of fires (e.g., forest, savanna, fuelwood, agricultural residues) depends on both the extent of burning and the emission factors associated with the burning. Table 6.1 shows various estimates of different types of biomass burning. For methane, biomass burning contributes about 8% to the global annual budget (comparable to the industrial sources). The amount of benzene emitted from biomass burning is about twice the amount emitted from industrial activities. Emissions of benzene are of particular interest because it is toxic and may affect human health in tropical countries.

The atmospheric importance of emissions of trace gases from biomass burning depends largely on the transport of these gases away from the site of burning. The biomass burning footprint for ozone covers much of Central and Southern Africa and much of the Amazon basin and some emissions of long-lived trace gases, such as CO, can be transported to the Northern Hemisphere.

There is significant uncertainty in the estimates of trace gas emissions from biomass burning. Most of this uncertainty is associated with estimates of the amount of land that is cleared and the amount of vegetation that is burned following clearing. Improving these estimates is critical to our understanding of the effects of biomass burning on global atmospheric chemistry and the radiative balance of the Earth.

Table 6.1

Comparison of Amount of Biomass Burned in the Tropics (Tg/year)

Year		**1980**				
Source	Seiler & Crutzen [1980]	Hao et al. [1990]	Crutzen & Andreae [2990]	Andreae [1991]	Hao & Liu [1994]	This Work
Deforestation	550-880	280-560	440-1560	420 (c)	730	980
Shifting Cultivation	900-2500	750-940	1110-2220	840 (c)	1310	1310
Savanna Fires	480-1900	3690	670-3560	3690 (c)	2640	3380
Fuelwood	620 (a)	680	670-1330	1260 (c)	620	780
Agricultural Residues	710 (b)	660	1110-1780	1360	280	380
Wild Fires					20	20
Prescribed Fires					<10	10
Total	**3260-6610**	**6060-6530**	**4000-10450**	**7570**	**5610**	**6860**

(a) Revised to include only topical countries [FAO, 1989a].
(b) Assuming 70% of the agricultural residues to be produced in the tropics.
(c) From Hao *et al.* [1990].

A Private, Decentralized Approach to a Climate Change Regime

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A privately-based regime has greater potential to bring global warming under control than does a regime based on international regulation.

Dealing with the risk of climate change is politically a very difficult issue. The way we deal with this problem and the outcomes will be affected by the time in which we attack the problem. Some strategies available now will not be available in the future. Heller is not confident that a direct multilateral negotiation to create a climate change treaty is the way to reach the kind of agreement about climate change we want to have. There are, however, indirect routes to get us where we want to go. Such a process will probably include unilateral actions, bilateral agreements, etc., and Heller believes such a process may be a more effective way of achieving our climate change goals than the prospect of bringing some 195 nations into agreement. Private firms can bring substantial resources to bear on the problem of climate change. A privately-based regime has greater potential to bring global warming under control than does a regime based on international regulation.

Joint Implementation (JI) is one of the methods for reaching these goals. JI sets up a market in which a country or company can limit emissions anywhere in the world and receive credit as though they had limited emissions at their own site. JI leaves the actors free to decide how to meet their environmental commitments. Rules and processes for JI are now being developed in several fora.

China is at the core of this issue because of its huge population and its economic growth, which is the fastest in the world. Judgments must be made about growth, and about the relationship between growth and emissions. Also, what is the actual relationship between emissions and climate, both regionally and globally? These are complicated relationships, and there is a great deal of uncertainty that enters into the political process.

With the single substantial correction of accounting for the offsetting effect of sulfate aerosols, climate models are now pretty credible, Heller says. What is the policy response appropriate to the anticipated economic, agricultural, health, and environmental impacts of climate change if indeed we believe it constitutes a serious problem? Political systems have trouble dealing with climate change for three reasons. First, there is great risk in setting policy due to the substantial uncertain ties that exist about climate change. Second, the climate problem will manifest itself in the future, and future generations are notoriously under-represented in the political process. Third, the actors that bear the costs are very spread out and unorganized.

There are two major paths that have evolved as the dominant strategies for dealing with climate change: mitigation and adaptation. Mitigation strategies deal with controlling emissions, while adaptation strategies address investments that help society adapt to a warmer climate. Adaptation strategies can be relatively local, and can be undertaken through existing regimes.

Mitigation strategies, on the other hand, must be much more globally coordinated, so there is a "collective goods" problem. Everyone gets the benefits and detriments of anyone's actions. For example, if a utility company in California mitigates emissions in China, the effects are the same globally as if they had mitigated emissions in California.

The standard path suggested in the UN process for a mitigation regime is that each country is assigned a target and then passes internal regulations to reach that goal. The other half of the regime involves some method of transferring funds from rich to poor nations. The alternative model for a mitigation regime favored by Heller is based on economic instruments and places much less emphasis on bureaucratic types of regulation. Instead, it sets up a tax rate for emissions, or some scheme of tradable permits for emissions that are distributed and then traded in the market (just as sulfur dioxide pollution is handled in the U.S.).

Many business people think this is a preferable way of handling this issue for a couple of reasons. First, it is left to the actor to decide what is the least expensive way of dealing with an emissions problem, and many find this decentralized method preferable to a command and control mechanism. Secondly, the transfer payments differ in amount and in who decides on their use. The amount of each transfer will be decided by the market place and by the parties to the transaction. So people who prefer market-based solutions over regulation argue that the market will provide more efficient, lower cost solutions, less political resistance, and better results. Which of these regimes is going to prevail?

People who prefer market-based solutions over regulation argue that the market will provide more efficient, lower cost solutions, less political resistance, and better results.

Heller thinks the UN climate change negotiation process is deadlocked for a number of reasons. First, in the current treaty, only the developed OECD countries made any commitment to reduce greenhouse gas emissions. Second, very few of these signatories will meet the commitment to return to 1990 carbon dioxide emission levels by the year 2000. Third, no commitments exist at all after the year 2000. So there is nothing remotely like a global commitment to substantive reductions. Joint implementation was buried at the Berlin meeting, Heller says, due to the inability to reach any commitments.

If international operations are shifted from one forum to another, away from a multilateral negotiation and to a less formal process, that can change the dynamics of the regime and provide a decentralized, more effective outcome.

When economists and others simulate climate negotiations, they conclude that it is possible that a bargain could be struck. In order to mitigate greenhouse gas emissions, we can either slow their growth and reduce their emissions now or we can make a massive effort in 30 or 40 years when the science is more certain. This is not really a choice, Heller says. The most people would be willing to pay to mitigate climate change is equal to the cost of adaptation to the change. If China continues on its current trajectory of greenhouse gas emissions, its carbon dioxide production will triple between 1990 and 2020. The most we can expect from the OECD countries is stabilization, or at best a very slight reduction in greenhouse gas emissions. With this being the case, it is probably best to invest in adaptation, since mitigation will not be practical. If we don't have a way to control the enormous growth in China, the world will shift its strategy from mitigation to adaptation, and then will not want to invest in mitigation. Adaptation costs are lumped (for example, once you invest in building a sea wall, it doesn't cost much more to build it a bit higher). This is what Heller calls the "China Trap."

Regarding the notion of joint implementation, Heller offers the following example. The cost of carbon reduction in Japan is about $600-$700 a ton; in China, it is much lower. Perhaps

Japanese money can be used to help China develop in such a way that greenhouse gas emissions per person are less than in the developed world. By pursuing such a path, more carbon emissions would be abated at a lower cost and with less resistance. This is the essence of why JI makes sense. In conclusion, Heller says, there are two nations in the world whose participation in a joint implementation regime is absolutely necessary for success: the U.S. (because it is the world's largest emitter) and China (because of its population and economic growth).

There are two nations in the world whose participation in a joint implementation regime is absolutely necessary for success: the U.S. (because it is the world's largest emitter) and China (because of its population and economic growth).

Changes in Global Tropospheric Chemistry

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The concentrations of many atmospheric trace gases are increasing, and the implications of the increases in some of these gases, such as carbon dioxide, are widely appreciated. There is not as wide a concern, however, about increasing concentrations of tropospheric ozone and the reactive nitric oxides, despite clear evidence that these gases are important to atmospheric chemistry, terrestrial ecology and human health.

> Concentrations of tropospheric ozone and reactive nitric oxides are increasing and there is clear evidence that these gases are important to atmospheric chemistry, terrestrial ecology and human health.

Tropospheric ozone is both a potent greenhouse gas and one of the major atmospheric pollutants. Ozone is produced though a series of reactions involving both hydrocarbons and NOx (NO + NO2). In many non-urban settings, NOx concentrations control whether ozone is produced or destroyed during these reactions. At NOx concentrations below approximately 50 parts per trillion by volume (pptv), the series of reactions involving NOx, atmospheric oxygen and hydrocarbons result in net ozone destruction. When NOx concentrations rise above this

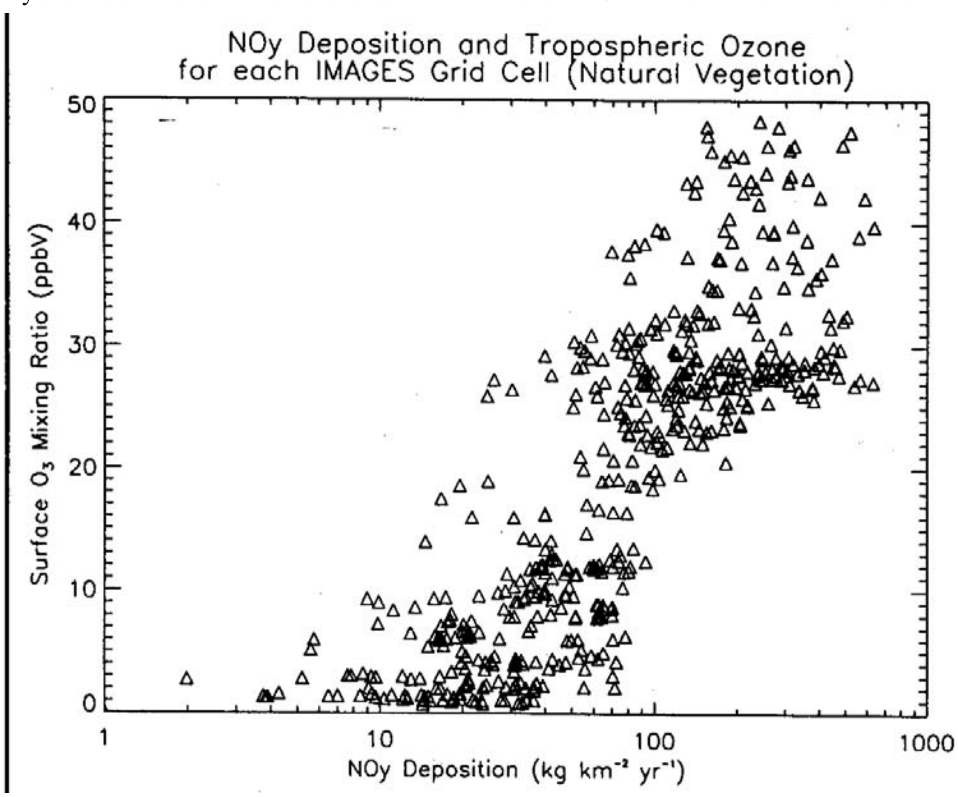

Figure 8.1
Correspondence between nitrogen deposition and surface ozone concentrations simulated by IMAGES. The r2 of a linear fit is .68

"critical value," the reactions lead to net ozone production. Measurements of the relationships between ozone and NOx concentrations in the atmosphere generally result in positive correlations between the two gases, until very high levels of NOx are reached (greater than ~0.5 ppb) when all of the available OH is consumed and net ozone production declines. The interdependency between NOx concentrations and ozone production results in a correlation between NOy (all N oxides except for N2O) deposition and ozone concentrations (figure 8.1). High levels of NOy deposition are generally found in industrial/urban areas with high NOx emissions and high ozone concentrations.

NOx is emitted by a variety of pathways including combustion, lightning, aircraft, soil microbiological reactions and biomass burning. The relative importance of these different production pathways varies both spatially and seasonally. In urban areas the combustion pathway generally dominates while in rural areas, soil and biomass burning emissions of NOx can be the major source. Natural sources of NOx, lightning, biomass burning, and soil emissions are the most difficult to quantify and thus have the greatest uncertainty associated with them. Comparisons of emissions amongst 3-D chemical transport models shows that they vary by 2 to 3 fold (table 8.1).

In addition to controlling concentrations of ozone, NOx emissions represent a major vector for the transport of reactive nitrogen between ecosystems.

In addition to controlling concentrations of ozone, NOx emissions represent a major vector for the transport of reactive nitrogen between ecosystems. Because nitrogen is a limiting nutrient in many ecosystems, the increased deposition of nitrogen may result in increased plant growth and thus increased sequestration of atmospheric CO2 in the biosphere. This effect has been modeled by Townsend, Holland and Braswell using a simple terrestrial ecosystem model known as N-Dep.

NOx sources in Tg N.y-1 for five 3-D chemical transport models					
NOx Emissions	ECHAM (1)	GCTM (2)	GRANTOUR (3)	IMAGES (4)	MOGUNTIA (5)
Fossil Fuel	20.0	21.0	22.4	21.9	20.0
Lightning	4.0	3.0	10.0	5.0	5.0
Soils	10.0	5.6	5.0	7.3	4.0
Aircraft			0.2	0.5	
Biomass burning	6.0	8.5	10.0	4.7	6.0
Stratosphere		0.6	0.2	0.2	
Total	40.0	38.7	48.8	39.6	35.0
(1) Roelofs and Lelieveld in press					
(2) Galloway et al. 1994; Kasibhalta et al. 1993; Yienger and Levy 1995					
(3) Penner et al. 1991; 1993					
(4) Muller 1992; Muller and Brasseur 1995; Lamarque pers. comm.					
(5) Dentener and Crutzen 1993					

Table 8.1
NOx sources in Tg N.y-1 for five 3-D chemical transport models

The N-Dep model is a perturbation model that is run in conjunction with a full ecosystem model (CENTURY). N-Dep calculates the effects of increased nitrogen availability on plant and microbial dynamics. Using stoichometric relationships between carbon and nitrogen and assumptions about the allocation of carbon in plants, N-Dep can be used to estimate the amount of carbon that is fixed through photosynthesis as the result of nitrogen deposition to the

terrestrial biosphere. In addition, the model can be used to track the residence time of the carbon in the biosphere following fixation and the relative importance of changes in plant allocation patterns to the retention of carbon in terrestrial ecosystems.

N deposition fields to drive N-Dep were generated using five different 3-dimensional (3 -D) chemical transport models. Previous work had demonstrated the importance of both the quantity and spatial distribution of the deposited nitrogen. The distinct spatial distributions of the N deposition reflected the different modeling approaches including differences in sources, transport, chemistry, and deposition parameterizations. Thus the results reflect uncertainties in our understanding of all the processes involved. The five 3 -D chemistry transport models used were: ECHAM, GCTM, GRANTOUR, IMAGES, and MOGUNTIA.

In addition to the spatial distribution of deposition, it is important to consider the spatial distribution of the ecosystems receiving the nitrogen. Only natural ecosystems are capable of responding to the added nitrogen by storing additional carbon. Forests, which store carbon in wood at a C:N ratio greater than 150, can store more than an order of magnitude more carbon per mole of nitrogen deposited than grasslands, which store carbon in soil organic matter at a C:N ratio of 12:16. The difference between agricultural and natural systems is due to the large amounts of nitrogen fertilizer already added during agricultural activities. Because there is already a great deal of nitrogen in agricultural systems, it is unlikely that any additional nitrogen in deposition will significantly increase carbon storage.

The deposition of N on land, oceans and natural vegetation was different between the five atmospheric chemistry models compared in this experiment. While all the models estimated maximum deposition rates near 50 degrees north latitude, there was considerable North and South spread. In addition, the partitioning of deposition between oceans, land and natural vegetation varied considerably between the models. As a result, the estimated carbon uptake due to nitrogen deposition for the five atmospheric chemistry models ranged from 0.45 to 0.6 Pg C yr-1 (Table 8.2).

The inclusion of ammonia deposition into annual estimates of nitrogen deposition could significantly alter estimates of carbon storage in natural ecosystems.

Global Carbon Sink from Fossil Fuel NOy Deposition					
	ECHAM (1)	GCTM (2)	GRANTOUR (3)	IMAGES (4)	MOGUNTIA (5)
N deposition on natural vegetation (Tg N)	4.90	5.50	5.40	5.00	5.70
1990 C sink nloss=.2 ndep (Pg C.y-1)	0.45	0.50	0.50	0.46	0.45
(1) Roelofs and Lelieveld 1995					
(2) Galloway et al. 1994; Kasibhalta et al. 1993; Yienger and Levy 1995					
(3) Penner et al. 1991; 1993					
(4) Muller 1992; Muller and Brasseur 1995; Lamarque pers. comm.					
(5) Dentener and Crutzen 1993					

Table 8.2
Global Carbon Sink from Fossil Fuel NOy Deposition

It is also important to note that none of these models included a consideration of ammonia deposition which could add significantly to the total amount of nitrogen deposited on terrestrial ecosystems. Total ammonia fluxes are estimated to be currently 45 Tg N yr-1 by Dentener and Crutzen for the MOGUNTIA model. In comparison, total annual NO X fluxes are estimated to be 35 Tg N yr-1 (Table 8.3). Inclusion of ammonia in the carbon storage calculation increased the globally integrated sink to 1.1-1.6 Pg C yr -1 depending on the assumption used.

The inclusion of ammonia deposition into annual estimates of nitrogen deposition could significantly alter estimates of carbon storage in natural ecosystems. In addition, ammonia fluxes represent another form of biosphere/atmosphere nitrogen exchange that occurs in addition to the changes in the global fluxes of the nitrogen oxides. Taken together, these changes in the global nitrogen cycle represent a dramatic human perturbation to one of the most important global biogeochemical cycles. Improved understanding of the ecological controls and atmospheric dynamics of these changes in the nitrogen cycle will be critical to assessments of the ecological, atmospheric and human implications of an altered nitrogen cycle.

The inclusion of ammonia deposition into annual estimates of nitrogen deposition could significantly alter estimates of carbon storage in natural ecosystems.

