National Aeronautics and
Space Administration

Food Security from Space

Impact of Air Pollution on Crop Yields

One issue that is often overlooked is the negative effects of air pollution on crops. The economic impact of crop yield loss due to pollution is significant all over the world. Global crop yield losses for wheat, corn, and soybeans are estimated to range from \$11-18 billion annually, with the greatest economic loss estimated to occur in the United States. Scientists can use satellites to gain important knowledge of how air quality affects food security and make decisions to ensure access to food resources.

Effects of Air Pollution on Plants

Most economic crop losses continue to occur from one major air pollutant, ozone (O_3), even though scientists within universities and numerous major agricultural crop industries continue to identify, select, and then propagate ozone tolerant varieties for maintaining highest crop productivity at the farm level. These losses are projected to increase for many world regions over the next decade.

Characteristic ozone–induced injury on the topside of green bean plant leaves. The stippling, which does not occur on veins, is associated with dark pigments accumulating within injured cells. Ozone injury symptoms often vary with different crops.

Surface-level O_3, at elevated concentrations above injury thresholds, reduces crop yields following uptake through plant's stomata (i.e., tiny pores on the lower leaf surface) and chemical reaction with plant cells. O_3 injury to plants is evident often as a fine tan to dark colored stippling pattern on the upper leaf surface that accumulates throughout the growing season. Therefore, the greatest injury is often observed following season-long exposures to the lower, oldest leaves on O_3-sensitive plants. However, the impact of O_3 on plants is not always obvious to the naked eye. When O_3 air pollution exceeds injury thresholds during air stagnations, the pollutant can seriously affect overall plant health, ultimately reducing growth and yields.This effect is referred to as "hidden" O_3 injury.

As shown in an early field study in the 1970s, ozone-sensitive varieties of potatoes (left rows) show reduced growth and lower yields than ozone-tolerant varieties (right rows).

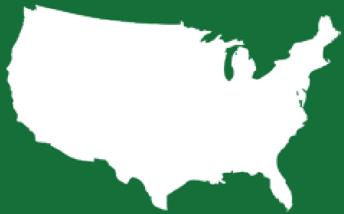
While the impact of O_3 pollution has been shown to have a clear, negative impact on plant health, the impact of particulate matter (PM) pollution, such as dust and smoke, is more complicated. Depending on concentration, PM in the atmosphere can either reduce or enhance crop yields by scattering light. For instance, PM can diffuse sunlight, creating a more even and efficient distribution of photons, which can offset the haze-induced reduction in total sunlight reaching the plant.

Air pollution can also have negative effects on crops by impacting pollinators. About 40 percent of crops rely on insect pollination to some extent. By pollinating many crop and flower species, honey bees and other pollinators are integral to ecosystem health and food resource security. Overall, air pollution likely has contributed to the decline in honey bees, but there are many other factors that 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 yield losses for wheat, corn, and soybeans



\$3.1 Billion

in crop yield losses for the United States, the country with the greatest economic loss

8.6 Billion

estimated global population by 2030, increasing demand for food resources (UN)

Satellite Observations Track Air Pollution

Nitrogen dioxide (NO_2) data from the Dutch-Finnish Ozone Monitoring Instrument (OMI) on NASA's Aura satellite have given us an unprecedented look at how NO_2 has varied around the world, including agricultural regions, since 2005.

Tracking Ozone from Space

Ozone is not directly emitted to the atmosphere from human activities. Instead, it is formed within the atmosphere through a series of complex chemical reactions involving volatile organic compounds (VOCs) and nitrogen oxides ($NO_x = NO + NO_2$). Satellite observations of these ingredients provide valuable information on O_3 levels since it is not currently feasible to infer surface O_3 from satellite data. Both of these compounds occur naturally in the atmosphere, but human activities, such as the burning of fossil fuels, elevate their concentrations, allowing unhealthy levels of surface O_3 to form.

