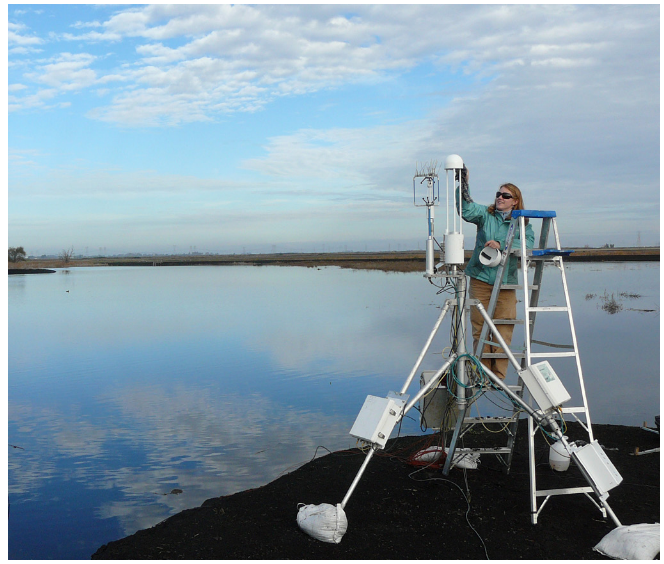
Physics Wins, Biology Is How It's Done!

The Role of Wetlands in Climate, Water, and the 5th Largest Economy

by Katrina Cone

At the mouth of the Sacramento River where freshwater meets the Bay, a system of islands inhabited by farmers are a scatter of green across an expanse of blue. It's sweet and quaint to see the island farms connected by bridges and motorboats with names like *The Zucchini* dotting the water, but the simplicity of the scene is misleading. This region supports billions of dollars worth of California agriculture and supplies water to 30 million people—and it's in crisis.



You can stand in the middle of a cornfield on an island and look *up* to see a boat sailing by above you. Aggressive farming of the region has led to land subsidence, meaning that so much soil has been removed that the region is now actually below sea level. The only reason sea water hasn't flooded the islands is because of the construction of levees, which leaves the Delta looking "like a bathtub trying to keep seawater out," as Professor Dennis Baldocchi of UC Berkeley's Biometeorology lab puts it.

Dennis Baldocchi, known to many as one of the pioneering forefathers of eddy flux covariance (a way of measuring gas emission and mixing in the atmosphere) has been studying biophysical and biochemical processes in the Sacramento-San Joaquin Delta region for more than ten years in collaboration with the Department of Water Resources. They aim to not only reverse the effects of land subsidence but even reap some additional benefits on climate and carbon sequestration in the process of doing so. It's a lofty goal, but the means to reach it are actually less complicated than you'd expect—wetland restoration.

Even though for most people rainforests are all the talk, wetlands are an underdog ecosystem that really could be game changing. They're effective at rebuilding soils that have been lost to agirulture because they're productive ecosystems that undergo a lot of photosynthesis. This means they uptake a great deal of carbon dioxide.

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To put it simply, plants take carbon from the atmosphere, and when they die that carbon is incorporated into new, rich soil that will replace what's been lost to agriculture. The hope is that enough soil will be regenerated that the Delta will no longer be below sea level (imagine filling a pothole) and therefore no longer have a need for levees to hold seawater back. It's a seemingly simple and serendipitous solution to a problem that could result in statewide devastation. In the instance of a massive earthquake—which all Californians know we're due for—the levees will almost certainly fail.

"This region is estimated to be worth several billion dollars in agriculture, and this water supports 30 million plus Californians. We're the fifth largest economy in the world. So if we lose our supply of freshwater, it could have dire consequences on how our state functions and our economy."

The stakes in this region are especially high for Baldocchi, as it's not just the location of his field sites but also where he was born and raised. His upbringing on a farm eventually lead him to study biometeorology, the study of atmosphere-biosphere interactions or, as he puts it, how weather affects life.

The Baldocchi lab studies their wetland and agricultural sites in the Delta using a method known as eddy flux covariance—a complicated sounding term that's based on a simple concept: all living things breathe.

"You breathe in oxygen because that's what's needed for you to metabolize the food that you eat, and that metabolism releases energy. Ecosystems work much the same way," Baldocchi explains.

Using remote sensing methods, the Baldocchi lab receives continuous streams of data over 24-hour periods for a much larger area than previous methods could manage.

Large "flux towers" have sensors that measure wind turbulence as well as how gases in eddies of wind correlate with turbulence. Baldocchi explains eddy flux to me with some simple imagery. Imagine standing in a field and feeling the wind blow around you. You'll feel some updrafts and some downdrafts. Those gusts of wind are all travelling at different velocities, which causes turbulence in the atmosphere.

Gas sensors at the top of a flux tower.

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Eddies, or wind traveling in circular motions due to turbulent mixing, will have different concentrations of gases in them. These different concentrations are determined by how much gas is being taken up by photosynthesis or added to the atmosphere by respiration at that time.

"Essentially our method is counting all those updrafts and downdrafts, and we can come up with a continuous measurement," Baldocchi says.

Measuring gas fluxes over restored wetlands means that the Baldocchi lab can monitor the impacts of wetland restoration on climate. Wetland vegetation that serves as a net carbon sink, as opposed to a carbon source, is a "natural carbon solution" Baldocchi says. Wetland plant uptake of carbon could offset carbon emissions from fossil fuel burning and agriculture.

Wetland restoration is becoming an increasingly popular climate mitigation solution, but climate change is a complex problem that's going to require a multi-pronged solution.

“Everyone wants to find the silver bullet for climate change, but there really is none. “

No solution is perfect, however. Using wetland restoration as a means of climate mitigation does have some drawbacks. Biological processes must abide by the laws and limitations of physics, after all.

Ecosystem carbon uptake is limited by the rate at which photosynthesis occurs, which in turn is limited by availability of plant nutrients and ambient conditions. Meanwhile, the burning of fossil fuels emits carbon at a much faster rate than that of photosynthesis—meaning that humans are putting carbon dioxide into the atmosphere too fast for ecosystems to keep up.

Another issue that is specific to wetlands is the emission of methane, which is a much stronger greenhouse gas than carbon dioxide. Because wetlands are, by nature, flooded landscapes, they create anoxic (which means “without oxygen”) conditions in underwater soils. This means that the bacteria that live in these soils must respire “anaerobically”, which is a process that emits methane as a byproduct.

This doesn’t necessarily cancel out the other benefits of wetlands on climate, however. While methane is a stronger greenhouse gas than carbon dioxide, its atmospheric lifetime is much shorter—for methane it’s ten years, in comparison to 200 years for carbon dioxide. A study from the Baldocchi lab suggests that while in the short term wetlands may be carbon sources due to methane emission, over longer timescales that take into account methane’s short lifetime in the atmosphere and carbon accumulated in soils over time, they are carbon sinks. An analysis by Kyle Hemes, recent PhD graduate of the Baldocchi lab, there’s an approximate hundred year “switchover time” in which a restored wetland transitions from a source to a sink. Essentially, wetlands older than one hundred years are net carbon sinks while younger wetlands are sources.

“Everyone wants to find the silver bullet for climate change, but there really is none. Solutions that have taken ecosystem timescales to emerge are going to take ecosystem timescales to resolve.”

While it’s not an all-encompassing solution, wetland restoration in the Delta will at least have major impacts on the stability of water resources and agriculture, and will have additional benefits for both the state of California and the state of global climate.