Comparison of NOx & NH3 emissions for MOGUNTIA		
(Dentener and Crutzen 1994)		
Emissions		
Tg N.y-1	NOx	NH3
Fossil fuel	20.0	
Animals		25.0
Soils	4.0	5.0
Fertilizer		6.0
Biomass burning	6.0	2.0
Lightning	5.0	
Total	35.0	45.0
NOx lifetime: 1 day		
NHx lifetime: 4.8 months		

Table 8.3

Comparison of NOx and NH3 emissions for MOGUNTIA

Demography & Systems Engineering in China

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The accuracy of demographic data is critical to an understanding of regional and global environmental issues. The need for accurate and unbiased information is particularly acute in China where population growth could outpace agricultural yields and undermine economic development. While there is a general perception that government statistics are correct and unbiased, a number of social, economic and policy factors can result in significant errors. Jiang described many of the problems associated with the collection of statistical data in China and particularly emphasized the factors that lead to under - and over - reporting of population data from the 1950s to the 1990s. In addition, he described the factors that have influenced the development of official Chinese population policy and the prospects for agricultural development to support the growing population into the future.

One common misperception is that China's policy is strictly one child per family. In reality, the population program should be viewed as a 1 to 2 children per family policy, with some families reaching 3 to 4 children.

To gain a better understanding of the problems associated with census taking in China, one can examine four censuses in China between the 1950s and 1990s (1953, 1964, 1982, 1990). Each of these censuses has been used to correct the under- or over-reporting of population in the regular population registration. To understand the causes and extent of these errors, additional surveys have been conducted by the Chinese government. The results of these surveys allow an examination of the reasons that underlie the biases in the final population data so that the demographic data published in the year books will be reliable.

In 1964, a survey was conducted in which 8 million people were removed from the population registry. Of these 8 million, about 6 million were found to be dead and the remainder were found to be non-existent. The significant over-reporting of population during this period was likely the result of a quota system and the control of agricultural land by production teams. Because of these government policies, agricultural resources were allocated on the basis of family size, creating a tremendous incentive for over-reporting.

In the 1970s and 1980s, government surveys indicated significant under-reporting, particularly in rural regions of China. These errors probably were the result of population control/responsibility programs that levied taxes based on family size. Allocation of agricultural resources no longer favored over-reporting as families were given control over land and the production team system was discontinued. In addition to policy-oriented biases, social traditions contributed to under-reporting. Because females are traditionally associated with their future husband's family, they are sometimes not reported as the children of their biological parents.

The Chinese government uses two primary methods to correct reported population data. The first is a sample survey of roughly 1.8 million people annually. In addition to the primary survey, an additional small survey is undertaken with highly trained personal and is used to

correct the larger survey. In some cases, the results of the small survey can in crease birth rate estimates by 2 percentage points. Starting in 1990, censuses are conducted every 10 years with smaller sample censuses in the intercensus years. These data from the smaller sample censuses can also be used to correct economic data. For example, in industrial towns there is often an over-reporting of economic outputs. In one instance, a townships' output was scaled down by 30% following corrections. The reasons for these errors vary from region to region and are not always overestimates. In rich areas there tends to be an under-reporting of income because only direct forms of income are taken into account. The reasons for under-reporting are probably related to a desire to not appear overly wealthy and thus subject to greater taxation. In poor areas, the opposite is true, and the tendency is to report all economic activity that roughly qualifies as income. This may be due to the desire of local officials to appear economically successful. In addition, there is a pressure to demonstrate year-to-year increases in economic activity as decreases would be viewed as a failure.

Per capita energy consumption in China averages less than 0.4 tons of standard coal. Compared to an average of 1.7 in developed countries and 8 to 9 in the United States, the Chinese average has no direction to go but up.

In the last several decades, the Chinese population problem has become a major focus of government policy. In the 1950s, Chinese population had already reached 600 million (about 25% of the world population at the time). But at that time, there was not much serious government attention. Although the 1956 five-year agricultural production plan contained population targets, these targets were not taken seriously or rigorously encouraged. The rapid population increases in the 1960s began to result in serious government attention. In calculations based on the 1960s growth rates, doubling time amounted to 30 years. By 2000 then, China would have had a population of 1.6 to 1.7 billion people and this would have reached 6 billion by the mid 2000s. As a result, the population problem became a focus for the national government. By 1962, a family planning program was introduced to major cities and some of the coastal areas. But after 1966, the process was interrupted by the cultural revolution. The programs were started again in 1972 and were expanded to the whole country. By the end of the 1970s, Chinese population approached one billion and the government tightened its program, making it one of the most rigorous in the world. One common misperception of this period however, is that the policy is strictly one child per family. In reality, the population program should be viewed as a 1 to 2 children per family policy, with some families reaching 3 to 4 children.

As China moves into the future there are several major problems that will need to be addressed. Chief among these is energy consumption. Per capita energy consumption in China averages less than 0.4 tons of standard coal. Compared to an average of 1.7 in developed countries and 8 to 9 in the United States, the Chinese average has no direction to go but up.

Another serious problem is soil erosion which is estimated to affect 38% of the total land area of China. Desert expansion due to the degradation of grassland is also a major problem as one third of the total grassland area is degraded. As a result, fewer cows can be grazed on a given area of land and grazing efficiency is lowered. Water use is also a critical issue as current Chinese water availability is roughly 1/4 of the global average and groundwater stores are already threatened.

Use of grain in China will also be an important issue as China continues to increase the amount of grain imported from abroad. Grain production in some areas of China has been somewhat decreased due to conversion to cash crops and conversion of land from agricultural to industrial uses. It is also important to note that current grain imports are directed to urban areas and in many rural farming areas, individual families have grain stores. Development of cities will then be a critical component in future Chinese agricultural policy.

At the moment, the Chinese government is hoping to increase grain production by increasing areas used for grain production, increasing the use of two cropping systems, and increasing the contribution of technology to grain production by increasing nitrogen and phosphorous fertilizer use and through soil surveys and land analysis. Efforts are also being made to create new high-yield varieties of grain and improved irrigation systems.

Development of cities will then be a critical component in future Chinese agricultural policy.

Technology and Environment in China in the Coming Decades

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The shifting of migrants in China from rural areas to cities is a more significant problem than sheer numbers of people.

One of the first hurdles to be surmounted in the effort to work together across cultures on important environmental issues is how to integrate the different thought processes that can create communication gaps between people. Kiang quotes Sun Tze as saying "knowing one's self, knowing others; one hundred encounters, one hundred wins," and updates it to say "knowing one's self, knowing others; one hundred cooperations, one hundred win-wins."

Kiang believes that the human race must recognize that there are constraints to development. In this regard, population is the number one issue. At the current rate of growth, we will not have the resources to educate the future population. And if we cannot do that, how can economic development be sustained? A simple example of a constraint is that the world doesn't have enough lead for the batteries of all the cars that would be driven by all the Chinese in the future.

In addition to the numbers of people in China, there are the issues of population distribution and urbanization. About 90% of Chinese live in a wide band along the coast. Of the ~800 million rural dwellers, only about 200 million are engaged in growing food. This leaves a flood of humanity heading for the cities, generating crime and other social problems driven by the process of urbanization. This shifting of migrants from rural areas to cities is a more significant problem than sheer numbers of people.

The major issues for Chinese science and technology reform are that science and technology must advance in coordination with social and economic development, and that the primary purpose of science and technology reform must be the acceleration of economic development. Emphasis must be placed on research into production technologies and the development and popularization of technologies that can help to improve the growth of the national economy. Basic research must expand steadily. And the grasp and assimilation of foreign scientific and technological achievement is regarded as an important way to develop China's science and technology.

To implement this policy, China has established the "Spark Plan" and the "Torch Plan." The main purpose of the "Spark Plan" is to industrialize the rural regions by promoting small and medium-sized enterprises. Such enterprises constitute 90% of the total industrial enterprises in China, producing over 70% of the gross industrial output value. Serious problems including weak technical capability, shortage of financial resources, out-of-date processes, and obsolete products still exist in this arena. Five hundred showcase enterprises have been selected to promote the necessary technological transformation.

The "Torch Plan" is designed to commercialize high-tech products in the targeted areas such as biotechnology, information technology, automation, new materials, energy, laser technology, and space technology. Three special zones in Beijing, Shanghai, and Wuhan have been designated to promote the commercialization of high-tech products. Preferential treatment (such as tax incentives and attractive salaries) has been given to these special zones.

China's science and technology policy is closely related to economic reforms and is intended to facilitate technology transfer and promote trade. Under the "open door" policy, intended to create a window for technology transfer, economic zones and coastal cities have been open to foreign investment, joint ventures and cooperative manufacturing arrangements. To date, however, the results have been somewhat disappointing. There are serious impediments to economic reform: a cumbersome bureaucracy, friction between the old and new ideology, and out of date management systems. Despite these impediments, China's economy has been growing very rapidly.

China's economic growth is characterized by

* annual GNP growth of 10% since 1978,
* annual GNP growth of 13% for the last three years,
* the world's third largest economy in terms of purchasing power,
* could surpass the U.S. economy in the early 21st century.

As it shifted from a socialist-controlled economy to a free enterprise economy, China allowed the formation of privately owned enterprises, known as township enterprises. In 1991, China began to privatize some of its state-owned enterprises by permitting them to sell stock domestically and overseas. Today, 50% of the economy is conducted through private enterprises.

The open-door policy has been expanded to allow 100% foreign ownership for most ventures, ventures are allowed to exist in perpetuity, there is no limit on imports of raw materials, and no profit repatriation restrictions. Under the new policies, China has attracted an enormous amount of foreign investment, with investment from the U.S. alone rising from $4 billion in 1991 to $34 billion in 1994. Energy investments are not included in these numbers, and are negotiated as a completely separate issue. There are questions about who operates and manages power plants, what the equity shares should be, etc. U.S. investors insist on 15% of profit due to the high risk, but China only wants to give them 12%. This is an ongoing negotiation.

Under the new policies, China has attracted an enormous amount of foreign investment, with investment from the U.S. alone rising from $4 billion in 1991 to $34 billion in 1994.a

Kiang made a number of observations about the political outlook and possible risk factors in China. First, there does not appear to be a clear successor to Deng Xiaoping. Also, some of China's deepest problems have not been addressed, including its archaic political structure, corrupt Communist Party officials, large and inefficient state-run enterprises, and an inflation rate of 25%. There is great unevenness in economic development in coastal versus inland areas. Similarly, the large gap between rich and poor and absence of a middle class generates social instability. There has also been explosive growth in and around Beijing. Future prospects include short term instability and substantial long term growth.

Kiang focused on Jiangsu Province, one of China's largest, with a population of 70 million people. It has the largest provincial gross economic product, accounting for 13% of the nation's total output. It is the fastest growing province, with an economy driven by Shanghai's reemergence as a major financial center. Roughly 70% of the economy is accounted for by private enterprises. Around Shanghai, three satellite cities have emerged. Suzhou, with 6.3

million people in the greater metropolitan area, is located 60 miles from Shanghai. Wuxi, with 4.3 million, is 75 miles from Shanghai. Changhou has 3.2 million people and is 90 miles from Shanghai. Foreign investment in this region has taken a number of forms including townships set up with foreign money. For example, 70 square kilometers of prime agricultural land was carved out to establish the Suzhou-Singapore township in 1993 by the government of Singapore. The U.S. has already invested $1 billion in this enterprise. Two other smaller townships have since been established by Singapore in 1994.

Small and medium size businesses in the townships are often major polluters because they are not state owned or controlled and they generally do not pay attention to the environmental effects of their production. Because free market businesses are not subject to the same restrictions, state owned businesses can not compete with the market businesses.

In one month in Shanghai, Otis Elevator will install more elevators than in all of the U. S. in one year.

The enormous economic growth China is experiencing has many implications, one of the most important of which is the effect on energy demand. Jiangsu province will need to quadruple its power supply by the year 2000. What is the best energy source for this huge expansion? Hydroelectric? Nuclear? There is a need for small (1 megawatt) power plants to provide for the new energy requirements of small and medium industries. What is the best energy source for these and how can the best technologies be acquired?

Transportation is another key challenge facing China, particularly Jiangsu Province. Some 700,000 to 1,000,000 people will be traveling through this area daily. Six-lane highways are already under construction to accommodate anticipated future traffic. There is a major push to provide cars for nearly all Chinese families; this may be a big mistake, Kiang says.

Water is perhaps the most serious problem. Some 100,000,000 people in China are infected with hepatitis B due to the lack of safe drinking water. In Shanghai, this safe water problem has reached crisis proportions. Efforts are underway to improve the situation, including establishing water purification systems in industrial parks. Solid waste is an other problem, driven in part by the enormous amount of construction underway. In Shanghai alone, there are 5,500 sites under construction simultaneously. In one month in Shanghai, Otis Elevator will install more elevators than in all of the U.S. in one year.

With a billion square feet of construction underway, China’s future is both bright and full of dust, Kiang says. This makes reference to the fact that while growth can lead to many positive outcomes, there are down sides, such a the huge problem of air pollution in Chinese cities and the social instability that is accompanying this rapid growth.

Land Use and Atmospheric Trace Gases

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Land use and agricultural management can strongly affect the atmospheric concentrations of trace gases such as the nitrogen oxides (NOx), ammonia (NH3), carbon dioxide (CO2) and methane (NH4). Unfortunately, fluxes of trace gases from agricultural systems vary dramatically in both space and time and thus it is difficult to use field measurements to accurately scale to regional and global estimates of emissions. For this reason, it is helpful to develop models of biogeochemical dynamics in order to better understand and predict the exchange of trace gases between the atmosphere and the biosphere.

One such ecosystem model is the denitrification/decomposition (DNDC) model developed by Li and colleagues at the University of New Hampshire. DNDC is a multi-level, process-based model that links climate, soil and vegetation processes in order to predict fluxes of trace gases from agricultural ecosystems. The model uses linked submodels including soil climate, denitrification, plant growth and decomposition. The model requires multiple inputs including daily/monthly air temperature and precipitation, soil texture, bulk density, organic carbon and pH. In addition, agricultural practices such as crop rotation, tillage, fertilization, manure amendment, and irrigation are input as management techniques, and atmospheric N deposition can be included as an input. The model provides output for multiple traces gases including CO2 (broken into root and soil respiration), nitric oxide (NO), nitrous oxide (N2O), dinitrogen (N2), NH3 as well as N uptake by plants, and nitrate (NO3) available for leaching. Carbon and nitrogen pools are also monitored and are available as outputs. These pools include above-ground biomass, roots, soil litter, soil microbial biomass, humads and passive humus.

DNDC is a multi-level, process-based model that links climate, soil and vegetation processes in order to predict fluxes of trace gases from agricultural ecosystems.

The DNDC model was validated against CO2 efflux data from fields under varied agricultural treatments in Columbia, Missouri. The model did a reasonably good job of capturing the seasonal changes in respiration and came fairly close to matching the observed data. Additional validation has been done using the Rothamsted Station in the United Kingdom to test DNDC's ability to predict longer term soil organic carbon dynamics (up to 150 years). In these runs, the simulated output again tracked the field data fairly well.

To assess the ability of DNDC to simulate N2O emissions, simulations were performed for one year of emissions from a research site in Florida. In these simulations, DNDC captured the trends in the data but tended to overestimate the actual fluxes. Further validations for N2O were done using data from multiple sites using one-year simulations. In these comparisons, which included farmlands, forest, grasslands, and marshes, DNDC came very close to the annual N2O emissions for the majority of the sites.

In addition to assessments of the ability of DNDC to simulate fluxes of trace gases, a number of sensitivity studies have been carried out in order to examine the effects of management on N2O production and organic matter accumulation in agricultural ecosystems. In these series of model runs, six agricultural practice scenarios were simulated. These scenarios included a baseline scenario (conventional tillage, 50 kg ammonium nitrate (NH4NO3), no manure, no irrigation), a reduced tillage scenario (conversion from conventional to conservation tillage), another reduced tillage scenario (conversion from conventional tillage to no-till), an enhanced fertilization scenario (increasing fertilization to 150 kg NH4NO3 per year), a manure amendment scenario (2000 kg manure/ha), and an irrigation scenario (irrigation of 5 times with 5 cm of water). These various scenarios were run under a variety of conditions which included a wide range in temperature, precipitation, soil texture, soil organic carbon (SOC) and soil pH. The changes in soil C storage associated with changing conventional tillage to no-tillage varied with temperature, precipitation, soil texture, SOC and soil pH. The most dramatic sensitivity of C storage to changes in tillage appears to be related to soil texture with the largest soil C increases occurring in sandy soils and the smallest occurring in clay soils.

In 40-year runs examining the effects of tillage on soil C storage at 7 sites in the U.S., no-till agriculture generally resulted in the largest increases in soil C.

In 40-year runs examining the effects of tillage on soil C storage at 7 sites in the U.S., no-till agriculture generally resulted in the largest increases in soil C, followed by conservation tillage and conventional tillage. In sites where C was lost over the 40-year period (2 of 7 sites), the largest losses were associated with conventional tillage and the smallest with no-till agriculture. N2O losses from no-till simulations were somewhat less than conventional and conservation tillage in the 40-year simulations but the differences were not great. Additions of manure, however, resulted in increased N2O annual loss over the 40-year period.

Fertilization effects on soil C storage were quite variable along gradients in precipitation, soil texture, and SOC. In general, the largest increases in soil C storage in response to fertilization occurred in wet regions, clay soils and soils with low SOC. Irrigation also affected soil C storage and with the largest increases in soil C occurring with low precipitation, sandy soils, and high SOC and pH.

N2O flux responses to fertilization were varied and especially sensitive to soil texture, SOC and pH. Manure amendments always increased N2O fluxes, suggesting that the availability of organic carbon plays an important role in the control of N2O fluxes. N2O fluxes with manure amendments were also highly sensitive to changes in temperature, precipitation, soil texture, SOC and soil pH. Reductions in tillage generally reduced annual N2O fluxes with the degree of reduction strongly influenced by SOC.

The sensitivity of N2O fluxes to changes in climate was assessed for a corn field in the corn belt. In these simulations, N2O fluxes generally increased with temperature, showed a varied response to changing precipitation and increased proportionately with increasing N concentrations in rainfall.

Comparisons of simulations of Chinese agriculture and U.S. agriculture yield somewhat different results. In North China, the soils tend to be more N poor than the soils in the major croplands of the northern U.S. As a result, plant N demand seems to be higher, resulting in relatively smaller losses of nitrate to leaching and similar ammonia and nitrogen oxide losses. Similarly, in South China, the unique soil-water-plant conditions tend to result in relatively smaller losses of nitrate to leaching.

DNDC can be used for regional estimates of trace gas flux using a combination of statistical and remotely sensed data. In regional simulations using Florida as a sample, it was found that 9% of the land area with organic soils in Florida was responsible for 40% of the N_2O flux. These types of simulations offer a great deal of promise for identifying areas of significant trace gas source strength. Additional work has been done to estimate emissions of N_2O from the U.S. and further validation of DNDC is currently underway at a Costa Rican tropical site.

