should reassure humanity that its food supply is not being improved with a wild wastage of fertilizer.

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KINZIG AND SOCOLOW REPLY: The plateau in Paul E. Waggoner's graph of fertilizer demand versus time is almost certainly temporary. The respite from steady growth is the combined result of the deindustrialization of the formerly Communist countries and the reduction of agricultural subsidies in Western Europe. Expansion of modern agriculture in developing countries is likely to cause a resumption of the previous steady growth in nitrogen fertilizer use.

Waggoner notes that when summed over the whole world, the rate of application of nitrogen to land as fertilizer and the rate of removal of nitrogen from land as harvested crops are "reasonably in balance." There is little comfort to be derived from this apparent balance, for two reasons. First, the fertilizer nitrogen supplied to agricultural systems, whether or not it is removed in harvested crops, still represents an addition of fixed nitrogen to the biosphere in excess of natural flows. The nitrogen contained in harvested crops does not remain there, sequestered against any further mobilization. The disposal and decomposition of crop wastes, food wastes, and human and animal wastes causes this fertilizer-derived nitrogen to reappear in terrestrial ecosystems, surface water, groundwater, the atmosphere and the oceans. The amount of nitrogen fixed in fertilizer production each year is small compared with global stocks of nitrogen, but it is the presence of this nitrogen in quickly decomposable or mobilizable forms, and the potential for concentration of this anthropogenically fixed nitrogen in sensitive ecosystems, that is cause for concern.

Second, the apparent global balance between nitrogen applied in fertilizer and nitrogen removed in crops is the coincidental result of summing local or regional imbalances of opposite signs. Average fertilizer use intensities in 1993 varied from only 12 kilograms of nitrogen per hectare of arable land on the African continent to 86 kg(N) per hectare on the Asian continent,[1,2] a sevenfold difference. At the same time, average crop yields in Asia and Africa differed by less than threefold.[2] Thus nitrogen inputs in the form of fertilizer and nitrogen outputs in the form of harvested crops could not have been balanced in both Africa and Asia.

In fact, in fields where nitrogen fertilizer application is low or nonexistent and where crop, human and animal wastes are not being returned to agricultural systems, nitrogen is almost certainly being mined from the native soils.[3] In fields of medium or high fertilizer application, on the other hand, losses of fertilizer nitrogen due to denitrification, volatilization, leaching and runoff can frequently add up to over half of the applied total.[4] This "lost" nitrogen fertilizes the surrounding countryside, with largely unexplored ecological consequences.

The question is not whether or not to use nitrogen fertilizers to feed the world's people; their use is necessary. But use without consideration of the potential negative impacts of anthropogenically fixed nitrogen on the Earth's ecosystems is irresponsible. A major shift of attention toward a more efficient use of fixed nitrogen is overdue.

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Cloud Microphysics from the Ground Up

In his discussion of the problems posed by clouds in modeling climate, Jeffrey Kiehl (November 1994, page 36) complains that ground-based remote sensors are unable to observe microphysical properties of clouds. He was apparently unaware of recent work by scientists at the Environmental Technology Laboratory of the National Oceanic and Atmospheric Administration, in which we have made considerable progress using multi-instrument observations.

One approach combines millimeter-wavelength radar and infrared measurements (either lidar or radiometer) to obtain useful microphysical information on cirrus particles. The infrared signature depends (to first order) on the cross-sectional area of the particles, while radar backscatter depends primarily on the square of their mass, and Doppler radar can measure size-dependent fall speeds. These techniques[1] have provided vertical profiles of the effective radius, ice water content and (with less accuracy) number density of the particles. The microphysics of water clouds also can be addressed by a combination of mm-wavelength radar reflectivity and microwave radiometry.[2] Direct comparisons of these ground-based remote sensing techniques with instrumented aircraft measurements have been very encouraging.[3]

We are pursuing techniques for observing ice particle shapes and orientations, based on polarization measurements by mm-wavelength radar[4] and vertical enhancement of lidar backscatter at vertical.[5]

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