Rising Human Population

Rising human population, particularly when coupled with rapid industrial and economic development, is a major cause of global environmental change. One of the most visible types of change caused by human activities is land cover change: the conversion of land cover from one cover type (such as forest or grassland) to another type (such as agriculture or urban). Land cover change typically involves altering or removing the vegetation in the landscape. Such disturbances to the landscape reduce the capacity of a region's ecosystems to contribute to important biosphere processes, including the terrestrial carbon cycle. The most common types of land cover change cause a net loss of vegetation from the landscape and disturb the underlying soil. This can result in a net release of carbon stored in vegetation and soils to the atmosphere, where it contributes to rising atmospheric CO2 concentrations, and potentially, global warming.

An improved understanding of the terrestrial carbon cycle and its role in global climate change requires information on the patterns and rates of land cover change and their effects on ecosystem functioning. Satellite remote sensing and ecosystem modelling work in the Ecosystem Change Research Program of Frontier Research System for Global Change (FRSGC) are designed to help achieve this understanding. Some of this research has focused on land cover change in a rapidly developing region in the southern part of the People's Republic of China (PRC)

Satellite-based studies indicate that land cover change in the PRC is occurring at unprecedented rates. A recent remote sensing analysis by Seta (2000) showed that between 1988 and 1996, urban land areas in the greater Pearl River Delta region in the southern PRC increased by over 300%, while natural and agricultural land declined by approximately 6% and 10%, respectively (Fig. 2). How have these changes affected the terrestrial carbon cycle in the region? To answer this question, we employed satellite remote sensing, ecosystem process modelling, and ecological data to investigate the effects of the land cover change on two components of the carbon cycle: net primary production (NPP) and ecosystem carbon storage (Dye et al., 2002).

The results from our analysis suggest that land cover change in the Pearl River Delta region between 1988 and 1996 affected the regional carbon cycle by reducing both the annual rate of NPP and the size of the terrestrial carbon pool. The dominant mode of land use change was the conversion of natural and agricultural land to urban uses. Urbanization generally involves the removal of vegetation (forests, grassland, or agricultural crops) and replacing it with roads, buildings, and other urban infrastructure. As a consequence of the urbanization, the annual amount of atmospheric carbon assimilated into vegetation through NPP declined by approximately 1.5 Megatons (-7.5%).

This result indicates a reduction in the total photosynthetic capacity and carbon sequestration potential of the region's ecosystems. More than half (55%) of this reduction in NPP is attributable to the loss of agricultural land. The urbanization released about 12 Megatons carbon from the terrestrial carbon storage pool, of which 19% was from soils and 81% from vegetation. This amount of carbon released is about 13% the estimated annual amount of carbon released by fossil fuel combustion in the Pearl River Delta region. Because urbanization is the dominant type of change, there is low potential for the ecosystems to recapture the lost carbon through vegetation regrowth. Thus, land cover change is responsible for a sustained reduction in the size of the terrestrial carbon pool in the Pearl River Delta region.

The future course of the socioeconomic driving forces that influence land cover change in the PRC, in combination with potential climate change, will determine whether these effects on the region's carbon cycle become exacerbated or diminished in the coming decades.

Effects on the temperature

Neither question is easily answered, in more than very general terms. Meteorologists have worked hard to identify the physical consequences of possible CO2 doubling in the next 50 to 100 years, but not much effort has gone into evaluating the long-term consequences of even larger CO2 increases. Among the likely physical effects, one of the more worrisome is the rise in sea level that would likely follow. A warming of 3-10° or more in the mean temperature of the Earth implies a larger change in surface temperature at higher latitudes. This will likely melt some of the polar ice and add to the more certain rise in sea level that will come about because of the natural expansion of the warmed water in the oceans.

The "permanent" Arctic and Antarctic ice caps hold enough water to raise sea level by many tens of meters, were a significant fraction of the ice to melt. And while the thermal inertia of these large masses of ice normally dampens the effects of short-term temperature excursions, were atmospheric CO2 levels to remain substantially elevated year after year for several centuries large increases in sea level would almost certainly ensue. Fully half of the world's people live on or near coastlines, and in some countries--for example, Bangladesh--nearly all the land area lies within a few meters of the present sea level. The political, economic, and humanitarian problems that could be involved in relocating environmental refugees on such a large scale can hardly be imagined.

We talk so often of the consequences of doubling the present levels of atmospheric CO2 that some may think that this defines the ultimate threat. But a quick calculation reveals that if we were to burn all the world's fossil fuel reserves in a short period of time, atmospheric CO2 would rise by about a factor of eight compared to its current value--which is not one, but three, doublings in what is presently there. The air around us would then hold almost ten times more CO2 than was the case in pre-industrial times, when for millennia the concentration held relatively steady at 280 ppm.

Climate model calculations predict that each doubling of atmospheric CO2 should produce an increase of 1.5 to 5° C (about 3 to 9° F) in the mean surface temperature of the Earth, so three of them could drive the temperature 4.5 to 15° C higher than what it is today. For comparison, during the warmest time interval of the past 200 million years--the Mid-Cretaceous Period, when dinosaurs dominated a far different and more tropical Earth--the mean temperature is thought to have been from 6 to 9° C above that of today. Thus, fossil fuels have the potential, in theory, of inducing a change in temperature that rivals anything that has occurred during recent geologic time.

This back-of-the-envelope calculation is obviously unrealistic, for all the coal and oil and natural gas will not be expended that quickly. At today's rates of consumption, burning all that is there would require several hundred years, which will allow natural processes time to dispose of a part of the added CO2. As we shall see, however, Nature's CO2 removal mechanisms are far from fast, and they get slower and slower as more and more CO2 is added to the system. As a result, consuming what remains of fossil fuels could well lead to a 4- to 8-fold increase in CO2.