The results of multiple validations and sensitivity analyses demonstrate the utility of the DNDC biogeochemical model. By modeling biogeochemical processes in agricultural and natural ecosystems, it is possible to gain insight into both the spatial and temporal variability in trace gas production. In addition, models such as DNDC allow us to test our understanding of the processes responsible for organic matter dynamics and trace gas production in terrestrial ecosystems while also working to develop regional budgets of trace gas fluxes.

By modeling biogeochemical processes in agricultural and natural ecosystems, it is possible to gain insight into both the spatial and temporal variability in trace gas production.

Large-scale Tropospheric Air Chemistry Measurements

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The results of the PEM-West experiment suggest that the Pacific is not as pristine as many researchers had previously thought.

Much of the northern hemisphere has been significantly affected by atmospheric pollution. As a result, many scientists and policymakers are interested in relatively pristine regions such as the remote Western Pacific. This interest arises from both the relatively remote nature of the region and because the rapid growth of Asia and the Pacific Rim makes this region particularly sensitive to regional/global changes in tropospheric chemistry resulting from human activity.

To examine the tropospheric chemistry of the Western Pacific region, the Western Pacific Exploratory Missions (PEM-West) were initiated in 1991. The PEM-West experiment was designed as part of the NASA Global Troposphere Experiment (GTE). The project's primary objective was to examine the atmospheric chemistry of ozone and ozone precursors in the Western Pacific region and to establish the effect of anthropogenic influences on tropospheric chemistry. In addition, the project investigated the chemistry and transport of sulfur species throughout the region with the intent of differentiating between oceanic and atmospheric sources. The region also contains several large-scale meteorological features such as the Asian dust storms, the Japan Jet, monsoons and the El Niño-Southern Oscillation (ENSO) phenomenon that make it particularly interesting to study.

The PEM-West missions were separated into two phases designed to capture the impact of seasonal meteorological dynamics of the region. The first phase, carried out in the Fall of 1991, examined the atmospheric chemistry of the region during a period characterized by relatively clean southwesterly flows from the Pacific and over the Asian continent. The second phase, in Spring of 1994, focused on the atmospheric chemistry of the region during the period when the flow patterns are reversed and the Western Pacific region receives air masses that have traveled over the Asian continent. By focusing on these two periods, researchers were able to examine the importance of emissions from the Asian continent and compare tropospheric chemistry during the Spring to the chemistry during the more pristine Fall conditions.

The experiment combined data from both aircraft flights and ground stations distributed through the Western Pacific region. The data obtained during the experiment included measurements of ozone and a suite of ozone precursors which included the nitrogen oxides NO and NO2 (NOx), carbon monoxide (CO), methane (CH4) and the non-methane hydrocarbons (NMHC). In addition measurements of sulfur species and radiatively important species such as nitrous oxide (N2O), CH4, and carbon dioxide (CO2) were made.

The PEM-West campaign allowed researchers to evaluate the distribution of trace gases and aerosols in the remote troposphere while also allowing a quantitative evaluation of the

vertical transport of trace atmospheric species from the Asian continent and Pacific Rim to the atmosphere over the Pacific Ocean. The results of the experiment suggest that the Pacific is not as pristine as many researchers had previously thought. Even in the upper levels of the troposphere during the Phase A portion of the experiment, researchers found evidence of pollution from surface emissions over Asia and perhaps the whole of the northern hemisphere. CO concentrations were found to reach twice those observed in the Southern Hemisphere and the upper troposphere was established as the major ozone production regime in the area. Researchers also found that typhoons were very effective in transferring lower tropospheric trace species up to the upper troposphere. Transport of stratospheric air into the troposphere appears to be significantly slower in the Fall than in the Spring.

During Phase B of the experiment, lightning was established as the major source of NOx in the upper troposphere. In addition, winds behind cold fronts were found to sweep large quantities of pollutants from Asia as far as Alaska. Anthropogenic signatures were found in both reactive species and radiatively important species. Interestingly, strong correlations were found between pairs of greenhouse gases such as in CH4 and N2O and in CH4 and CO2. During Phase A, however, an inverse correlation between CH4 and CO2 was found. These correlations can be used to gain information about continental sources and sinks.

Sulfur concentrations at altitudes as high as 10 km show very significant anthropogenic influences. As much as two-thirds of the sulfur dioxide above 8 km seems to be anthropogenically derived and probably most is from Asian emissions with a lesser contribution from Europe and perhaps even North America.

As much as two-thirds of the sulfur dioxide above 8 km seems to be anthropogenically derived.

The impact of anthropogenic pollutants is also significant on a local to regional level through the effects of aerosols. Aerosols can act to directly affect climate through the scattering of incoming solar radiation back to space and the absorption of solar radiation. There are also indirect effects which are less well understood but may include the behavior of aerosols as cloud condensation nuclei (CCN). Most of the aerosol effects on climate tend to counteract warming due to the greenhouse gases. The magnitude of the radiative effects is not well understood.

Using a case study for the eastern U.S., it is possible to examine the potential local to regional effects of aerosols. Using simulations for a high pressure system in the Eastern U.S., aerosols resulted in a 0.9° K decrease in surface temperature near noon, as well as decreases in the height of the planetary boundary layer, latent heat flux and sensible heat flux. These changes may be negligible with respect to day-to-day weather but may be very significant for long term regional to global climate change. Anecdotal evidence suggests that aerosol effects in China could be very important and could result in significant human health impacts. Additional study will be needed to fully understand the regional and global effects of aerosols but studies such as PEM-West provide an excellent opportunity to examine the effects of large land regions on tropospheric chemistry.

Acid Deposition and Ozone Monitoring and Modeling in China

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Summertime short-term average levels of tropospheric ozone reach 200 to 300 ppbv, and the frequency of exceeding standard levels increases each year due to increases in emissions of NOX, SOX, aerosols, and hydrocarbons from burning fossil fuels.

Measuring and modeling acid deposition in China

Acid deposition has become an important topic of research in China over the past several years. As a result of China's extensive fossil fuel burning, sulfur dioxide (SO2) and other pollutants are emitted into the atmosphere, and many cities have levels of these pollutants that exceed standard levels. This is especially true in cities in northern China which use a good deal of space heating in homes and other buildings. In the southern part of China, acid precipitation is becoming a significant issue. As a result, China's meteorological administration has set up a series of 100 monitoring stations, including 30 permanent ones, to monitor pH values, and various pollutants in order to better understand acid rain trends. These stations have been collecting measurements for two years and data is now available.

This measurement data is being used to simulate acid deposition in a regional acid deposition model (RADM). The RADM is a meso-scale meteorological model which uses emissions data on NOx, SOx and aerosols as input parameters to simulate acid deposition in China. After using the model to simulate acid deposition, this output is compared with measurements of acid deposition from the monitoring network with good results. So far, only wet deposition has been measured but it is hoped that dry deposition can soon be added to the measurement program.

Measuring and modeling ozone in China

Ozone in both the stratosphere and troposphere is an important species for study. The concern over ozone stems from the fact that the "good ozone" in the stratosphere which protects the biosphere from harmful ultraviolet radiation from the sun is decreasing, while "bad ozone" in the troposphere, which is a pollutant that is harmful to ecosystems, is increasing in recent decades.

Ozone is produced in a photochemical reaction by NOx, hydrocarbons and other precursors in the presence of sunlight. Recent research suggests that China has a significant ozone problem. Ozone concentrations are now measured at five monitoring stations. In rural areas, annual average concentrations are 40-50 ppbv, while urban annual averages are around 60 ppbv. Summertime short-term average levels are much higher, reaching 200 to 300 ppbv and the frequency of exceeding standard levels increases each year due to increases in emissions of NOx, SOx, aerosols, and hydrocarbons from burning fossil fuels. Concern over this situation prompted the formation of the China Ozone Research Program (CORP).

Some interesting results have already come out of this program, including the fact that there is strong diurnal variation in ozone measured at stations in Linan and Waliguan (Figure 13.1). Data also reveal a very different ozone pattern between east and west in China. Extremely low summertime ozone levels over the Tibetan plateau have also been discovered by the CORP. Though the reasons for these ozone variations are not yet understood, additional research is underway to explain these phenomena and also to explain fundamental chemical and meteorological processes with these data.

When data from the Total Ozone Mapping Spectrometer (TOMS) were compared with that of the CORP stations, the results were encouraging. There was less than a 6% difference between them.

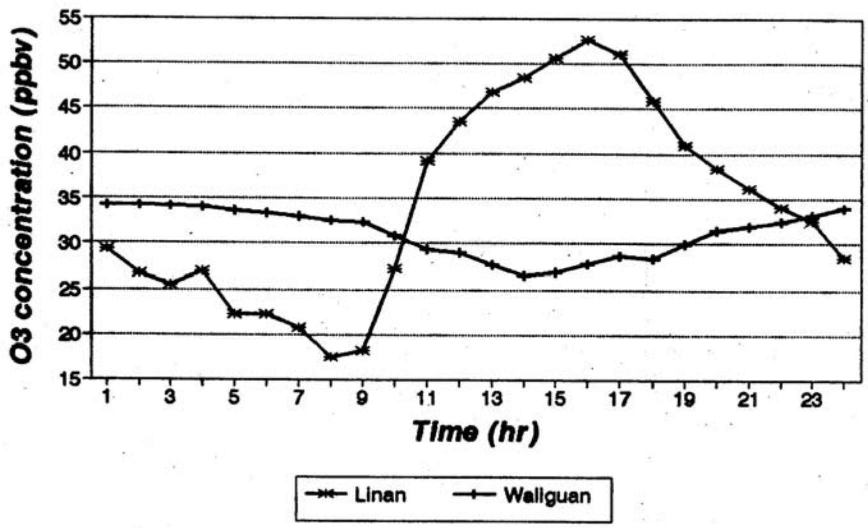

Figure 13.1
Diurnal variation of O3 measured in Linan and Waliguan

Extremely low summertime ozone levels over the Tibetan plateau have been discovered by the CORP.

As part of the search for new and improved scientific models to explain the ozone data, a box model based strictly on chemical reactions (no chemical transport is included) has been developed. In this model, all the parameters come from the measurement data: temperature, relative humidity, ozone concentrations, etc. The ozone loss and ozone production rates are simulated and net ozone production is determined. The model is as yet unable to reproduce net negative results like those observed at Waliguan Mountain, but can produce high concentrations of ozone such as those observed at Linan. The researchers have also developed a regional ozone model for simulating tropospheric ozone.

Some of the scientific research issues that need to be addressed in the future include:

* How do ozone and its precursors influence climate?
* What meteorological factors influence ozone production and loss?
* How does ozone influence ecosystems and crop yields?
* What is the relationship between ozone and its precursors with aerosols?
* What control strategies should we adopt?

The fact that high ozone concentrations are quite episodic makes experiments to measure ozone damage on crops very difficult.

Agricultural Development and Urbanization

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By the year 2020, as much as 30 to 75% of global cereal production will be exposed to potentially damaging thresholds of ozone concentrations.

This AGCI session on "The Metro-Agro-Plex" grew out of a paper published in Science 264 : 74+, 1994 by Bill Chameides and colleagues, as well as previous AGCI sessions. The focus of this work is on three regions of the northern mid-latitudes that dominate global industrial and agricultural productivity; although the regions cover only 23% of the Earth's continents, they account for most of the world's commercial energy consumption, fertilizer use, food crop production, and food exports. These regions also account for more than one-half of global atmospheric nitrogen oxide emissions and are thus prone to high levels of tropospheric ozone pollution during certain periods of the year. Chameides et al. used global simulation models of atmospheric reactive nitrogen compounds to show that between 9 and 35% of the world's cereal crops are presently exposed over the growing season to average ozone concentrations above a damage threshold of 50-70 ppbv which could significantly lower crop productivity. They estimate that by the year 2020, as much as 30 to 75% of global cereal production will be exposed to potentially damaging thresholds of ozone concentrations.

Percentage of population living in urban areas and urban population: 1990, 2000, 2025				
Population in urban areas (%)	World Total	Less Developed Regions (1)	More Developed Regions (2)	China
1990	43.1	34.3	72.7	26.2
2000	47.6	40.3	75.8	34.5
2025	61.2	56.7	83.8	54.5
Urban population (billions)				
1990	2.3	1.4	0.9	0.30
2000	3.0	2.0	1.0	0.45
2025	5.2	4.0	1.2	0.84

Table 14.1
Percentage of Population Living in Urban Areas and Urban Population

(1) Less developed regions comprise all regions of Africa, Latin America, Asia (excluding Japan) and Melanesia, Micronesia and Polynesia.
(2) More developed regions comprise North America, Japan, Europe, Australia, New Zealand, and the former Union of Soviet Socialist Republics.

Source: United Nations, World Urbanization Prospects: The 1992 Revision (New York, 1993).

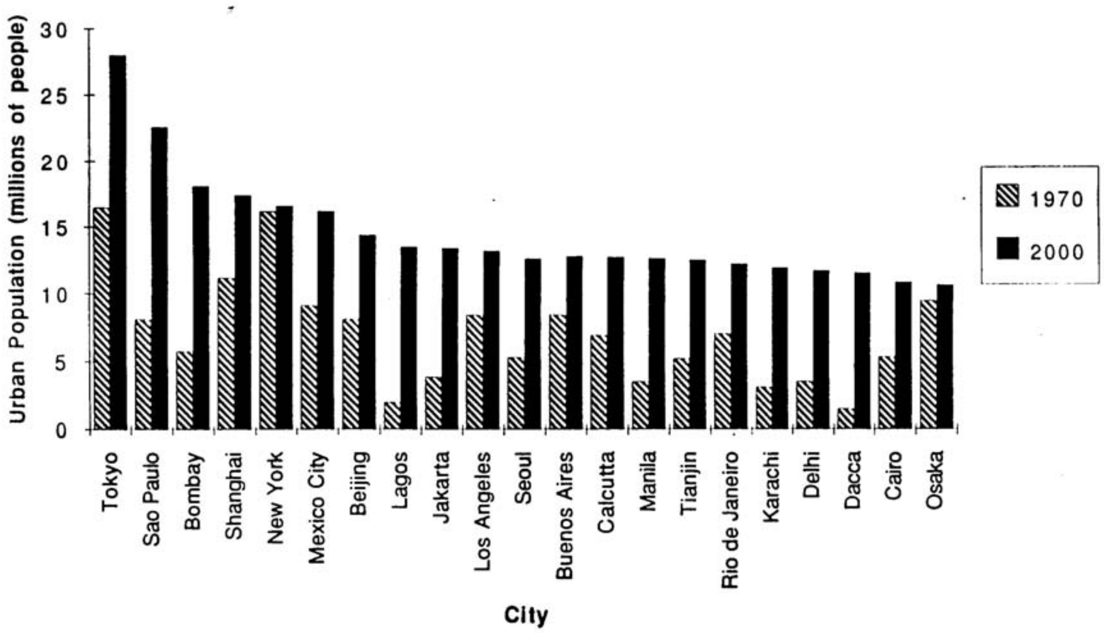

Table 14.2
Cities with Projected Populations over 10 million in 2000
Source: UN World Urbanization Prospects (1993).

During the past 35 years, over 90% of global production growth in cereals has been attributed to yield increases and less than 10% to area expansion.

The major goals of this AGCI session are to look more closely at nitrogen, carbon, and sulfur cycles in the context of urban/industrial and agricultural development; to expand the use of the Metro-Agro-Plex (MAP) to investigate competition for land and water resources between urban/industrial and agricultural sectors; and to explore how the growth in MAPs in developing regions of the world are affecting the global food economy. Developing countries are of particular interest in this context because a significant decline in agricultural productivity resulting from high concentrations of tropospheric ozone, other air pollutants, or resource constraints could have important impacts on food prices, rural incomes, and the incidence of hunger. In addition, urbanization rates in the developing world are much higher than in the currently industrialized world. By 2025, an estimated 5.2 billion people will be living in cities; 4 billion of these people will be in developing countries (Table 14.1). Of the 21 cities projected to have populations of over 10 million in the year 2000, 17 will be in the developing world and more than one-half will be in Asia (Table 14.2).

China was chosen as a special case study for this AGCI session because of its overwhelming importance in the world food economy, its extremely rapid rate of agricultural, urban and industrial growth, and its high level of dependence on soft coal for economic development. The combination of these factors serves as an excellent model for studying the dynamics of the MAP.

Three questions are particularly interesting in considering the relation between China's MAPs and the world food economy:

1. what are the effects of urbanization and industrialization on agricultural productivity?

2. how does the process of agricultural productivity growth itself contribute to changes

in biogeochemical cycles, increased concentrations of photochemical oxidants, and resource depletion? and

3. how do changes in agricultural productivity in China affect world food availability and prices? This set of issues is relevant to the ongoing debate over whether China will “starve the world” in the process of its economic development and income growth.

Both the socio-economic and the physical dimensions of these issues are of interest in this AGCI session.

One of the most important dietary changes in the region is the increase in meat consumption. About 2 to 5 times more grain is required to produce the same amount of calories through livestock as through direct grain consumption (and as much as 10 times in the case of grain-fed beef in the U. S.).

1993-94 AGRICULTURAL PRODUCTION						
	CHINA			WORLD		
	Area	Yield	Output	Area	Yield	Output
	mil. ha.	ton/ha.	mil. tons	mil. ha.	ton/ha.	mil. tons
Rice (Milled)	30.4	4.1	124.4	144.3	2.4	350.3
Wheat	30.2	3.5	106.4	222.4	2.5	560.5
Corn	20.7	5.0	102.7	128.9	3.6	467.9
Soybeans	9.7	1.6	15.3	60.3	1.9	115.4
Peanuts	3.4	2.5	8.4	19.4	1.2	23.8
Cotton	5.0	0.8	17.2*	30.5	0.5	76.4*
Sugarcane	1.1	59.0	64.2	12.5	58.0	723.7
Source: USDA, Agricultural Statistics, 1994.						
*Million bales of 480 pounds (net).						

Table 14.3
1993-94 Agricultural Production

China plays a major role in the world food economy in terms of production as well as consumption. For example, it accounts for about 1/5 of the global output of rice, wheat, corn, soybeans, and peanuts, and it has substantially higher yields particularly in the case of cereals than the global average (Table 14.3). China also has an extremely limited arable land base per capita compared with the global average. Its per capita arable land base is small even compared with the average for Asia, which, as a region, is very densely populated. As a result, China has intensified its agricultural production by growing more crops per year per hectare and achieving higher yields per hectare for individual crops. This intensification process is characteristic of agricultural development for the world as a whole; during the past 35 years, over 90% of global production growth in cereals has been attributed to yield increases and less than 10% to area expansion.

