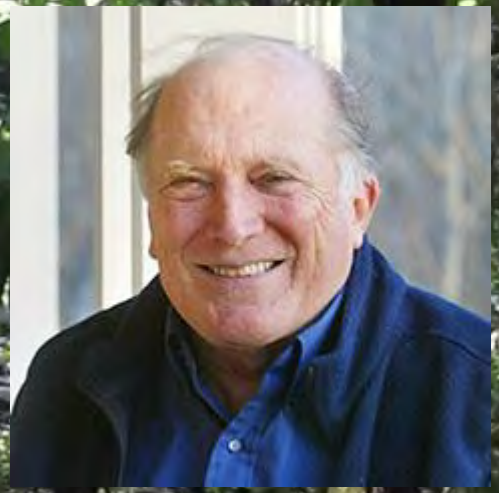
Seeing the Forest for the Streams:

Managing the impacts of land use and climate change on local watersheds

Marcia N. Macedo

July 18, 2021

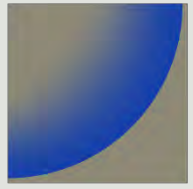
Quissett Harbor, Falmouth, MA



Woodwell Climate Research Center

IPAM Amazônia

Woodwell Arctic

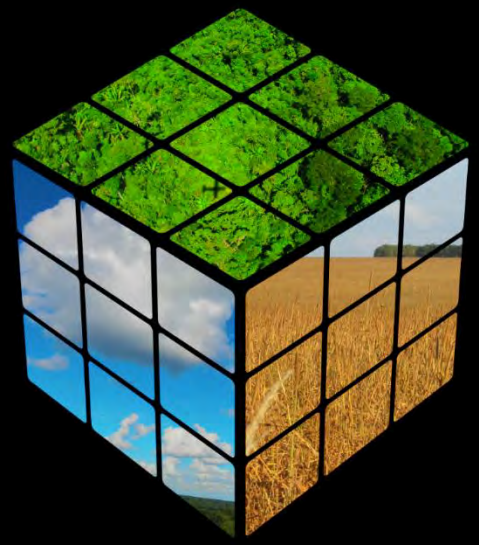


Woodwell Carbon

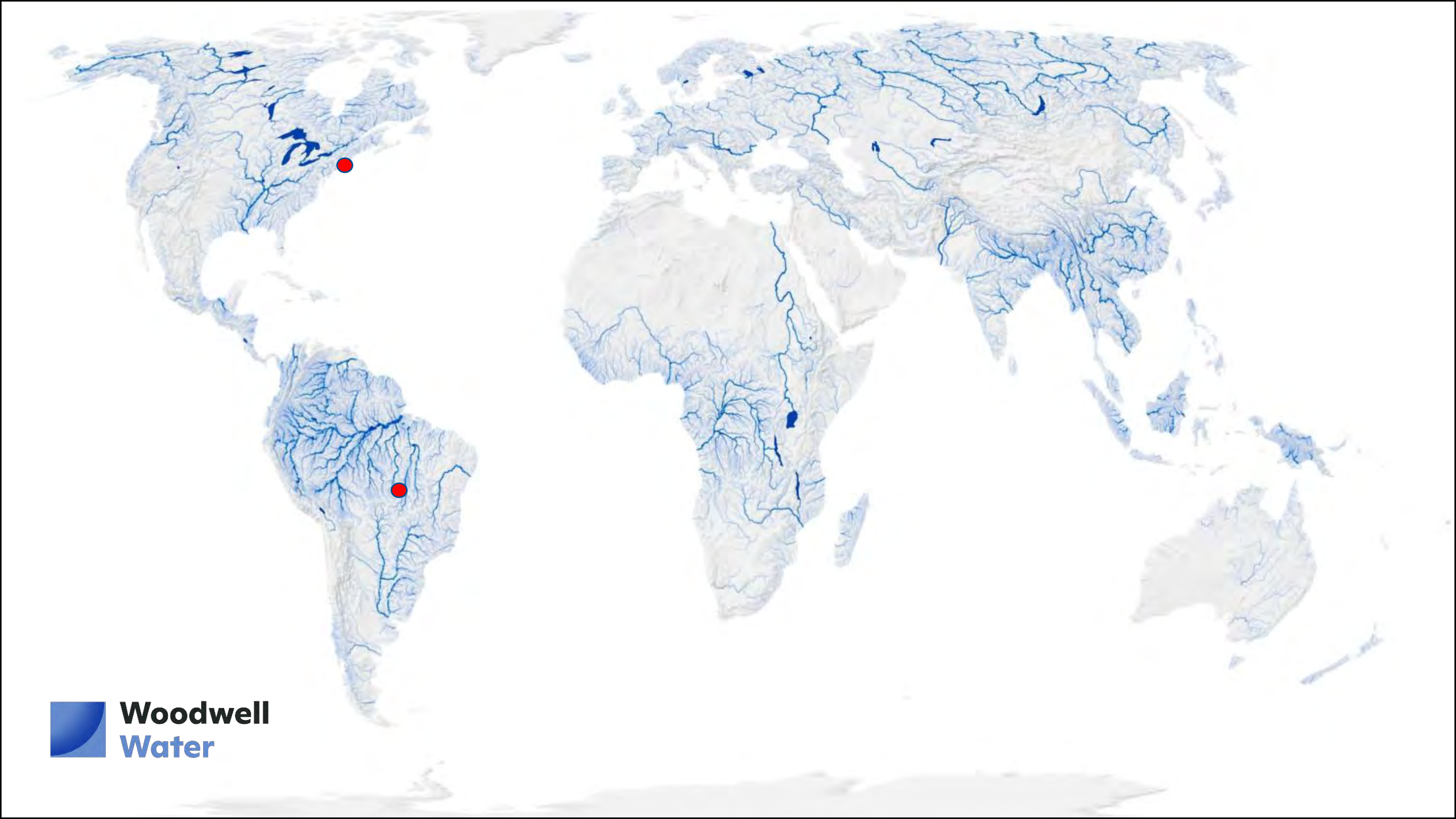
Woodwell Risk

Woodwell Tropics

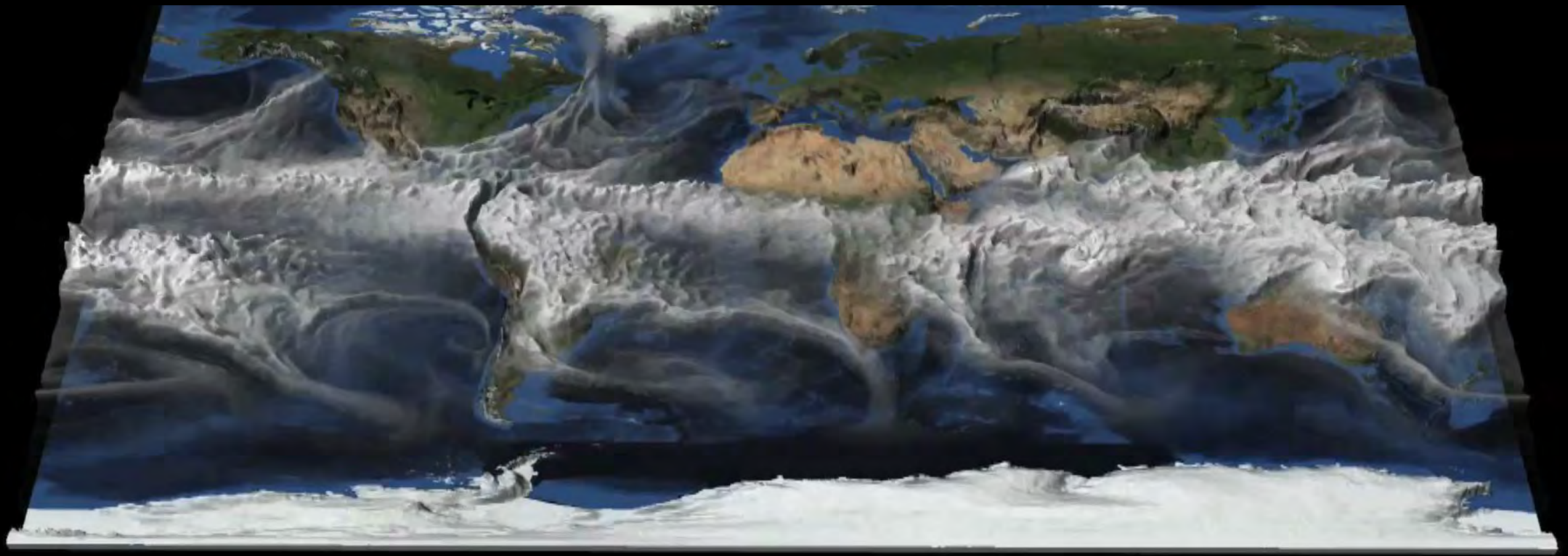
Woodwell Water



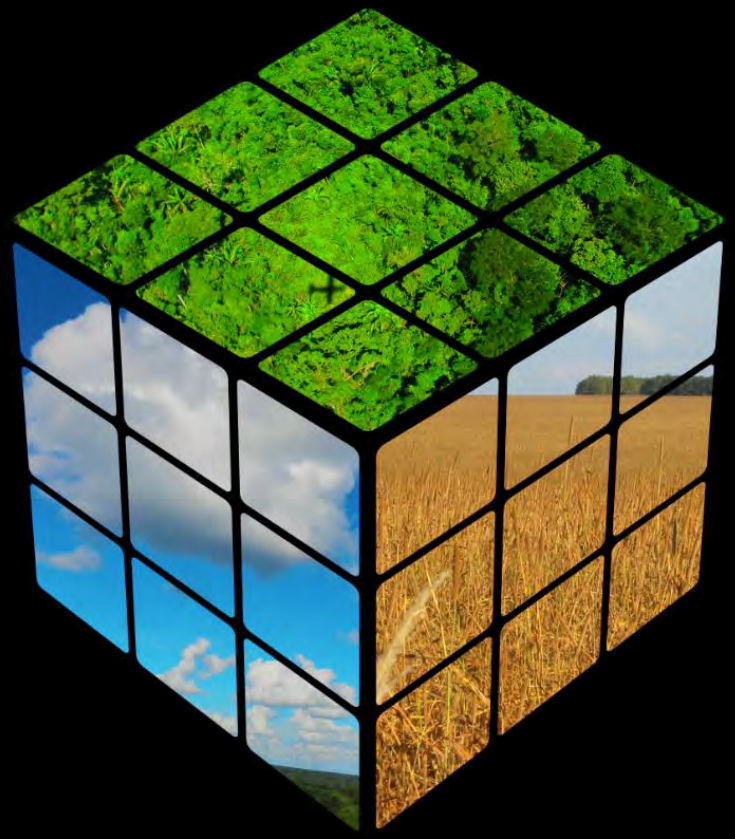
I spend my days trying to figure out how to use land efficiently to conserve natural ecosystems, feed people, and avoid climate collapse.



