National Aeronautics and Space Administration

Food Security from Space

Monitoring Indicators of Water Quality for Agriculture and Aquaculture

Access to clean water is essential to human health and plays a critical role in food safety and security. From space, satellites observe water supplies to detect and monitor harmful algal blooms and dissolved and suspended matter. These contaminants have implications across the food web.

Water Quality Affects Seafood and Aquaculture

As Earth's population grows, our waterways face increasing pressures. Pollutants such as agricultural fertilizers and livestock waste make their way into our streams, rivers and lakes, with detrimental impacts on water quality.

PHOTO: NOAA

NOAA established the National Shellfish Initiative in partnership with shellfish farmers and restoration organizations to increase populations of bivalves in coastal waters.

Runoff of sediments impacts water clarity and starves submerged aquatic vegetation of adequate light, adversely impacting the habitat of crabs and other bottom dwellers. Runoff of nitrogen and phosphorous from farms contributes to an imbalance of nutrients that can fuel the growth of algal blooms that are larger than aquatic life forms that consume algae can eat. When these large blooms decompose, they leave behind areas of water with low oxygen content, popularly referred to as 'dead zones,' that kill almost all fish and marine life there. As runoff has increased, so too have the number of such dead zones. In fact, by 2017 a dead zone in the Gulf of Mexico had expanded to the size of New Jersey.

In addition to localized runoff, large-scale climate changes also adversely impact aquatic ecosystems. For example, shellfish face a dual threat. Not only are they harmed by more frequent algal blooms, but excess atmospheric carbon dioxide is being absorbed into their waters, changing its pH and leading to acidification. Some species are able to adapt to warming and changing chemistry; others shift their habitats poleward. Those who cannot adapt or move, perish.

Water Quality Affects Livestock

While runoff from animal mortality and byproducts adversely impacts the quality of waters downstream, water quality, in turn, impacts the health of livestock.

Livestock are less sensitive to poor water quality than humans, but can nevertheless be adversely affected by contaminants. Poor water quality degrades livestock growth, lactation and reproduction, resulting in economic losses to farmers. Higher-quality water sources result in larger, healthier livestock, with decreased incidences of disease.

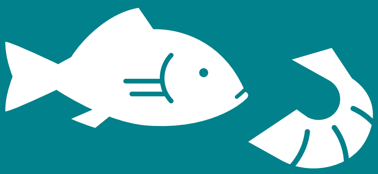
PHOTO: SHUTTERSTOCK

Water quality impacts livestock health, growth, lactation, and reproduction.

$4.6 billion

estimated U.S. annual economic losses from declining quality of freshwater systems[1]

According to the U.S. EPA, the fishing and shellfish industries lose tens of millions of dollars each year due to harmful algal blooms[2]



Excess nutrient runoff necessitates installation of expensive nitrate removal systems at water treatment facilities, raising costs 80-fold[3]

Water Quality Affects Crops

The quality of water in catchments and reservoirs is important for healthy crops. Surface water supplies stored for agricultural use can be compromised by the runoff of sediments, excess nutrients, pesticides, salts and by other sources of urban pollution. Consumption of fresh vegetables that have been irrigated with water containing harmful algal blooms can also cause illness and mortality in humans. The contamination of water bodies due to excess nutrients has socioeconomic implications for a number of sectors, including agriculture. In the United States alone, declining freshwater quality has been estimated to cause economic losses of $4.6 billion annually[1].

Satellite Observations of Water Quality

For the past 20 years, NASA ocean color spectrometers have continuously monitored aquatic ecosystems from space. These instruments provide users with a daily view of the open ocean, where direct sampling opportunities are rare and expensive. The sensors work by measuring visible to near-infrared light reflected from the ocean's surface. From these data, users can derive information on water clarity, turbidity, sediments and detritus, chlorophyll-a and other pigments that indicate phytoplankton biomass and community composition, shallow submerged and floating aquatic vegetation, surface oil slicks, and other variables that can be estimated or inferred by making regional correlations between field measurements and remotely sensed proxies (e.g. harmful algal blooms). Invisible indicators of water quality that are not directly sensed but can be derived using models include nutrients, dissolved oxygen, dead zones, acidity or pH, microbes and pollutants.

IMAGE: NORMAN KURING / NASA

Landsat 8 true-color scene of Bohai Bay, China, acquired September 24, 2018. The land and water in this region are cultivated for agriculture, aquaculture, fishing and other purposes.