A main tenant of the agricultural intensification process during this period has been the introduction and dissemination of Green Revolution seed technologies for staple crops, such as rice and wheat, in the developing world. The modern plant varieties have been designed with a new architecture that is capable of taking up more nitrogen inputs and allocating a higher share of nutrients to grain production as opposed to plant biomass production. Global nitrogen fertilizer applications have increased substantially as a result (Table 14.4). Despite research efforts to improve nitrogen uptake efficiency, only 40-60% of the applied nitrogen is actually taken up by the plant in most rice and wheat systems. The rest is lost to the environment through various pathways such as nitrification, denitrification, and ammonia volatilization. Nitrogen loss from fertilization has important implications for ground water quality, tropospheric ozone

concentrations, the accumulation of nitrous oxide in the stratosphere, and the destruction of the stratospheric ozone layer. Its potential effects on ecosystem processes and atmospheric chemistry are significant at local, regional, and global scales.

Consumption of Nitrogen Fertilizer (1000 metric tons N)					
REGION	1961/62	1971/72	1981/82	1991/92	Annualized Growth Rate 1961-1991 (%)
Africa	366	976	1,889	2,065	5.9
NC America	3,434	8,471	12,646	13,316	4.6
S America	182	596	1,156	1,664	7.2
Asia	1,751	7,754	21,526	37,864	10.8
China	630	3,410	11,528	19,958	12.2
Japan		676	643	574	* -0.7
Europe	4,397	10,207	14,417	12,101	3.4
Former USSR	859	5,182	8,383	7,502	7.5
Oceania	43	138	272	547	8.9
WORLD	11,030	33,324	60,309	75,058	6.6
* growth rate 1971 - 1991					
Source: FAO Fertilizer Yearbook, various issues.					

Table 14.4
Consumption of Nitrogen Fertilizer

Given the large and growing use of nitrogen fertilizers in China shown in Table 14.4, it is clear that China has the potential to substantially alter regional and global nitrogen balances. It is also likely that the agricultural sector in China will increasingly contribute to tropospheric ozone concentrations in the region which, in turn, could lower agricultural productivity itself. Whether or not ozone originating from agricultural and industrial processes will significantly alter Chinese agricultural yields is not yet known. Other factors that could lower agricultural productivity include water constraints, soil erosion, climate change, and pest outbreaks. A decline in investments and producer incentives in the farm sector could also reduce productivity. Indeed, a major debate concerning future agricultural output is whether biotic and abiotic constraints are more or less important than policy changes in terms of their impact on future productivity growth.

In order to understand the role of food and agriculture as a driving force of biogeochemical and atmospheric change in China, it is necessary to study the dynamics of consumption as well as production. One of the most important dietary changes in the region is the increase in meat consumption. This switch from direct to indirect (livestock-based) grain consumption is common in most countries (with the exception, for instance, of India) as per capita incomes rise. Although China consumes much less meat per capita than industrialized countries, it consumes measurably more than some of its southeast Asian neighbors. For example, per capita meat consumption in China is currently about 25 kilograms per person per year and rising rapidly, whereas in Indonesia, per capita meat consumption is only 5 to 6 kg/person/year.

The emergence of China as a livestock economy has implications for nitrogen fertilizer use, nitrate leaching and ammonia loss from animals, and grain balances in the country. About 2 to 5 times more grain is required to produce the same amount of calories through livestock as through direct grain consumption (and as much as 10 times in the case of grain-fed beef in the U.S.). As meat consumption increases, therefore, China's grain requirements will also increase. This trend will place pressure on the country to produce more grain (with more fertilizer) or to import more grain. China's feed grain imports are already rising; in 1994/95, it purchased most of the U.S. surplus corn production. The rising demand for feed grains in Asia more generally has caused the region to become a major cereal importer (Table 14.5).

Given the increasing population- and income-driven demand for grains in China, any significant decline in the level or rate of growth in domestic productivity of cereals could dramatically affect prices both within China and in world markets. If environmental or resource constraints were to force the country to purchase an increasing share of its grain needs in world markets, for example, international grain prices would probably increase, and poor countries like those in Sub-Saharan Africa might not be able to afford grain imports in the short run. A more likely scenario one which is already being played out to some extent is that changes in agricultural policy and a decline in economic incentives to agricultural producers in China will cause the country to enter more predominantly into world grain markets. In either case, it is clear that what happens in China in terms of grain production, consumption, and trade is important for the world food economy as a whole. Similarly, what happens in China in terms of alterations in biogeochemical cycles and atmospheric chemistry is important for regional and global environmental change.

What happens in China in terms of grain production, consumption, and trade is important for the world food economy as a whole.

World Grain Trade by Region, 1950-90* (Million Tons)	1950	1960	1970	1980	1990
N. America	23	39	56	131	113
L. America	1	0	4	-10	-11
W. Europe	-22	-25	-30	-16	22
E. Europe/USSR	0	0	0	-46	-31
Africa	0	-2	-5	-15	-25
Asia	-6	-17	-37	-63	-83
Australia/NZ	3	6	12	19	14

*No sign indicates net exports, minus sign net imports.

Source: FAO Trade Yearbook, Various Issues.

Table 14.5
World Grain Trade by Region, 1950-90*

Soil Nitrogen Transformations & Agricultural Effects on the Emissions of Nitrogen Oxides

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Emissions of nitrogen-containing trace gases from agricultural systems may be a significant local to regional flux of reactive nitrogen. In China, the combined emissions of ammonia (NH3) and nitric oxide (NO) rival the emissions of NOx from industrial sources. But perhaps more importantly from a management stand point, emissions of the nitrogen oxides and ammonia from agricultural systems can be reduced though agricultural techniques while emissions from energy use may be less amenable to reductions. For this reason it is important to understand the processes responsible for trace gas production in soils and the effects of management activities and land use change on these processes and fluxes. There are numerous techniques available for process level studies of trace gas emissions, and the effects of management techniques on these fluxes and use of these techniques can provide the information necessary for attempts to reduce nitrogen oxide emissions from soils.

From a management standpoint, emissions of the nitrogen oxides and ammonia from agricultural systems can be reduced though agricultural techniques while emissions from energy use may be less amenable to reductions.

In order to control emissions of N-containing trace gases from soils, it is important to understand the mechanisms responsible for their production in soils. Emissions of NO, N2O and NH3 all occur as byproducts of the cycling nitrogen in soils. The cycling of nitrogen through soils occurs in three distinct conceptual stages. These stages include the conversion of organic nitrogen to ammonium (NH 4), known as mineralization, followed by the conversion of NH4 to nitrate (NO3), known as nitrification, and finally by the reduction of NO3 to NO, N2O or N2, a process called denitrification.

The production of NO and N2O can occur during either nitrification or denitrification and in some cases, NO may be produced during the chemodenitrification (chemical denitrification) of nitrite (NO2). Both nitrification and denitrification can be affected by a number of factors including oxygen availability (nitrification requires oxygen and denitrification requires near-absence to absence of oxygen), substrate availability (NH4 for nitrification and carbon and NO3 for denitrification). These factors can then be affected by a wide range of additional soil characteristics many of which can be significantly affected by agricultural activities. There are two steps to understanding trace gas production in soils. The first step requires the identification of the process or processes responsible for the production of a trace gas, and the second requires understanding the factors that control these processes.

To determine the effects of biomass clearing and burning on soil NO emissions and the processes responsible for the production of NO, Neff et al. conducted a series of experiments at sites in the Atlantic Lowlands of Costa Rica. These experiments provided a case study of the techniques available for determining process controls on NO production in soils. Clearing and burning of secondary tropical rain forest significantly increased soil NO emissions. Soil NO fluxes averaged 0.5 ng NO-N cm-2 hr-1 prior to clearing and increased to 4.1 ng NO-N

cm-2 hr-1 following clearing and to 12.0 ng NO-N cm -2 hr-1 following burning. In order to determine the probable mechanism responsible for elevated NO emissions, substrates were added to simulate microbial nitrification (ammonium), denitrification (nitrate) and chemical denitrification (nitrite) to autoclaved (killed) and non-autoclaved (live) soil cores.

Compared to water or nitrate additions, ammonium caused a significant increase in NO emissions from live cores. Nitrite additions resulted in highly significant increases in NO emissions from both killed and live soil cores. In a second experiment, soil cores were treated with acetylene (1 Kpa C2H2) to selectively inhibit nitrification, and oxygen to inhibit denitrification. The oxygen treatment had no effect on NO production while acetylene significantly reduced NO production. The results from the substrate addition and inhibition experiments demonstrate that microbial denitrification is not a major pathway for NO production in these soils. In contrast, microbial nitrification appears to be a critical process responsible for NO emissions throughout the clearing and burning period. Techniques such as these can be used in both agricultural and natural ecosystems in order to determine process level controls on soil trace gas production.

When fertilizer was added, both NO and N2O fluxes increased dramatically, and in the case of N2O, these emissions remained high for at least 30 days.

To examine the effects of fertilization on NO and N2O emissions from a palm plantation in Costa Rica, Michael Keller of the U.S. Forest Service conducted a study in which fluxes of these gases were monitored following fertilization additions. When fertilizer was added, both NO and N2O fluxes increased dramatically, and in the case of N2O, these emissions remained high for at least 30 days. Integrated losses of added fertilizer nitrogen through trace gas emissions averaged approximately 15% via N2O and 2% via NO. These losses were strongly seasonal with the bulk of the N2O lost during Winter months when soil moisture was high and with NO loss occur ring primarily in the Spring dry season. These results highlight the effect of oxygen availability on nitrification and denitrification. Nitrification rates are reduced when the soils are wet probably due to oxygen limitations. Conversely, denitrification rates are highest when soil oxygen is limited. Again it appears that NO is primarily produced during nitrification while denitrification is probably responsible for N2O production and so losses of these gases from soils are closely tied to both fertilization and seasonal changes in the soil moisture content and thus oxygen availability.

Once the processes responsible for trace gas losses are known, it is possible to structure management techniques in such a way as to reduce these losses. For example there are commercially available nitrification inhibitors which could potentially reduce both NO and N2O loss. The use of these inhibitors will, of course, have multiple impacts on the soil-plant system and a complete understanding of these effects should precede any decisions to use these chemicals. A more simple approach to trace gas emission control can be taken though the use of fertilizers. In general, increases in fertilizer use cause increases in trace gas emissions. In addition, the type, timing and manner of fertilizer application can dramatically alter trace gas losses from agricultural systems. It is possible to significantly reduce trace gas losses simply through an understanding of the soil nitrogen cycle and plant phenological demands for nitrogen. As fertilizer use rates increase into the future, management of the emissions of nitrogen-containing trace gases will become increasingly important.

Modeling the Carbon Cycle on Landscape, Regional and Global Scales

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There have been many advances in the modeling of terrestrial biogeochemical cycling in recent years based on improvements in our understanding of the carbon and nitrogen dynamics of terrestrial ecosystems. However, despite these improvements, ecosystem models still differ significantly from one another in their simulated results. To understand these differences and to improve our understanding of ecosystem processes, it is important to perform sensitivity analyses using several models and common inputs. These analyses allow a piece by piece examination of the factors that contribute to any particular model output (e.g., net ecosystem productivity). Similarly, sensitivity analyses can be used to examine the effects of increased CO2, nitrogen deposition and climate perturbations on terrestrial ecosystem dynamics as well as the ecosystem level controls on these responses.

Each terrestrial ecosystem model tended to do well in the region in which it was developed. However, it was far more difficult to correctly simulate a variety of regions spanning a range of climatic conditions.

To assess the sensitivity of ecosystem processes to climate change and changing CO2, three terrestrial ecosystem models (CENTURY, BIOME BGC and TEM) were compared in the vegetation mapping (VEMAP) project. In order to compare the outputs from these three models, they were run with common input data sets that included natural vegetation type, soil type, climate and global change scenarios. Precipitation was input monthly and daily where appropriate. Each of the ecosystem models also required some ecosystem specific parameterizations in order to determine the vegetation at a particular location. Climate was determined from general circulation model (GCM) output under current and doubled CO2. Because GCM climate data is output on a scale larger than that used in the three ecosystem models and without consideration of topography, the GCM output was changed into a "bioclimate" which was much closer to the real climate experienced by the vegetation. This was done by considering topography, elevation, and precipitation changes with elevation. The development of these climate data sets has been very important to ecosystem modeling on this scale and without this development, there is little hope of getting the simulations close to a representation of actual vegetation.

During the VEMAP comparisons, multiple ecosystem properties were monitored under the different climate scenarios. In general, each terrestrial ecosystem model tended to do well in the region in which it was developed. However, it was far more difficult to correctly simulate a variety of regions spanning a range of climatic conditions. Carbon storage was increased with doubled CO2 in all of the models, with the increases ranging from +2.2 to +8.5%. Net primary productivity (NPP) increased in the models from 5.0 to 10.8%. When both climate and CO2 were considered, the changes in carbon storage and NPP were much larger. The reason for this effect is probably related to the nitrogen cycle. Each of the models can respond to increasing CO2 at the leaf physiological level. But the additional carbon uptake requires additional N for growth. This fixation of carbon and nitrogen causes a reduction in the amount of labile N in the

system. When temperatures increase, N is released from soils while soil ratios average about 10. In contrast, woody tissues C:N ratios average 100. When changes in climate and CO2 result in a transfer from soil to woody tissue, this nitrogen is removed from rapid circulation in soils and in this way can act as an important internal regulator of ecosystem dynamics.

Nitrogen deposition can act in much the same way as warming in that it increases the capacity of the system to respond to CO2 increases. The different responses of the models result from the models' differential sensitivities to water versus N stress. In the U.S. domain used for the VEMAP study, N is usually the limiting nutrient, however this is not the case in the tropics where phosphorus can be the primary limiting nutrient. This is important in the consideration of how tropical regions will respond to climate and CO2 changes as phosphorus is not as well understood or modeled as nitrogen.

The traditional ecological assumption of a steady state terrestrial ecosystem net carbon flux of zero is almost never seen in model and experimental results.

To examine the effects of climate and land use on production in the inner Mongolian region, Schimel presented the work of a graduate student, Xiao Ming who assembled data sets and used these data to run the CENTURY ecosystem model. Before it was possible to run the CENTURY model, input parameters for soils and vegetation had be as signed to the region. After assembling a soil map of the region, Xiao Ming assigned soil properties (texture, hydrological properties) to each of the soil types. Vegetation distributions were determined from land cover images using two Landsat images. Using climate information from the National Center for Atmospheric Research (NCAR), the region was split up into climate areas.

This inner Mongolian region is subject to high year-to-year variability in precipitation, but interannual variability in temperature is modest. Equally important for the water balance, the distribution of rainfall into event categories (amount of precipitation for each rain event) changes considerably from year to year. There can be large differences between intense and infrequent rainfall and low but frequent rainfall events. Small events can induce trace gas production but probably don't affect plants as the water stays in the top layers of the soils. More intense events have much more of a possibility of influencing plant productivity.

Comparing measured above-ground productivity and simulated productivity resulted in fairly robust comparisons. The comparison of simulated versus observed NPP yielded an R2 of 0.71 to 0.73 for two different grass types with a higher R2 for a grass type similar to one in Colorado where the CENTURY model was developed. Simulations of carbon dioxide flux resulted in consistently non-zero results. This result is interesting because the traditional ecological assumption of a steady state terrestrial ecosystem net carbon flux of zero is almost never seen in model and experimental results. This is probably due, in large part, to interannual variability in climate.

On a global scale, the effects of interannual variability in climate can also affect carbon fluxes. On average, the growth rate of the interannual variability of atmospheric CO2 is increasing. This increase can not be explained by changes in fossil fuel use from year to year. Near the end of the CO2 record (1990), fossil fuel growth rates were nearly level, perhaps due to a slow-down in the world economy and particularly in the former USSR. But following 1991, there is a drop in CO2 and in the amplitude of the seasonal cycle. This change followed the eruption of Mount Pinatubo. This volcanic eruption was an important geophysical event because many climatic forcing factors were affected, and this provided a unique opportunity to test model-based understanding from the GCM-scale down to the level of terrestrial ecosystem models. The Pinatubo anomaly has a distinct spatial component to its effects on temperature. In northern regions, there was as much as a 3 degree drop in growing season temperatures.

There is now a global version of the CENTURY model which can be used to look at a variety of ecosystem factors. Using the Pinatubo anomaly as input into the global version of CENTURY, it is possible to calculate net ecosystem productivity (NEP) changes as a function of latitude. These simulations result in a net carbon release from high northern latitudes (60 to 90°), however there is not much land area in this region so these changes do not have a large global impact. At the 30 to 60 degree North latitude region, the model shows a strong increase in NEP (carbon uptake). Because this latitude band contains a large area of land, these changes in NEP could drive changes in the interannual variability in atmospheric CO2. Although this is a preliminary model result, it is similar to recent analyses using inverse tracer transport techniques.

Terrestrial ecosystem models can yield important information about the carbon cycle from the local to the global scale. In some cases, the results of simulations can challenge traditional assumptions regarding carbon cycling. One such case is the long-standing belief that as ecosystems warm, ecosystem respiration (carbon efflux) will increase. But in the VEMAP simulations, ecosystems tend to take up more carbon when they warm. While ecosystems may lose carbon in transient responses to warming, the steady state carbon dynamics are strongly influenced by nitrogen feedbacks which act to reduce carbon uptake. It is important to note that if forests are cut, the N cycle feedbacks that lead to carbon uptake under warming will disappear. These feedbacks may be critical to carbon dynamics on a global scale and recent IPCC estimates suggest that atmospheric CO2 trajectories are very different with and without biospheric carbon uptake. As a result, the understanding of terrestrial and oceanic carbon dynamics will be critical to predicting the effects of human perturbations to the carbon cycle in the future.

Atmospheric CO2 trajectories are very different with and without biospheric carbon uptake.

Natural Hazards and Disasters in China

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> The eastern part of China has more natural hazards than the west. But the western area is not nearly as conducive to human habitability and the eastern part.

A database system for natural hazards and natural disasters for China's 2364 counties has been set up with six subsystems: 1) natural hazards, 2) modern natural disasters (1950 -1990), 3) disaster losses in regional agriculture, 4) historical natural disasters (1501 -1949), 5) economic status, and 6) country administrative division of China (1990). Information from this integrated system is used to generate a set of maps that identify regionalizations of natural hazards and disasters in China.

There are many types of natural hazards identified in the database, including meteorological hazards such as wind storms, marine hazards such as red tide and storms, geological hazards such as landslides and severe soil erosion, and biological hazards such as plant diseases and insect pests.

In maps created using this database, different colors or shading techniques are used to designate different types of hazards. For example, in one map, red designates earthquakes and the size of the red spot on the map reflects the magnitude of the disaster. This map reveals that earthquakes are primarily distributed in three areas, the western, northern, and southwestern areas of China, with a few in the southeast coastal zone.

