

**Breathing In**

Featured scientists: Dr. Kristina J. Anderson-Teixeira, Smithsonian Conservation Biology Institute & Dr. Susan C. Cook-Patton, The Nature Conservancy. Written by Ryan Helcoski

*Research Background:*

Plants use the process of **photosynthesis** to trap the energy of the sun within the molecular bonds of **glucose** (C6H12O6, a type of sugar).

All living things require oxygen for **cellular respiration** to free the energy stored within those glucose molecules for all cellular processes.

We get our glucose from the food we eat and our oxygen from the air we breathe. Since trees and other photosynthetic organisms, like algae, provide us with oxygen as a byproduct of photosynthesis they’re often portrayed as the lungs of the planet “breathing out” oxygen. But there’s another aspect of photosynthesis that’s just as important. Look at the photo of the massive tree below (to the right/left?). How did that tree get so big? The answer is in the equation for photosynthesis where carbon dioxide and water provide the carbon, hydrogen, and oxygen necessary to build glucose. Trees use glucose as both an energy source and construction material. They arrange glucose in long winding structures as they grow and some of it becomes part of them for as long as they live. This process of pulling carbon out of the atmosphere and holding on to it like that for long periods of time is known as **carbon sequestration**, it’s what the trees do when they “breathe in.” And that’s what Kristina and Susan were interested in.

They knew that the Earth’s climate was heating up due to human activities like burning fossil fuels which release **greenhouse gases** like carbon dioxide into the atmosphere. They also knew that many forests around the world had been cut down and regrowing them was a natural climate solution, since more trees means more carbon sequestration and more carbon sequestration means less carbon dioxide in the atmosphere. However, they wanted to know how carbon sequestration rates differ between habitat types. They also wanted a more accurate assessment of the full potential of forest regrowth since they believed that current estimates were limited by uncertainty and variability.

To answer these questions they needed to do a lot more than a few studies in a single area, they needed to analyze thousands of studies in locations from all over the world. So that’s exactly what Kristina did when she and other researchers from around the world began their work on creating **ForC,** the Global Forest Carbon Database.

ForC is an open-access database containing over 30,000 records from 5,000 plots in 3,325 geographically distinct areas. All of the data comes from published research by accredited scientists and includes studies from every forested biogeographic and climate zone. It is a living database that is continually updated as scientists publish their work, making it the most complete source of forest carbon data in the world.

Together with many other researchers Kristina and Susan used the ForC database to investigate global carbon capture. They predicted that regrowing tropical forests would have the highest rate of carbon accumulation. They also wanted to check whether the default forest regrowth rates from the Intergovernmental Panel on Climate Change (IPCC) were accurate.

In order to measure carbon sequestration they chose the unit **MgC/ha/yr** which is a measure of the **megagrams** (a metric ton, which is a little less than a U.S. ton)of **carbon** (from carbon dioxide) sequestered by a **hectare** (2.5 acres, about 75 football fields)of forest per year. Using ForC they selected a total of 13,112 georeferenced measurements of carbon accumulation from around the world. Then they grouped the measurements by forest type, averaged them, and compared that to the IPCC values. With these values they could help to better inform policy decisions and prioritize forest regrowth in different parts of the world.

*Scientific Question*: How does forest carbon sequestration differ by habitat type? How do the estimates of ForC compare to those predicted by the IPCC?

*What is the hypothesis?* Find the hypothesis in the Research Background and underline it. A hypothesis is a proposed explanation for an observation, which can then be tested with experimentation or other types of studies.

*Scientific Data:*

**Use the data below to answer the scientific question:**

Instructions Part 1:

* Students will create a line graph or scatterplot. The data is not a time series so a line graph isn’t the best choice, but it does help in visualization.
* The specific location goes on the x axis and the annual carbon sequestration goes on the y axis.
* Students should graph both the ForC and IPCC estimates
* It may be useful to also section off the four forest types and/or color code them. This looks a bit too messy in Excel but could look better in R or if done by hand.
* The idea is to get a decent visualization of the different locations and an idea of the difference between ForC and IPCC

Instructions Part 2:



* Get an average for each biome from both ForC and the IPCC
* Create a graph with the Biome on the x-axis and the Annual Carbon Sequestration on the y axis.
* Graph the averages from the IPCC and ForC side by side for each biome
* Calculate the percent difference between ForC and IPCC ((ForC/IPCC) – 1) x 100, but do not graph it. This will only be for later data analysis.

What data will you graph to answer the question?

Independent variable: Habitat

Dependent variable: Annual Carbon Sequestation (MgC/ha/yr)

*Draw your graph below*: Identify any changes, trends, or differences you see in your graph. Draw arrows pointing out what you see, and write one sentence describing what you see next to each arrow.

*Interpret the data:*

Make a claim that answers the scientific question.

The data show that Forest carbon accumulation is, on average highest in the tropical forests as estimated by both ForC (3.07 Mg/ha/yr) and the IPCC (2.09 Mg/Ha/yr). Forest carbon accumulation calculated as estimated by the IPCC is on, average, lower than these more precise measurements. ForC’s average regrowth rate in tropics was 46% higher than IPCC’s estimate, and 92% higher than the IPCC’s estimate in the boreal forest.

What evidence was used to write your claim? Reference specific parts of the table or graph.

Students should discuss how the average annual carbon accumulation rate in the tropical forests is higher than that of other forests. While there are some locations outside of the topics with higher rates of accumulation, more than half of the tropical rates are higher than every other forest. They may choose to discuss specific forests or just compare averages. They can also compare the tropical average of forest accumulation to the overall average. In addition, the IPCC underestimated carbon sequestration in most ecozones, students may discuss the topics where the difference is very obvious or discuss differences per zone. Overall the IPCC underestimated carbon sequestration by 33%.

Did the data support Kristina and Susan’s hypotheses?  Use evidence to explain why or why not.  If you feel the data was inconclusive, explain why.

Hypothesis 1: That regrowing tropical forests have the highest rate of carbon accumulation. This hypothesis was supported by both the average ForC (3.07) and IPCC (2.09) measurements that are higher than any other Biome.

Hypothesis 2: That the IPCC estimates on forest regrowth are accurate. This hypothesis was not supported, especially in the tropical biome. The temperate and subtropical biomes were very close in estimation, but the Boreal forest was calculated as 92% higher by ForC and the Topical forest was 46% higher.

Make a recommendation on where in the world reforestation efforts should be intensified if your goal was to have the biggest possible impact on fighting global warming. Connect the data back to what you learned about photosynthesis.

Students should discuss how regrowth in the tropics would be best due to the high rates of sequestration. They should explain how photosynthesis is necessary for carbon accumulation and may choose to write the formula.

*Your next steps as a scientist:* Science is an ongoing process. What new question do you think should be investigated? What future data should be collected to answer your question? What do you think should come next?

Natural forest regrowth is a very real strategy to help in climate mitigation that not only captures carbon but also provides additional benefits such as stabilizing biodiversity. The biggest finding here is that the IPCC underestimated the rates of carbon accumulation meaning this strategy is even more beneficial than previously thought. Students can suggest using the data to carry out regrowth efforts and then measuring those efforts over time to carry out even larger scale regrowth.

It is undeniable that the current goal of stabilizing carbon emissions is challenging. It will require not only a reduction in emissions but also an increase in sequestration. Students may suggest further research on other forms of sequestration or studies that delve into different types of regrowth. There are some species of trees that sequester carbon more rapidly than others, students may suggest trying to figure out the ideal combination of tropical plants to achieve the highest rate of carbon accumulation. It is possible students will also suggest studies of soil carb accumulation, which is another major aspect of the published study.