

Can Earth's plants keep up with us?



“Worldwide, we have some very vulnerable populations that could never survive just on the productivity of the land on which they live.”

Marc Imhoff
NASA

by Stephanie Renfrow

Our lives depend on plants. Plants turn the energy of the sun into our most basic needs: lumber for houses, fuel for cooking, fiber for clothing, feed for livestock, and food for our own growing bodies. But as global population and incomes rise, will plants be able to keep up with the human appetite? And if they cannot, which regions will be short on food and other plant-based resources, and what will that mean for nations as they try to assure food security for their citizens?

Marc Imhoff, a biophysical scientist with NASA, has been exploring these questions with colleagues from the University of Maryland's Earth System Science Interdisciplinary Center, the World Wildlife Fund, and the International Food Policy Research Institute for six years. He said, “Our primary motivation has been to find out where we stand relative to our survival on the planet, and what our needs are compared to the capability of the biosphere to sustain them. In fact, it goes beyond just need; it includes our different lifestyles—our appetites.” To build some answers, Imhoff set about measuring global plant productivity, calculating human consumption levels on a cultural level, and then comparing what he learned. His findings remind us that we all rely on the same finite Earth.

The green supply

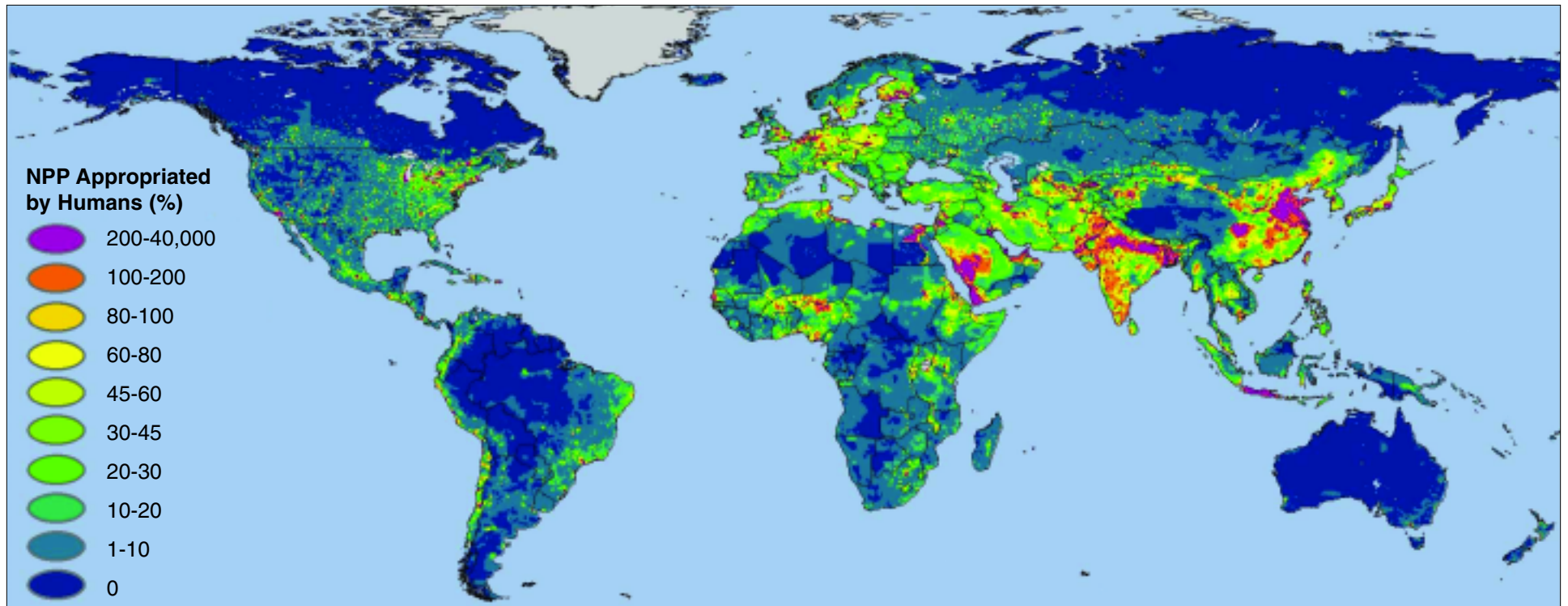
Net primary production is a measure of plant productivity, the amount of plant material left

over after respiration. Imhoff put it this way: “Net primary production is the plant material that we see above ground, as well as what is below ground, like root systems. All of our food, much of our fiber, and—for many people in developing countries—fuel for cooking, is derived from plant material.”

