Bringing Wetlands to Market Part 1 Exercise 2
Interpreting Data on Wetlands and Carbon Storage

Focus questions
Where do plants get the carbon used to make structures such as leaves, stems, trunks, and roots?
Why do increasing amounts of carbon dioxide in the atmosphere represent an issue of global concern?
How does the rate of carbon uptake in wetlands compare to that of other ecosystems?

Performance tasks
Students will construct models to show how carbon is taken from the air and incorporated into plant materials in photosynthesis
Students will be able to explain the concept of "blue carbon."
Students will analyze charts to compare the rates of carbon uptake and sequestration in various ecosystems

Overview
In this exercise, students will build models to show how plants take carbon from the atmosphere in photosynthesis, and compare the carbon uptake and storage rates of plants in several types of ecosystems.

Time required
One 45 minute class period for each section

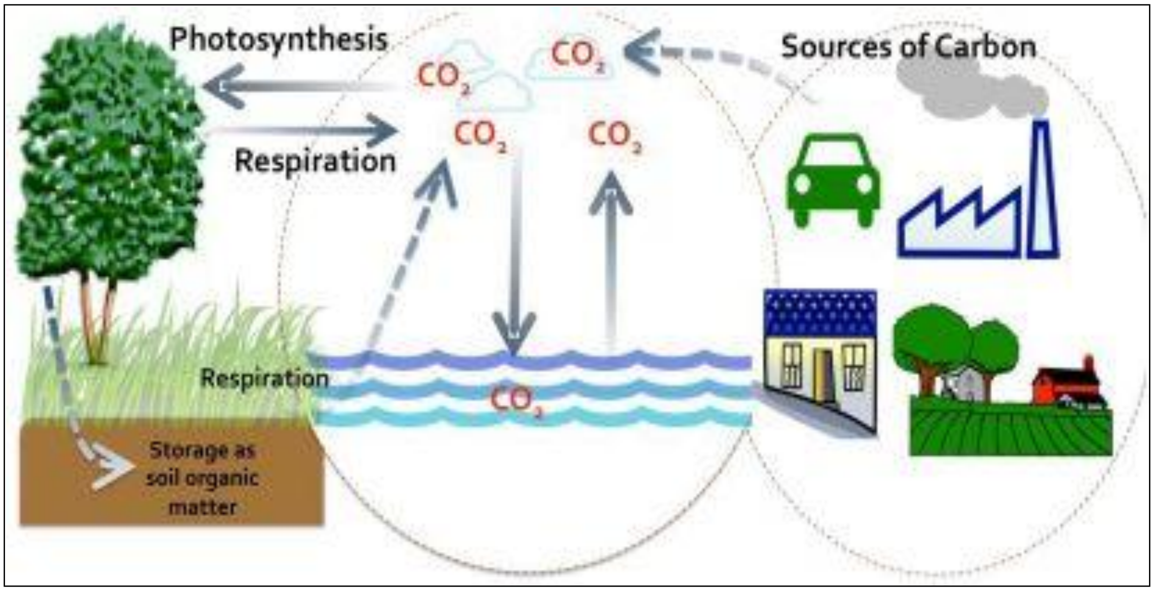
Materials
Lego© Photosynthesis Lesson

Student pages:
"Blue Carbon Fact Sheet"
Charts of Carbon in Coastal Ecosystems
Images of wetland ecosystems

Links
Youtube video: Two minutes on oceans with Jim Toomey: Blue Carbon
Reading "Salt Marsh Carbon May Play Role in Slowing Climate Warming"

Background for teaching
Biological carbon sequestration is a process in which carbon is captured through photosynthesis by trees, shrubs, grasses and other organisms, and stored in soils or other organic matter such as leaves and roots. We can help balance the amount of carbon in our atmosphere and maximize biological carbon sequestration by protecting and restoring ecosystems which naturally do this efficiently.

Through photosynthesis, forests take in and store large amounts of atmospheric carbon; this is known as **green carbon**. However, less is known about carbon that is absorbed and stored by the ocean (where carbon dioxide is taken in by phytoplankton, and carbon-rich organic matter sinks to ocean sediments) and coastal wetlands and ecosystems such as salt marshes, submerged eel grass meadows, and tropical mangroves, known as **blue carbon**.