In order to see how agricultural areas are impacted by natural hazards, a map of agriculture areas is overlaid with a map of natural disasters. This analysis reveals that the agricultural areas of the north, northeast , and southeast coastal zones are most affected by natural hazards. A similar analysis is performed for forest areas.

Each of the six sub databases in the Database System for Natural Disasters in China is based on appropriate sources of data; the major contents of each sub database varies based on the credible information available. For example, if newspaper accounts are the major source, only three parameters can be trusted to always be correct: time, area, and type of disaster, so only these three are used.

For other sub databases, information comes from statistical materials on disaster losses, written records from water conservancy departments and meteorological departments, etc.

Regionalization principles and methods

In regionalizing natural hazards and disasters, three principles are considered:

1. differentiation of natural disaster system: hazards, hazard-formative environment, hazard-affected bodies

2. differentiation of hazard and disaster intensity

3. Integrity of country administrative boundary division

Index System:

* Stability of hazard-formative environment: The land forms of the east, middle, and western high plateau, mountains, and basins are clearly distinguished from each other in climate and topography.
* Complicity and intensity of natural hazards: formulas are included to account for: hazard diversity, hazard intensity, hazard area index, hazard index, disaster diversity, ratio of disaster times, disaster years, disaster index
* Stability of hazard-affected bodies: formulas included to account for agricultural population density, grain output level, level of gross output value of agriculture, level of gross output value, methods
* combination of natural hazards: i.e. , ratio of drought to flooding and water logging

Method of Regionalization

* cluster analysis
* regional comprehensive analysis

Figure 17.1 shows a map of China with the natural hazard index. Frequency and intensity of natural hazards go up with darkness on the map. It can be seen that hazard types differ in the different regions of China. The eastern part of China has more natural hazards than the west. But the western area is not nearly as conducive to human habitability and the eastern part. So despite the hazards, the physical environment is more desirable to more people. In general, from east to west the index decreases. Figure 17.2 shows a map of China with the natural disaster index. Frequency and intensity go up with darkness on the map.

Integrated hazard and disaster maps show distribution of natural hazards and disasters affected by land form, climate, and human activities. Regional differentiation of natural hazards and disasters is clear, but hazard distribution differs from disaster distribution in eastern China. Hazard intensity is the highest in middle-eastern China, but disaster intensity is the highest in the area between Huaihe River and Yangtze River in eastern China.

Regionalizing natural disasters, China can be divided into 6 regions:

I Ocean Disaster Region

II Southeast Coastal Disaster Region (3.6%)

III East Mainland Disaster Region (20.7%)

IV Central Mainland Disaster Region (27.9%)

V Northwest Mainland Disaster Region (21.9%)

VI Qinghai-Xizang Plateau Disaster Region (25.9%)

These are then sub-regionalized in 26 subregions, and then sub-subregionalized into 93

It is important to distinguish hazard from disaster. A hazard is a natural physical phenomenon, whereas disaster is generally related to the situation, such as what human activity is taking place on the site.

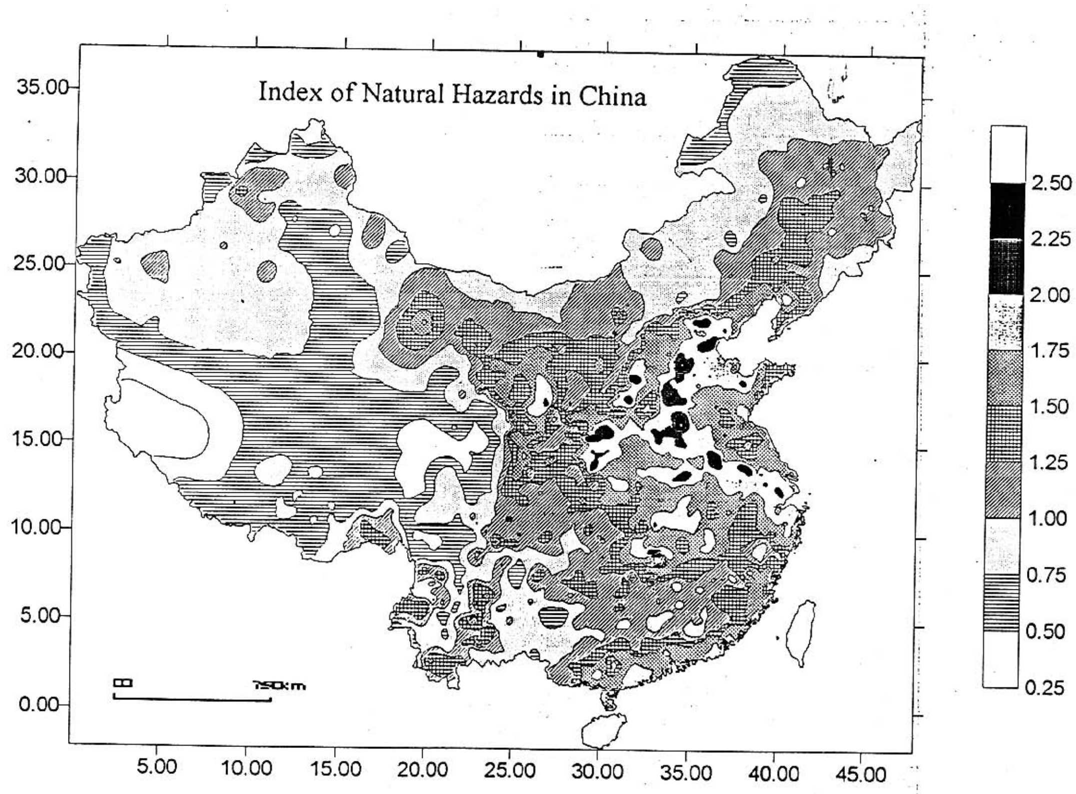

Figure 17.1
Index of Natural Hazards in China

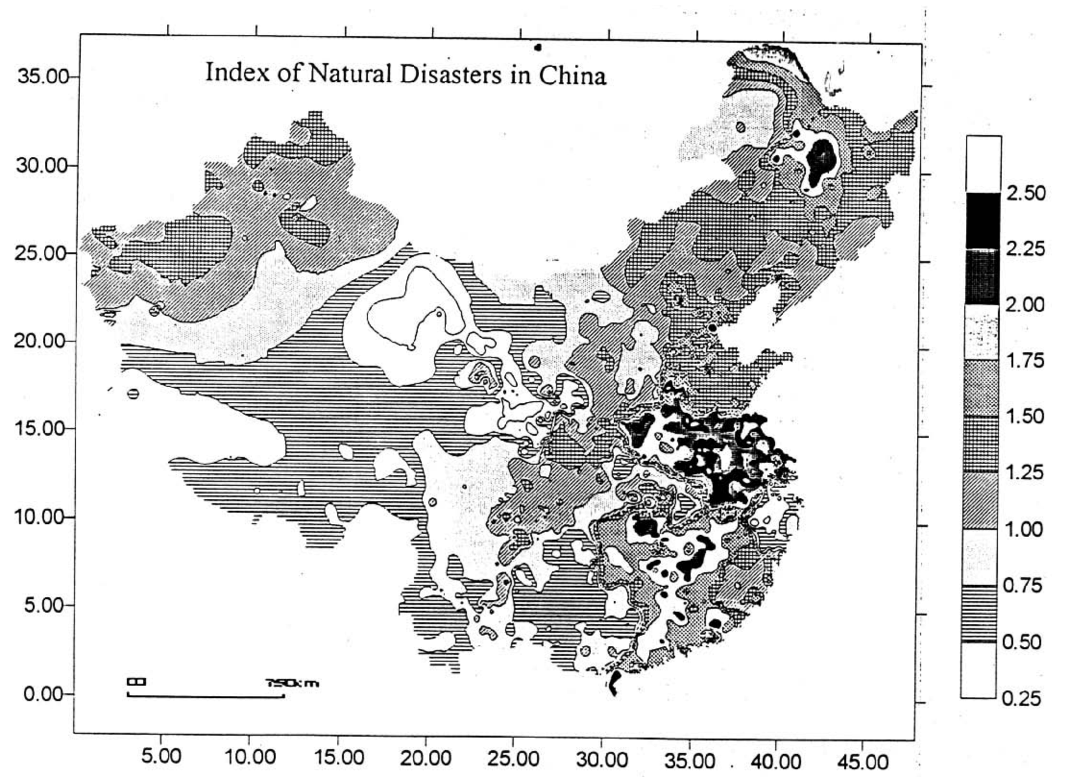

Figure 17.2
Index of Natural Disasters in China

The major natural hazards in China fall into four major categories;

* drought, flood and water-logging, tropical cyclones
* earthquakes, landslides, mud-rock flows
* disease and insect pests
* red tide, sea storms and waves

In conclusion, Shi pointed out that:

* Frequently occurring hazards cause great economic losses in China ranging from 3.3% of GNP to 6.1% of GNP between 1989 and 1994.
* It is very important to set up a disaster database for China. Disaster regionalization work is an important scientific base for disaster reduction.
* It is important to study how natural hazards, natural disasters and human populations overlap and effect each other.
* The study of combinations and relationships between the different types of natural hazards and disasters is critical.
* It is important to distinguish hazard from disaster. A hazard is a natural physical phenomenon, whereas disaster is generally related to the situation, such as what human activity is taking place on the site.

In China, great economic losses result from hazards and range from 3.3% of GNP to 6.1% of GNP between 1989 and 1994.

Environmental Issues and the Food Supply Situation in China

Vaclav Smil

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Deforestation is the costliest of China's environmental ills. The amount of soil lost from deforested land is massive.

What China's worst environmental problem is depends upon who one asks. Chinese experts believe water pollution is the biggest problem because the largest number of people are affected by contamination of both surface and groundwater. Those with another perspective might say that air pollution is the worst problem, because the Chinese ambient concentrations of particulates, sulfur dioxide, nitrogen oxides, and other pollutants are some of the highest in the world. Globally oriented scientists might say that China's emissions of greenhouse gases are its biggest problem, and will soon swamp the world, though this problem is not seen domestically as a pressing one.

According to Smil, deforestation is China's biggest environmental problem. China is cutting less roundwood than a decade ago, and it has also made progress in afforestation. But because of the amount of recent cutting and replanting, China now has a large proportion of very young forests which will not be available for commercial logging for decades. Consequently, the total number of trees may be increasing, but the volume of mature timber is still declining. This disparity brings up an important point with regard to the quality of data coming out of China. In general, data accuracy is quite poor and careful interpretation is necessary for all but a few basic data sets, such as most population and some industrial output statistics.

There are also major problems with how the Chinese economy is represented in international statistics. Per capita Chinese income is much higher than is widely known. One problem is that Chinese money should not be translated to U.S. dollars using the official exchange rate which has been steadily declining since the early 1980s, while the Chinese economy has grown more than any in the world (except South Korea). A more appropriate measure of Chinese economic strength might be per capita purchasing power, which falls most likely between $1500 and $2000.

In regard to the economic costs of China's environmental problems, Smil cited Chinese studies which found that 6 to 8% of Chinese gross domestic product (GDP) is lost to environmental pollution, leaving aside biodiversity losses and other hard-to-quantify values. More recent studies find that the effects of air, water, and land pollution and ecosystem degradation cost the country up to 15% of its GDP every year. Meanwhile, China spends less than 1% of GDP per year on these problems and so could clearly benefit by increasing this investment.

Deforestation is the costliest of China's environmental ills. The amount of soil lost from deforested land is massive -- up to several orders of magnitude greater than that lost from well-treed land, reaching hundreds of tons per hectare. Because China irrigates more land than any country in the world, and because it also relies heavily on hydroelectric generation, silting of streams and reservoirs results in serious economic losses. The main costs involve shortened lifetime of water storage, and the necessity of more frequent canal dredging. Furthermore, nitrogen loss in eroded topsoil is equal to the total amount of the nutrient applied in fertilizer, that is about 20 million tons. The cost of this loss is estimated at $20 billion a year.

Commercial harvesting of wood, both legal and illegal, is just one cause of deforestation. There is also still a good deal of wood harvesting for household cooking and heating. The availability of household fuel has increased significantly with the opening of many small coal

mines during the 1980s, but in many areas, wood is still harvested for basic fuel. There are great province to province differences; in the northern provinces, cutting has decreased because of coal availability, but in the southern provinces, there has actually been an increase in wood cutting.

On the subject of land for food production, official Chinese statistics put China's farmland at 95 million hectares, but it is now known that there are closer to 120-130 million hectares. This difference, of up to 40%, is due to a number of factors. One is that land is not measured in a standard way in much of rural China, but partly by how much it can produce. Also, people are taxed on the amount of land they cultivate so they often hide as much as they can where this is possible. Therefore, in areas near cities, numbers will vary by less than 20%, but in rural areas, they can be off by up to 60%. On average, China's agricultural land grows 1.5 crops per year, with a few areas triple cropping.

Data on rice yields are pretty good, on wheat, fair, and on corn, they are the most uncertain. Actual average corn yield is about four tons per hectare -- about half the U.S. average. Total crop production figures are more accurate than the land figures.

China is now the world's largest producer and user of nitrogen fertilizer, applying almost 20 million tons per year. Roughly two-fifths of this is produced in small coal-based plants. Their product is ammonium bicarbonate, a highly volatile compound with high pre-application and application losses.

Regarding irrigation, there is the key problem of water subsidies. Like Californians, Chinese farmers pay only about one-tenth of the real price of water and so pay little attention to efficient water use. In addition, out of 47 million hectares of irrigated land, only about half is effectively irrigated. Tremendous opportunities to expand production therefore exist in fertilizer and irrigation use. There are major opportunities for improvement in agroecosystem management such as greater use of inter-cropping, water retention methods, etc. There has been a major collapse in the use of traditional ecoefficient ways, and a return to some of these ways could greatly boost production efficiency.

As for the implications of Chinese population growth on world food supply, Smil says that there are other countries to be concerned about in addition to China. Japan is now the world's largest importer of food, self-sufficient only in rice production. Japan, South Korea and Taiwan together now import more than three times as much food and feed grain as China. Chinese per capita meat consumption of 25 kg/year is still only about half that of these other three countries, but as China develops, it will likely dip into the international feed grain market. Further, Smil says that problems of chronic food shortages are more a matter of distribution and access than of food production. In total, there is more food in China than ever, and the country should be able to feed itself for the next two decades.

China is now the world's largest producer and user of nitrogen fertilizer, applying almost 20 million tons per year. Nitrogen lost in eroded topsoil is equal to the total N applied in fertilizer a loss estimated at $20 billion per year.

Local and Regional Impacts of Emissions on Agriculture

Norton D. Strommen

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Urban areas can modify rainfall patterns significantly and this can affect agriculture near cities. Convergence zones tend to develop over cities and then move more frequent and intense showers downwind.

In discussing agriculture, Strommen says, global averages are meaningless. Agriculture and its practices take place on a local and regional basis and must be studied on this basis. Strommen offered a number of cases of applied climatology and agricultural system analysis relevant to the Metro-Agro-Plex concept.

Strommen discussed research in Detroit and Lansing, Michigan regarding urban influences on agriculture. A study was undertaken in Detroit to deal with a flooding problem. It was clear that hydrological curves in the area around the city had changed dramatically. Engineers concluded that the problem was from paving of shopping centers and roads. Using a network of 85 recording rain gauges, the researchers extracted onset time of rain fall, duration intensities, etc. They could see that something was producing thunderstorms that were exceeding the expected 100-year return period precipitation amounts 4 to 7 times a year.

On closer examination of temperature data from three city and rural stations, a couple of distinct patterns emerged. One was a clear documentation of urban heat island expansion. It was also seen that a shift in location of rainfall normally based on lake effects had occurred. A seasonal break down showed that all the high precipitation events were concentrated in the summer. When the climatology of the synoptic field was added, it was clear that these events occurred with no significant storm systems in the area, and the intense rain fell only in the urban area and on the nearby surrounding agricultural land.

Wind field data verified that a convergence zone along the lake breeze front was the trigger mechanism for these thunderstorms, taking place in a band only 5-15 miles wide. This convergence zone moved the naturally occurring rainfall events further inland. The urban heat island is one contributing factor in driving these events. Another is the added cloud condensation nuclei (CCN) from urban air pollution. The lake breeze front acts as the trigger mechanism. The lesson from this use of applied climatology was that urban areas can modify rainfall patterns significantly and this can affect agriculture near cities.

What size urban area does it take to produce some alteration in rainfall pattern? Detroit was obviously large enough to create this effect but what about Lansing, a city of 50,000 people? Using a one-mile grid of recording rain gauges, it was found that Lansing was indeed shifting the downwind areas of maximum rainfall. As an industrial area, the pollution did increase CCN and there was also some degree of urban heat island effect. Further research in other urban areas has confirmed that convergence zones tend to develop over cities and then move more frequent and intense showers downwind.

This information can be important to farmers in terms of their fertilizer applications. Downwind of prevailing wind over a city, many trace elements are deposited on agricultural land by these anomalous rains and this alters farmers' fertilizer needs. Farmers need to know more about these events so they can alter their fertilizer applications appropriately.

In another case, Strommen and colleagues measured the pH levels of every rainfall event and analyzed these data, added the synoptic pattern, etc. This allowed the tracing of sources of pollution that were previously unknown, and found some pH levels down to around 2, compared to a norm of 6 or 7. This also provides information that would be important to farmers for obvious reasons. The pattern of pH measurements precisely followed the plume from the steel mills of Gary, Indiana which became more dilute as it moved away from this source. Strommen says it is critically important to help politicians see the practical applications of such research or it will not be supported.

In another case, there was a drive to build cooling towers for a nuclear power plant on the shore of Lake Michigan so as not to introduce warm water into the lake and perturb the salmon environment. Strommen believed that this was a mistake, due to the frequent strong inversion over western Michigan. The cooling tower discharge would put a warm, moist air plume over the interstate highway and create hazardous driving conditions from icing of windshields and could also increase disease problems in the nearby agricultural areas. The towers were built, and the predicted hazardous conditions did indeed result. Eventually data were collected that proved Strommen's hypothesis.

The lesson here is that it is important to understand the total system when considering response strategies, and not make decisions based on a single issue. It is necessary to understand the implications of fallout, downwash, etc., as cities are developed with agricultural areas nearby. As power generation expands, it is necessary to understand the implications for agricultural lands down wind. Comprehensive, interdisciplinary planning is needed.

It is important to understand the total system when considering response strategies, and not make decisions based on a single issue.

