INVASIVE, INDEED

One species—*Homo sapiens*—consumes nearly a quarter of Earth's natural productivity

BY SID PERKINS

Some people live lightly on the land: Bedouin clans roam the deserts of the Middle East and North Africa; small groups of indigenous people follow reindeer herds across frigid Arctic terrain; and tribes of hunter-gatherers forage the plains of southern Africa and the forests of Amazonia and Papua New Guinea.

Then there's the other 6.6 billion of us.

When we farm, clear forests, and build cities, dams, and roads, we dramatically alter the landscape. In some places, we increase the land's productivity—measured as the amount of plant life at the base of the food chain—by adding immense amounts of water and fertilizer. New research indicates that on the whole, however, human presence significantly decreases Earth's biological productivity. For instance, many of today's cities occupy large patches of what had been some of the world's most fertile land.

Of the biological productivity that remains, people are gathering an ever-increasing share, sometimes by boosting their quality of life, but often merely by dint of their burgeoning numbers. In some regions, each spanning millions of square kilometers, human activity consumes almost two-thirds of the biological productivity that would otherwise be available.

"We were surprised how intensively these regions were being affected" by human presence, says K. Heinz Erb, an ecologist at Klagenfurt University in Vienna. "Only one-third of the natural productivity is left for all the other species."

Overall, nearly one-quarter of Earth's land-based biological productivity ends up in people's hands and bellies, Erb and his colleagues estimate. Other research suggests that people appropriate a comparable, but slightly smaller, share of the ocean's productivity—defined as the mass of photosynthetic organisms at the base of the sea's food chain.

A projected 25 percent increase in the world's population by 2030 is bound to strain ecosystems even further. Increasing agricultural efficiency by irrigating and fertilizing the land can add to the strain by boosting erosion and the nutrient runoff that creates toxic algal blooms and large anoxic zones in oceans. Adding insult to injury, proposals to transition from fossil fuels to renewable biofuels would place yet more of Earth's productivity in people's hands.

Some scientists now wonder: At what point do the world's ecosystems begin to break down? Or, more frighteningly, has that process already begun?

REAPING, SOWING Before people invented agriculture, they roamed the landscape in search of sustenance. When resources became too scarce to nourish the group, it was time to move on. When people began to farm the land, however, their habits changed considerably, to the detriment of many ecosystems. Settlers built year-round shelters and often cleared acreage for their crops.

"The rise of modern agriculture and forestry has been one of the most transformative events in human history," says Jonathan A. Foley, an environmental scientist at the University of Wisconsin–Madison.

LAND GRAB — About half of the 15.6 billion metric tons of carbon that people remove from Earth's ecosystems each year is harvested in the form of crops.

PHOTODISC

Practices vary somewhat, but typically, people heavily farm the most fertile land, use marginal lands for grazing domestic animals, and plant single-species tree farms in areas where forests once stood. Whatever the use, the production of forest or agricultural goods comes at the expense of natural ecosystems, observes Foley.

Today, croplands and pastures are among the largest ecosystems on the planet. People farm about 12 percent of the land outside of Antarctica and Greenland and use about 23 percent for grazing, says Foley. Together, land devoted to these uses equals the 35 percent of Earth's surface that natural forests occupy, he notes.

To estimate the effect that humans wreak on the world's land-based ecosystems, Erb and his colleagues used agricultural and forestry statistics compiled for 161 nations that account for 97.4 percent of Earth's icefree land. Most of the remaining area is located on small, uninhabited islands, Erb notes. In their computer model, the researchers divided the planet's land surface into grid squares no larger than 10 kilometers per side.

The team estimates that if people weren't around to alter the landscape, the world's natural vegetation would absorb enough carbon dioxide from the atmosphere to lock away about 65.5 billion metric tons of carbon each year. However, in 2000, the year for which the data were compiled, Earth's vegetation locked away only about 59.2 billion metric tons of

carbon, or 9.6 percent less than it should have, says Erb. Of that smaller carbon total, human activities removed about 15.6 billion metric tons—a whopping 23.8 percent—from the world's ecosystems. A little more than half of the carbon that people appropriated was harvested and used as food, forage, and wood, Erb and his colleagues note in the July 31 *Proceedings of the National Academy of Sciences*. Most of the rest was lost to inefficiencies of agriculture, including the inability of crops to store as much carbon as natural vegetation would have stored. A small amount, about 7 percent of the carbon that people take out of the system, went up in smoke produced primarily by slash-and-burn agriculture, says Erb. All of this human-appropriated carbon became unavailable to other species.

Human harvests don't stop at the shoreline, either. The world's most productive fisheries typically lie in and near the shallow waters that fringe the coasts of large islands and continents, says Daniel Pauly, a fisheries biologist at the University of British Columbia in Vancouver. Scientists have divided such coastal waters into 64 large marine ecosystems. These areas can vary in character and inhabitants as much as arctic tundra differs from an Amazonian rain forest.

About 95 percent of the world's fish catch comes from large marine ecosystems, says Pauly. For the past decade or so, that haul has represented about 20 percent of the natural productivity of those regions, as measured by the amount of carbon locked away by organisms at the base of the ocean's food chain.

EFFICIENCY MATTERS While wilderness areas remain relatively unaffected by people, other parts of the world are packed cheek by jowl with cities, farms, and other human imprints.

Southern Asia, a 6.7-million-square-kilometer region that includes India, is one of the most densely populated and heavily irrigated regions on the planet, says Erb. There, human activity co-opts about 63 percent of the area's natural productivity each year, he and his colleagues estimate. In eastern and southeastern Europe, people appropriate about 52 percent of the land's productivity.

At the other extreme, in Australia, central Asia, and Latin America, the percentage of productivity that ends up in human hands ranges between 11 and 16 percent. Increasing the use of fertilizers and irrigation could boost those percentages and help meet the needs of a growing world population. However, long-term irrigation sometimes renders the soil too salty for crops, and fertilizer, if used unsparingly, runs off into rivers and streams and ends up in the ocean, where it overfertilizes algae and thus creates huge zones devoid of other life. "There's no free biomass," Erb cautions.

STATS

35 percent

Portion of Earth's icefree land in crops and pasture

In the stampede to replace fossil fuels, some scientists have proposed the large-scale cultivation of crops that can be transformed into supposedly eco-friendly biofuels. That, too, might be ecologically unwise.

"If the whole world begins to look like Iowa cornfields, we'll have to take an even larger share of global biological production into human hands, and that leaves a lot less for other things," says Foley. "And those other things won't be just pretty butterflies and tigers and charismatic animals, they'll be things that matter to us, like the things that clean our water, preserve our soils, clean our atmosphere, and pollinate our crops."

"At what point does human activity begin to compromise a lot of our environmental systems?" Foley continues. "At what point does this get to be scary?" ■