Woodwell
Water



Woodwell
Water



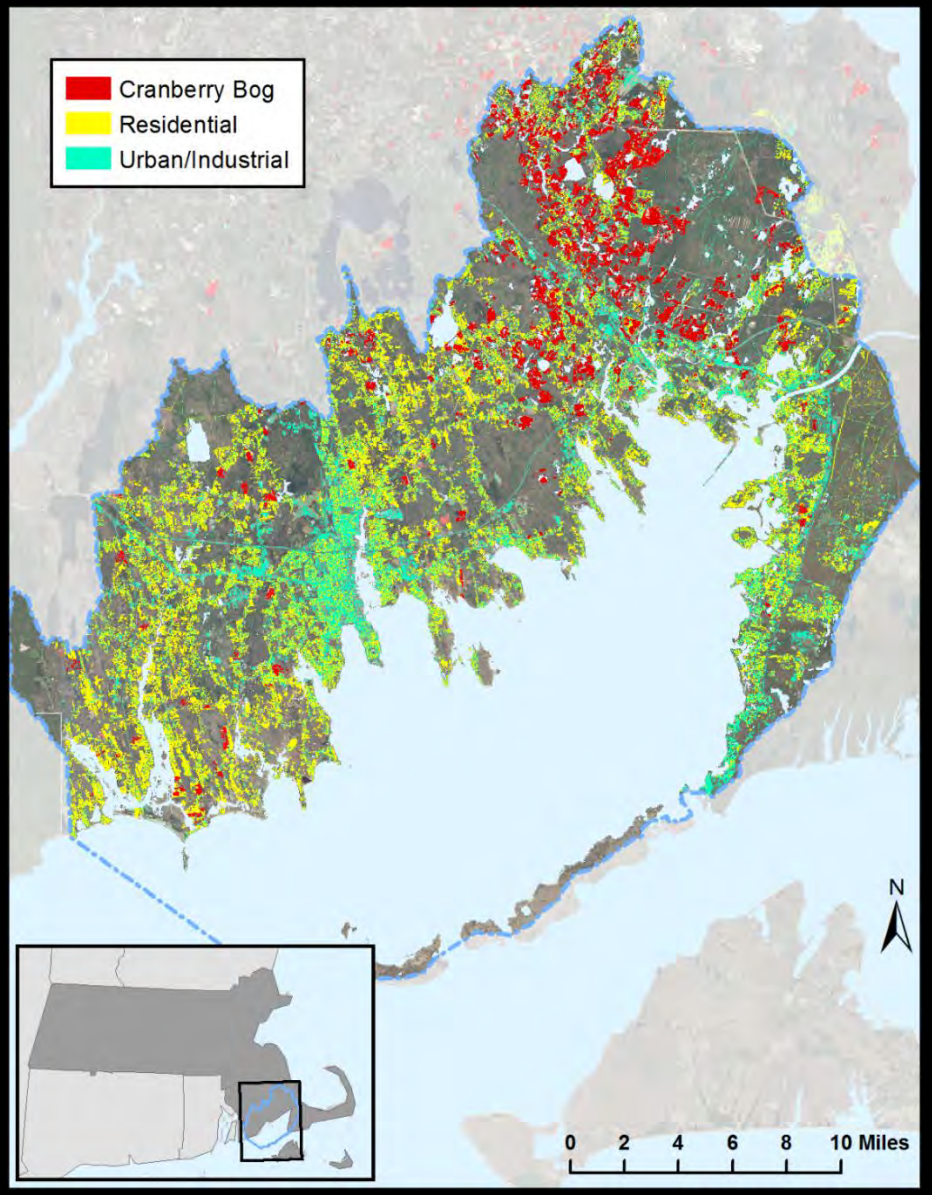
grant us the serenity
to accept the things
we cannot change,
the courage to change
the things we can,
and the wisdom to
know the difference.

- niebuhr

Buzzards Bay
MA, USA

buzzards BAY COALITION

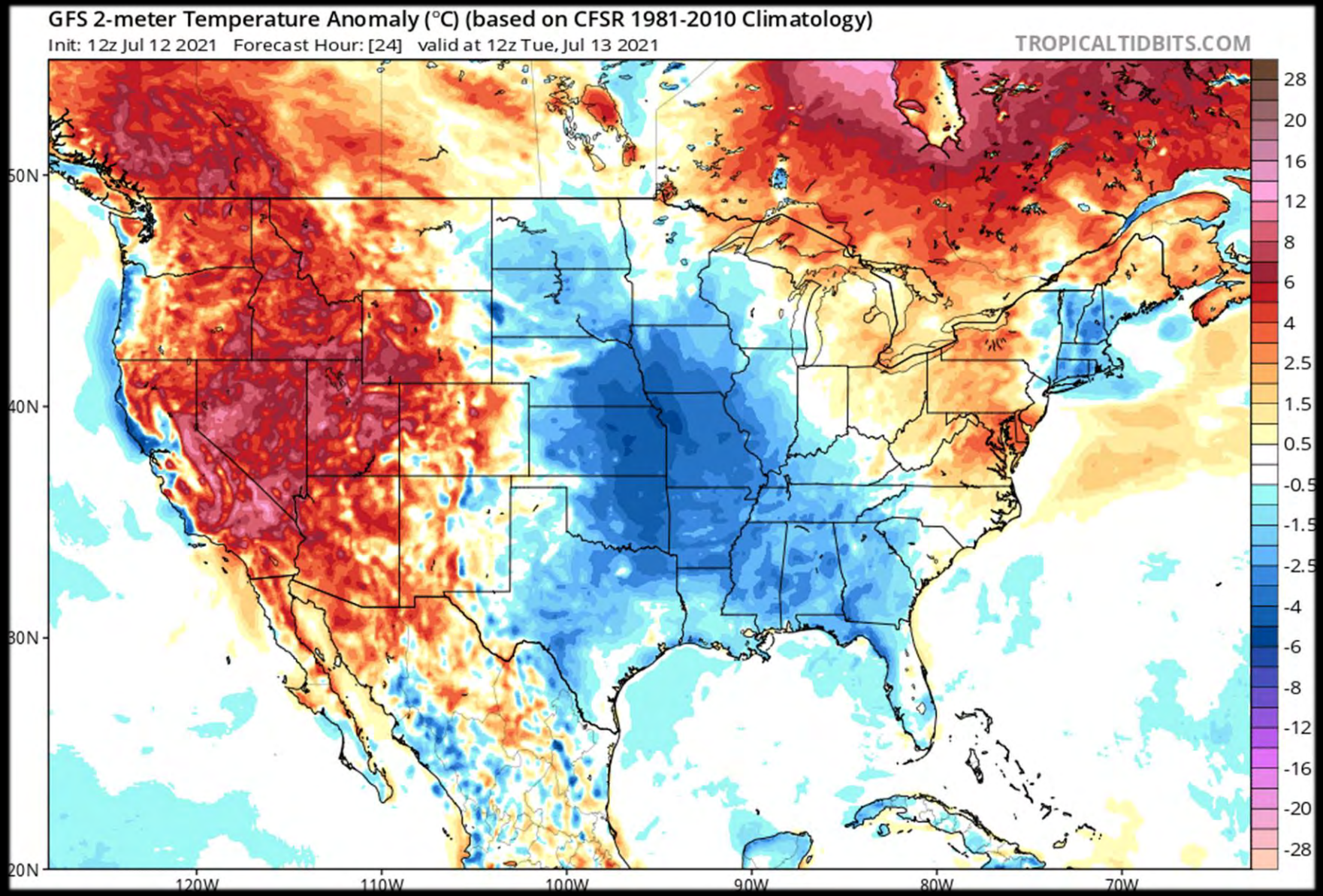
The landscape reflects past land uses and current management.



Buzzards Bay by the numbers:

- 590 km^2 estuary
- 1120 km^2 watershed
- 563 km coastline
- 17 municipalities
- 250,000 people
- 11 m mean depth

Regional climate is expected to get wetter, with more extreme events.



Signs of bad water quality are everywhere.

Algae washing up,
West Falmouth Harbor

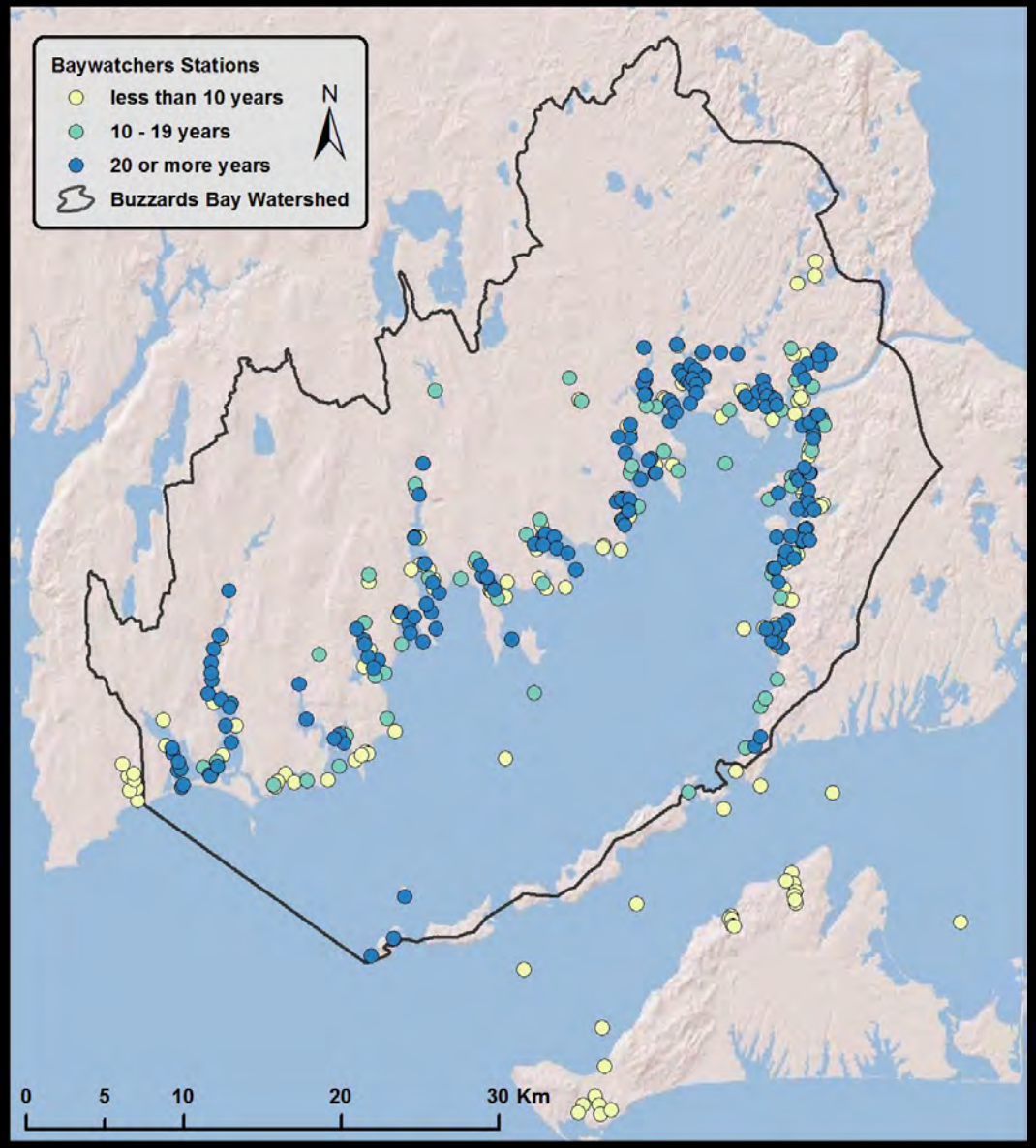
Rusty tide bloom,
Wareham River

Rusty tide bloom,
Apponagansett Bay

Fish kill,
Acushnet River

Photos: BBC

The Baywatchers Program has monitored Buzzards Bay since 1992.



SCIENTIFIC DATA

Check for updates

OPEN

DATA DESCRIPTOR

Water quality measurements in Buzzards Bay by the Buzzards Bay Coalition *Baywatchers* Program from 1992 to 2018

Rachel W. Jakuba[1], Tony Williams[1], Christopher Neill[2,3], Joseph E. Costa[4], Richard McHorney[2], Lindsay Scott[2,3], Brian L. Howes[5], Hugh Ducklow[2,6], Matthew Erickson[2,7] & Mark Rasmussen[1]

The Buzzards Bay Coalition's Baywatchers Monitoring Program (*Baywatchers*) collected summertime water quality information at more than 150 stations around Buzzards Bay, Massachusetts from 1992 to 2018. *Baywatchers* documents nutrient-related water quality and the effects of nitrogen pollution. The large majority of stations are located in sub-estuaries of the main Bay, although stations in central Buzzards Bay and Vineyard Sound were added beginning in 2007. Measurements include temperature, salinity, Secchi depth and concentrations of dissolved oxygen, ammonium, nitrate + nitrite, total dissolved nitrogen, particulate organic nitrogen, particulate organic carbon, ortho-phosphate, chlorophyll *a*, pheophytin *a*, and in lower salinity waters, total phosphorus and dissolved organic carbon. The *Baywatchers* dataset provides a long-term record of the water quality of Buzzards Bay and its sub-estuaries. The data have been used to identify impaired waters, evaluate discharge permits, support the development of nitrogen total maximum daily loads, develop strategies for reducing nitrogen inputs, and increase public awareness and generate support for management actions to control nutrient pollution and improve water quality.

