EarthTrends: Featured Topic

Title:	Nutrient Overload: Unbalancing the Global Nitrogen Cycle
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Source:	*World Resources 1998–99*
Date written:	1998

As a basic building block of plant and animal proteins, nitrogen is a nutrient essential to all forms of life. But it is possible to have too much of a good thing. Recent studies have shown that excess nitrogen from human activities such as agriculture, energy production, and transport has begun to overwhelm the natural nitrogen cycle with a range of ill effects—from diminished soil fertility to toxic algal blooms (Vitousek et al. 1997:2; Jordan et al. 1996:665; Asner et al. 1997:232).

Until recently, the supply of nitrogen available to plants—and ultimately to animals—has been quite limited. Although it is the most abundant element in the atmosphere, nitrogen from the air cannot be used by plants until it is chemically transformed, or fixed, into ammonium or nitrate compounds that plants can metabolize. In nature, only certain bacteria and algae (and, to a lesser extent, lightning) have this ability to fix atmospheric nitrogen, and the amount that they make available to plants is comparatively small. Other bacteria break down nitrogen compounds in dead matter and release it to the atmosphere again. As a consequence, nitrogen is a precious commodity—a limiting nutrient—in most undisturbed natural systems.

All that has changed in the past several decades. Driven by a massive increase in the use of fertilizer, the burning of fossil fuels, and a surge in land clearing and deforestation, the amount of nitrogen available for uptake at any given time has more than doubled since the 1940s. In other words, human activities now contribute more to the global supply of fixed nitrogen each year than natural processes do, with human-generated nitrogen totaling about 210 million metric tons per year, while natural processes contribute about 140 million metric tons (Vitousek et al. 1997:5–6). (See Figure 1: Global Sources of Biologically Available (Fixed) Nitrogen.)

This influx of extra nitrogen has caused serious distortions of the natural nutrient cycle, especially where intensive agriculture and high fossil fuel use coincide. In some parts of northern Europe, for example, forests are receiving 10 times the natural levels of nitrogen from airborne deposition (Pearce 1997:10), while coastal rivers in the northeastern United States and northern Europe are receiving as much as 20 times the natural amount from both agricultural and airborne sources (Vitousek et al. 1997:10). Nitrate levels in many Norwegian lakes have doubled in less than a decade (Vitousek et al. 1997:10). Although many of the nitrogen trouble spots tend to be in North America and Europe, the threat of nitrogen overload is global in scope, as both fertilizer use and energy use are growing quickly in the developing world. In fact, global nitrogen deposition may as much as double in the next 25 years as agriculture and energy use continue to intensify (Asner et al. 1997:228).

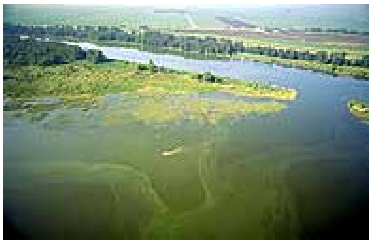
The effects of this surfeit of nutrients reach every environmental domain, threatening air and water quality and disrupting the health of terrestrial and aquatic ecosystems. Natural systems may be able to absorb a limited amount of additional nitrogen by producing more plant mass, just as garden vegetables do when fertilized. Atmospheric deposition of nitrogen emissions on some heavily cut forests in North

A Global Glut of Nitrogen

Figure 1: Global Sources of Biologically Available (Fixed) Nitrogen

ANTHROPOGENIC SOURCES	**ANNUAL RELEASE OF FIXED NITROGEN (TERAGRAMS)**
Fertilizer	80
Legumes and other plants	40
Fossil fuels	20
Biomass burning	40
Wetland draining	10
Land clearing	20
Total from human sources	**210**
NATURAL SOURCES	
Soil bacteria, algae, lightning, etc.	140

Source: Vitousek et al. 1997:4-6.



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America and Europe seems to have spurred additional growth in this manner. But there is a limit to the amount of nitrogen that natural systems can take up; beyond this level, serious harm can ensue. In terrestrial ecosystems, nitrogen saturation can disrupt soil chemistry, leading to loss of other soil nutrients such as calcium, magnesium, and potassium and ultimately to a decline in fertility (Vitousek et al. 1997:7–9).

Excess nitrogen can also wreak havoc with the structure of ecosystems, affecting the number and kind of species found. Researchers in the United Kingdom and the United States have found that applying nitrogen fertilizer to grasslands enables a few nitrogen-responsive grass species to dominate, while others disappear. In one British experiment, this effect led to a fivefold reduction in the number of species in the most heavily fertilized plots (Vitousek et al. 1997:9–10; Wedin et al. 1996:1720–1721). In the Netherlands, where nitrogen deposition rates are among the highest in the world, whole ecosystems have been altered because of this shift in dominant plants, with species-rich heathlands being converted to species-poor forests and grasslands that better accommodate the nitrogen load (Vitousek et al. 1997:9–10).