Simplified carbon cycle from "Blue Carbon Fact Sheet"

High rates of carbon sequestration occur in ecosystems where plants take up lot of carbon dioxide through photosynthesis and where there is a lot of organic matter. Wet soils have the highest capacity for carbon storage because they have low oxygen levels, which slows down the process of decomposition. This means the carbon in the soil can remain there for centuries.

Procedure

1. Review photosynthesis and clarify with students that the carbon in the biomass of plants comes from the air. See Lego© Photosynthesis Lesson for detailed, illustrated instructions on how students can construct carbohydrates and cellulose using Legos©.

Optional activity to introduce this concept: In this activity, students learn about how 17th century scientist Jan Baptista van Helmont's studies on where the mass of trees comes from, and will review the concept that the carbon making up much of the mass of plants comes from the air: Putting on mass: How do trees grow?

2. As an introduction to the topic of carbon storage in wetlands, have students view the engaging video, Two minutes on oceans with Jim Toomey: Blue Carbon

Briefly discuss: What is "blue carbon" and why is it important?
Blue carbon refers to carbon that is taken up and stored in marine and coastal ecosystems. It is important because these systems can take up and sequester carbon at higher rates than occurs in other ecosystems.

You may also wish to have students view the Bringing Wetlands to Market Overview, a nine-minute video which describes the reasons for the research, what is being done, and what the researchers hope to learn. Guiding questions are provided in "*Bringing Wetlands to Market Overview Video and Questions"* posted here

3. Have students read the "Blue Carbon Fact Sheet" and "Salt Marsh Carbon May Play Role in Slowing Climate Warming" and answer these questions in writing or as a discussion.

a. What is the main point being made about wetlands and carbon?
   Wetlands take up and store more carbon dioxide per unit of surface area than other types of ecosystems.

b. From the readings, can you determine what part of the plants in a wetland system stores the most carbon? Are there parts of the plant that store carbon only for a single season?
   Most of the carbon storage is in organic soils and roots. Some of the leaf and stem material above ground may decompose after a single season.

c. Why is the role of wetlands in taking up and storing carbon important in the context of climate change?
   Carbon dioxide is a heat trapping gas that is considered a major factor in accelerating the warming trend of the global climate system. Wetlands can remove carbon dioxide from the atmosphere via photosynthesis and can store it for long periods in the soil.

4. Have students examine the two "*Charts of Carbon in Coastal Ecosystems*" and answer the Guiding Questions individually, in groups, or as a class.

Guiding questions for charts of carbon in coastal ecosystems

a. What is being measured?
   In Chart 1, Rates of carbon sequestration; in Chart 2, Average amount of carbon stored per hectare (a hectare is about 2.5 acres)

b. If there are two or more factors, what is being compared?
   Various types of ecosystems are being compared.

c. What are the units of measurement?
   In chart 1, grams of carbon per square meter per year; in chart 2, tonnes of CO2 equivalent per hectare (see notes in captions for explanations)

   What is the range of values?
   Chart 1, from < 10 to > 1000 grams of carbon per square meter per year;
   Chart 2, from 500 to > 2500 tonnes of CO2 equivalent per hectare

   Is the scale linear or logarithmic?
   Chart 1: logarithmic; Chart 2, linear

d. Describe the general pattern of values.
   Answers will vary

e. Describe the major point made in the chart.
Chart 1: wetlands sequester C at greater rates than other types of ecosystems;
Chart 2: most wetlands carbon is stored in soils, and mangrove ecosystems have the highest rates of carbon storage in soil.

f. What parts of the chart appear to have the greatest differences? The smallest differences?
Answers will vary

g. Make a prediction based on the data in one of the tables or charts; for example, if you were to measure the carbon in the soil of a nearby forest and a salt marsh, what would you expect to find?
Answers will vary

5. Discuss with students:
    a. What observations or statements can you make based on this data?
    Answers will vary

    b. What questions do you have? Where could you find information to answer the question?
    Answers will vary

    c. According to these graphs and tables, how do wetlands compare with other habitats in their ability to take up and store carbon?
    Wetlands take up and store carbon at greater rates than other ecosystems shown in these charts.

    d. Compare the rate of carbon uptake or the long term rate of carbon accumulation in various habitats. Choose two habitats and calculate the comparison of carbon storage between them using a ratio.