Background & Summary

Nutrient pollution is an important driver of water quality degradation in the U.S. and around the world[1–4]. In coastal waters, nitrogen inputs are linked to greater phytoplankton growth, reduced water clarity, hypoxia, and declines in seagrass coverage, fish, and shellfish populations[5–7]. Because the magnitude and effects of nitrogen pollution vary with the characteristics of watersheds and receiving waters, water quality responses to nitrogen inputs—and potential strategies to mitigate those inputs—are site specific. Long-term records of coastal water quality are essential to document the effectiveness of management action, consequences of inaction, and related water quality drivers, like climate change.

Buzzards Bay is a 650 km^2 estuary in Southeastern Massachusetts with a 1,123 km^2 watershed that encompasses all or parts of 21 municipalities in two states and has a current year-round population of 250,000[8]. Buzzards Bay's coastline spans 563 km and includes shallow river- and groundwater-fed sub-estuaries. The central Bay is 45 km long, averages 13 km wide, and has a mean depth of 11 m. Sub-estuaries range from several hectares to 19 km^2. The Bay's shoreline includes 21 km of heavily-used public beaches.

Beginning in 1984, Buzzards Bay received federal recognition and funding because toxic chemicals, bacteria, and nutrients threatened its economic and natural resources. In 1991, the Buzzards Bay National Estuary Program (NEP) developed a Comprehensive Conservation and Management Plan[9] to protect and restore the

Jakuba et al. 2021, Nature Scientific Data

Translating this information for the public is crucial.

What does my Bay Health score mean?

0-35

Poor

There is too much nitrogen pollution in the water. Underwater habitats are unhealthy for fish and shellfish. The waterway is not functioning as a viable ecosystem.

35-65

Fair

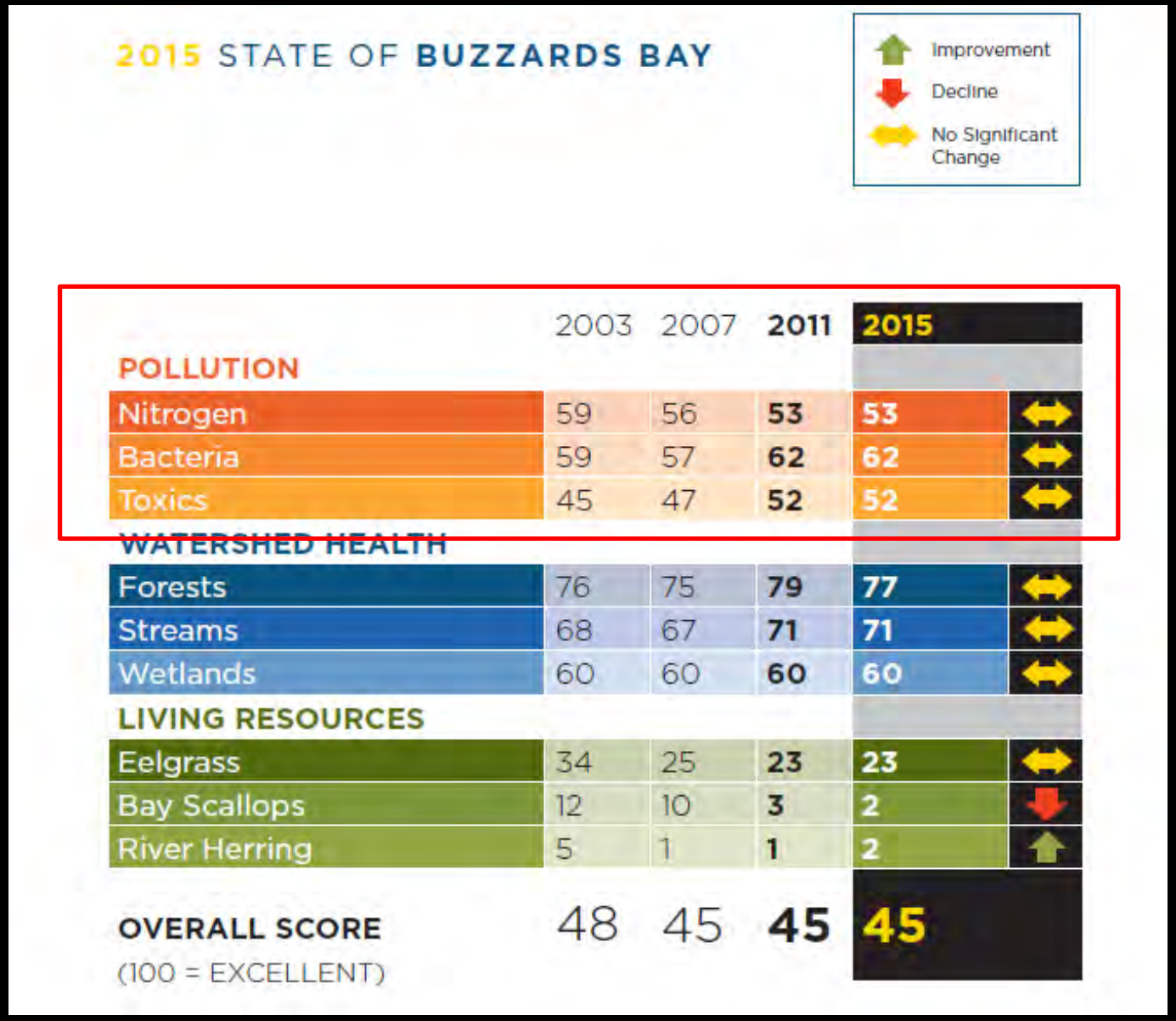
These are transitional areas that are either improving or, more likely, becoming more polluted with nitrogen. The habitat health is damaged.

65-100

Good

There is little nitrogen pollution in th
The waterway offers healthy underwa
habitats for fish and shellfish. Overall
ecosystem is in balance.

Monitoring allows us to detect and report on long term trends.

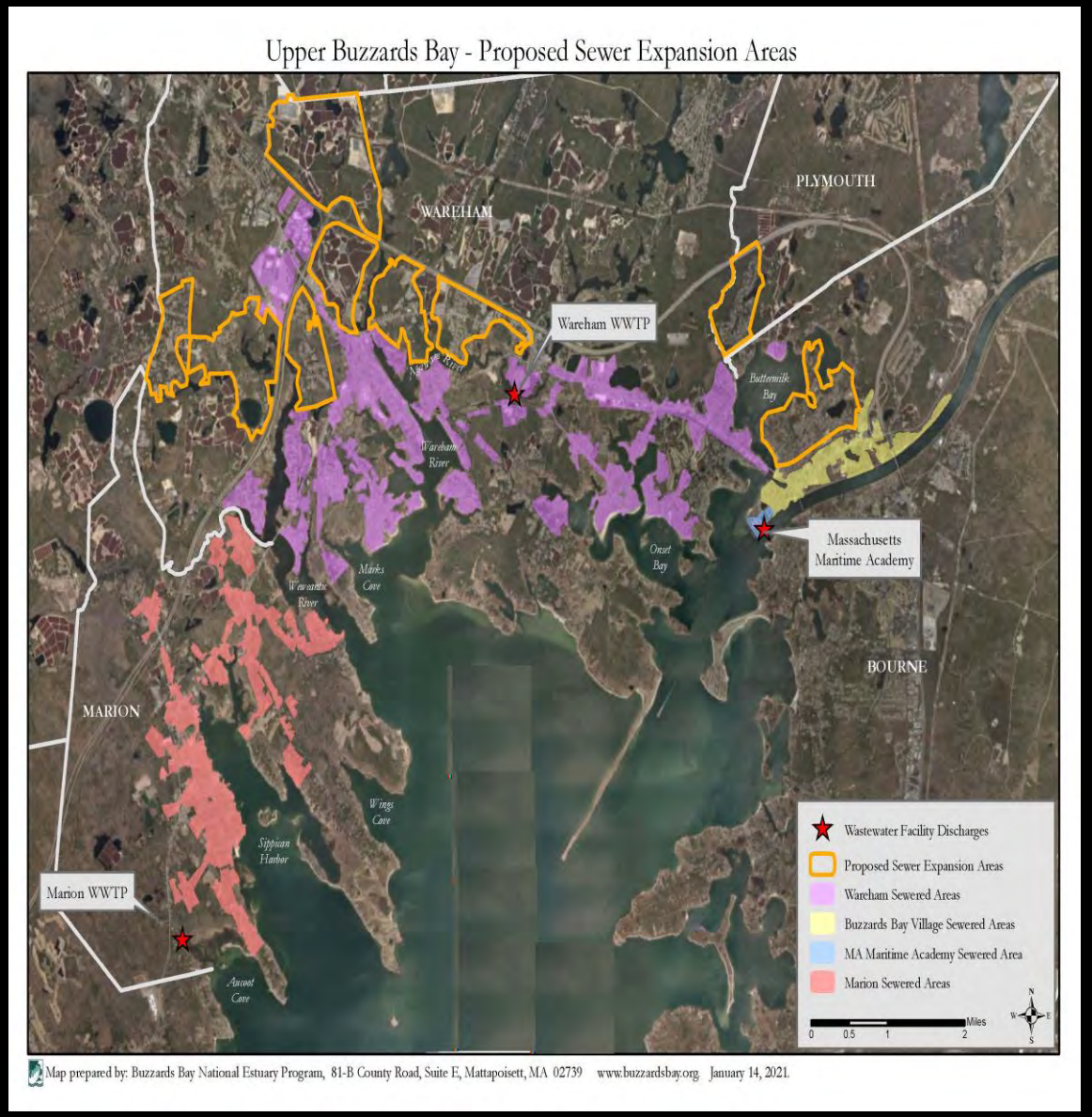


2015 STATE OF BUZZARDS BAY

Improvement
Decline
No Significant Change

	2003	2007	2011	2015	
POLLUTION					
Nitrogen	59	56	53	53	↔
Bacteria	59	57	62	62	↔
Toxics	45	47	52	52	↔
WATERSHED HEALTH					
Forests	76	75	79	77	↔
Streams	68	67	71	71	↔
Wetlands	60	60	60	60	↔
LIVING RESOURCES					
Eelgrass	34	25	23	23	↔
Bay Scallops	12	10	3	2	↓
River Herring	5	1	1	2	↑
OVERALL SCORE (100 = EXCELLENT)	48	45	45	45	

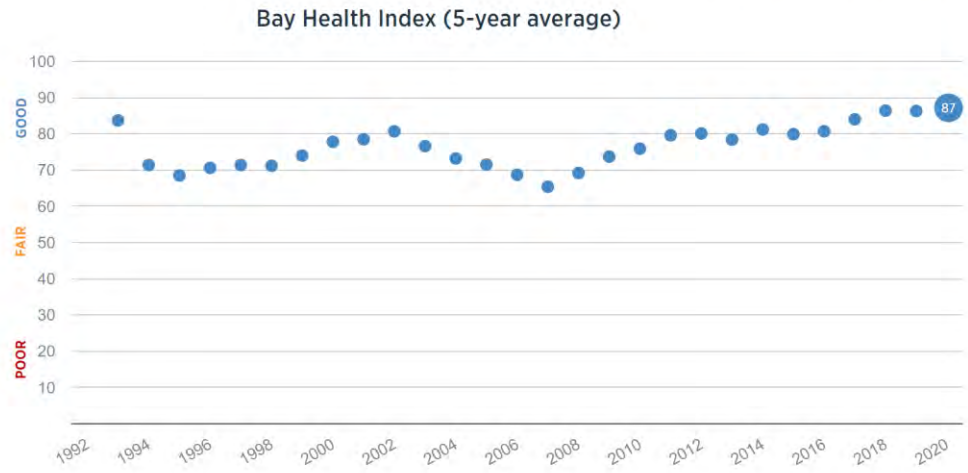
Long-term data enables us to tailor policies for specific places.