Although terrestrial ecosystems are vulnerable to the global nitrogen glut, aquatic ecosystems in lakes, rivers, and coastal estuaries have probably suffered the most so far. They are the ultimate receptacles of much of the nutrient overload, which tends to accumulate in runoff or to be delivered directly in the form of raw or treated sewage. (Sewage is very high in nitrogen from protein in the human diet.) In these aquaticsystems, excess nitrogen can often stimulate the growth of algae and other plants. When this extra plant matter dies and decays, it can rob the water of its dissolved oxygen, suffocating many aquatic organisms.

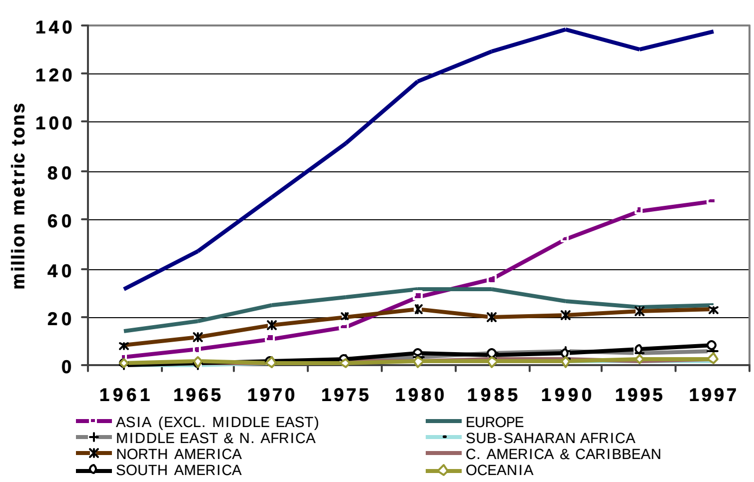
This overfertilization process, called eutrophication, is one of the most serious threats to aquatic environments today, particularly in coastal estuaries and inshore waters where most commercial fish and shellfish species breed (Vitousek et al. 1997:11; Diaz et al. 1995:245). Partially enclosed seas such as the Baltic Sea, the Black Sea, and even the Mediterranean have also been hard hit by nitrogen-caused eutrophication, and an extensive “dead zone” of diminished productivity has developed at the mouth of the Mississippi River in the Gulf of Mexico because of the large influx of nitrogen from agricultural runoff (Warrick 1997:A1). One of the more troubling aspects of this nutrient assault on aquatic systems has been a steady rise in toxic algal blooms, which can take a heavy toll on fish, seabirds, and marine mammals (Anderson 1994:62–68).

The nitrogen glut also impinges on the health of the atmosphere when the nitrogen-containing gases—nitric oxide and nitrous oxide—are released into the air, either from fossil fuel burning, land clearing, or agriculture-related activities. Nitric oxide, for example, is a potent precursor of smog and acid rain, and nitrous oxide is a long-lived greenhouse gas that traps some 200 times more heat than carbon dioxide. Nitrous oxide can also play a role in depleting the stratospheric ozone layer; concentrations in the atmosphere are rising rapidly—about 0.2 to 0.3 percent per year (Socci 1997; Vitousek et al. 1997:6-7).

Curbing the world's nitrogen overload will mean acting on several fronts. Making fertilizer applications more efficient is one of the most promising options. Agriculture accounts for by far the largest amount of human-generated nitrogen—some 86 percent (Jordan et al. 1996:655). Fertilizer use was scant until the

More Fertilizer: More Food, But More Pollution, Too

Figure 2: Trends in Fertilizer Consumption, 1961-1997



Source: Food and Agriculture Organization of the United Nations (FAO)

1950s but since then has increased exponentially. (See Figure 2: Trends in Fertilizer Consumption, 1961–1997)

In fact, one half of all the commercial fertilizer ever produced has been applied since 1984 (Socci 1997). The problem is that about one half of every metric ton of fertilizer applied to fields never even makes it into plant tissue but ends up evaporating or being washed into local watercourses (Vitousek et al. 1997:13). A combination of better timing of fertilizer applications, more exact calculation of doses, and more accurate delivery could cut this waste substantially.

Cutting airborne nitrogen emissions from fossil fuels will also be important and will benefit from many of the same strategies used to reduce carbon dioxide emissions, including a greater emphasis on energy efficiency, a gradual shift toward alternative energy sources, and the use of low-nitrogen technology in power plants and cars. Other strategies make sense as well, such as restoration of wetlands, which are natural nutrient traps that sponge up excess nitrogen before it can damage aquatic systems.

But none of these steps is easy or obvious, and there seems little likelihood of concerted action until the nitrogen threat is elevated to a higher global profile. While the risks of global warming from a buildup of greenhouse gases in the atmosphere are fairly common knowledge today, the dangers of the world's heavy nitrogen habit have gone largely unheralded so far, although this habit may be as pervasive and as hard to address as cutting greenhouse gas emissions.

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