In another example, Strommen was asked to visit Haiti, which was experiencing a huge decline in food production which was being blamed on climate change. Strommen found that in fact, the climate had not changed, and that the problem seemed to be the result of poor agricultural management practices that had led to the loss of enormous amounts of topsoil. A model demonstrated that changing the water-holding capacity of soil could create up to a four-fold increase in the variability of crop yields. Upon examination, it was found that the A and B horizon of the soil profile was no longer visible and the farmers were trying to grow crops in the C horizon of the soil. Low nutrient uptake and low water retention, resulting from mismanagement, had caused the problem. Sustainable farming techniques do exist, and are being utilized in some places; but when production capabilities are destroyed through bad management, restoring them is a very slow and extremely expensive process.

Research should be followed by a testing and evaluation phase involving users, not just scientific researchers. This is a major missing link in getting research transferred into applications.

In another case, the management technique of applying fungicide every fourteen days to ward off peanut leaf spot was used with good results. When research was conducted and data gathered over a three-year test period, it was found that fungicide applications could be reduced by almost 50%, saving farmers huge amounts of money, reducing energy use, and reducing the amount of fungicides in the environment without loss of crop quality or yield reduction. A real payoff of research is in such applications that protect the environment in many ways while saving money for the farmer, thus creating win-win solutions.

Application of Geochemistry and Spatial Analysis in Environmental Science Research

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High concentrations of mercury were generally found in patty fields. Evidence of mercury contamination through agricultural activity includes the recorded extensive use of mercury as fungicide in the paddy fields before the middle 1970s.

Beginning in 1972, The Department of Urban and Environmental Science (formally the Department of Geography) at Peking University launched its environmental research and education program. The initial projects included a baseline investigation of trace metals in Chinese soils. The Division of Environmental Science of the department has carried out over 50 studies including analyses of the amount, distribution, characterization, and origin of naturally-occurring organic compounds in major rivers of eastern China, a preliminary study of organic pollutants in soil in the Beijing-Tianjing area, and the development of a database management system for routine environmental monitoring of Tianjing. Currently the division is carrying out an environmental impact assessment of the Shenzhen River Regulation Project. The department's recent focus is environmental geochemistry, geostatistical analysis, environmental planning, environmental assessment, and environmental database management system development. The following three case studies are examples of how the department has worked to gain insight into the environmental problems facing China.

Case 1: Soil pollution study using geostatistical techniques [Tao, 1,2,3,4]

To establish a baseline for trace element concentrations in the soils of the Shenzhen area, a project was initiated as part of the nation-wide effort. In this study, data on the amounts and distributions of 12 metals, soil pH, clay, and soil organic matter (SOM) was collected from 83 locations. The study provided many conclusions including documentations of unusual distributions and concentrations of mercury in local agricultural soils.

To study the spatial distribution pattern and to map the metal contents in the soil of the area, the contents of all metals were analyzed using semi-variance analysis and Kriging analysis. While the experimental semi-variograms of all metals can be fitted well using spherical models with zero nugget, the range value of the variogram of mercury was considerably smaller than those of all other elements suggesting localized high concentrations of the element. In addition, the analysis of mercury distributions yielded a geometrically isotropic (circular) variogram. In contrast, the other elements studied exhibited anisotropic distributions (directional). The short variogram range and non-directional distribution pattern of mercury indicate that the high-value patches on a mercury map tend to be circular and are generally smaller in size than those of the other elements.

The results of a principle component analysis followed by the semi-variance analysis, Kriging analysis, and factor score mapping demonstrated that 12 elements can be divided into three categories for their spatial distribution patterns. The similarity in spatial distribution patterns between the first two components (F1: Cu, Co, Ni, Cr, and V; F2: Pb, Zn, and Mn) and parent material indicates that the levels of these elements are governed by the parent material from

which the soil was derived. The one exception to this pattern was mercury which is the only major element to fall into the third component, though it is geochemically similar to the elements in the first component. Unlike the others elements, mercury distributions seem to fit well with the land use map. High concentrations of mercury were generally found in patty fields. This result suggests that there is some degree of mercury pollution associated with agricultural practices in this region.

In addition, the results of an analysis of variance and SNK multiple comparisons show that mercury content in all other soils are significantly lower than in paddy soil in which mercury had accumulated in the surface horizon. Other evidence of mercury contamination through agricultural activity includes the recorded extensive use of mercury as fungicide in the paddy fields before the middle 1970s.

This conclusion can also explain the wide spread mercury contamination associated with paddy-based agriculture throughout much of Southern China.

Case 2: Contamination of wastewater-irrigated soil in Beijing-Tianjing area [Tao, 5]

The Beijing-Tianjing region is one of the fastest growing areas in China. Unfortunately the region is also characterized by limited wastewater treatment facilities, drastic water short ages, and more than a 20-year history of wastewater irrigation which has probably resulted in significant soil contamination.

Although a series of wastewater treatment plants have been built recently or are planned for the near future (using external funding), the facilities are not fully operational because of the financial limitations of the local governments and improper management systems (e.g. low water prices and free discharge of domestic wastewater). Wastewater (with and without treatment) is used by local farmers, together with sludge from wastewater treatment plants, to irrigate and fertilize their land. Without effective regulations on waste water irrigation, the agricultural soils, as well as crops which go directly to the local markets, become contaminated.

The results of many studies show that there is significant heavy metal accumulation in these soils. A preliminary study has also revealed that a wide variety of organic compounds, including PAHs, chlorinated pesticides, phthalates, alkanes, isoprenoids, fatty acids, triterpanes, steranes, etc., are present in these soils at elevated levels as the likely result of wastewater irrigation and industrial fallout. In the future, both science and policy research efforts will be necessary in order to develop technical and managerial mitigation measures to solve these pollution problems.

The Beijing-Tianjing region is one of the fastest growing areas in China, and has a 20-year history of wastewater irrigation which has probably resulted in significant soil contamination.

Case 3: A specific database management system for an EIA study [Peking Univ., 6,7]

One of the major recent projects carried out by the Division is an Environmental Impact Assessment for the Shenzhen River Regulation Project.

The Shenzhen River will be realigned, widened and deepened in a three-stage project for flood control. The Shenzhen River flows along the border between Shenzhen and Hong Kong and empties into Deep Bay. At the river mouth, there is a wetland system of international importance with mudflats, mangroves, fishponds, and a number of birds including some rare and endangered species. The potential impacts of the project on various habitats in the wetland system through changes in hydrology, water quality, erosion and sedimentation pattern is one of

the key issues to be assessed by the EIA study.

In addition to primary consulting by Peking University (led by the Department of Urban and Environmental Sciences), there are also a number of sub-consultants, including two environmental consulting companies based in Hong Kong, involved in the Environmental Impact Assessment (EIA). Data management and distribution became a critical issue during this study. A database management system with demonstration modules showing the major findings was developed during the early stages of the study. This helped facilitate internal data exchange and management as well as provide clients with a computer-based information system for evaluation of the environmental performance of regulation projects. The database was then distributed among the various teams and delivered together with the final report of the EIA (the system is also available by request from the Tao).

The results of many studies show that there is significant heavy metal accumulation in soils in the Beijing-Tianjing region.

Since the database was a project-oriented system for internal use and not all the participants had the adequate hardware needed for commercially-available database and GIS packages, the database management system was coded using Turbo-Pascal with limited hardware requirements (any PC compatible with DOS and VGA card). The system is bilingual (it uses one optional parameter to select English or Chinese interfaces) and fully menu-driven. The Chinese version can be run under regular DOS without a Chinese platform. Forty-six subsystems of the database are available for water, air and noise, sediment and soil, ecology, and engineering. All data collected in the study has been entered into the database system through spreadsheet-like interfaces defined by the user. The data can be either analyzed statistically or mapped two-dimensionally to show the results of the investigation on the screen graphically. The results of two-dimensional dynamic modeling of water quality in the Deep Bay can be simulated for a 24-hour cycle to show the predicted temporal change in water quality.

Other examples graphically presented using the database include the results of the mud contamination assessment based on either a Hong Kong regulation or the Harkenson Index, the TSP modeling with or without mitigation measures, a conceptual model of nutrient flow within the ecosystem, the variation in the number of birds in the wetland system, and the results of the survival experiments of planned mangrove along the river with or without protection.

Techniques such as these show considerable promise in facilitating both effective internal data management and decision making during large-scale environmental impact assessment projects.

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Agroenvironmental Protection

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China has worked to develop agroenvironmental protection programs since 1971. During this time, networks for management, research, monitoring and agroenvironmental education programs have been established. The development of these systems has focused on integrating agricultural development and environmental protection. There are currently more than 2000 experimental agriculture sites designed to reduce environmental damage associated with agriculture and to conserve natural resources. This program includes more than 500 monitoring stations country-wide.

There are three types of serious environmental problems in China: pollution, natural resource deterioration, and ecosystem damage. Pollution from both urban sources and agricultural chemicals is becoming increasingly serious. An estimated 10 million hectares (ha) of farmland are currently polluted resulting in a direct economic loss of 15 billion Yuan (RMB). This is a particularly serious problem in China because the arable land per capita is less than 0.1 hectare (one-third the global average). Water resources are also scarce and are threatened by pollution and forests. Grasslands are becoming increasingly degraded due to human activities and pollution. For these reasons, there is now a very significant attempt to develop sustainable, non-polluting agricultural systems in China.

An estimated 10 million hectares of farmland are currently polluted resulting in a direct economic loss of 15 billion Yuan (RMB). This is a particularly serious problem in China because the arable land per capita is less than 0.1 hectare (one-third the global average).

Chinese eco-agriculture (CEA) is based on principles that arose from numerous ecological, agricultural and economic studies. CEA was designed to treat the agricultural system as a living eco-economic system and thus to ensure that the flow of material, energy and information must be reasonably recyclable while maintaining relatively high yields. To obtain these goals, the CEA program seeks to scientifically manage the human agricultural relationship in order to maintain sustainable agricultural systems. The CEA system has been applied from the level of the single household up to the level of an entire county.

Several examples follow:

1. Village with 285 households, 1000 people and 135 ha of farmland.

This village has been in the CEA system since 1982. Farmland and animal husbandry are closely tied to one another to allow maximum reuse of wastes, resulting in a highly efficient agricultural system. The total income per capita is 1480 yuan (up from 75 yuan in 1980). In addition to increases in per capita income, there have also been improvements in ecological protection as waste has been reduced.

2. Village with 170 households.

This village has been a CEA site since 1982. Part of the farmland is used to grow feedcrops for animal husbandry as well as for biofuel production. These efforts are linked with the market system and the results have been dramatic increases in grain production and income.

3. Household

This example of an eco-household is a house located on 27 ha of sloped land with very serious soil erosion problems. To address these problems, the family planted 20 ha of forest and added water drops and checkdams to reduce erosion. Farming, animal husbandry and resource use were linked together in order to reduce wastes. The household income was over 6000 yuan compared to an average income of <1500 yuan for non-CEA households.

4. State farm

On this state farm with a fish pond, conifers were planted in 1985 and an irrigation system was installed. Production value from the fish pond was over eight fold higher than other fish ponds in the area and the income in 1992 was over 80 times higher than non-CEA fish ponds nearby. In addition to the economic gains, over 37 new species of birds were attracted to the habitat.

5. County

In a county with over 3,500 square kilometers, 23 townships and a population of over half a million, 670 km2 of land were reforested, resulting in reduced soil erosion. In addition, animal husbandry and waste recycling systems were put into place. Legume crops were planted to increase N fixation and for use in the weaving industry. Following the initiation of the CEA system, the county went from being grain limited to being a producer of excess grain. In addition, there were large increases in per capita income (90 to 820 yuan).

Fifty CEA counties have been created in recent years for a total of about 100. Since 1992, the National Environmental Protection Agency (NEPA) in China has developed a system of grain production that is based on sustainable agriculture principles. The benefits of the CEA systems range from increased preservation of the natural environment to increased yields and per capita income among its participating households, villages and counties. As a result, the system is viewed favorably by both farmers and agricultural administrators. Eventually, the system may become the nationwide strategy for agricultural development. However, the system relies on a large amount of labor and human wisdom and there is still a great deal of research to be done. Nonetheless, the system is a dramatic example of the potential to combine sustainable development and an improved life for agriculturally-based communities.

During the process of the CEA experiment, the concepts of eco-agriculture and eco-economics have been raised in China. As part of a general development model for the region, these concepts may be helpful in addressing the issue of sustainable development.

The benefits of the CEA systems range from increased preservation of the natural environment to increased yields and per capita income among its participating households, villages and counties.

Anthropogenic Nitrogen Inputs to North Atlantic Watersheds: How Much Reaches the Rivers?

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Each year an increasing amount of atmospheric nitrogen is fixed through combustion, fertilizer production and legume cultivation. These increases may have significant effects on terrestrial and aquatic ecosystems.

Global nitrogen dynamics have changed dramatically since the turn of the century. Each year an increasing amount of atmospheric nitrogen is fixed through combustion, fertilizer production and legume cultivation. These increases may have significant effects on terrestrial and aquatic ecosystems yet these effects are not well understood. To address this question, a Scientific Committee on Problems in the Environment (SCOPE) led by Bob Howarth of Cornell held a meeting in Block Island, Rhode Island. The result of this meeting was an in-depth examination of the nitrogen dynamics of the major watersheds that empty into the North Atlantic Basin.

The highest rates of global fertilizer applications are found in Europe, the Eastern U.S. and China. The Northern Atlantic region was chosen for this study because it is bounded by both Europe and the Eastern U.S. To examine the effects of increased nitrogen input to the regions that surround the North Atlantic, the region was divided into 14 watershed regions that spanned a wide range of social and environmental characteristics such as population density, fertilizer use, N deposition, soil type, and vegetation composition. At first glance, nitrogen efflux in watersheds was well correlated with population density, with some distinct and interesting differences between the tropics and temperate latitudes.

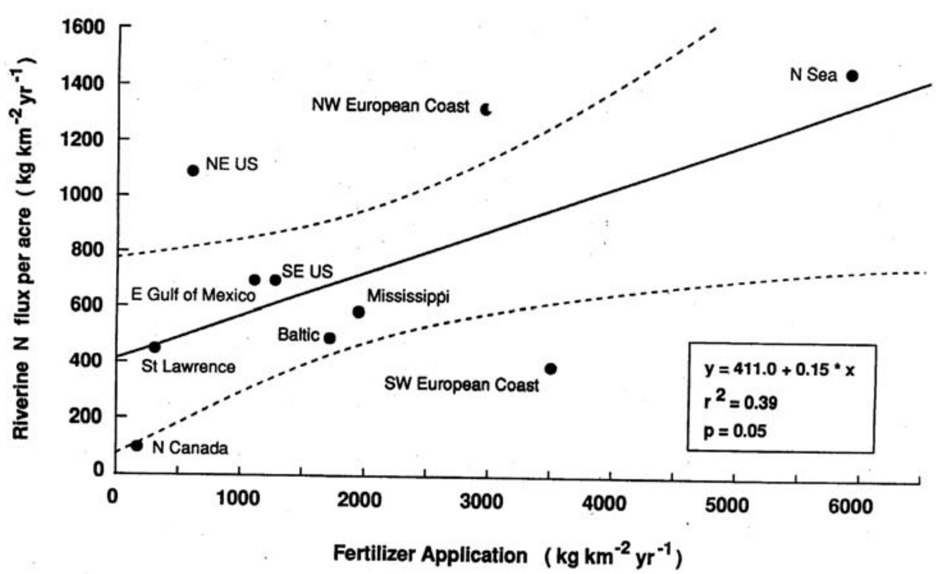

Figure 22.1
Correlation between fertilizer application and riverine N flux.

One of the primary questions of the SCOPE study was to determine the degree to which nitrogen fluxes have changed in the watershed regions since pre-industrial times. To do this, major anthropogenic nitrogen inputs and outputs were estimated for each watershed region. Ammonia was not included in deposition inputs because it comes largely from fertilizer and would be counted twice if included again in deposition. Fertilizer and industrially derived deposition (NOy) are the principle inputs to most of the regions. Figure 22.1 shows the correlation between fertilizer application and riverine N flux.

In order to examine the impacts of anthropogenic activity on the nitrogen cycle in the watersheds, total watershed N inputs were compared to riverine N flux. This comparison resulted in a roughly linear correlation across more than an order of magnitude of variation in both values. Simple regressions of fertilizer or NOy deposition versus river N also showed significant linear correlations in each case, and surprisingly, the correlation with deposition was stronger.

It is difficult to determine the fluxes of nitrogen prior to the influence of humans as it is usually necessary to substitute space for time by examining fluxes from pristine regions. Estimates for baseline fluxes from the temperate regions in this study ranged from 74 to 114 kg N km -2 yr-1 (see Table 22.1). These values represent a number of independent data sources ranging from Canada to Oregon to 1890s Connecticut River data. When current fluxes from the North Atlantic watersheds are compared to these baseline estimates, the ratios of current to baseline fluxes range from 3.4 to 5.3 in North America and 6.8 to 10.6 in Europe (see Table 22.2). Thus, even if there are errors in estimates in the baseline flux estimates, it is clear that efflux from many of the Northern Atlantic regions has been significantly increased due to anthropogenic forces.

Results indicate that 60-80% of the nitrogen going into terrestrial ecosystems is being retained or transformed to N2. Many of the possible upstream pathways may eventually saturate, thereby increasing N loads to aquatic systems and the coastal ocean.

Estimates of "Pristine Baseline" for N Export from Temperate Rivers of the N. Atlantic Region	
N. Canadian Region (this study)	74 kgN/km2/yr
N. Canada (Clair et al, 1994)	79 kgN/km2/yr
1890's Connecticut River Data	110 kgN/km2/yr
Andrews Forest, Oregon, USA	114 kgN/km2/yr

Table 22.1

Estimates of "Pristine Baseline" for N Export from Temperate Rivers of the N. Atlantic Region in kg N km^{-2} yr^{-1}

Despite the increases in river N efflux in many of the North Atlantic watersheds, most of the excess N is not reaching the rivers. In general, the ratios of river N exports to N inputs in temperate regions were low and ranged from 20 to 40%. This result indicates that 60 -80% of the nitrogen going into terrestrial ecosystems is being retained or transformed to N2. The fate of this excess nitrogen is not currently known, but the resolution of this question is critical to our understanding of nitrogen cycling, as many of the possible upstream pathways may eventually saturate, thereby increasing N loads to aquatic systems and the coastal ocean.