Inner Quissett Harbor Snapshot

buzzards BAY COALITION

Bay Health Index (5-year average)



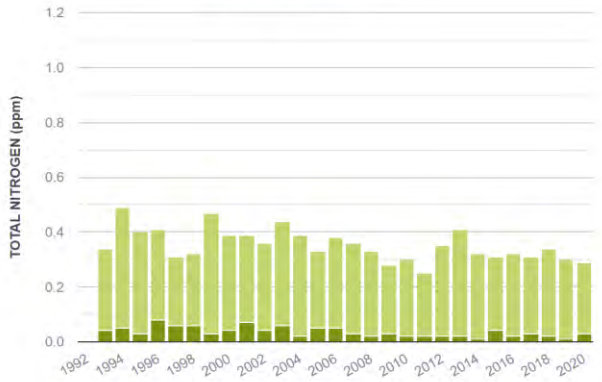
87
OUT OF 100

Supporting Data

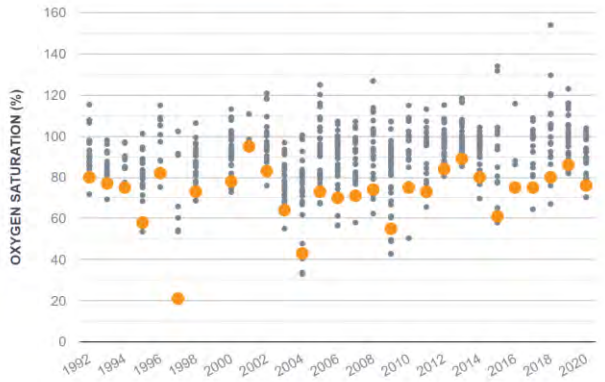
Inner Quissett Harbor: Site QH2

(41.54402563, -70.65273587)

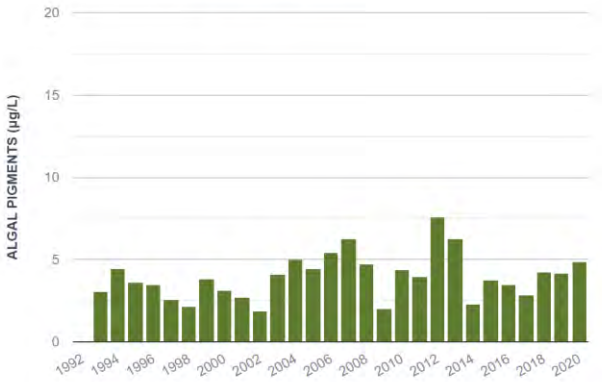
Total Nitrogen



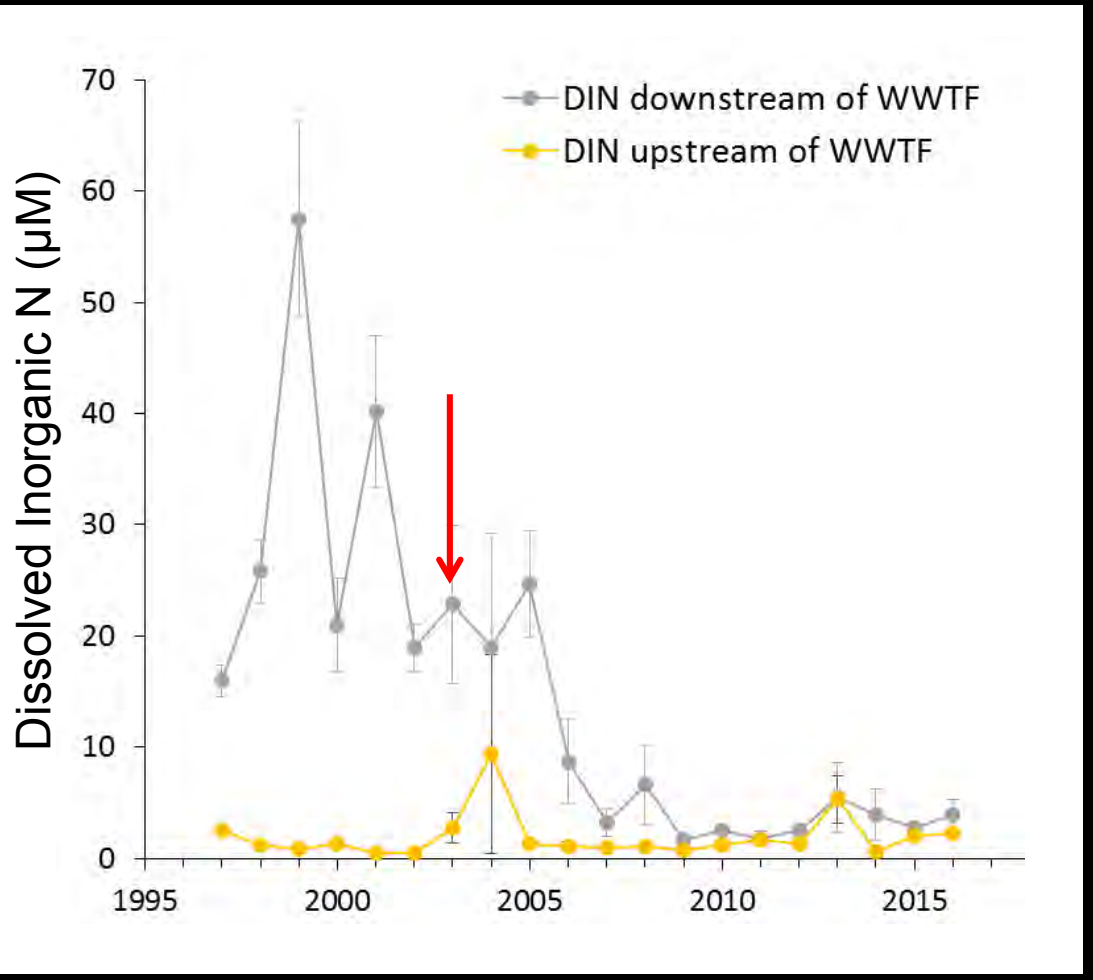
Dissolved Oxygen



Algal Pigments



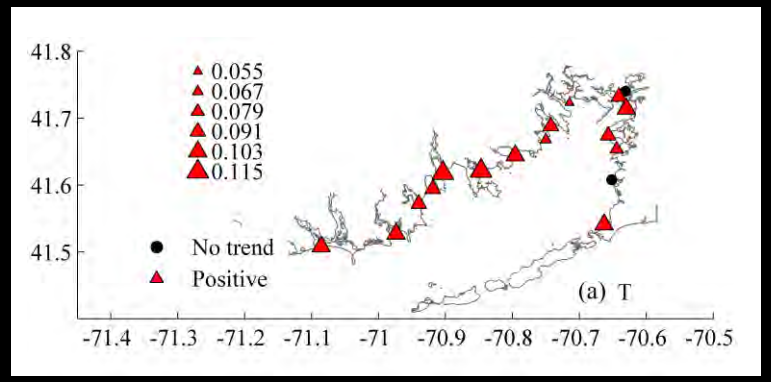
Time series data allows us to evaluate response to management.



- Nitrogen loading on the Agawam River
- Data helped set limits on wastewater to 4 mg/L

Climate change will make it even harder to clean up Buzzards Bay.

Summer Temperature



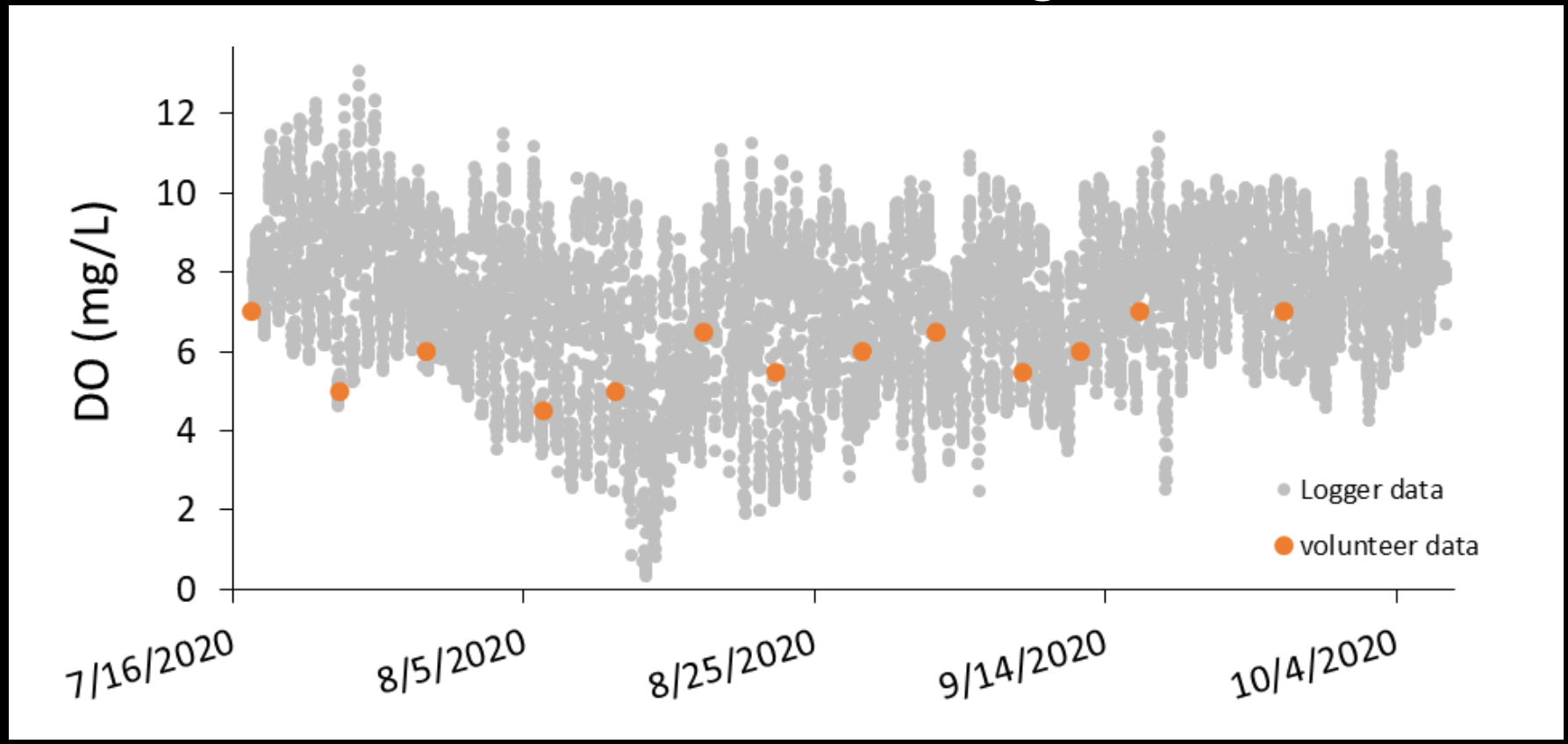
Chlorophyll a

Total Nitrogen

Rheuban et al. 2016, Biogeosciences

- Mean summer temperatures warmed by ~2°C
- Same level of N results in greater algal growth.
- Need to rethink water quality targets.

Adding automated measurements will enhance our understanding.



