

# Communicating Climate Change

Module 7

An initiative of the National Agriculture and Climate Change Action Plan

August 2008

## The carbon cycle and land management

### Key facts

- The carbon cycle is the movement of carbon between the Earth's four major carbon stores—its atmosphere, oceans, living organisms (vegetation and soil) and the Earth's crust.
- The carbon cycle was broadly in balance before the industrial revolution in the 18th century. Human activities, such as deforestation and the burning of fossil fuels, have significantly upset the natural balance by rapidly releasing more carbon into the atmosphere from long-term carbon stores.
- The atmosphere contains about 750 billion tonnes of carbon, more than 99 per cent of which is in the form of carbon dioxide. Vegetation contains about 610 billion tonnes. Soils contain about 1580 billion tonnes.
- Human activities add 7.9 billion tonnes of carbon a year to the atmosphere. About half of this is absorbed by the oceans and plants. The other half stays in the atmosphere and is responsible for much of the enhanced greenhouse effect and global warming.
- Deforestation and the burning of fossil fuels are the main contributors to higher greenhouse gas concentrations, as caused by humans.
- Cultivating soil also releases carbon dioxide from organic matter in the soil.
- Using nitrogen fertiliser releases nitrous oxide to the atmosphere. Nitrous oxide has a global warming impact around 300 times that of carbon dioxide.
- Grazing livestock releases methane (from rumen digestion and manure) and nitrous oxide from manure. Methane has a global warming impact 25 times that of carbon dioxide.
- Research into land use and agricultural management practices is seeking to provide practical ways to reduce emissions from cropping and grazing activities.

### About carbon

The chemical element carbon is an essential component of all living organisms. All living things, from bacteria to plants, animals and humans, contain carbon.

Dead and decaying matter that was once living (organic matter) still contains carbon.

Material derived from organic matter, such as timber, leather and humus in the soil, also contains carbon. Over millions of years some of this organic matter has been transformed in the Earth's crust by heat and pressure to form high-energy fossil fuels such as coal and oil. The energy in these forms of carbon is released when they are burnt.

A cooperative venture between



**Australian Government**  
**Department of Agriculture,**  
**Fisheries and Forestry**  
**Bureau of Meteorology**



## The carbon cycle

The carbon in living organisms and in the products derived from them has been absorbed from the atmosphere. It is returned to the atmosphere by a number of processes that occur over different time periods. We call this the carbon cycle (Figure 1).

The atmosphere, the oceans, the Earth's crust and its living organisms (the biosphere) are major reservoirs of carbon. These reservoirs are sometimes called **carbon stores** or **carbon sinks**.

The complex processes by which the carbon moves from one store to another are referred to as **carbon fluxes**.

