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What is Carbon and the Carbon Cycle?*

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This publication describes carbon and the carbon cycle to give a basic understanding of what it means to sequester carbon in the soil.

Carbon (C) is *the* building block of life. It is the fourth most abundant element in the universe, after hydrogen (H), helium (He) and oxygen (O). All life is made up of carbon. Fifty percent of the dry weight in the human body is made up of it. It also exists in the environment as an element in carbonate rocks, petroleum, natural gas, steel, organic matter, and the air we breathe.

In the form of carbon dioxide, carbon is a greenhouse gas. Massing of greenhouse gases in the atmosphere threatens to raise the temperature of the earth, raising sea levels and disrupting the climates that agricultural systems depend on. The concentration of CO_2 in the atmosphere has increased by 30 percent since the beginning of the industrial revolution. Most of the increase has come from -- and will continue to come from -- the use of fossil fuels. However, 20 to 25 percent of the increase over the last 150 years has come from changes in land use, such as the clearing of forests and the cultivation of soils for food production.[1]

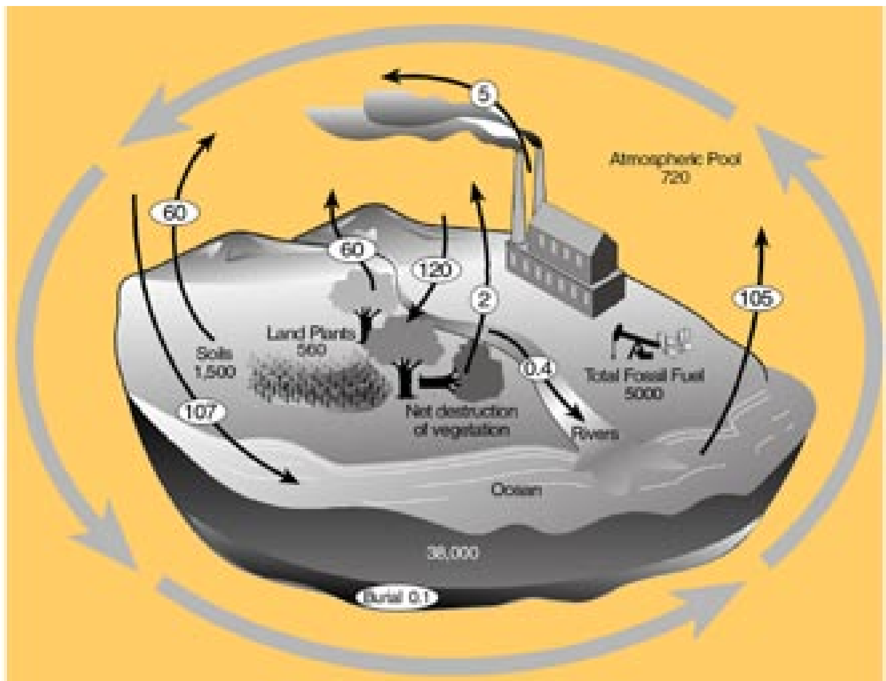

Figure 1. The present-day global carbon cycle, illustrating the movement of carbon between the five carbon sinks. Carbon is expressed in units of gigatons and rates are expressed as gigatons of carbon per year.

Carbon Sinks

Forests, soils, oceans and the atmosphere store carbon. These stores can act as *sources* or *sinks* at different times. *Sources* release more carbon than they absorb, while *sinks* soak up more than they emit. A carbon sink can store carbon for a long period of time. Carbon on Earth is stored in the following major sinks: [2]

1. ***Lithosphere*** (Earth's crust). The lithosphere consists of fossil fuels and sedimentary rock deposits such as limestone, dolomite and chalk. It is by far the largest carbon sink on earth.
2. ***Oceans.*** Ocean waters contain dissolved carbon dioxide and calcium

CASMGS
Consortium for Agricultural Soils Mitigation of Greenhouse Gases

This MontGuide is one in a series exploring the potential of agricultural sequestration of carbon. Soil carbon sequestration can be used to reduce the level of greenhouse gases in the atmosphere. Montana State University - Bozeman in collaboration with nine institutions will provide the data and analysis needed to explore the potential of this new market for agricultural producers. More information and accompanying publications can be found at **www.casmgs.montana.edu.**

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carbonate in the form of shells and marine organisms.

3. *Soil Organic Matter.* In general, soil organic matter is the organic constituent of soil and includes decaying plant and animal tissues, chemical by-products created during decay, and soil biomass (anything living in the soil such as plant roots, microbes or fungus).
4. ***Atmosphere.*** Carbon exists in the atmosphere in the form of carbon dioxide.
5. ***Biosphere.*** This pool consists of all living and dead organisms not yet converted into soil organic matter.

Carbon cycle

The movement of carbon, in its many forms, between the five major sinks mentioned above is described as the *carbon cycle*.

