SOLUTIONS TO ENVIRONMENTAL

Experts tell SCIENTIFIC AMERICAN which actions will keep key processes

BIODIVERSITY LOSS

Gretchen C. Daily, *professor of environmental science, Stanford University*

RAIN FOREST, COSTA RICA

It is time to confront the hard truth that traditional approaches to conservation, taken alone, are doomed to fail. Nature reserves are too small, too few, too isolated and too subject to change to support more than a tiny fraction of Earth's biodiversity. The challenge is to make conservation attractive—from economic and cultural perspectives. We cannot go on treating nature like an all-you-can-eat buffet.

We depend on nature for food security, clean water, climate stability, seafood, timber, and other biological and physical services. To maintain these benefits, we need not just remote reserves but places everywhere—more like "ecosystem service stations."

A few pioneers are integrating conservation and human development. The Costa Rican government is paying landowners for ecosystem services from tropical forests, including carbon offsets, hydropower production, biodiversity conservation and scenic beauty. China is investing $100 billion in "ecocompensation," including innovative policy and finance mechanisms that reward conservation and restoration. The country is also creating "ecosystem function conservation areas" that make up 18 percent of its land area. Colombia and South Africa have made dramatic policy changes, too.

Three advances would help the rest of the world scale such models of success. One: new science and tools to value and account for natural capital, in biophysical, economic and other terms. For example, the Natural Capital Project has developed InVEST software that integrates valuation of ecosystem services with trade-offs, which governments and corporations can use in planning land and resource use and infrastructure development. Two: compelling demonstrations of such tools in resource policy. Three: cooperation among governments, development organizations, corporations and communities to help nations build more durable economies while also maintaining critical ecosystem services.

NITROGEN CYCLE

Robert Howarth, *professor of ecology and environmental biology, Cornell University*

Human activity has greatly altered the flow of nitrogen across the globe. The single largest contributor is fertilizer use. But the burning of fossil fuels actually dominates the problem in some regions, such as the northeastern U.S. The solution in that case is to conserve energy and use it more efficiently. Hybrid vehicles are another excellent fix; their nitrogen emissions are significantly less than traditional vehicles because their engines turn off while the vehicle is stopped. (Emissions from conventional vehicles actually rise when the engine is idling.) Nitrogen emissions from U.S. power plants could be greatly reduced, too, if plants that predate the Clean Air Act and its amendments were required to comply; these plants pollute far out of proportion to the amount of electricity they produce.

In agriculture, many farmers could use less fertilizer, and the reductions in crop yields would be small or nonexistent. Runoff from corn fields is particularly avoidable because corn's roots penetrate only the top few inches of soil and assimilate nutrients for only two months of the year. In addition, nitrogen losses can be reduced by 30 percent or more if farmers plant winter cover crops, such as rye or wheat, which can help the soil hold nitrogen. These crops also increase carbon sequestration in soils, mitigating climate change. Better yet is to grow perennial plants such as grasses rather than corn; nitrogen losses are many times lower.

Nitrogen pollution from concentrated animal feeding operations (CAFOs) is a huge problem. As recently as the 1970s, most animals were fed local crops, and the animals' wastes were returned to the fields as fertilizer. Today most U.S. animals are fed crops grown hundreds of miles away, making it "uneconomical" to return the manure. The solution? Require CAFO owners to treat their wastes, just as municipalities must do with human wastes. Further, if we ate less meat, less waste would be generated and less synthetic fertilizer would be needed to grow animal feed. Eating meat from animals that are range-fed on perennial grasses would be ideal.

The explosive growth in the production of ethanol as a biofuel is greatly aggravating nitrogen pollution. Several studies have suggested that if mandated U.S. ethanol targets are met, the amount of nitrogen flowing down the Mississippi River and fueling the Gulf of Mexico dead zone may increase by 30 to 40 percent. The best alternative would be to forgo the production of ethanol from corn. If the country wants to rely on biofuels, it should instead grow grasses and trees and burn these to co-generate heat and electricity; nitrogen pollution and greenhouse gas emissions would be much lower.

DOUG WECHSLER *Animals Animals/Earth Scenes*

THREATS

in bounds

PHOSPHORUS CYCLE

David A. Vaccari, *director of civil, environmental and ocean engineering, Stevens Institute of Technology*

Phosphorus demand is increasing faster than population because of rising living standards. At current rates, the readily accessible reserves will last less than a century. Thus, our two objectives are to conserve phosphorus as a resource as well as reduce its runoff, which damages coastal ecosystems.