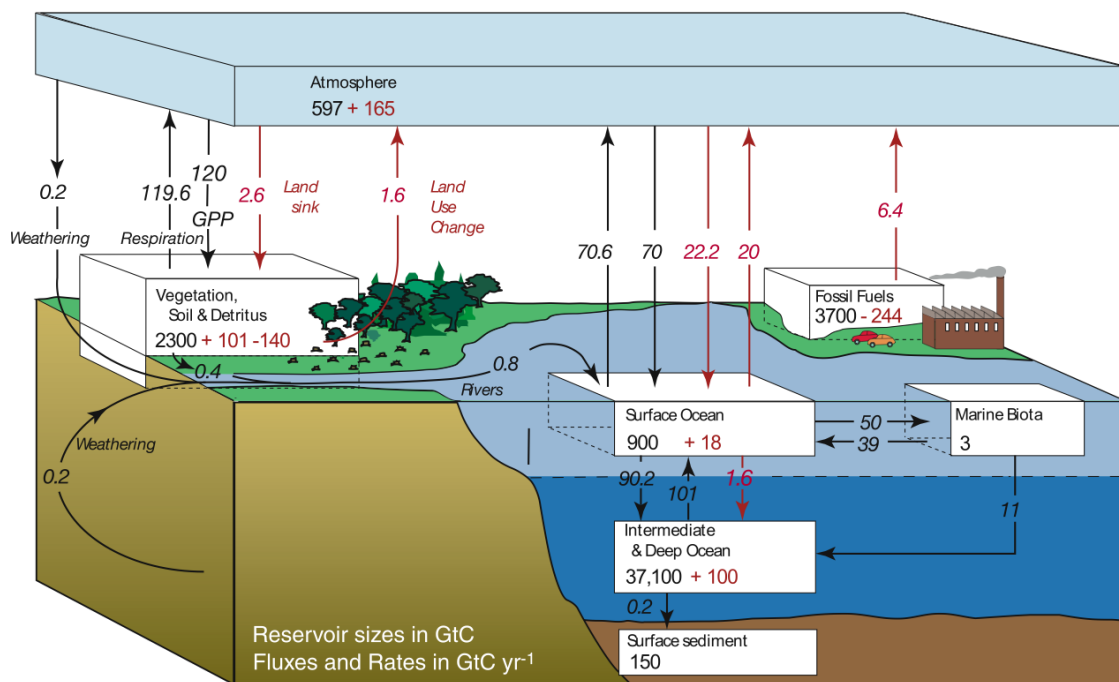


Figure 1: The global carbon cycle showing the natural (black) and the human-induced (red) stores and fluxes (IPCC 2007)

Carbon moves naturally between and within the major reservoirs and humans are a natural part of this cycle.

However, since the industrial revolution the amount of carbon being added to the atmosphere by human activities has exceeded the amount that can be processed in the natural flows. This is upsetting the natural balance. The result is an increase in carbon-containing molecules in the atmosphere, particularly carbon dioxide.

The amount of carbon stored in or moving between reservoirs in the cycle is large. It is measured in units of billions of tonnes, or gigatonnes.

1 gigatonne (Gt) = 1 billion tonnes = 1000 million tonnes

There are now about 750 billion tonnes of carbon in the atmosphere, mostly in the form of carbon dioxide.

Understanding how our activities affect the natural carbon cycle is a first step in addressing climate change.

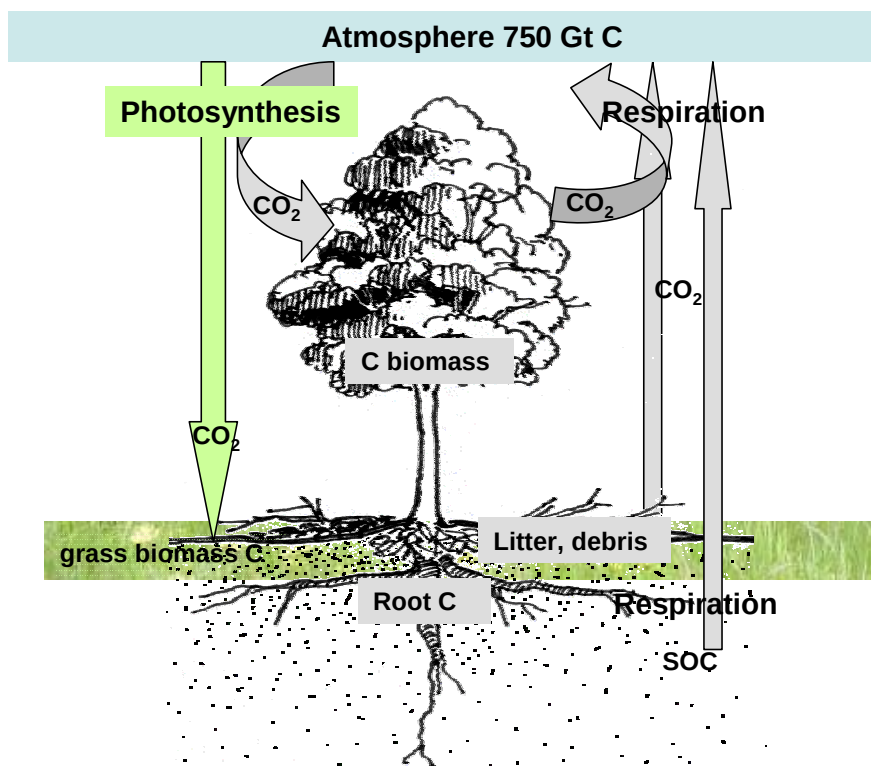


Figure 2: In natural systems, the carbon exchange between the biosphere and the atmosphere is roughly in balance.

## How we affect the carbon cycle

Carbon dioxide and several other gases in the atmosphere are called **greenhouse gases** because they have the effect of trapping heat from the sun. This trapped heat keeps the temperature of the Earth's surface at the level necessary to support life.

Water vapour is the most abundant greenhouse gas but our activities have only an indirect effect on its concentration.