    For example, from the first chart on carbon burial rates, temperate forests sequester about 7 grams of carbon per square meter per year, while seagrasses sequester about 150 grams of carbon per square meter per year; dividing the ration of 150/7 tells us that seagrasses sequester carbon at a rate about 21.4 times that of temperate forests.

Blue is the New Green

carbon storage in coastal wetlands

Benefits of a Healthy Coast

Most of us who live or vacation on Cape Cod are attracted by the beauty, recreational, and economic opportunities of the coast. However, coastal communities like ours are among the most vulnerable to threats such as sea level rise, intense storms, erosion, and flooding.

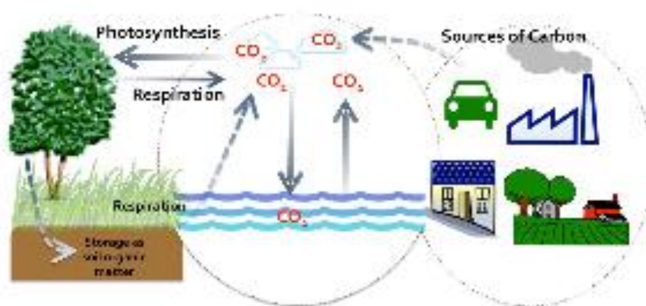
WETLANDS are one line of defense against these threats. Characterized by plants adapted to frequent flooding, they are a widespread feature of our landscape. In fact, wetlands make up 12-16% of the land on Cape Cod – an area about the size of Nantucket Island. In addition to comprising a central and important part of our landscape, wetlands provide a number of **ECOSYSTEM SERVICES** – essential benefits to our economy and culture. These services include:

- **Erosion control**
- **Flood protection**
- **Clean water**
- **Healthy fisheries**
- **Biodiversity protection**
- **Aesthetics and recreation**
- **Carbon sequestration (storage)**

Wetlands on Waquoit Bay, MA.

Carbon Storage

Of these many benefits, **CARBON SEQUESTRATION**, or storage, is getting increased attention as a way to reduce excess carbon dioxide (CO_2) and other greenhouse gases in our atmosphere from the burning of fossil fuels. These gases are leading to negative impacts worldwide on climate, food production, and human health and livelihoods. To counteract this trend, people are looking not only at reducing greenhouse gas emissions, but also at protecting and enhancing ecosystems that naturally sequester them.



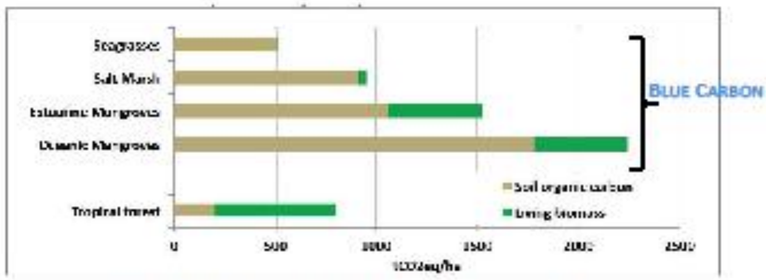
The Carbon Cycle

BIOLOGICAL CARBON SEQUESTRATION is a process in which carbon is captured through photosynthesis by trees, plants, or other organisms, and stored in soils or other organic matter such as leaves and roots. Maximizing biological carbon sequestration by protecting and restoring ecosystems which naturally do this well, can help balance the amount of carbon in our atmosphere.

Blue Carbon

It is well known that forests take in and store large amounts of atmospheric carbon; this is known as *GREEN CARBON*. However, less is known about carbon that is absorbed and stored by ocean and coastal ecosystems like wetlands and tropical mangroves, known as *BLUE CARBON*.

Research suggests that coastal wetlands capture and store carbon at rates three to five times greater than tropical forests, which makes them efficient and essential carbon sinks (Murray et al., 2011).



Carbon storage abilities of different habitat types.
Units are in tons of carbon dioxide equivalent per hectare.
Source: Murray et al., 2011

How do wetlands store carbon?

High carbon sequestration occurs in ecosystems where plants convert a lot of carbon dioxide to oxygen (*photosynthesis*) and where there is a lot of organic matter. Wet soils have the highest capacity for carbon storage because they have low oxygen levels, which slows down decomposition. This means the carbon in the soil can remain there for centuries.