The most sustainable flow of phosphorus through the environment would be the natural flux: seven million metric tons per year (Mt/yr). To hit that mark yet satisfy our usage of 22 Mt/yr, we would have to recycle or reuse 72 percent of our phosphorus, and if demand rose further, even more recycling would have to be done.

The flow could be reduced with existing technologies. Conservation agriculture techniques, such as no-till farming and terracing, could reduce the flow entering rivers by 7.2 Mt/yr. Most farm animal phosphorus waste that is not recycled—about 5.5 Mt/yr finds its way to the sea—could essentially be eliminated by transporting it to agricultural areas where it could be used. For human waste, technologies can increase recovery from 50 to about 85 percent, saving 1.05 Mt/yr.

These actions are the "low-hanging fruit," based on what is doable rather than what is needed to avoid dangerous scenarios. Yet they would lower the loss to waterways from 22 to 8.25 Mt/yr, not very much above the natural flux.

CLIMATE CHANGE

Adele C. Morris, *policy director, Climate and Energy Economics Project, Brookings Institution*

Choosing an atmospheric concentration at which to stabilize greenhouse gases, though seemingly a scientific decision, requires weighing the benefits and costs of achieving different targets and determining who will pay. Given how hard that is, we should adopt policies that minimize costs and preserve the consensus for action for many years.

The first step is to not kill consensus in the cradle with short-term ambition, because angry voters will demand defeat of a program they view as excessively costly.

Price-based climate policies can avoid such economic and political thresholds. Domestically, one option is a rising but reasonable economy-wide greenhouse gas tax. Another option is a cap-and-trade system in which emissions permits trade at prices within a preset range that rises over time. A regulated price range would keep the cost of emissions high enough to prompt ambitious reductions but would limit the risk to the economy (and the program itself) if the cap turned out to be inadvertently stringent.

International agreements should also allow price-based commitments as an alternative to strict emissions limits that might prove infeasible. A climate treaty could allow countries to commit to a tax of an agreed level. This flexibility could allay concerns in developing countries that caps could stifle poverty alleviation. Staying within a "safe operating space" will require staying within all the relevant boundaries, including the electorate's willingness to pay.

LAND USE

Eric F. Lambin, *professor of earth systems, Stanford University and University of Louvain*

To control the impact of land use, we should focus on the distribution of cropland globally. Intensive agriculture should be concentrated on land that has the best potential for high-yield crops. But a significant fraction of this prime land is being lost. We risk reaching a point where any increase in food (not to mention biofuel) production would prompt rapid clearing of tropical forests and other ecosystems, as well as cropland expansion onto marginal tracts that have lower yields.

We can avoid losing the best agricultural land by controlling land degradation, freshwater depletion and urban sprawl. This step will require zoning and the adoption of more efficient agricultural practices, especially in developing countries. The need for farmland can be lessened, too, by decreasing waste along the food distribution chain, encouraging slower population growth, ensuring more equitable food distribution worldwide and significantly reducing meat consumption in rich countries.

More land for nature can also be spared by enacting strong set-aside policies, as the European Union has done. A few developing countries (China, Vietnam, Costa Rica) have managed to shift from deforestation to reforestation thanks to better environmental governance, a strong political will to modernize land use, cultural changes and policies that rely on land-use regulations, and incentives to maintain ecosystem services. The challenge for these nations is to continue such policies without having to import more food.

CROPS AND SPRAWL

JEN CHRISTIANSEN (*graphic display*); CORBIS (*aerial landscape*)

OCEAN ACIDIFICATION

Scott C. Doney, *senior scientist, Woods Hole Oceanographic Institution*

The oceans are becoming more acidic because of worldwide carbon dioxide emissions, yet global, regional and local solutions are possible. Globally, we need to stop putting CO_2 into the atmosphere and to perhaps, eventually, reduce the concentration toward preindustrial levels. The main tactics are raising energy efficiency, switching to renewable and nuclear power, protecting forests and exploring carbon sequestration technologies.

Regionally, nutrient runoff to coastal waters not only creates dead zones but also amplifies acidification. The excess nutrients cause more phytoplankton to grow, and as they die the added CO_2 from their decay acidifies the water. We have to be smarter about how we fertilize fields and lawns and treat livestock manure and sewage. Another measure is to lessen acid rain, caused mostly by power plant and industry emissions; the rain does not stop when it reaches the coastline.

Locally, acidic water could be buffered with limestone or chemical bases produced electrochemically from seawater and rocks. More practical may be protecting specific shellfish beds and aquaculture fisheries. Larval mollusks such as clams and oysters appear to be more susceptible to acidification than adults, and recycling old clamshells into the mud may help buffer pH and provide better substrate for larval attachment. Shellfish hatcheries can control water chemistry and switch to more robust species.