To measure net primary production, Imhoff used Normalized Difference Vegetation Index (NDVI) data, which quantify the presence of healthy vegetation. The data, originally from the Advanced Very High Resolution Radiometer (AVHRR) instrument, were reprocessed under the International Satellite Land-Surface Climatology Project to retrieve NDVI. The data were taken every sixteen days from 1982 to 1998, allowing Imhoff to compute an average maximum NDVI for each month of the year. The monthly NDVI data were input to a biophysical model together



Human beings rely on our planet's net primary production for survival. Plants provide food and fiber, as well as support the animals we use for food and clothing. (Courtesy Gillian Bolsover)



This map shows the net primary production (NPP) supply versus human demand, with demand as a percentage of supply. Red and orange indicate areas where human demand outstrips nature's supply. (Courtesy M. Imhoff, L. Bounoua/GSFC, with collaborators T. Ricketts, C. Loucks, R. Harriss, W. Lawrence)

with temperature, humidity, rainfall, and land-cover type. The model output provided Imhoff and his colleagues with an estimate of the planet's net primary production. Imhoff said, "This information gave us the planetary supply of plant production on land that is available to humans in an average year."

The human appetite

Imhoff's next step was to measure the amount of net primary production that humans use worldwide in an average year, and then tie it to cultural consumption habits. To do that, he turned to statistics from the United Nations Food and Agricultural Organization (FAO) on food and fiber consumption by country,

taking the data from 1995 as a typical year that matched the satellite timeline. He said, "We divided the consumption statistics into food, both plant- and animal-derived; and fiber, including wood, wood-based fuel, and paper. Then, we backed out what you would need to see in the field to get those products," he said. "This way, we could double-check what the AVHRR data would have shown in the field with what the consumption statistics indicated was actually used."

Next, Imhoff requested the Gridded Population of the World (GPW) data set, which provides population numbers and density on a regular latitude-longitude grid,

from the NASA Socioeconomic Data and Applications Center (SEDAC). "We overlaid the consumption data on the population map and ended up with a gridded surface map showing the amount of net primary production required to support the consumption habits of different human populations all over the world." This map gave Imhoff the information he needed to compare production supply with human demand.

Keeping up with demand

When he compared the global supply of net primary production to the human appetite, Imhoff confirmed some ideas that did not surprise him. "Some things were a no-brainer,"

he said. “For example, urban populations with a high density consume way more primary production than local ecosystems can produce.” One sharp example of this was New York City, which consumed 300 times more primary production than it created. “That says a lot about the dependence of urban areas on our transportation networks and agricultural infrastructure,” he said. The ratio of consumption to regional net primary productivity might prove to be a useful indicator of potential trouble spots should natural disasters, economic insecurity, or other problems undermine networks or infrastructure.

Having enough food may seem like a concern only for developing countries, but industrialized countries also have concerns about food security, which is defined simply as always having enough food for an active, healthy life. Developed countries may have dense urban populations, import more food, and be accustomed to high levels of consumption—all of which make these countries susceptible to transitory food supply disruptions. In addition, developed countries may have poor populations that are vulnerable to rising food prices in spite of typical governmental support services. Imhoff said, “Worldwide, we have some very vulnerable populations that could never survive just on the productivity of the land on which they live—with some important implications for national and regional food security.”

Closely tied to the question of having enough food for survival is the idea of having enough fuel, clothing, and building materials for survival. The availability of everything from firewood to winter coats begins with plants. Consumption of material goods is

an important factor in economic stability and security, as well as in maintaining or improving lifestyle levels. The more a population consumes, the more effort it takes to maintain that standard of consumption. Imhoff found that there were two big factors that lead to high consumption levels. The first is high per-capita consumption rates, as seen in much of the developed world; the second is large populations. Even a low per-capita consumption rate can result in a huge overall level of total consumption if multiplied over a large number of people.