Xingu River
MT, Brazil

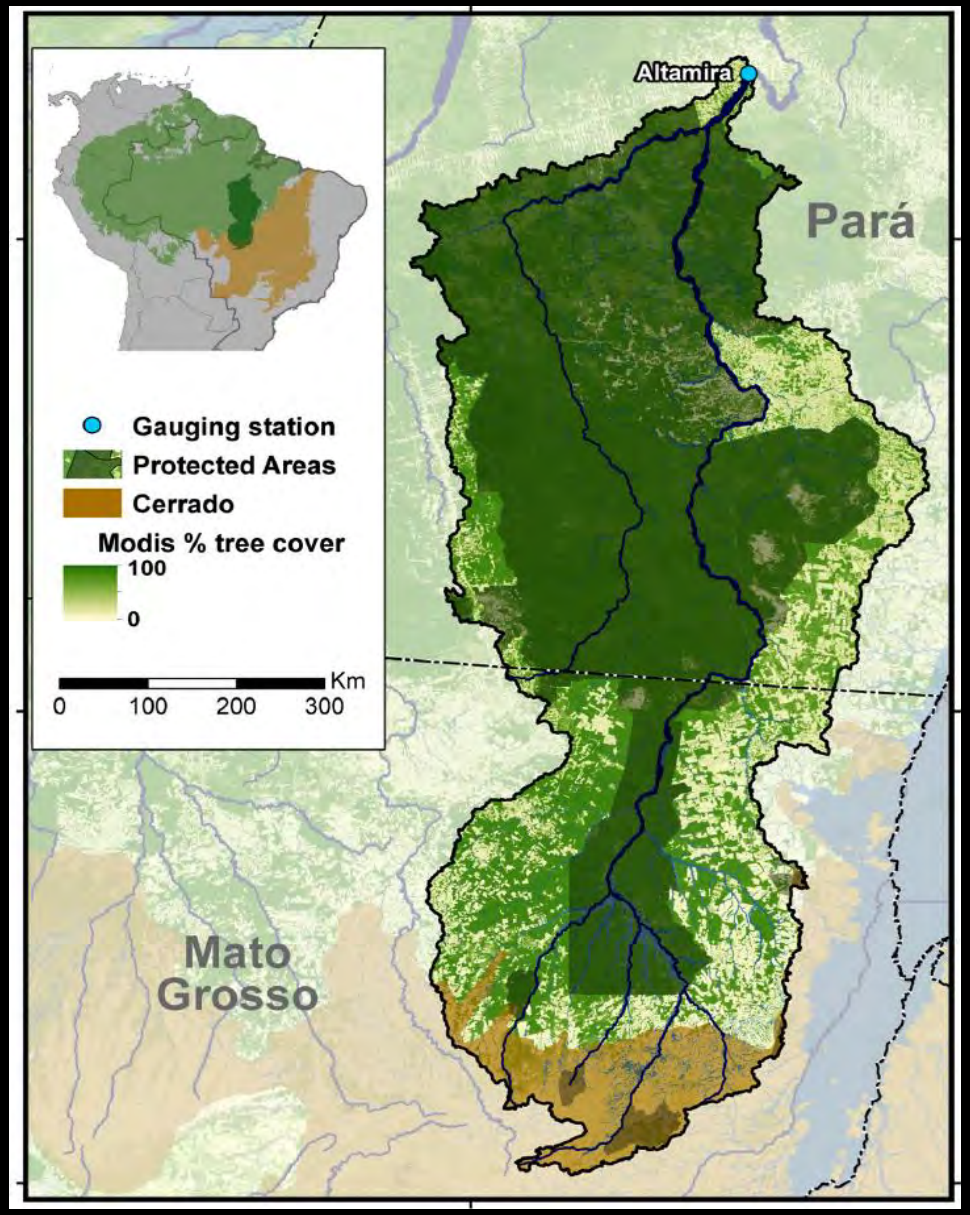
IPAM
Amazônia

The landscape today is a legacy of past agricultural land uses.

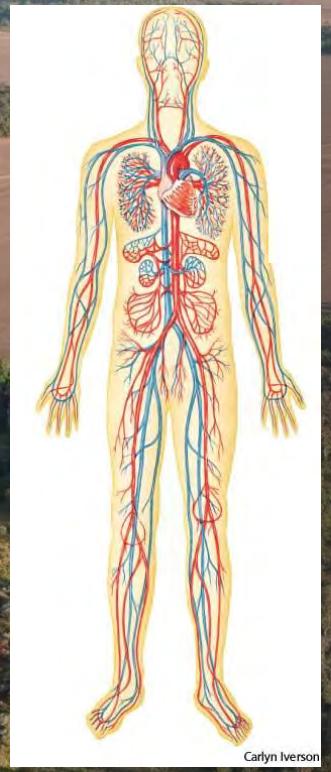
1980s

2000s

Rivers connect agricultural lands with Indigenous lands downstream,.



Where does all the nitrogen fertilizer end up?



GHG Emissions (N_2O, NO)

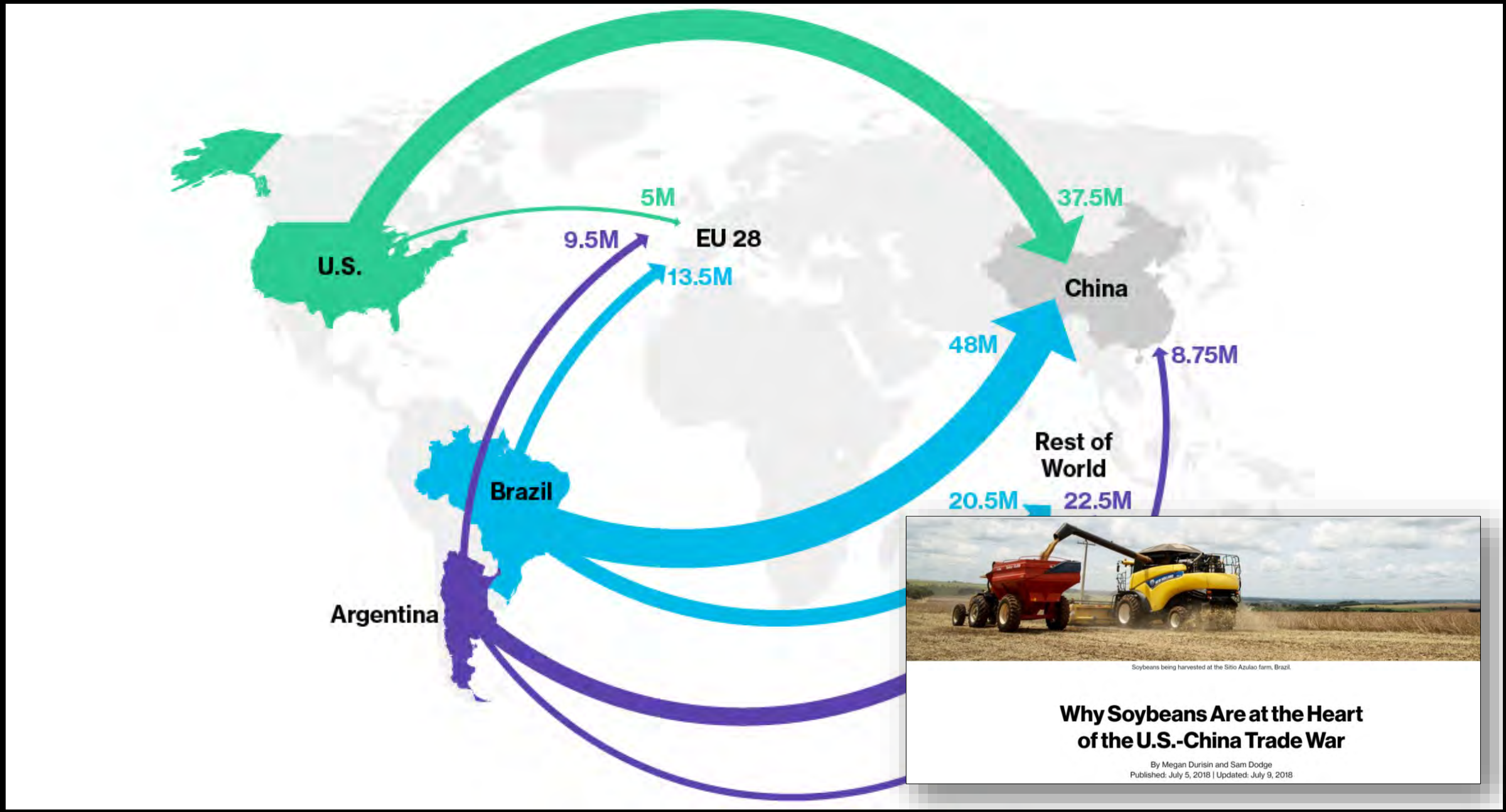
Taken up by maize and harvested

Exported downstream

Retained in soils

Runoff into water table

Assimilated by forests

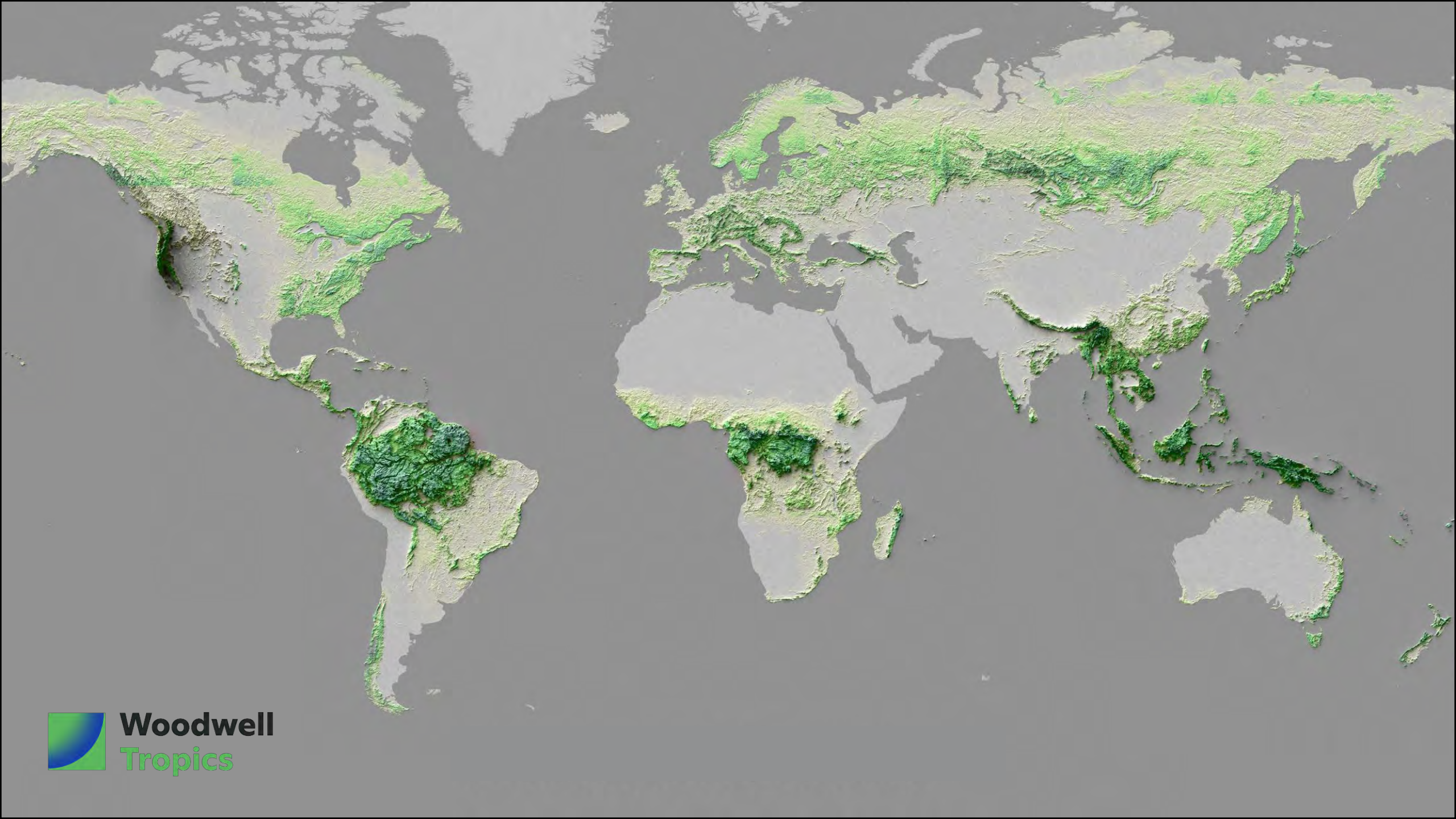


Soybeans being harvested at the Sitio Azulao farm, Brazil.