The drop in ocean pH is expected to accelerate in coming decades, so marine ecosystems will have to adapt. We can enhance their chances for success by reducing other insults such as water pollution and overfishing, making them better able to withstand some acidification while we transition away from a fossil-fuel energy economy.

FRESHWATER USE

Peter H. Gleick, *president, Pacific Institute*

DRIP IRRIGATION

Few rational observers deny the need for boundaries to freshwater use. More controversial is defining where those limits are or what steps to take to constrain ourselves within them.

Another way to describe these boundaries is the concept of peak water. Three different ideas are useful. "Peak renewable" water limits are the total renewable flows in a watershed. Many of the world's major rivers are already approaching this threshold—when evaporation and consumption surpass natural replenishment from precipitation and other sources. "Peak nonrenewable" limits apply where human use of water far exceeds natural recharge rates, such as in fossil groundwater basins of the Great Plains, Libya, India, northern China and parts of California's Central Valley. In these basins, an increase in extraction is followed by a leveling off and then reduction, as the costs and amount of effort needed to acquire the dwindling resource rise—a concept similar to that of peak oil.

"Peak ecological" water is the idea that for any hydrological system, increasing withdrawals eventually reach the point where any additional economic benefit of taking the water is outweighed by the additional ecological destruction that causes. Although it is difficult to quantify this point accurately, we have clearly passed the point of peak ecological water in many basins around the world where huge damage has occurred, including the Aral Sea, the Everglades, the Sacramento–San Joaquin Valley and many watersheds in China.

The good news is that the potential for savings, without hurting human health or economic productivity, is vast. Improvements in water-use efficiency are possible in every sector. More food can be grown with less water (and less water contamination) by shifting from conventional flood irrigation to drip and precision sprinklers, along with more accurately monitoring and managing soil moisture. Conventional power plants can change from water cooling to dry cooling, and more energy can be generated by sources that use extremely little water, such as photovoltaics and wind. Domestically, millions of people can replace water-inefficient appliances with efficient ones, notably washing machines, toilets and showerheads.

OZONE DEPLETION

David W. Fahey, *physicist, National Oceanic and Atmospheric Administration*

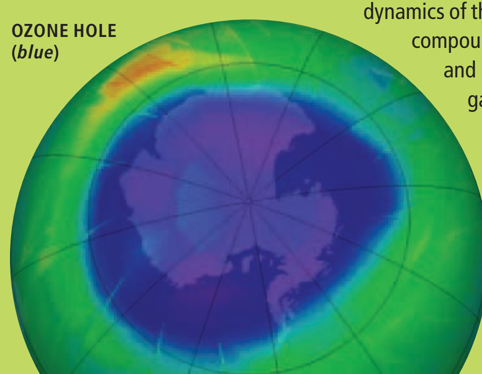
The Montreal Protocol under the Vienna Convention for the Protection of the Ozone Layer has reduced use of ozone-depleting substances—primarily chlorofluorocarbons (CFCs) and halons—by 95 percent over two decades. As of January 1, no more production is to occur in the 195 nations that signed the protocol. As a result, stratospheric ozone depletion will largely reverse by 2100. The gain has relied, in part, on intermediate substitutes, notably hydrochlorofluorocarbons (HCFCs), and the growing use of compounds that cause no depletion, such as hydrofluorocarbons (HFCs).

Ongoing success depends on several steps:

- Continue observing the ozone layer to promptly reveal unexpected changes. Ensure that nations adhere to regulations; for example, the HCFC phaseout will not be complete until 2030.
- Maintain the Scientific Assessment Panel under the protocol. It attributes causes of changes in the ozone layer and evaluates new chemicals for their potential to destroy ozone and contribute to climate change.
- Maintain the Technology and Economic Assessment Panel. It provides information on technologies and substitute compounds that helps nations assess how the demand for applications such as refrigeration, air-conditioning and foam insulation can be met while protecting the ozone layer.

The two panels will also have to evaluate climate change and ozone recovery together. Climate change affects ozone abundance by altering the chemical composition and dynamics of the stratosphere, and compounds such as HCFCs and HFCs are greenhouse gases. For example, the large projected demand for HFCs could significantly contribute to climate change.

OZONE HOLE (*blue*)



BOB ROWAN *Progressive Image/Corbis (drip irrigation)*; COURTESY OF OZONE HOLE WATCH/NASA *(globe)*