To Imhoff, a more surprising finding was the importance of technology in helping balance the equation between supply and consumption. “We found that using improved technology—especially in harvesting and storage techniques—can actually halve the amount of waste in agricultural production,” he said. “Take logging. Without the benefits of improved harvesting technology, you might literally lose a tree for every one that you use.”

The interplay between population, consumption rates, affluence, and technology leads to some thought-provoking realizations. “For example, Asia’s per-capita consumption is on the rise,” he said. “If consumption begins to match Western levels, there will be a significant increase in demand for food and fiber products. If technology improvements do not come with that growth, then you’ll see populations that are outstripping their regional food production capacity. They’ll be more dependent on resources elsewhere, and will have to compete for them.” Although citizens in industrialized countries may not find the rising population in developing nations of immediate concern, poverty has been

connected to terrorism, war, underemployment, border pressures, disease, and political unrest.

“It’s a question of how much we are willing to pay to keep getting the level of production that we want, and to transport it from one place to another,” Imhoff said.

Can we afford it?

Stanley Wood, of the International Food Policy Research Institute (IFPRI), agreed with Imhoff’s emphasis on the question of costs. “The bottom line is food availability and food affordability. How stretched will our incomes be to meet our food requirements?” Wood works with a team from the IFPRI that collaborated with Imhoff on the net primary production research and which has joined with him on a new proposal that builds on the initial work.

Imhoff and the IFPRI team hope to improve their understanding of the flow of net primary production between countries. Wood said, “For example, let’s say that energy security becomes an increasing concern and the U.S. turns to biofuels. The global price of maize could rise steeply because of competition between maize for food and feed, and maize for biofuels. This would create a double-edged sword for poor countries: the increased prices would generate more income for developing country farmers, but would be bad news for poor consumers.”

Widening the global picture is also something that Imhoff hopes to do. “We have begun projecting what would happen to plant production with climate change, and you don’t have to look very far to see that the geopolitics of food production could change significantly, with some countries winning and others losing.

Even without climate change, we are already rubbing up against some limits in our planet's ability to supply us," he said.

Both Wood and Imhoff hope their data set on human use of net primary productivity, which is now available through SEDAC, will be useful to policy and decision makers, both in governmental and nongovernmental agencies. "We hope to have more one-on-one conversations with users in the future," Imhoff said. "With the unprecedented population levels that we have, now, surprises can develop very quickly. We need to be ready."

However, even with a growing global population, increasing consumption levels, and other global changes bearing down on us, Imhoff emphasized the positive. "We have the technology to get out ahead of this. The data isn't just showing us the bad news; it is also giving us the power to study the changes ahead and understand them," he said. "We are far from being helpless. Our ability to assess our environment and our situation should give us a sense of empowerment."

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- World Watch Institute: Global security <http://www.worldwatch.org/taxonomy/term/54/>

For more information

- NASA Socioeconomic Data and Applications Center (SEDAC)
<http://sedac.ciesin.columbia.edu/>
- Human Appropriation of Net Primary Productivity
<http://sedac.ciesin.columbia.edu/es/hanpp.html/>
- International Food Policy Research Institute
<http://www.ifpri.org/>

About the data used

Satellite	Census data	Polar-Orbiting Operational Environmental Satellite (POES)
Sensor		Advanced Very High Resolution Radiometer (AVHRR)
Data sets used	Gridded Population of the World	International Satellite Land-Surface Climatology Project (ISLSCP) II Global Inventory Modelling and Mapping Studies (GIMMS) Monthly Normalized Difference Vegetation Index (NDVI) 1981–2002
Resolution	2.5 minutes latitude/longitude; 1990–2015, every 5 years	1 kilometer; 16 days
Parameter	Human population density	NDVI
Data center	NASA Socioeconomic Data and Applications Center (SEDAC)	NASA Oak Ridge National Laboratory DAAC

About the scientists



Marc Imhoff is a project scientist in the Biospheric Sciences Branch at the NASA Goddard Space Flight Center. He specializes in applying remote sensing to human population and biodiversity issues, particularly urban sprawl and global biological productivity. Imhoff's primary funding for the net primary productivity work is from NASA.



Stanley Wood is a scientist with the Consultative Group on International Agricultural Research at the International Food Policy Research Institute in Washington, D.C. He and his team specialize in using agricultural research to help eradicate poverty and understand human appropriation of ecosystems. Wood's primary source of funding for his collaboration with Imhoff is NASA.