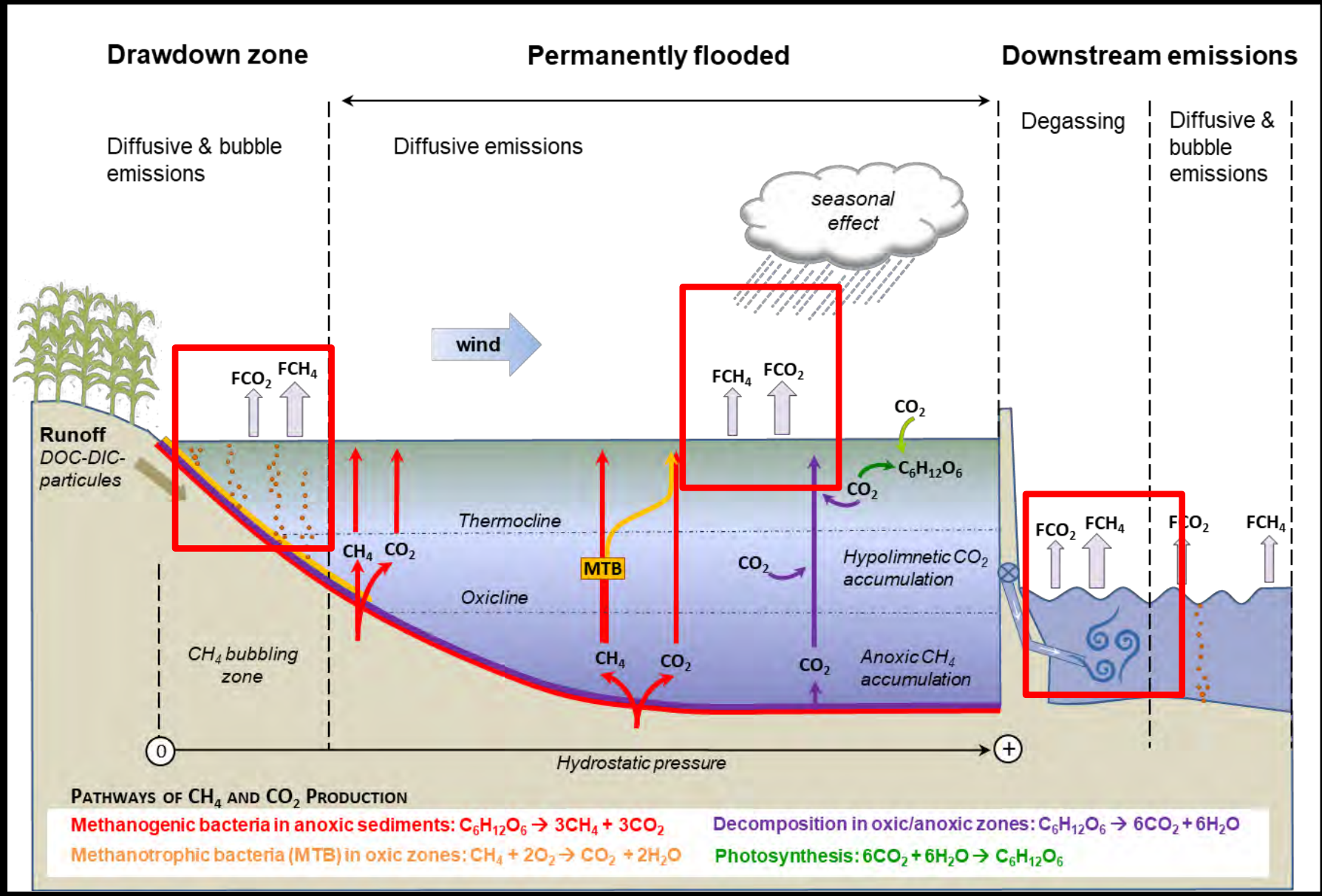
Why Soybeans Are at the Heart of the U.S.-China Trade War

By Megan Durisin and Sam Dodge
Published: July 5, 2018 | Updated: July 9, 2018

Bloomberg News, 2018


Woodwell
Tropics

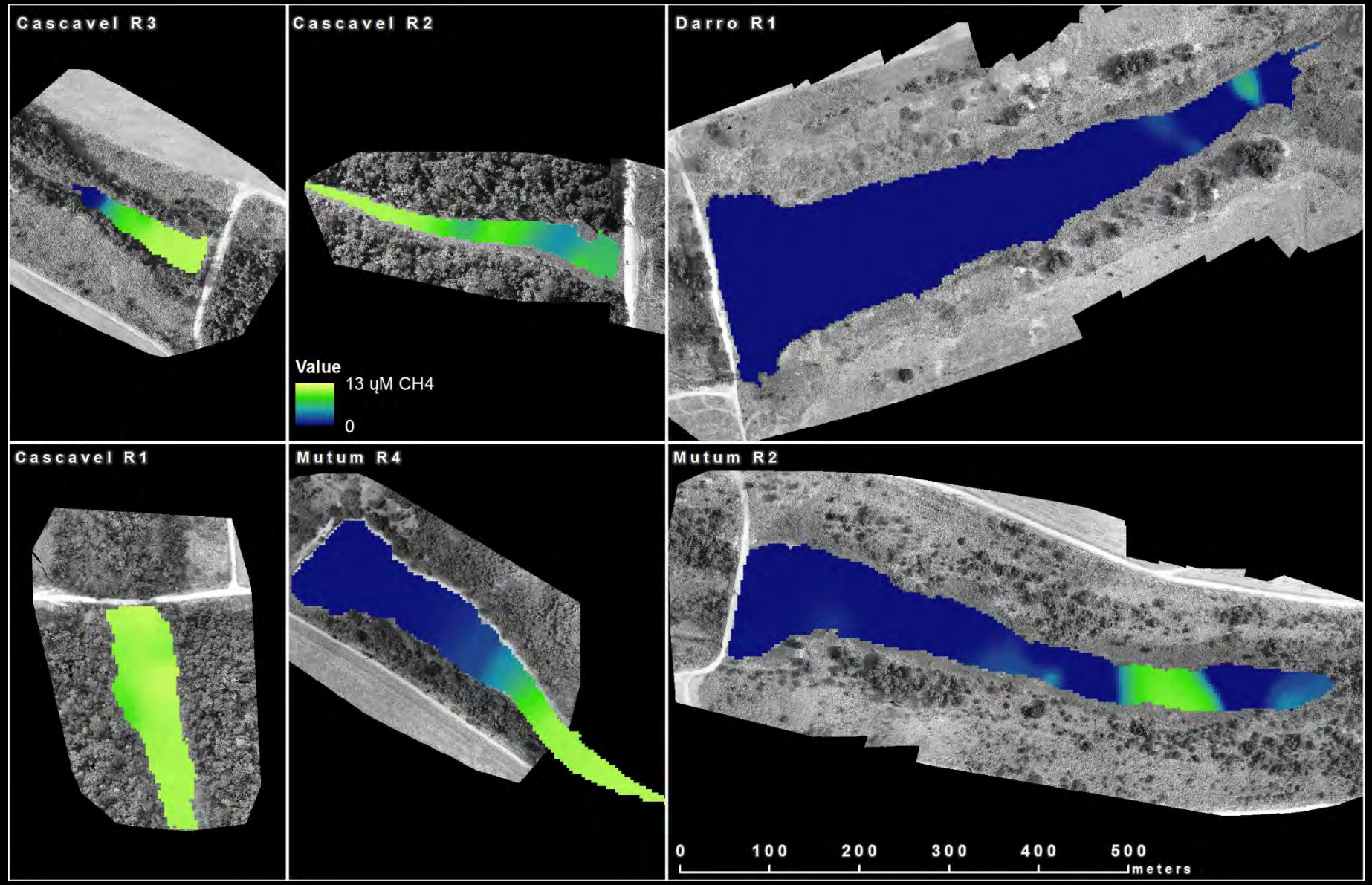
Methane and carbon dioxide leave reservoirs via several key pathways.



Adapted from Demarty and Bastien 2011


24-hour
diffusive
fluxes
24-hour
bubble
fluxes

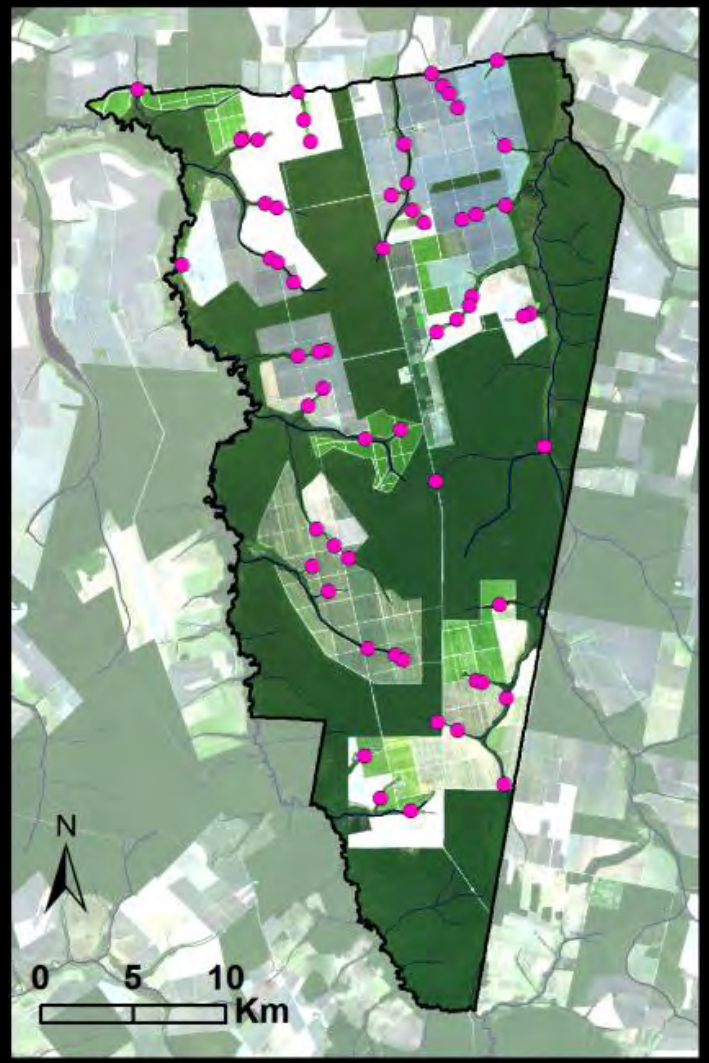
The smallest reservoirs have the largest methane emissions.



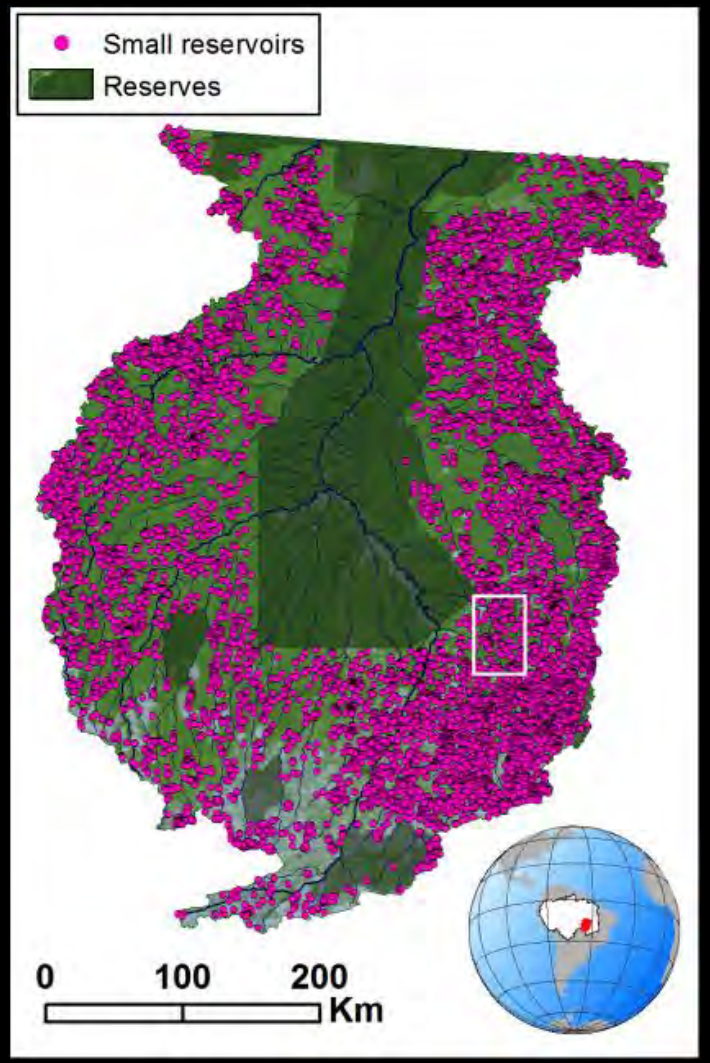
Macedo et al. In Prep.

Small dams have a big impact on stream temperature and connectivity.