Estimated Increase in River N Export Since Pre-Industrial Times (Temperate Regions Only)	
Region	Current River N Export / "Pristine" River N Export
N. Canada	.64-1
St. Lawrence	3.5-5.4
NE US	9.1-14.1
SE US	5.7-8.9
E Gulf of Mexico	5.7-8.9
Mississippi	4.8-7.4
W Gulf of Mexico	5.1-7.9
Baltic	4.2-6.5
North Sea	12.3-19.1
NW European Coast	11.0-17.1
SW European Coast	3.1-4.8
North America	**3.4-5.3**
Europe	**6.8-10.6**

Table 22.2

Estimated Increase in River N Export Since Pre-Industrial Times (Temperate Regions Only) In Ratios of Current to Baseline Fluxes

Why are river N effluxes not increasing with the same exponential trend that inputs exhibit? This raises the important question of when terrestrial ecosystems will become N saturated.

Interestingly, the ratio of river N efflux to N inputs in the Amazon/Tocantins basin is 2.5, and in the Central America/Orinoco basin is 0.88. This result highlights one of the major differences between temperate and tropical latitudes. Whereas N limitation of plant growth in temperate ecosystems appears nearly ubiquitous, humid tropical ecosystems are relatively N rich and are not likely to tightly retain excess N inputs. Because the most dramatic increases in N deposition and fertilizer use in the next century will be in the tropics, the probability of increased losses to both atmospheric and aquatic environments appears quite high.

One of the major outstanding questions from this study is why river N effluxes are not increasing with the same exponential trend that inputs exhibit. This raises the important question of when terrestrial ecosystems will become N saturated. The nitrogen that is missing in the current mass balance estimates may experience several different fates. One possibility is that increased nitrogen deposition increases carbon uptake in vegetation and thus results in nitrogen and carbon storage in biomass. However carbon and nitrogen storage due to nitrogen deposition is not likely to occur in agricultural systems where there is ample N due to fertilizer use. This leaves only the natural systems to provide such a sink for excess N. At best, 24% of all anthropogenic inputs could reach natural systems, thus, even with 100% retention of this N, natural systems can only account for one forth of the missing N. The other possibilities for N storage are aquifer storage of nitrate and denitrification to N2. Using nitrate increases in ground water (with poor data), it still appears that all the N cannot be accounted for. Some combination of these three factors is likely to be responsible for the retention of N in terrestrial ecosystems.

Several conclusions were drawn from this study. One, only 20-30% of anthropogenic inputs of N to temperate watersheds could be accounted for in the rivers. Two, river N efflux, from most areas, still appears to be several fold higher than in pristine times. Three, both agricultural (fertilizer use and legume cultivation) and industrial activity (NOy deposition) appear to influence river N values. Finally, tropical regions still appear relatively unchanged, but the projected increases in N loading combined with a naturally rich N cycle suggests that N losses from tropical regions may increase dramatically in the coming decades.

Industrialization and Urbanization in China

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During the last four decades, China's regional development policy has twice been changed significantly. Beginning in 1953, the Chinese government sought to balance the distribution of industrial production by shifting the nation's industrial center inland from eastern China. To achieve this goal, the central government invested national funds in construction in the inland areas. This policy slowed development in eastern China, especially in many coastal cities, reducing the economic dominance of the region. This, in turn, affected the government's ability to support inland development. This 25-year policy sacrificed efficiency for regional equality and is regarded as a period of balanced regional development.

The second major change began in 1979, when the government sought to alter some of the ineffective policies of the past. Some of the policies it planned to change were total public ownership of industry, a completely planned economy, and the priority that had been given to heavy industry, reducing efficiency for the sake of regional equality. At that time, the government tried to turn the planned economy into a more market-based economy in order to improve resource allocation and optimize industrial structure. As a result, under the principle of giving efficiency priority over regional equality, the coastal area reemerged as the region of principal investment. This began a period of so-called imbalanced regional development policy.

Because these different regional development policies determined the orientation of investment in China, they resulted in different regional features. Therefore, these policies are key to understanding regional urbanization and industrialization in China over the past four decades.

Wang discussed data which, when aggregated with China's socioeconomic circumstances, reveal some of the major characteristics of urbanization in China. First, the urbanization process is accelerating along with vigorous industrial development. On the basis of adjusted data for the country as a whole, the percentage of Chinese population which is urbanized has risen steadily from the 1978 level of 18% to the 1993 level of 28%. From 1978 to 1993, the percentage of urban population increased by 10% in 15 years, compared to the 7% rise that took place over the previous 30 years (1949-78).

It is very difficult to truly determine urban population. While a figure of around 28% is often quoted, demographers believe it is already over 30%, and official estimates are that it will be close to 60% in the early part of the next century.

Secondly, the disparity of urbanization momentum between the coastal and inland regions is widening due to the new emphasis on efficiency rather than regional equality. (A number of factors are used to determine the mean efficiency of different provinces including secondary

The percentage of Chinese population which is urbanized has risen steadily from the 1978 level of 18% to the 1993 level of 28%, and official estimates are that it will be close to 60% in the early part of the next century.

and tertiary industrial output value, power consumption, water consumption, profit margin, and tax rates.) Differences in geographical conditions are also partly responsible for the regional imbalance. Statistical information on the disparity in urbanization by province or region does not truly reflect how distinct these patterns are because the urban population registration system and related policies have not been fully reformed. In interpreting statistics, for example, it is important to understand what the definition of a city is. In China, there are a number of factors used in defining cities, including: 1) population over 100,000; 2) proportion of agricultural output to other out put; 70% must come from non-agricultural sources to be considered a city; 3) administratively, cities must be approved by state council for tax purposes.

Third, most of the non-agriculturally based population in relatively developed areas are asked to remain in local industries in order to lighten the burden on cities, especially in eastern China. A series of measures are in place to restrict migration from rural to urban areas. Though part of the rural population is no longer engaged in agricultural activities, they are not allowed to move freely to urban areas. Instead, they are employed in township enterprises which afford a lifestyle that is different from that of the peasants. This phenomenon is very prominent in the coastal area.

Though part of the rural population is no longer engaged in agricultural activities, they are not allowed to move freely to urban areas.

Fourth, the increase in regional urbanization disparities has led to large-scale temporary migration from inland to coastal areas. These temporary migrants leave their native regions and move to cities to seek jobs without the government's permission. They are not counted as urban inhabitants by the population registry, even though many have lived in certain cities for an extended period of time. In recent years, this type of migration has increased dramatically. Based on a survey in Shanghai in 1988, there were 817,000 temporary migrants in the Shanghai city limits. According to a survey in Beijing this year, some 2,877,000 people are living in the city "temporarily." These people are not recognized as migrants, but are instead regarded as "mobile or floating population."

Today, there are three serious problems for the Chinese government:

1. It must expand the capacity of the cities to accept the growing labor force coming in from rural areas by reforming urban administration and accelerating development of the urban economy.

2. It must continue to develop township-owned, village-owned and private enterprises, in order to keep more of the labor force in the rural areas and avoid over-urbanization of the population. These rurally-based enterprises must be appropriately concentrated in small towns to raise production efficiency, economize on the use of cultivated land, reduce waste of resources, and limit the scope of environmental pollution.

3. It must protect the basic cultivated land area from urbanization pressures and work toward sustainable agricultural practices.

Geographic Information Systems (GIS) as a Cartographic Modeling Tool for Urbanization and Resource Interface

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Scientists have the challenge of educating policymakers about the distribution and magnitude of environmental processes and their implications. The increase in remote sensing systems, availability of digital data, and geographic information systems can help to provide the kinds of visual information that can be useful in this arena. We now have the ability to assemble datasets that can describe, in broad ways, changes in Earth systems, and provide a baseline understanding of some processes. We can map the spatial distribution of forests, prime agricultural lands, and threats to the quality of resources using Geographic Information Systems (GIS).

We now have the ability to assemble datasets that can describe, in broad ways, changes in Earth systems, and provide a baseline understanding of some processes.

Way discussed two prototypes for using such systems. The first involved applications of a database for the conterminous United States, accomplished by 17 graduate students in a 10-week period. They gathered digital databases from a variety of sources including USGS and EROS Data Center's Vegetation Characterization Dataset, and used these data to produce a set of maps that work to define issues on the macro scale, and demonstrate the ability to generate useful secondary datasets from primary data sources. Way showed a set of maps that characterized land elements including: commercially valuable timberland, financially valuable agricultural land, heterogeneity of vegetation classes, water resources including subsurface aquifers and surface water sources, and a future urbanization scenario.

This project tested different types of land use projections. Perhaps most significantly, it helped to identify "red flags" -- areas particularly at risk or of interest -- and generated some unexpected results. For example, the mapping project that sought to identify commercially valuable forest areas most at risk flagged the southern U. S. pine forests as the area most at risk, rather than the old growth forests of the Pacific Northwest which, while they have strong wildlife value, are often on slopes too steep to make them very important commercially. In the mapping of agricultural land most at risk, California's San Joaquin Valley showed up as an area at risk from urbanization.

The researchers also experimented with future scenario planning using the maps they generated. They attempted to protect sensitive and valuable areas of forest, agriculture, wildlife habitat, and other key resources by reallocating human population from these areas to other parts of the U.S. Way showed examples of some of these reallocations.

The second prototype Way demonstrated was based on the effects of differential air pollution on forests, agriculture, and people in Eastern Europe. The researchers sought to determine the drag on gross domestic product related to air pollution on the economies of these countries.

Using AVHRR data and government maps, they first found out where the forests, agricultural land and people are located and then mapped the effects of ozone. Such maps can be powerful tools for informing policymakers.

In this study, emitters of sulfur dioxide (SO2) were mapped including high smoke stacks and residential areas. A dispersion model was developed and incorporated in the GIS. Pollution risk of regional sulfur deposition was plotted in tons of SO2 per 100 square kilometers and verified with published statistical data.

Landsat images were used to show in more detail the magnitude of long term SO2 damage in forested areas. As soils acidify, forests die and are immediately cut. Replanting is not successful; even removing the topsoil has not been effective. The study also examined the association of pollution and human disease rates in order to estimate the social costs of air pollution in dollars per ton. As a fraction of gross domestic product, these effects were shown to be significant in terms of drag on the national economy on -- the magnitude of 7-15%, in this study.

Sulfur dioxide effects were shown to be significant in terms of drag on the national economy on the magnitude of 7-15% of GDP, in this study.

This presentation helped to demonstrate what GIS can do well and what it can not currently be expected to do. It is difficult to incorporate time-dependent phenomenon in a GIS. Still, it is a good tool for getting a first cut on a problem. GIS is excellent for static mapping or for visualizing change from multiple points in time. It is useful for hypothesis formulation and can help to identify “red flags” to prioritize more detailed studies.

Vegetative Cover Change in China from 1982 to 1992

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Young presented an analysis of vegetative cover change in China using global-scale Advanced Very High Resolution Radiometer (AVHRR) data and the IDRISI Geographic Information System (GIS). Both the data set and the GIS system were chosen for their general availability and accessibility to anyone who might wish to work with them. IDRISI is a simple, inexpensive, raster-based GIS which can be used on most PCs. AVHRR data is very available, inexpensive, easy to handle, has low computer memory requirements (years of data covering the whole globe can be analyzed on a lap top), and potentially contains a great deal of information.

The AVHRR data used in Young's analysis (1982-92) comes from sensors on three satellites, NOAA 7 (1982-85), NOAA 9 (1985-88), and NOAA 11 (1988-92). AVHRR provides data on five channels, only two of which are used in this work, the visible red and the near infrared. The AVHRR data scales are:

* High Resolution Picture Transmission (1 km x 1 km) (HRPT)
* Local Area Coverage (1 km x 1 km) (LAC)
* Global Area Coverage (4 km x 4 km) (GAC)
* Global Vegetation Index (8,16 km) (GVI) which provides one band of data, the Normalized Difference Vegetation Index (NDVI).

AVHRR's NDVI is based on the relationship between near infrared light and visible red light (ir-r)/(ir+r). Vegetation absorbs highly in red light and reflects highly in infrared light. AVHRR's NDVI values range from -1 to +1, where water, snow, and ice are generally less than 0, rocks and bare soil around 0, and vegetation ranges from 0.1 to 0.6. For vegetated areas, the denser the vegetation the higher the NDVI.

The AVHRR sensor collects global data daily, however, about half the Earth is covered with clouds at any given time. A method known as Maximum Value Composites (MVC) has been developed where 7 days of data are overlaid taking the maximum NDVI value. In this way clouds are removed from the images. In some cases, 7 days aren't enough, so 10-day or monthly maximum value composites are used. Another potential problem with the AVHRR data used in this study is that there are three different satellites carrying the AVHRR sensor. This creates differences in NDVI between the three satellites. In addition, each of the satellites slows down as it circles the Earth creating later equatorial crossings over time. Calibration of these GVI data sets would reduce these sensor-related problems. Additional sensor problems were acknowledged by Young, but the emphasis of his talk was not on data formation.

The major change in vegetation for China is not temporal, but rather spatial. That is, there is a greater difference in NDVI between tropical China and the deserts of China than the difference in NDVI between summer and winter for those regions.

Two AVHRR data sets are used in this work, the NGDC (U.S. National Geophysical Data Center) Monthly Generalized GVI from NOAA 9 Weekly GVI data (1985-1988), and the NOAA Weekly GVI data via UNEP/GRID-Geneva (United Nations Environment Programme /Global Resource Information Database) from NOAA 7, 9, 11 (1982-92).

Data preparation was the most time-consuming element of producing the vegetation analysis. For the NGDC GVI data, NGDC checked registration, data were visually inspected for noise which when found was reduced, data were composited monthly in 10-minute grids, biased toward median values (well-processed, but not calibrated). For the NOAA Weekly GVI data, the first generation data (NOAA 7) were reprojected into Plate Caree to make it the same as data from NOAA 9 and 11, data were composed weekly in 10-minute grids, biased toward maximum values (data not fully processed, and uncalibrated). Young aggregated the data into monthly composites (13 per year, based on four weeks per month), reviewed data for noise, removed noise and reaggregated data (data clear of noise, but not calibrated).

The African studies showed that TSA can show annual vegetation change, sensor degradation effects, and the effects of El Niño-Southern Oscillation (ENSO) events on African vegetation.

The technique used in this study was Time Series Analysis (TSA), a form of Principle Components Analysis (PCA) where the only variation is time. It is understood that there are some changes caused by the need for atmospheric and sensor correction. PCA under takes a linear transformation of a set of image bands to create a new set of images that are uncorrelated and are ordered in terms of the amount of variance explained in the original data. TSA is area weighted, therefore the early components show change which has a great magnitude over a larger area, while later components either show low magnitude change over large areas or large magnitude change over small areas.

The products of TSA are known as components which are made up of two aspects:

1) Loadings (correlations of components showing temporal change). The loadings are presented in graphic form and show: i) annual vegetation patterns as reflected in annual patterns of rising and falling NDVI; ii) long-term trends as indicated by an overall increase or decrease of NDVI over long periods of time; and iii) extreme events which are seen as outliers from the general patterns.

2) Spatial Image (images show spatial change in the time series). The image shows the spatial distribution of vegetation change as described in the loading graphs.

To analyze broad vegetational changes in China, Young first attempted to determine the typical annual changes that occur. Five years of data for each month are averaged to get a typical year. As noted above, the components produced range from large over all changes to smaller changes. The first component produces a loading which shows no distinctive change in time and every month is highly correlated with the spatial image. The spatial image shows the NDVI for China as it would be regardless of season. That is, the tropical regions of southern China have a high NDVI while the deserts of Xinjiang have a low NDVI. This indicates that the major change in vegetation for China is not temporal, but rather spatial. That is, there is a greater difference in NDVI between tropical China and the deserts of China than the difference in NDVI between summer and winter for those regions. Component 1 turns out to be an integration of NDVI over the year. Some non-vegetation effects such as cloud and fog contamination, aerosols reducing light, and irrigation (water gives low NDVI) show up in this component. Component 2 shows the second-greatest variation, that between summer and winter. Here the deciduous forests of the Northeast show up very clearly. Component 3 shows the third-greatest variation, that between spring and fall which turns out to reflect various cropping patterns. Component 4 also shows some major cropping patterns in Eastern China. Later components were not as easily

distinguished as the early components and represent more local changes. This methodology captures different annual vegetation patterns in China.

Young next looked at interannual variations in three time series (1986-88; 1982-87; and 1987-92). Before showing results in China he showed results for Africa using the same data base for the years 1986-88. The African studies have shown that TSA can lump sensor degradation into specific components so this degradation doesn't effect the results shown in the other components. Work with calibrated data for Africa has confirmed this conclusion. The African studies showed that TSA can show annual vegetation change, sensor degradation effects, and the effects of El Niño-Southern Oscillation (ENSO) events on African vegetation.

Looking at the long-term TSAs for China, the first four components were very similar to those found in the "typical year" analysis. The major difference was that for the long-term data sets, the loadings showed variations in NDVI between years and the images showed the specific areas where NDVI was changing on an interannual basis. Some of the later components showed some local high magnitude changes which occurred in specific years. One clear example was the great forest fire in Northeast China in 1987.

Component 6 on the two long-term TSAs (1982-87; 1987-92) show the problems associated with the sensor degradation and the change of satellites. The NOAA satellites carrying the AVHRR sensors slow down as they circle the earth resulting in later equatorial crossings as time passes. The effect of this later and later passing is that the light reflected from the earth has to travel through more atmosphere as time passes. As the light travels through more atmosphere, the visible red light is attenuated more quickly than the infrared light. As time passes, this makes NDVI increase, giving the appearance that vegetation is increasing. This is particularly evident in low vegetation areas such as deserts. An interesting aspect of the image for component 6 is that certain areas of forest (not all forest areas) are shown as being highly uncorrelated with the general trend, which would indicate that they are loosing NDVI, perhaps because of deforestation.

Young then ran a TSA using component 1 (or the annually integrated NDVI) for each year from 1982 to 1992. As with all of the other TSAs the first component showed the integrated NDVI over the period. The second component showed the change of sensors and the degradation of the sensors. The third component possibly showed the effects from various ENSO events during the 11-year period. The most prominent effect of this analysis was that in component 2 many forest areas showed up decreasing in NDVI. This is not surprising as many reports have indicated widespread deforestation throughout China's forests in the 1980s. The areas of deforestation were confirmed by profiling the specific areas and following the abrupt changes in NDVI which indicates deforestation, as opposed to the profiles of desert regions which show a very smooth linear progression of in creasing NDVI caused by the sensor degradation. Of interest here is that the sensor degradation problem may in fact be helping highlight the areas of deforestation which might otherwise be difficult to see. The great forest fire of 1987 in northern Heilongjiang also helped to verify the forest change as seen in component 2.

Many forest areas showed up decreasing in NDVI. This is not surprising as many reports have indicated widespread deforestation throughout China's forests in the 1980s.

