Food Security from Space
Monitoring Indicators of Air Quality on Crop Yields

While its effects are often overlooked, air pollution negatively impacts crops around the world, resulting in significant economic losses, with the greatest economic loss occurring in the United States. Satellites can give farmers, scientists and policy makers important knowledge of how air quality affects food security, enabling more informed decision-making to ensure access to food resources.

Effects of Air Pollution on Plants

Ozone (O$_3$) is the most destructive pollutant to crops. While scientists have been working with farmers for decades to identify and breed ozone-tolerant varieties to maintain high crop productivity, the issue continues to persist, and resulting crop losses are projected to increase in many regions of the world over the next decade.

When elevated concentrations of surface-level ozone are taken up through a plant’s stomata (the tiny pores on the lower surfaces of leaves), it results in a chemical reaction that hurts the plant, resulting in reduced crop yields. Ozone injury to plants is often visible as a fine tan- to dark-colored stippling pattern on the upper surface of leaves that accumulates throughout the growing season. Therefore, the lowest, oldest leaves on ozone-sensitive plants typically show the greatest amount of damage by the end of the growing season. However, the impact of ozone on plants isn’t always obvious to the naked eye. Periods of stagnant air can cause ozone levels to exceed crop injury thresholds and seriously affect the overall health of plants, ultimately reducing their growth and yields. This effect is referred to as “hidden” ozone injury.

While ozone pollution has been shown to have a clear, negative impact on plant health, the impact of pollution from particulate matter (PM), such as dust and smoke, is more complicated. Depending on its concentration, particulate matter in the atmosphere can either reduce or enhance crop yields. For example, particulate matter can diffuse sunlight, creating a more even and efficient distribution of photons that can actually offset a reduction in total sunlight reaching a plant as a result of haze.

Air pollution can also negatively impact the pollinators of crops. About 40 percent of crops rely on insect pollination to some extent. By pollinating many species of crops and flowers, honey bees and other pollinators are integral to the health of ecosystems and the security of food resources. Overall, air pollution has likely contributed to a decline in honey bees, though many other factors may have contributed.

The economic impact of crop yield loss due to air pollution is significant in many world regions

- $11-18$ Billion in global annual crop losses for wheat, corn, and soybeans$^1$
- $3.1$ Billion in crop losses for the United States, the country with the greatest economic loss$^2$
- 8.6 Billion estimated global population by 2030, increasing demand for food resources (UN)$^3$
Global Nitrogen Dioxide

Data from NASA’s Aura satellite show that nitrogen dioxide levels decreased by 40 to 60 percent over U.S. cities between 2005 and 2014 because of emission controls on cars and power plants. (Compare this image to the image on p. 3) Ozone (not shown) decreased by about 14 percent as a consequence.
Geophysical Variables Monitored

<table>
<thead>
<tr>
<th>Product</th>
<th>Satellite Sensors*</th>
<th>Spatial Resolution</th>
<th>Period</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>NO₂ /HCHO</td>
<td>GOME ERS-1</td>
<td>320x40 km²</td>
<td>1995–2003</td>
<td>3 days</td>
</tr>
<tr>
<td>NO₂ /HCHO</td>
<td>SCIAMACHY ENVISAT</td>
<td>60x30 km²</td>
<td>2002–2012</td>
<td>6 days</td>
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<td>NH₃</td>
<td>AIRS Aqua</td>
<td>13.5x13.5 km²</td>
<td>2002–present</td>
<td>2 days</td>
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<tr>
<td>NH₃</td>
<td>TES Aura</td>
<td>5.3x8.5 km²</td>
<td>2004–2011</td>
<td>N/A</td>
</tr>
<tr>
<td>NO₂ /HCHO</td>
<td>OMI Aura</td>
<td>24x13 km²</td>
<td>2004–present</td>
<td>2 days</td>
</tr>
<tr>
<td>NO₂ /HCHO</td>
<td>GOME-2 MetOp</td>
<td>80x40 km²</td>
<td>2006–present</td>
<td>1 day</td>
</tr>
<tr>
<td>NH₃</td>
<td>IASI MetOp-A</td>
<td>12x12 km²</td>
<td>2007–present</td>
<td>1 day</td>
</tr>
<tr>
<td>NH₃</td>
<td>IASI MetOp-B</td>
<td>12x12 km²</td>
<td>2013–present</td>
<td>1 day</td>
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<tr>
<td>NH₃</td>
<td>CrIS Suomi NPP</td>
<td>14x14 km²</td>
<td>2014–present</td>
<td>1 day</td>
</tr>
<tr>
<td>NO₂ /HCHO</td>
<td>TROPOMI Sentinel-5 Precursor</td>
<td>7x7 km²</td>
<td>2017–present</td>
<td>1 day</td>
</tr>
<tr>
<td>NO₂ /HCHO</td>
<td>TEMPO**</td>
<td>2.1x4.7 km²</td>
<td>launch early 2020s</td>
<td>1 day (N. America)</td>
</tr>
</tbody>
</table>

* Satellites operated by NASA and other U.S. and international agencies  ** Geostationary orbit

Data Sources and Training

The information presented here focuses on NASA resources and datasets distributed through the Goddard Earth Science Data and Information Services Center. See airquality.gsfc.nasa.gov for further reading.

Webinar: arset.gsfc.nasa.gov/airquality/webinars/introduction-satellite-remote-sensing-air-quality-applications

References


Aura data show that nitrogen dioxide levels decreased from 2005 to 2014 in much of Europe and Japan, but increased in South Asia with increased energy usage as these country economies have grown.
NASA Food Security Program

We live in a hungry world. A rapidly growing world population, its socioeconomic development, and finite natural resources in the midst of more frequent extreme weather and a changing climate, all increase our vulnerability to any disruption in the food system. Maintaining situational awareness about food production requires the global view of Earth as a system that only a fleet of satellites can provide.

These researchers draw on the ingenuity of NASA with its unique technological and scientific capabilities in synergy with the NASA Harvest Consortium.

The Harvest Consortium is a NASA-funded collection of partners with domestic and international activities that are enhancing the use of satellite data in agricultural decision-making. Harvest places a strong emphasis on transitioning research to operations.

The NASA Food Security Program also:

- Fosters the assimilation of satellite and airborne remote sensing data into Earth systems models and other tools designed to address global food security challenges.
- Explores the research needs, sources of uncertainty and technical barriers that limit the operational use of Earth observations in decisions.
- Works with NASA’s Earth Science Technology Office to advance state-of-the-art technology to public and private agencies focused on global food security challenges.
- Works with current and future NASA missions before and during their formulation to ensure that food security science and applications are incorporated into new satellite missions.
- Represents NASA on government initiatives, assisting interagency programs in the use of NASA resources.

Further Reading

NASA Food Security Program: science.gsfc.nasa.gov/610/applied-sciences/food.html

NASA Harvest: nasaharvest.org