Water Clarity in the Chesapeake Bay

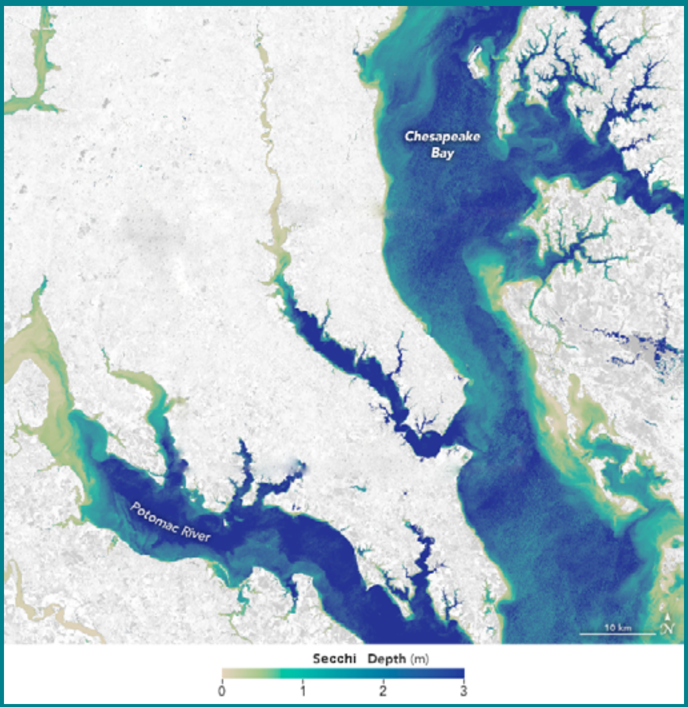


IMAGE: LACHLAN MCKINNA & NASA EARTH OBSERVATORY

IMAGE: USGS / NASA LANDSAT

Secchi depth of the upper Chesapeake Bay and several tributaries derived from the Landsat OLI (right), and the same April 13, 2016, Landsat scene in true color (left).

Geophysical Variables Monitored

Product	Satellite Sensors*	Spatial Resolution	Period	Frequency
Water clarity, chlorophyll-a, suspended sediments	SeaWiFS	4km globally; 1km where ground stations or recorder captured the data	1997–2010	2 days
Water clarity, chlorophyll-a, suspended sediments, plus sea-surface temperature (SST)	MODIS-Aqua	1 km	2002–present	2 days
Water clarity, suspended sediments, chlorophyll-a, cyanobacteria	MERIS	300m	2002–2012	3 days
Water clarity, chlorophyll-a, suspended sediments, plus sea-surface temperature (SST)	VIIRS-Suomi-NPP	750m	2012–present	1 day
Turbidity, suspended sediments, chlorophyll-a	OLI-Landsat 8	30m	2013–present	16 days
Turbidity, TSS, chlorophyll-a, cyanobacteria	MSI – Sentinel-2A/B	10/20/60m	2015–present	5 days
Turbidity, TSS, Chl, HAB indicators	OLCI – Sentinel-3A/B	300m	2016–present	2 days
Water clarity, chlorophyll-a, suspended sediments, plus sea-surface temperature (SST)	VIIRS-NOAA-20 (JPSS1)	750m	2018–present	1 day

* *Products available at* science.gsfc.nasa.gov/610/applied-sciences/food.html

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

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.

Webinar: Introduction to Harmful Algal Blooms: arset.gsfc.nasa.gov/water/webinars/HABs17

Webinar: Processing Satellite Imagery for Monitoring Water Quality: arset.gsfc.nasa.gov/water/webinars/wq-image-processing

Webinar: Integrating Remote Sensing into a Water Quality Monitoring Program: arset.gsfc.nasa.gov/water/webinars/water-quality-2019

References

[1] Dodds, W. et al. (2009). Eutrophication of U.S. freshwaters: analysis of potential economic damages. Environ. Sci.Technol. 43: 12–19.

[2, 3] EPA, www.epa.gov/nutrientpollution/effects-economy

IMAGE: NASA EARTH OBSERVATORY

Blooms of cyanobacteria—called "blue-green algae"— were detected across 90 percent of Florida's Lake Okeechobee during July 2018, from Landsat 8 OLI.

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.

IMAGE: NASA EARTH OBSERVATORY

Agribusiness in the Colorado River floodplain where the Mohave nation meets Arizona, Nevada, and California: commodity crops alfalfa, corn, and soybeans are grown in rectangular and round fields.

To help address these urgent challenges, NASA partners with operational agencies such as the U.S. Department of Agriculture (USDA), the U.S. Agency for International Development (USAID) and the National Oceanic and Atmospheric Administration (NOAA), along with international organizations and private industry, and sponsors Harvest, a Food Security and Agriculture Consortium led by the University of Maryland to advance the use of remotely-sensed data for more informed decision-making.

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.

We also have a team of NASA scientists with expertise in food and water systems, working with universities, governmental and non-governmental organizations to support the food security and agriculture communities in a more agile and futuristic way.

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

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.

PHOTO: SIMON SKAFAR/ISTOCK

A new generation of farmers uses aerial and satellite remote sensing imagery to help efficiently manage croplands. Farmers monitor a range of variables that affect their crops—such as soil moisture, surface temperature, photosynthetic activity, and more.

Further Reading

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

NASA Harvest: nasaharvest.org

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