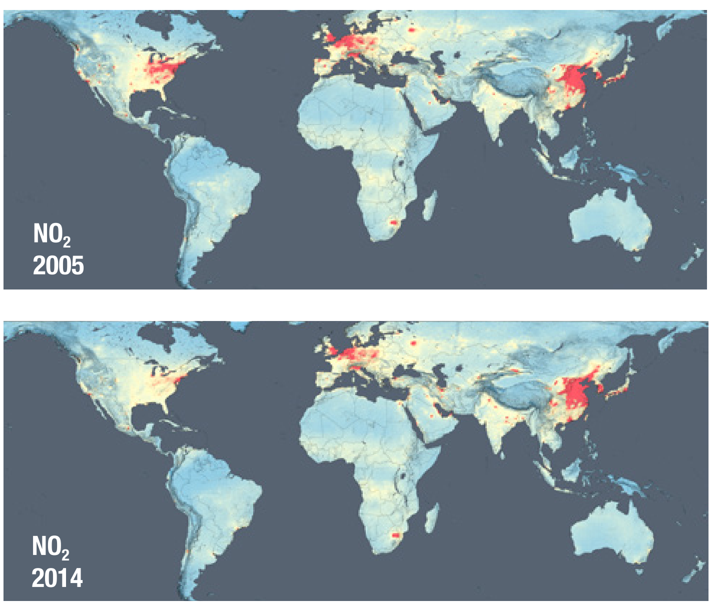
Nitrogen dioxide (NO_2) serves as a proxy for NO_x and is observable from space. It is possible to estimate surface O_3 pollution using NO_2 data from satellites as input to computer simulations of atmospheric chemistry and transport. These simulations give valuable information on O_3 levels in agricultural areas and how these levels are evolving over time.

Given its relatively long lifetime in the atmosphere, O_3 may be transported by winds far from the original NO_x sources downwind to agricultural regions, exposing crops to elevated levels of O_3. While thermal power plants and automobiles are the dominant NO_x sources in most areas, the application of nitrogen-based fertilizers may also be an important source of NO_x to the atmosphere in agricultural regions. If the atmospheric conditions are conducive, high levels of surface O_3 may form, exposing crops and potentially reducing overall yields of O_3-sensitive species.

Formaldehyde (HCHO), a VOC, is observable from space. It an effective proxy for many VOCs as HCHO is produced when they are oxidized (i.e., broken down) in the atmosphere via chemical reactions. However, abundant natural sources of VOCs (e.g., plants) typically make controlling anthropogenic NO_x emissions the only viable way, especially in agricultural areas, to reduce the formation of high levels of surface O_3. That is, observations of NO_2 are typically more important than HCHO for estimating O_3 with computer simulations.

Observations of atmospheric **ammonia** (NH_3) from satellite instruments give complementary information to NO_2 data by indicating when and where fertilizer is applied. However, the various NH_3 datasets from satellite instruments are still in development and, as such, are considered to be research products.

Global Nitrogen Dioxide



Data of NO_2 from NASA's Aura satellite show that NO_2 levels decreased by 40-60% over U.S. cities between 2005 and 2014. Ozone decreased by about 14% as a consequence.

Upcoming Satellite Observations

Several new satellite instruments promise to provide even better NO_2 data. For instance, the European Space Agency's TROPOspheric Monitoring Instrument (TROPOMI; launched in 2017) collects data on NO_2 at sub-urban spatial resolutions (e.g., a few kilometers), a much finer resolution than OMI. Additionally, a fleet of satellites in geosynchronous orbit over East Asia, North America, and Europe will provide much needed information on how air pollutant concentrations and emissions vary throughout the day; launches are expected in the early 2020s. (A satellite in geosynchronous orbit will appear to remain in a fixed location in the sky relative to an observer on the ground. OMI and TROPOMI are on polar-orbiting satellites, which provide only one overpass over a given location on Earth's surface around 2 pm each day.)

Stakeholders

OMI and TROPOMI data products are freely available for those seeking to understand the impacts of ozone air pollution on crops. The Environmental Protection Agency (EPA) and state air quality agencies use OMI NO_2 measurements. While the ammonia products are relatively new, they may prove useful for food security issues.

Further Reading

The sources of information presented in this factsheet may be found at airquality.gsfc.nasa.gov. Information of how satellite data are used for various food security issues, visit science.gsfc.nasa.gov/610/applied-sciences/nasa_food_security_initiative.html. Visit arset.gsfc.nasa.gov for information on accessing and visualizing NASA satellite data.