If wetlands are able to keep up with sea level rise (through a process known as accretion or the building up of soils), then they could potentially store even more carbon in their soils because of the increase in soil depth.

Threats to Blue Carbon

Research suggests that nitrogen from septic systems, stormwater runoff, and the air can significantly reduce a wetland's ability to store carbon.

In some cases, high nitrogen pollution can increase the rate at which carbon breaks down in coastal wetland soils, leading to the release of carbon dioxide and nitrous oxide (a greenhouse gas that is about 300 times more powerful than carbon dioxide). Additionally, when wetlands are damaged or destroyed for development or agriculture, they release their store of soil carbon, which contributes to climate change and permanently removes that wetland as a natural sink for future carbon. Maximizing the potential of wetlands to store carbon must not only include protecting and restoring these areas, but also reducing the amount of nitrogen that enters them.

- *Nationwide, wetlands are disappearing at a rapid rate.*
  In Massachusetts, we have lost more than 40% of our salt marshes since pre-colonial times.
- *Though wetland restoration goals & plans exist throughout the U.S., research has shown that we are meeting less than 3% of these goals annually.*
- *Nitrogen entering Cape Cod estuaries has increased dramatically over time following increases in population and development. Most of the nitrogen entering groundwater and adjacent estuaries comes from wastewater (residential septic systems).*

Importance to Local Communities

It is clear that our economy and way of life on Cape Cod are dependent on healthy wetlands, not only because of their aesthetic and recreational benefits, but because of the role they play in mitigating the impacts of climate change, cleaning up our water, protecting us from storms and erosion, and providing important habitat. Protection of the resources of the region and the natural benefits they provide should therefore be an integral part of planning and decision-making. For instance, preserving and restoring Cape Cod's wetlands will help buffer impacts of storms and store large quantities of atmospheric carbon, increasing resilience to climate change. By protecting coastal marsh integrity, towns will reduce future costs, minimize health and safety impacts, and lessen damage to natural resources and built infrastructure.

Monitoring fish populations in a Cape Cod estuary.

Osprey use wetlands for nesting and feeding.

Wetlands offering flood protection during Hurricane Sandy, 2012.

Bringing Wetlands to Market – *Nitrogen and Coastal Blue Carbon Project*

A 3-year project is currently underway, led by the Waquoit Bay National Estuarine Research Reserve, examining the relationship between coastal wetlands, climate change, and nitrogen pollution – critical issues facing many coastal communities. The project team aims to generate science and management tools to:

- Support wetlands protection and conservation efforts
- Manage nitrogen pollution
- Create policies and economic incentives to reduce greenhouse gases

The project team is working collaboratively with end-users, such as the wetlands restoration community, coastal resource managers, conservation organizations, and local towns to ensure that the project results and tools are used.

Scientists measuring dissolved gases between the salt marsh and adjacent estuary.

Gas chamber on marsh measuring greenhouse gas exchange between the salt marsh and the air.