The basic carbon cycle is:

1. Plants convert atmospheric carbon dioxide to carbohydrates by photosynthesis;
2. Animals and microorganisms consume and oxidize these carbohydrates to produce carbon dioxide and other products; and
3. Carbon dioxide returns to the atmosphere. On a global level, the total carbon cycle is more complex and involves carbon stored in fossil fuels, soils, oceans and rocks.

Carbon in the earth's crust

Carbon moves back and forth among the various sinks through respiration, decay and burning. However, nearly all of the carbon on earth is confined within the lithosphere. Within the lithosphere, carbon exists in many inorganic and organic forms. Carbonate minerals are among the most abundant and widely distributed on Earth. They take the form of limestone, dolomite and marble, among others. In its organic form, carbon is distributed in the lithosphere as coal, oil, natural gas, and plant and animal tissue. Only the carbon stored in the lithosphere as fossil fuels enters the carbon cycle, and then, only through human activities.

Carbon in the oceans

Carbon dioxide can be diffused within ocean waters. The ocean absorbs 2.5 gigatons more carbon from the atmosphere than it gives off, but that extra amount of carbon is utilized by marine organisms and eventually gets incorporated into deep sea deposits and sediments. Thus the net level of carbon in the ocean remains roughly the same every year.

When atmospheric carbon is dissolved in seawater, it can be converted into carbonate or bicarbonate. Certain forms of sea life biologically fix bicarbonate with calcium to produce calcium carbonate. Coral, clams, oysters and other organisms use this substance to produce shells and other body parts.. When the organisms die, the calcium carbonate materials sink to the ocean floor, where they eventually become part of sedimentary rocks.

Carbon in the soil. The soil organic matter sink is currently losing about 1 to 2 gigatons of carbon per year to the atmospheric pool. Changes in land use patterns and agricultural practices can affect the amount of carbon released into the atmosphere from organic matter in the soil. For example, switching from conventional tillage to no-till practices can reduce the amount of carbon dioxide released from the soil.

As the carbon cycle undergoes shifts and fluxes throughout the years, the amount of carbon in the atmosphere tends to increase or decrease. Currently, the atmospheric carbon sink is expanding by about 6.1 gigatons per year, and the fossil fuel carbon pool is shrinking by about 4 to 5 gigatons per year. This aspect of the carbon cycle can be manipulated by human activity.

Carbon in the biosphere

Finally, the biosphere represents a significant carbon pool. Plant life absorbs about 110 gigatons of atmospheric carbon per year through photosynthesis. Of that amount, about 60 gigatons are released back into the atmosphere through respiration, decay and gaseous waste from living organisms, both on land and in the ocean. The other 50 gigatons are incorporated into soil organic carbon, part of which can be readily oxidized and part of which is relatively stable for many years.

Table 1, The Atmospheric Carbon Balance Sheet, illustrates where atmospheric carbon originates and where it goes. By noting what changes can be made to reduce carbon buildup in the atmosphere, humans may be able to manipulate the carbon cycle to stop or slow the increase of atmospheric carbon.

Table 1. Atmospheric Carbon Balance Sheet

Factor	**Carbon emissions flux into atmosphere** (gigatons C/year)	**Movement of C out of atmosphere** (gigatons C/year)
Fossil fuel burning	4 – 5	
Soil organic matter oxidation / erosion	61 - 62	
Respiration from organisms in biosphere	50	
Deforestation	2	
Incorporation into biosphere through photosynthesis		110
Diffusion into oceans		2.5
Net	117 - 119	112.5
Overall Annual Net Increase in Atmospheric Carbon	+ 4.5 - 6.5	

Summary

Where atmospheric carbon originates:

1. **Fossil fuel emissions.** This is the largest source of carbon buildup in the atmosphere.
2. **Soil organic carbon destruction.** Through tillage and soil erosion, soil organic carbon can be oxidized and lost to the atmosphere. The total amount of carbon stored as soil organic carbon is roughly equal to the sum of the amount in the atmosphere plus the amount existing in plant and animal life combined. Therefore, any changes in soil organic matter destruction or creation can have a significant impact on atmospheric carbon levels.
3. **Deforestation.** As forests are burned for land clearing or other reasons, a significant amount of carbon is released into the atmosphere.

Where atmospheric carbon goes:

1. **Diffuses into the ocean.** This part of the carbon cycle is difficult to manipulate.
2. **Into plant life.** This can be increased by increasing plant growth through reforestation, making changes in agricultural cropping systems, and reclaiming marginal land.
3. **Into soil organic carbon.** As plant life decays, part of its carbon is converted by microorganisms into soil organic matter. In the initial phases of this process, the organic matter is in a "short-term" pool and can be easily oxidized. Once this happens, the carbon is released back into the atmosphere. By changing agricultural practices such as cropping and tillage systems, it is possible to increase the amount of soil organic carbon in the intermediate and long-term pools.

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References

[1] The Woods Hole Research Center, http://www.whrc.org

[2] Forests and the European Union Resource Network, http://www.fern.org

http://www.montana.edu/wwwpb/pubs/mt200408.html

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