Young concluded that future work will use calibrated data with TSA to see if this method can effectively isolate sensor problems in the data base, and to confirm the areas of deforestation. Future work will also be done with the Institute of Remote Sensing Application, Chinese Academy of Sciences, to verify the regions of deforestation with Landsat data. Future cooperative work with the Chinese Academy of Sciences will also look at the ability of AVHRR data to isolate climate effects (such as those of ENSO events).

The Challenges of Agricultural Land Use in China

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> The crisis point for a country's basic food needs is 0.04 hectares per person. Today, one third of China's provinces are nearing this point.

It is necessary to combine science and technology with policy in order to solve the long-term, large-scale problems of agriculture in China. Agriculture is key to sustainable economic development in China for many reasons. First, the population is very large (1.2 billion in 1995, expected to reach about 1.6 billion by 2030) and thus requires a great deal of food. Second, China's level of economic development is still relatively low and so the country lacks the hard currency necessary to buy large amounts of food on the world market. Even if it could afford to import food, the large quantities required could probably not be supplied by the world market. Third, social development is altering eating patterns, requiring ever greater amounts of agricultural products. Fourth, a significant portion of the funding China has available to invest in development comes from agricultural taxes.

China's agricultural system has undergone many changes in recent years. First, there is now a system in which families rent land and are in charge of their own production. However, according to regulations, when peasants rent land, they must sell some of their products to the government. Some may not have enough to sell or may not wish to sell to the government for a number of reasons (price, etc.). Local government officials or agencies are responsible for collecting these products from the peasants and these officials are under a great deal of pressure. Also, sometimes local governments don't have enough money to buy the products so they give the farmers a paper IOU; essentially the farmers are forced to make a loan to the local government, hoping to be repaid later for their goods. In addition, the price of materials needed for production is subject to enormous inflation.

Second, there is a trend toward scientific industrialization of agriculture. Scientists conduct research that can take ten or more years to develop new types of products, seeds or animals. The traders and merchants become rich but the scientists remain proletarians.

The local agency does not have enough funds to adequately support such research, and there are no policies in place to protect researchers from unjust competition.

Third, people traditionally engaged in agriculture are moving to the cities in great numbers. Tens of millions of people are migrating to cities and towns in search of jobs. Some of them migrate to the suburbs of the big cities like Beijing. In one of these Beijing suburbs, Zhejiang Village, some 10,000 people, mostly from Zhejiang province, are making clothing. As a result of this tremendous wave of migration, the cities and suburbs are subject to rising levels of crime and associated problems.

Another set of problems has to do with the quantity of agricultural land in China. Though China's territory is very large, the amount of agricultural land per person is just one quarter of the world's average. Since 1985, with the acceleration of urbanization and development, 600,000 hectares of this land is converted to other uses each year, most of it fertile agricultural land. Once such land is converted, it is very difficult to recover.

The amount of agricultural land is falling while the population is rising, leading to a situation in which there will be just 0.04 hectares of agricultural land per person in 2030 when the population is projected to reach 1.6 billion. According to the Food and Agriculture Organization (FAO), the crisis point for a country's basic food needs is 0.04 hectares per person. Today, one third of China's provinces are nearing this point. The pressure of the population on the land becomes greater each year.

FAO reports say that in 1994, China produced 335 million tons of grain (others say it is actually closer to 450 million tons). Before the year 2000, this should be increased by 10 million tons each year to meet the food needs of the population. But the 600,000 hectares of land lost per year equates to the loss of 9 million tons of production each year. So the problem of land use seriously affects food production. Land degradation is another major problem. Some 16% of China is already desert and in the past ten years, 2,100 square kilometers per year of additional land is becoming desertified. This is expected to rise to 2,300 square kilometers per year if effective actions are not taken to reverse this trend. Soil erosion is also a huge problem.

Because the rental period is only 12 to 15 years, the peasants have no incentive to care for the soil and keep it productive. The soil is "mined" in essence, and soil erosion and degradation is rampant.

It is useful to have a brief history of land ownership and management practices in China. Before 1949, 1 to 3% of the people owned more than 80% of the agricultural land. The peasants who worked the land owned nothing, not even their clothes. From 1949 to 1951, through land reform policies, many peasants came to own their own land, but the amounts they owned were very small. From 1951 to 1955, groups of 3 to 5 families organized into small production groups to help each other, share tools and domestic animal power, etc. From 1956 to 1978, local governments gathered these groups into larger units (generally one village) and then into communes (several to tens of villages). The commune was also the local government.

All of the land belonged to the commune. The commune told the peasants what to do and they did it. They were not free to choose some of their own activities. The agricultural products from this farming method were distributed to the peasants based on the number of people in each family. They more babies the family had, the more food they received, but the amount of food the peasants were given was not enough to survive on. It became clear that the society could not feed itself under this system and in the late 1970s, the land management and ownership system was reformed.

Since 1979, a new system of land management, known as family land renting and production, has been in place. Under this system each peasant household can apply to rent a small piece of land, generally 0.1 to 0.3 hectares per person, and each family may plant 0.7 to 0.8 hectares, depending on the region (in northeast China, the areas may be larger; in the south, they may be smaller). Many people considered this to be a great revolution for farmers in China. The peasants could choose what type of crops to plant on their land. They could sell whatever agricultural products they had left after paying taxes and rental fees. They could move from place to place at will and could take another job if they found one. This system proved to be good for both the peasants and the nation, and food production reached its 30-year high in 1984.

However, this system has proven to be a double edged sword. Because the rental period is only 12 to 15 years, the peasants have no incentive to care for the soil and keep it productive. The soil is “mined” in essence, and soil erosion and degradation is rampant. In addition, this system cannot fulfill the peasants desire to become wealthy. According to the government’s plan, before the year 2000, the national average per capita income should be US$800. This would give an average peasant household of 5 people about $4000/year, but the small amounts of land they are currently allowed to farm can produce only a fraction of this amount.

If they used machines, tractors, etc., and were allowed to farm more land, they could farm 7-10 hectares, and have an income of $4000, but if this was done, there would be an even larger surplus labor force, the size of which is already a problem. Of the 0.9 billion people living in the Chinese countryside, 0.3 billion are engaged in agriculture, 0.2 billion in county factories, and 0.15 billion in third industries (service jobs), leaving 0.25 to 0.3 billion people without employment. With the population of the countryside expected to increase to 1.3 billion by the year 2030, the number of unemployed is expected to reach 0.4 to 0.5 billion in 2030.

People living in the countryside hope to look for wealth outside of their local villages. With economic development proceeding, 600,000 to 800,000 hectares of agricultural land will be lost each year, with one-fifth of China’s fertile land lost before 2030.

The peasants, especially young men and women, are moving to the cities to find jobs which might pay $500-$600 per year. Older peasants are left to farm the land, reducing production substantially. The major current limitation is not one of agricultural land short age, it is more a matter of how much land is not planted because people want to go to the city instead. The local governments of some districts also have an incentive to convert farm land to other uses. Agricultural land converted to tourism use is taxed at 500 times the tax rate.

In conclusion, the people living in the countryside hope to look for wealth outside of their local villages. With economic development proceeding, 600,000 to 800,000 hectares of agricultural land will be lost each year, with one-fifth of China’s fertile land lost before 2030. In addition, there will be half a billion additional mouths to feed by the year 2030, nearly equal to twice the current US population. There is also the problem of the aging population. In the coming decades, about 30% of China’s people will be over 60 years old, raising the issue of how to support an upside down population pyramid with so many old people and not enough young workers to support them.

The problems brought about by the migration of rural people to the cities, including abandonment of farm land, and how to accommodate all the new people in the cities, perhaps define China’s most significant dilemma. One third of Beijing’s population is now made up of immigrants from the countryside or small towns, according to reports. Solving this problem is very difficult for local governments; they cannot send enough peasants home, they just keep coming back. Air and water pollution problems, as bad as they are, are not as great a threat to China’s economic development as this migration of people and the problems discussed above. Certainly, for long term development, we must pay more attention to these issues.

Zhang outlined work undertaken in the past decade to deal with some of these problems:

1 Establishment of the National Land Management Bureau in 1986 to take charge of administration, management, research, and application of new techniques.

2 Department of Agricultural Resource Management, Agricultural Ministry of China, in charge of plants, crops yield estimation, water, fish, and agricultural land.

3 National project: Land Use Survey, 1989 -1994; results indicate:

* Agricultural land: 100 billion hectares
* Grassland: 225 billion hectares
* Forests: 13.0% coverage
* Desert: 153 billion hectares

4 National project: Land Use Change Survey, 1994-1996.

5 Crop yield estimation: related to the supply of food.

6 Disaster monitoring: drought, floods, insect pests.

New technology has been used in land management and surveys.

1 Photogrammetry

2 Satellite remotely-sensed data

3 Imaging Radar

4 GPS: Ground Positioning System

5 GIS (Geographic Information System), LIS & Computer Systems

6 Internet and Chinanet

The major current limitation is not one of agricultural land shortage, it is more a matter of how much land is not planted because people want to go to the city instead.

China Ozone Research Program

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Serious ozone depletion has been noticed over parts of China, about an 18% reduction from pre-depletion values, and falling at a rate of 8.5% per year. It is not clear why this ozone depletion is up to 20 times larger than the global average.

The China Ozone Research Program (CORP) is a four-year effort to understand the characteristics of the temporal variations and spatial distribution of ozone over China, to explain the mechanisms of these variations in tropospheric and stratospheric ozone, and to improve the methods for assessing and predicting ozone trends and their possible impacts on climate-environment-ecosystem changes.

CORP engages in intensive collection of measurements and data analysis with regard to surface ozone and related precursors: nitrogen oxides (NO_x), carbon monoxide (CO), methane (CH_4) and non-methane hydrocarbons (NMHC). Using data from the CORP stations as well as other sources, CORP analyzes total column ozone (from its ozone network), profile of ozone (using the Umkehyr method), Total Ozone Mapping Spectrometer (TOMS) data, SBUV and SBUV2 data (profile and residual tropospheric ozone), and stratospheric balloon soundings (for ozone and aerosol profiles from 0 to 35 kilometers).

To improve knowledge regarding ozone precursors over China, CORP has developed methods for improving measurements of trace gas fluxes for methane, carbon dioxide and nitrogen oxides. CORP is also studying distributions of sulfur dioxide (SO_2), nitrous oxide (N_2O), CO, NO_x, and CH_4 emissions over China.

CORP is conducting laboratory studies on homogeneous and heterogeneous photochemical reactions of ice and sulfate aerosols, photo dissociation of chlorofluorocarbons (CFCs), hydrochlorofluorocarbons (HCFCs) and dimethylsulfide (DMS), photochemical reactions of CFCs and N_2O with ozone in the stratosphere, and important photochemical reactions that produce high concentrations of ozone in the troposphere.

In order to better understand the mechanisms of atmospheric ozone variations, a modeling effort is also part of CORP. Researchers are modeling the formation of ice clouds, sulfate aerosols, and the effects on ozone. Estimations are being made of the vertical transfer of precursors (CH_4, CO, SO_2, NO_x) in the free atmosphere. A two-dimensional dynamic-radiative-chemical coupled model of atmospheric ozone is being developed, as well as a regional ozone model.

In the end, the project seeks to develop improved methods for assessing and predicting trends of atmospheric ozone and possible impacts of these variations on the regional climate and atmospheric chemistry of China.

Several extremely interesting outcomes of this research involve:

1. a center of ozone depletion over the Tibetan plateau

2. a climatic cooling of Sichuan province over the past 40 years, possibly due to effects of sulfate aerosol, and

3. high tropospheric ozone concentrations in Beijing (significant frequency of exceedance of 60 and 80 ppb at six stations in the city)

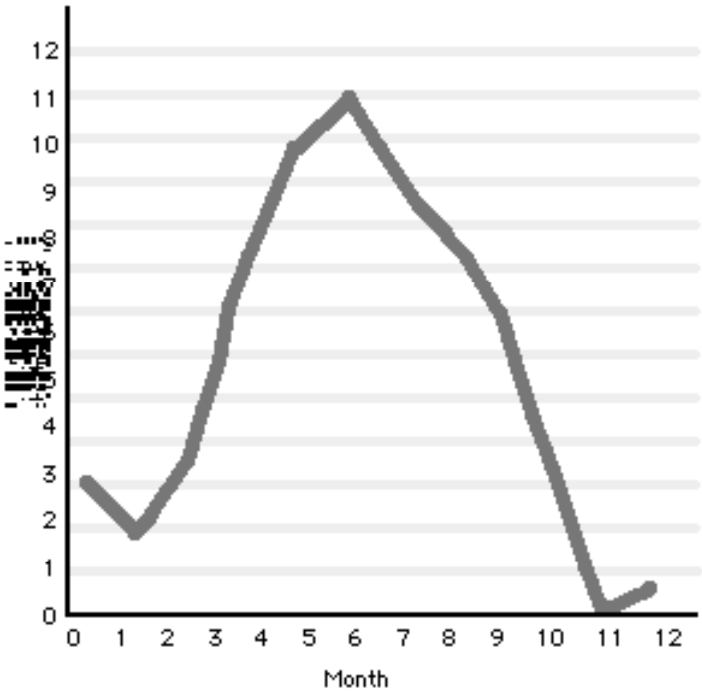

Figure 27.1
The difference of monthly mean (1979-1991) atmospheric total column ozone at same latitude. No. 1: 33.5°N, 131.9°E, No. 2: 33.5°N, 90.6°E (ozone valley).

During June through September each year, an "ozone valley" gradually forms over the Tibetan Plateau and gradually disappears after September.

Using TOMS ozone data, Zhou and colleagues plotted monthly mean total column ozone distributions over China from 1979 to 1991 and found that from June through September each year, an "ozone valley" gradually formed over the Tibetan Plateau and gradually disappeared after September (see Figure 27.1). The ozone value of the lower center is about 11% lower than the ozone value at the same latitude over the East China Sea area, though this difference is only 3% in winter. The mean annual decreasing rate of atmospheric total column ozone is about 0.375% per year according to the 13-year data record. Although the area and intensity of the summer ozone valley over the Tibetan Plateau is much smaller than the ozone hole over Antarctica, it may have stronger effects on the climate and environment of the Tibetan Plateau and East Asia, according to the researchers. Therefore, the study of the mechanisms of this ozone valley formation and its effects on regional climate and ecology are an important issue for further study.

In addition to this ozone valley, it has been found that monthly mean total column ozone over several of China's cities is generally decreasing. The rate of total column ozone decrease in Beijing is 0.43% per year, a bit more than the global average, despite the high levels of tropospheric ozone that result from air pollution. Serious ozone depletion has been noticed over parts of China, about an 18% reduction from pre-depletion values, and falling at a rate of 8.5% per year. It is not clear why this ozone depletion is up to 20 times larger than the global average.

No clear explanations yet exist for why dome areas, such as the Tibetan Plateau, are decreasing more than others. One idea is that due to mountain meteorology, in the summer, the Tibetan plateau is a significant heat source which maintains high pressure. By using an objective analysis derived wind field profile and diagnosing vertical motion it was found that in June, what is normally downward motion transforms to significant upward motion which is maintained until the end of September. This suggests a model for ozone concentrations over the Tibetan Plateau. When lower level air pollutants converge against the Plateau they rise to stratosphere. The large plume in the summer season influencing circulation may be an important factor in the ozone decline. An experiment, called TIPEXO, for Tibetan Plateau Experiment on Ozone, is scheduled to deal with this very interesting phenomenon.

While large parts of China's mainland warmed in the 1980s, there was cooling in the middle and lower reaches of the Changjiang River. The cooling center was located in the Sichuan basin and was characterized by a negative temperature anomaly of 0.3°C.

A second interesting finding has to do with climatic cooling over Sichuan province in the past 40 years. While large parts of China's mainland warmed in the 1980s, there was cooling in the middle and lower reaches of the Changjiang River. The cooling center was located in the Sichuan basin and was characterized by a negative temperature anomaly of 0.3°C (see Figure 27.2 and Table 27.1). This result is consistent with that of Chen et al ., who found that Sichuan province had cooled over the last 100 years. One explanation for this phenomenon is that industrial activities, especially the emission of SO2, contribute substantially to tropospheric aerosols that are effective at scattering solar radiation. In addition to this direct cooling effect, there is an indirect effect that occurs as small soluble aerosols provide additional cloud condensation nuclei, thereby enhancing the shortwave albedo of clouds, causing additional cooling.

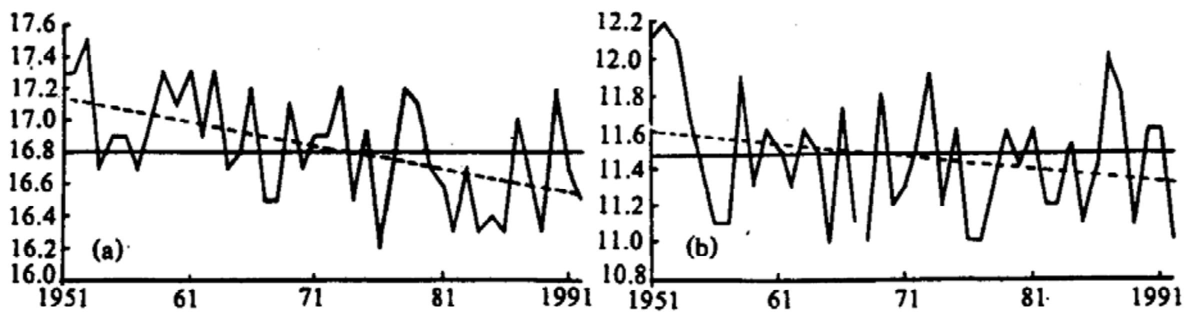

Figure 27.2
The annual mean temperature curves (solid lines) and the best-fitting line trends (dashed lines in Sichuan Province (a) eastern basin area; (b) western plateau area.

The 10-Year Mean Temperature in Sichuan (Unit: C)						
YEAR	EASTERN BASIN AREA			WESTERN PLATEAU AREA		
	Annual mean	Winter mean	Summer mean	Annual mean	Winter mean	Summer mean
1950s	17.1	7.5	26.1	11.6	3.5	18.7
1960s	16.9	7.2	25.9	11.4	3.0	18.4
1970s	16.8	7.1	25.9	11.4	3.2	18.5
1980s	16.6	7.1	25.5	11.4	3.4	18.6
Mean	16.8	7.2	25.8	11.5	3.3	18.6
1980s-mean	-0.2	-0.1	-0.3	-0.1	0.1	0.0
1980s-1950s	-0.5	-0.4	-0.6	-0.2	-0.1	-0.1

Table 27.1
The 10-Year Mean Temperature in Sichuan (°C)

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