To learn more about

BRINGING WETLANDS TO MARKET – NITROGEN AND COASTAL BLUE CARBON PROJECT

please visit: www.wbnerrwetlandscarbon.net

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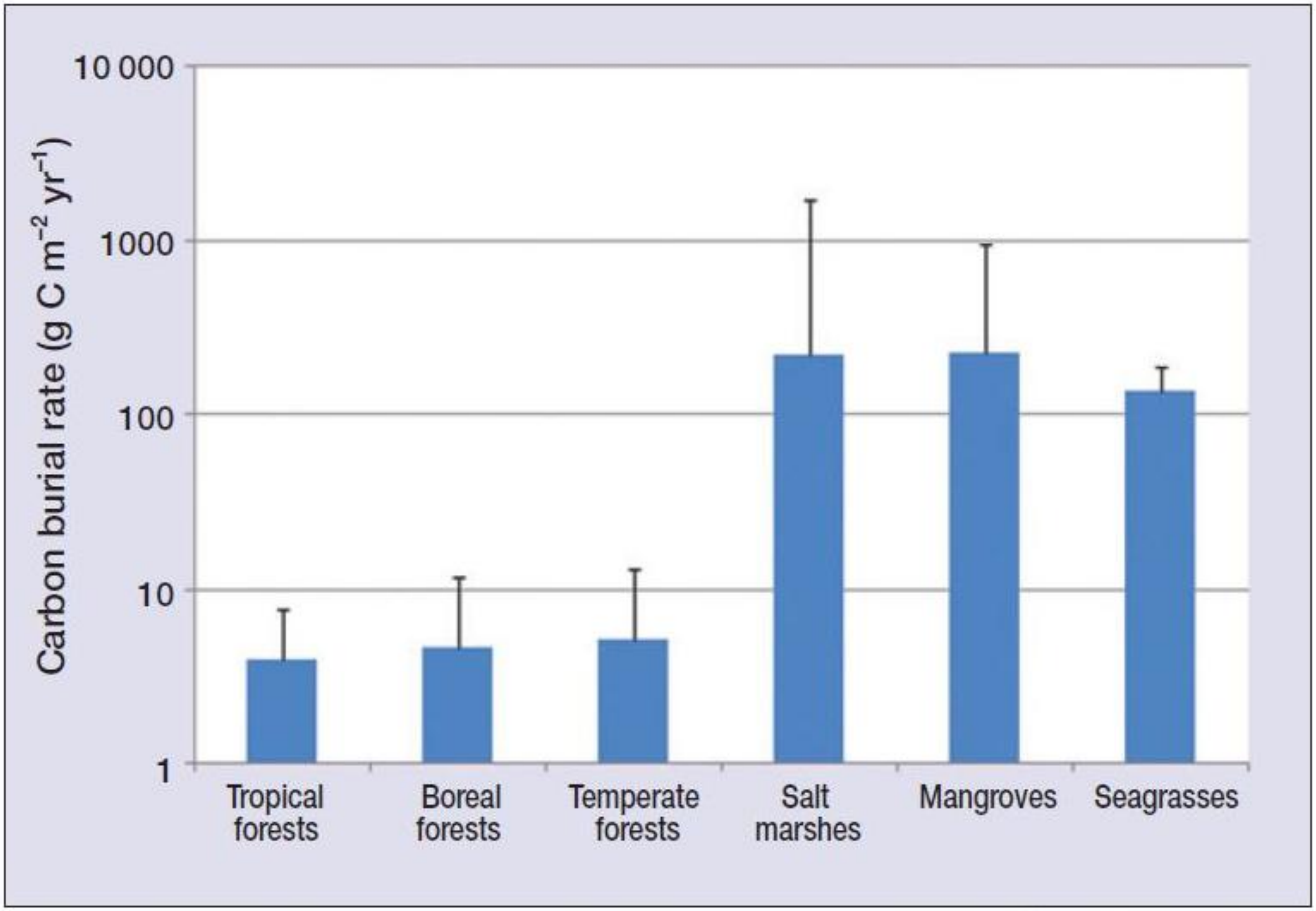
Project Partners:

Chart 1: Rates of carbon sequestration

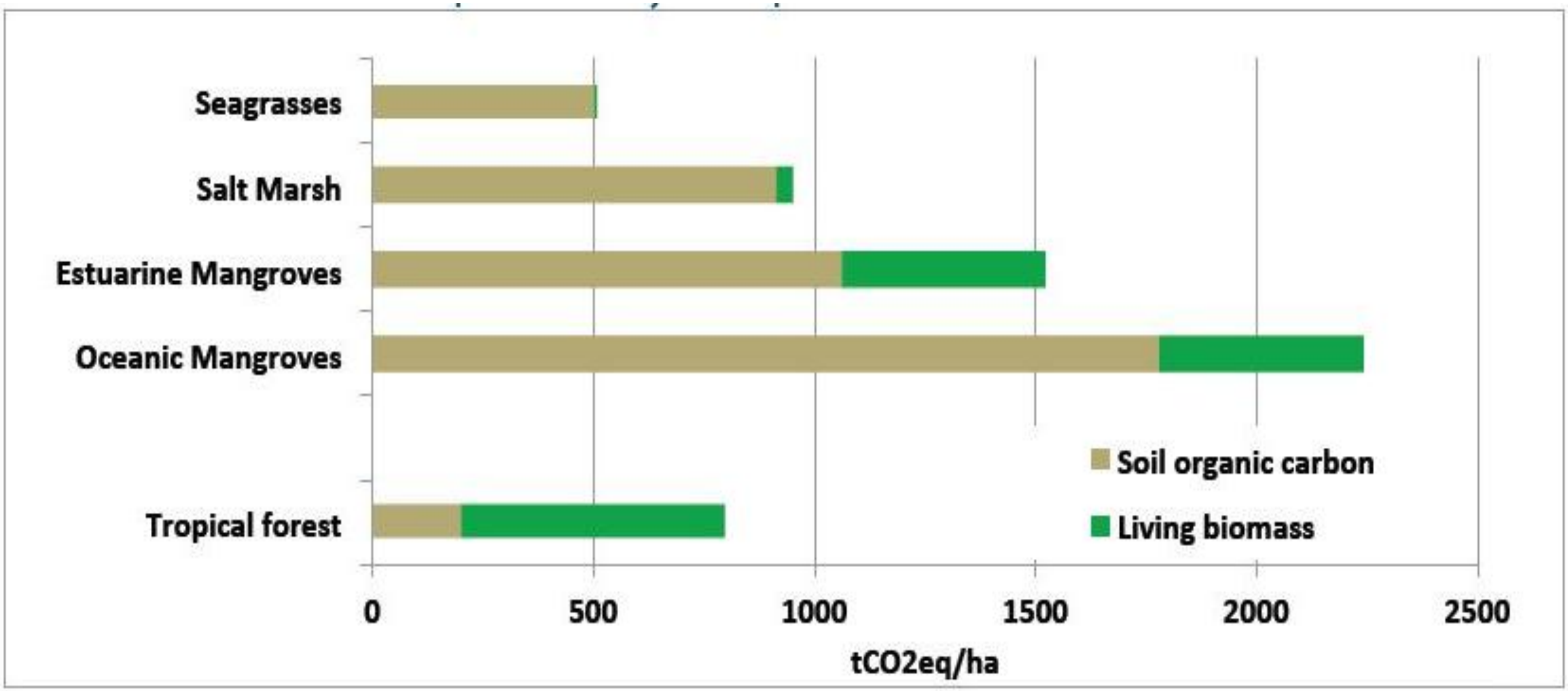


Mean long-term rates of C sequestration (g C m–2 yr–1) in soils in terrestrial forests and sediments in vegetated coastal ecosystems. Error bars indicate maximum rates of accumulation. Note the logarithmic scale of the y axis. Data sources are included in Tables 1 and 2.

Notes: 1. The Y axis label "carbon burial rate" refers to the carbon sequestration rate. 2. The term "g C m^{-2} yr^{-1}" is read "grams of carbon per square meter per year"

Source: *A blueprint for blue carbon: toward an improved understanding of the role of vegetated coastal habitats in sequestering CO_2*. 2011.Elizabeth Mcleod, Gail L Chmura, Steven Bouillon, Rodney Salm, Mats Björk, Carlos M Duarte, Catherine E Lovelock, William H Schlesinger, and Brian R Silliman *Front Ecol Environ*; 9(10): 552–560, doi:10.1890/110004 (published online 20 Jun 2011)

Chart 2: Average amount of carbon stored per hectare



Global averages for carbon pools (soil organic carbon and living biomass) of selected coastal habitats.
Tropical forests are included for comparison. Only the top meter of soil is included in the soil carbon estimates.

Notes: To clarify the term " t CO2 eq/ha" or "tonnes of CO2 equivalent per hectare": these systems store carbon, which if disturbed is returned to the atmosphere in the form of carbon dioxide (CO_2). The authors use CO_2 equivalent as units of measure here because of the emphasis on carbon in the climate system and the fact that carbon trading is based on CO_2 equivalent units. Metric tonnes (1,000 kg or about 1.1 US tons) and hectares (about 2.5 acres) are the unit of measure.

Source: Murray , B., Pendleton, L., Jenkins, W.A., and Sifleet, S. 2011. Green Payments for Blue Carbon: Economic Incentives for Protecting Threatened Coastal Habitats. Nicholas Institute Report. NI R 11-04.

Pictures of mangroves, eelgrass, and salt marsh (Images from NOAA)
These ecosystems take up and store carbon at higher rates than tropical forests, temperate forests, or boreal forests. See BWTM Part 1 Exercise 2 for more information.

Mangrove swamp

Eelgrass meadow

Salt marsh