Photo: Paulo Brando

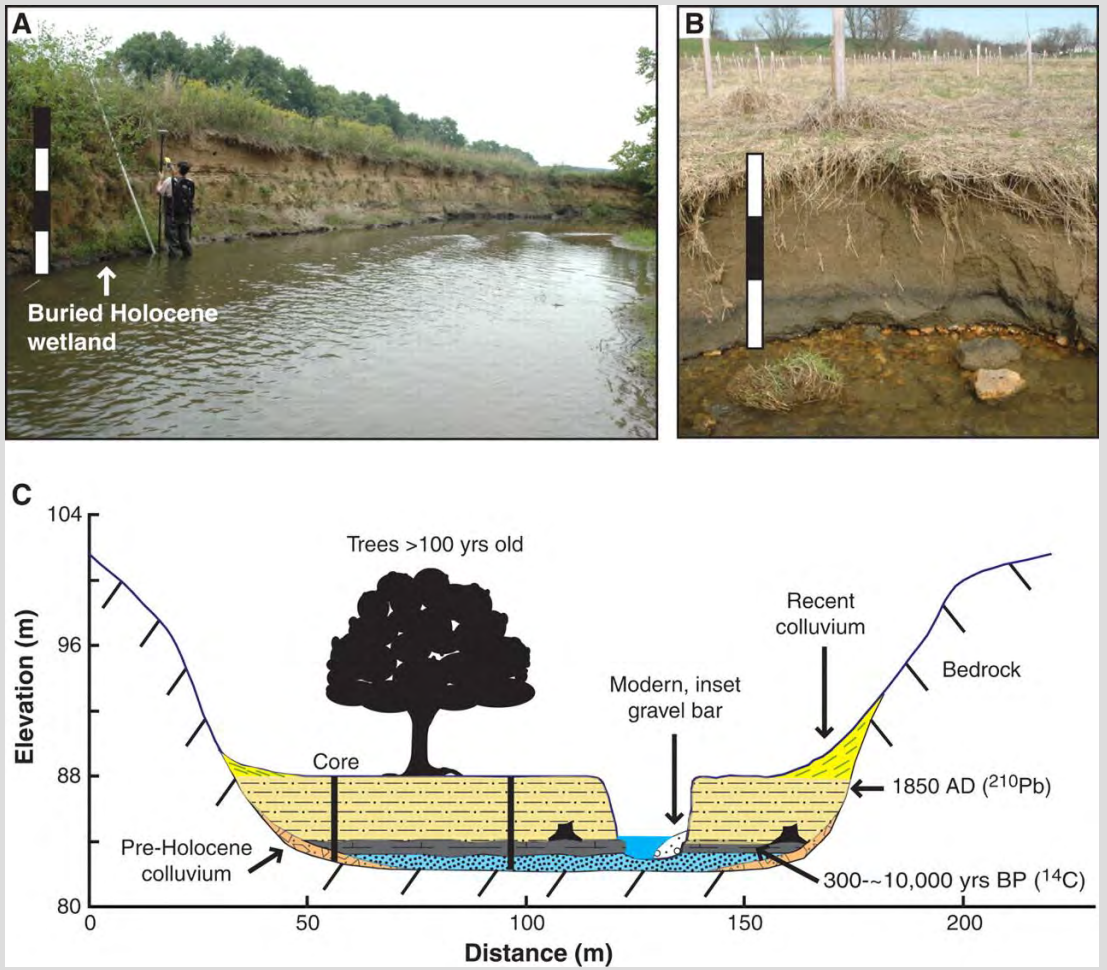


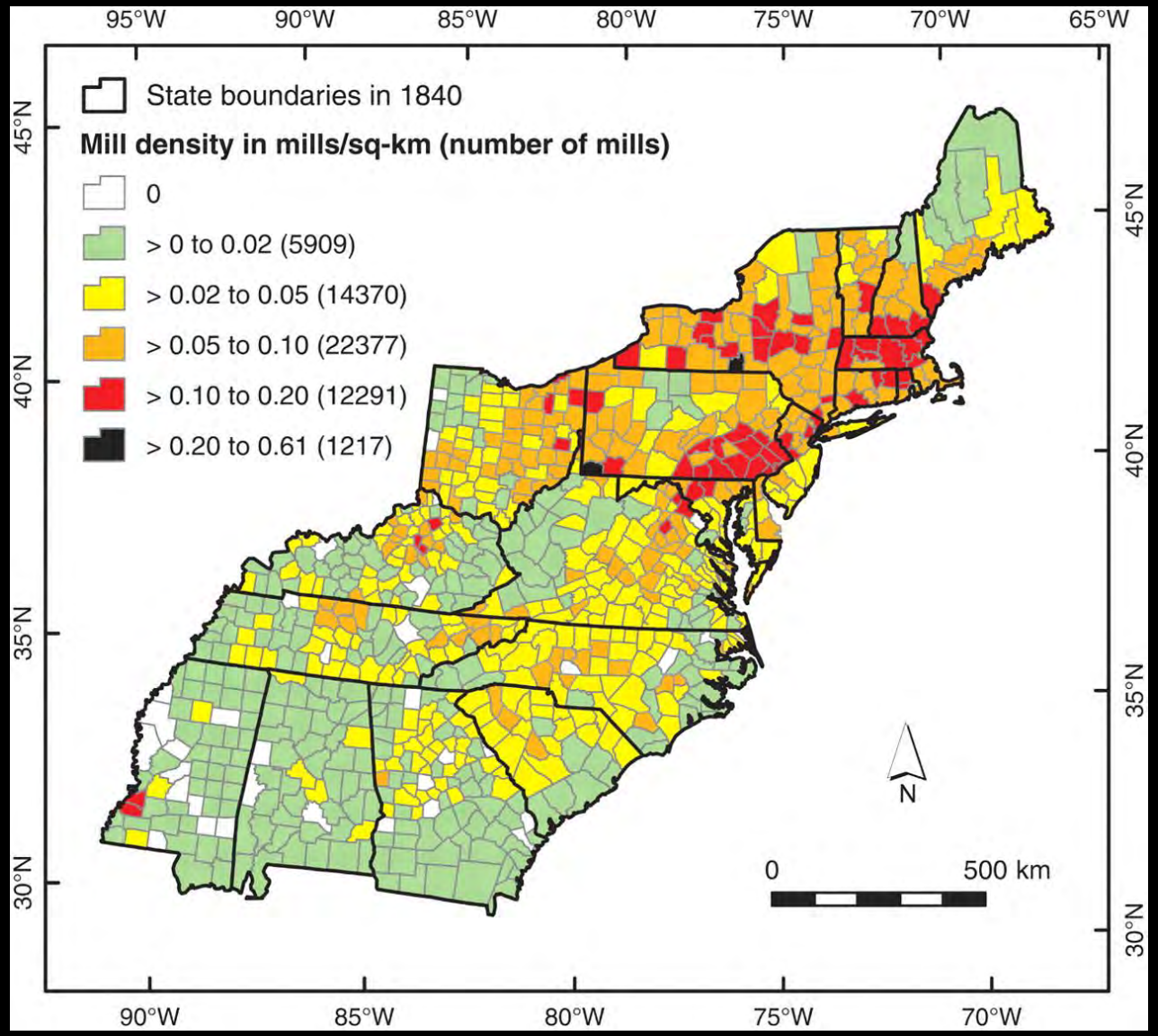
Map: Paul Lefebvre



Macedo et al. 2013, PTRS

The legacy of mill dams in the US Northeast is similar in scale.





Walter and Merritts 2008, Science

Finding solutions

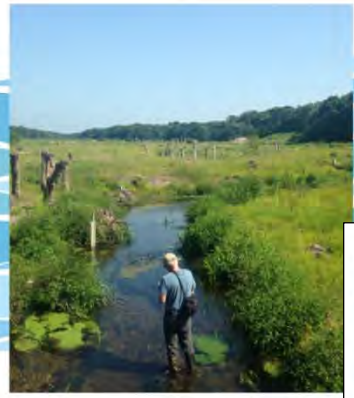
Horseshoe Mill Dam removal, Weweantic River

Restoration of the Coonamessett River

What's Going On?

Welcome to a self-guided tour of the restored lower Coonamessett River watershed, a former town-owned cranberry bog. Numbered posts correspond to informational paragraphs in this brochure.

The Coonamessett River, once known as the Five-Mile River, was important to the native people of Cape Cod and to the immigrants who settled here. Coonamessett means "long fish, white pine place" in the Wampanoag language. Just as the Coonamessett winds through the center of Falmouth, it also wove through the history of our town. As Falmouth grew and changed, the river was altered to fit different needs and uses over time.



How long will it take for the wetland and river to be fully restored?

The active phase of restoration for the lower river was completed in 2018. Now it is up to Mother Nature and Father Time. The restoration will continue to evolve. Growing trees will shade the river, keeping it cool enough perhaps for brook trout to return. Scientists have discovered that seed hidden in the wetland soils for hundreds of years are sprouting as they are exposed to sun and rain. The wetland will remove some excess nutrients which can help improve water quality in the Great Pond estuary. Now that the connection to Vineyard Sound is unobstructed, this area can provide flood storage and protection during large storms especially as sea levels rise.

Coonamessett River Trust

Produced by the Coonamessett River Trust

2 Why is this called the Turtle Pond?

4 What other changes did cranberry production bring?

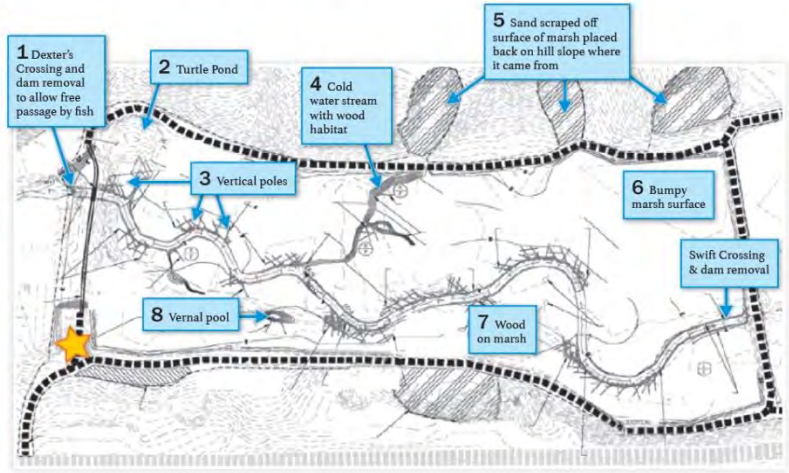
In 1890 when the small local mills could no longer compete with the large mills in New Bedford and Fall River, the land was converted to cranberry bogs. Trees or native plants were removed and the land was flattened. The river was straightened and ditches built to drain away excess water. The above photo was taken before restoration in 2004. Following restoration, the river is now narrower, 50% longer and has eight new bends. There are now also deep pools for fish to live in and gravel riffles that support insects the fish like to eat.

5 Why were several feet of earth scraped off the bog during restoration?

Up to three feet of sand had to be removed from the old bog surface to uncover the original wetland soils. For over 100 years sand was regularly spread over the bog to promote the growth of cranberry plants. As it washed into the river, the sand created poor living conditions for the many river inhabitants, making it too shallow and hot. The sand had to be removed for the wetland and the river to function properly again. Now the stream bottom also has rocks, cobble and wood that support a more diverse population of aquatic insects indicative of better stream health. The removed sand was spread on the adjacent upland areas to provide a place for turtles to lay their eggs.

6 Why is the wetland surface so lumpy?

This is referred to as pits and mounds. The marsh surface was intentionally made bumpy to increase plant and habitat diversity. Some plants are adapted to low, wet spots called pits while others prefer higher, drier sites called mounds. The wet and dry create conditions for a greater diversity of plants. This variety provides for the needs of many different animals and birds. Keep an eye out for butterflies and dragonflies attracted to the site. Logs were left on the marsh surface to provide shaded spots for frogs, turtles, and salamanders.



7 Why are there tree trunks scattered about on the wetland?

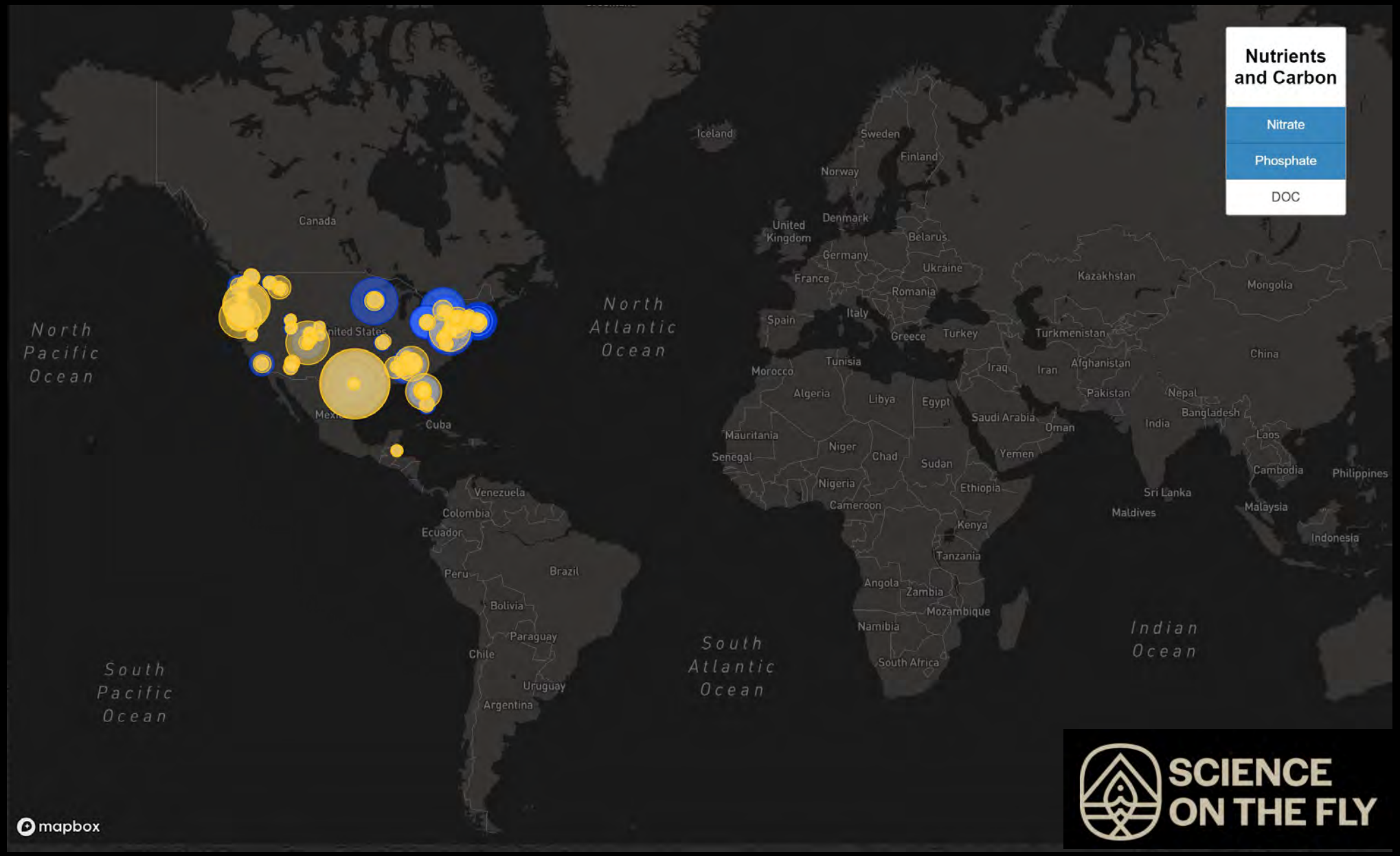
It may look like the scattered tree trunks were just left for no reason, but not so! The trees were left on the marsh surface to provide shady areas and cover for frogs, turtles, and salamanders.

8 What is special about this pool?

It was created to be a vernal pool, a unique type of wetland that is typically full of water in the spring. Vernal pools are rare and special places where wood frogs and salamanders lay their eggs in the spring. During dry summers it will likely dry up. Keep an ear out for the unique "quack" call of wood frogs in the spring.

We are harnessing the power of people to monitor rivers globally.

We are harnessing the power of people to monitor rivers globally.



Biodiversity could play a big role in restoring degraded forests.

PAPER

WILEY bioTROPICA ASSOCIATION FOR TROPICAL BIOLOGY AND CONSERVATION

Lowland tapirs facilitate seed dispersal in degraded Amazonian forests

Lucas N. Paolucci[1,2,*] | Rogério L. Pereira[3] | Ludmila Rattis[1,4] | Divino V. Silvério[1,3] | Nubia C. S. Marques[1,5] | Marcia N. Macedo[1,4] | Paulo M. Brando[1,4]

the advantages of being close to a river. That memories of disaster weigh more heavily in this calculation immediately after the flood is not surprising, says Dr Fanta. But that the memory is so short-lived is. He had expected people to heed history's warning for a century at least.

This collective forgetfulness is even more puzzling in light of a central preoccupation of ancient chroniclers, the communication of risk. Writing to preserve their eras for posterity, they recounted harrowing tales of extreme climatic events, fires, famines and plagues. Likewise, there is no shortage of written accounts of Hurricane Betsy or of historical floods in Prague—the maximum heights of many of which are marked along the Vltava's banks.

Such distant secondhand accounts are not enough, Dr Fanta concludes. To be deterred from placing themselves back in danger, people have to hear disaster tales from eye witnesses who can convey the visceral emotion of having lived through them. The group's findings thus suggest that one way of teaching history more effectively might be to bring eye witnesses into the classroom. That approach will not work for ever, of course. Over time, witnesses' own memories fade, and then the witnesses themselves expire.

The forgetting that Dr Fanta sees with respect to historical floods might also explain the recent rise of vaccine hesitancy and right-wing extremism, he suggests, as the survivors of now-preventable infectious diseases and Hitler, respectively, die of old age. Having not experienced those realities, or heard about them first-hand, many people alive today have quite simply forgotten the horror. ■

Ecology

Do tapirs defecate in the woods?

It seems they prefer burned-out scrub.

Just powdering my nose

animals often defecate pips and stones from fruit they have eaten in places distant from where the food were consumed. Much research has therefore been devoted to luring them into damaged areas—sometimes with success. There is a limit, however, to the size of seed that a bat or a bird can carry, and that constrains which plants can be regenerated in this manner.

Lowland tapirs suffer no such constraint. They are the region's biggest herbivores and swallow lots of large seeds. Dr Paolucci thus wondered to what extent tapirs were transporting seeds from pristine to damaged areas. To try to find out he and a team of colleagues set up a study of tapirs' defecatory habits.

The researchers used a mixture of field observations and camera traps to monitor tapirs in three adjacent plots that are part of a larger project to study the effect of fire on Amazonian rainforest. These plots were confirmed at the beginning of the study to be similar in such matters as plant-species richness, the relative abundance of the commonest species, the density and com-

Altogether, they found 163 dung piles. Of these 43 were in the pristine plot, 48 in the triennially burned plot and a surprising 72 in the plot that had endured annual fires. The piles contained, they found, a grand total of 129,204 seeds from 24 species of plant. Fewer than 1% of those seeds were so badly damaged as to suggest that they would not germinate. On the basis of these results Dr Paolucci calculated that tapirs pass an average of 9,822 seeds per hectare per year in degraded rainforest, compared with 2,950 in pristine forest.

The camera-trap data suggested that this might be because the animals preferred to spend time in the burned areas, rather than because they actually preferred to defecate there. The traps observed 306 independent visits by tapirs. (Photos taken within 30 minutes of one another were counted as part of the same visit.) Sixty-one of these sightings were in the pristine plot. A hundred and twenty five were in the triennially burned plot. And 120 were recorded in the annually burned plot.

Why tapirs would gravitate towards disturbed zones is a mystery. But it does suggest the animals play an important, if accidental, role in forest regeneration—and that, if the causes of their preference were better understood, they might be manipulated into sowing yet more seeds in places that need them. ■

Prospecting for minerals

Scoring boundaries

VIENNA

How to narrow the search for ore

AS TREASURE MAPS go, it will be hard to beat. Geologists from Harvard University, Geoscience Australia and the Australian National University are drawing up a map to show where mining companies should focus their search for the ores of metals such as lead, nickel, copper and

Paolucci et al. 2019, Biotropica

Opinion

We Know How to Stop the Fires

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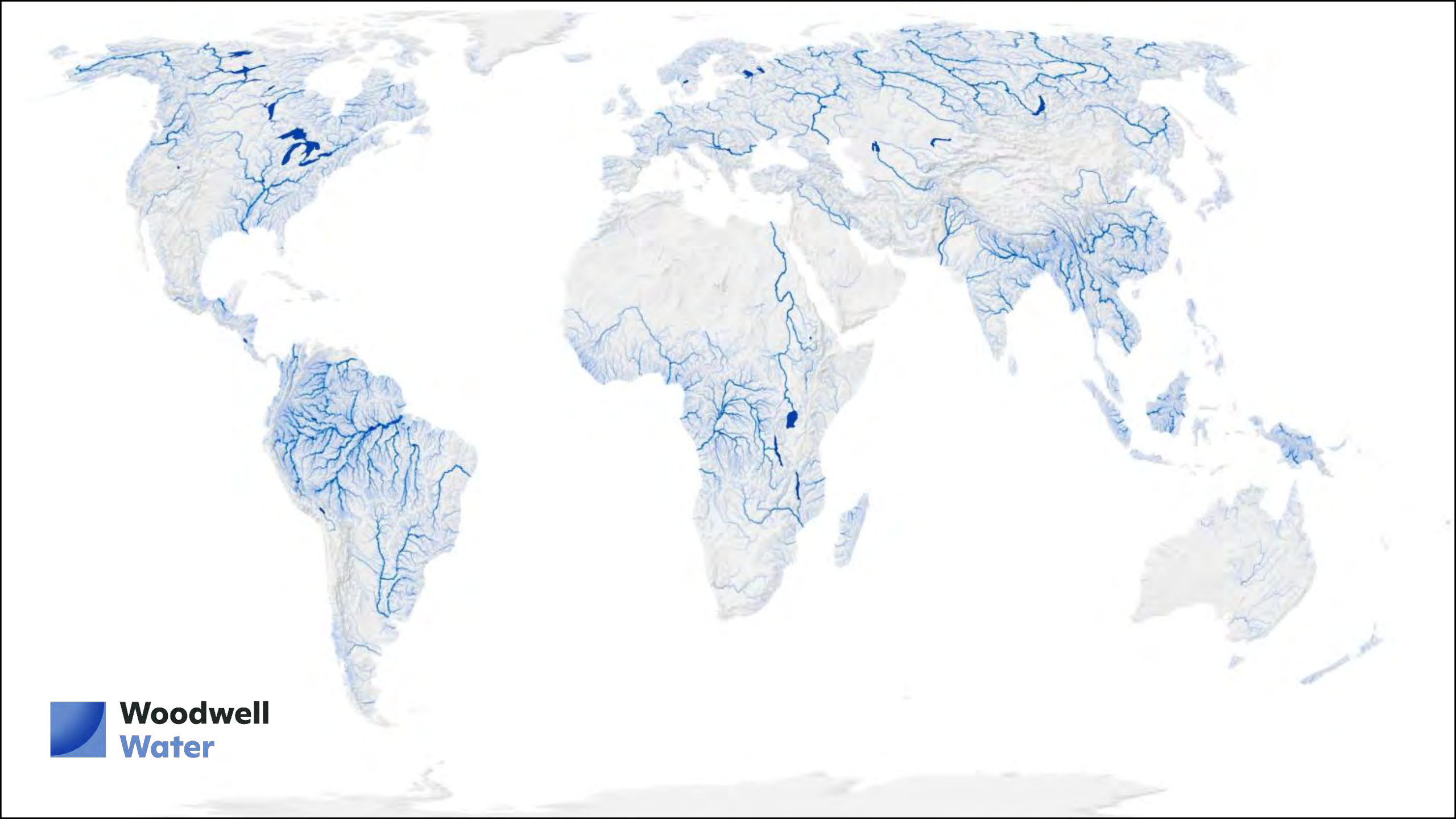

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