In contrast, we have a large impact on **carbon dioxide**, **methane** and **nitrous oxide**. Carbon dioxide is the most important greenhouse gas in terms of the human impact on global temperatures.

The measurement unit usually used for greenhouse gases is '**carbon dioxide equivalents**' or CO<sub>2</sub>-e. It relates different greenhouse gases to the amount of carbon dioxide that would cause the same amount of warming, allowing us to compare the different gases.

Carbon dioxide concentrations in the atmosphere are the highest they have been for 420 000 years. The rate of increase in greenhouse gas concentrations in the atmosphere is faster than it has been for at least 20 000 years and is important to our ability to adapt.

## How plants affect the carbon cycle

Plants grow by absorbing carbon dioxide from the atmosphere in the process of **photosynthesis**. Photosynthesis incorporates the energy from sunlight with the carbon from carbon dioxide to form simple sugars like glucose.

When plants use energy to grow—using a process called **respiration**—some of the carbon is returned to the atmosphere. The rest of the carbon is used to build leaves, wood and roots by converting the sugars to more complex compounds such as proteins. So some of the carbon dioxide absorbed by plants from the atmosphere is returned almost immediately and some may be stored for hundreds of years, for example as wood.



When plants die and decompose, carbon returns to the atmosphere over time. A dead tree may remain standing for decades, releasing carbon at a much slower rate than a fallen leaf.

Some decomposing plant litter, roots and woody debris is incorporated into soil. This happens when microbes break down complex molecules to use carbon and energy for their own growth. Some of the decomposing litter is incorporated into **soil organic carbon**, which provides the structure and water-holding capacity that allow soils to support growth of pastures and crops.

If plants are burnt in wildfires, by controlled **burning** or as firewood for heating in homes, carbon is rapidly released to the atmosphere, mostly as carbon dioxide but also as carbon monoxide and methane, depending on the conditions of burning. Following burning, carbon may also be added to the soil in the form of charcoal which remains stable for many years.

Some of the carbon absorbed from the atmosphere by plants may enter rivers or oceans as a result of **runoff and soil erosion**; it can be trapped in sediments for a long time.

## How animals affect the carbon cycle

When animals consume plants:

- they convert some of the plant carbon into energy and molecules to help them stay alive and grow
- they return some of the carbon to the atmosphere as carbon dioxide in the process of respiration
- they add some of the carbon to the soil through manure

Animals convert some carbon into new high-energy compounds, such as proteins and fats. These are in turn moved through the carbon cycle, for example when humans eat meat.

Ruminant or cud-chewing animals also return some carbon to the atmosphere as methane.

## How land use affects the carbon cycle

Since the industrial revolution in the 18th century, human activities have been adding billions of tonnes of carbon dioxide to the atmosphere each year. Most of the additional carbon is being emitted through the burning of fossil fuels (6.4 gigatonnes of carbon). Another 1.6 gigatonnes results from changes in land use, mainly deforestation.

Almost half of this additional carbon is re-absorbed by vegetation and oceans, and half remains in the atmosphere. The amount of carbon that humans add to the atmosphere is small relative to the large amounts exchanged naturally between the land and the atmosphere, but it significantly changes the balance.

## Agriculture and the carbon cycle

The concentration of greenhouse gases in the atmosphere is influenced by agricultural activities. For example:

- **Cultivating soils** can increase the breakdown of soil organic matter, resulting in higher emissions of **carbon dioxide** to the atmosphere.
- **Applying nitrogen fertiliser** results in emissions of **nitrous oxide**, a strong greenhouse gas.
- **Grazing livestock** can increase emissions of the greenhouse gas **methane** from rumen digestion, and both methane and **nitrous oxide** from manure.

In ruminants such as cattle and sheep, some carbon is converted to methane in the first stage of digestion and emitted when the animal burps. Carbon returned to the atmosphere as methane has a global warming impact 25 times that of carbon dioxide. So, introducing domestic livestock into a pasture system increases the human-induced greenhouse effect (Figure 3).

Researchers in Australia, New Zealand and other countries are trying to find ways to reduce methane emissions from the rumen. Since methane represents a loss of energy and carbon from feed, reducing methane emissions may also improve the efficiency of production for meat or milk.

When manure breaks down, more methane is released to the atmosphere, as is nitrous oxide which has a global warming potential 310 times greater than carbon dioxide.

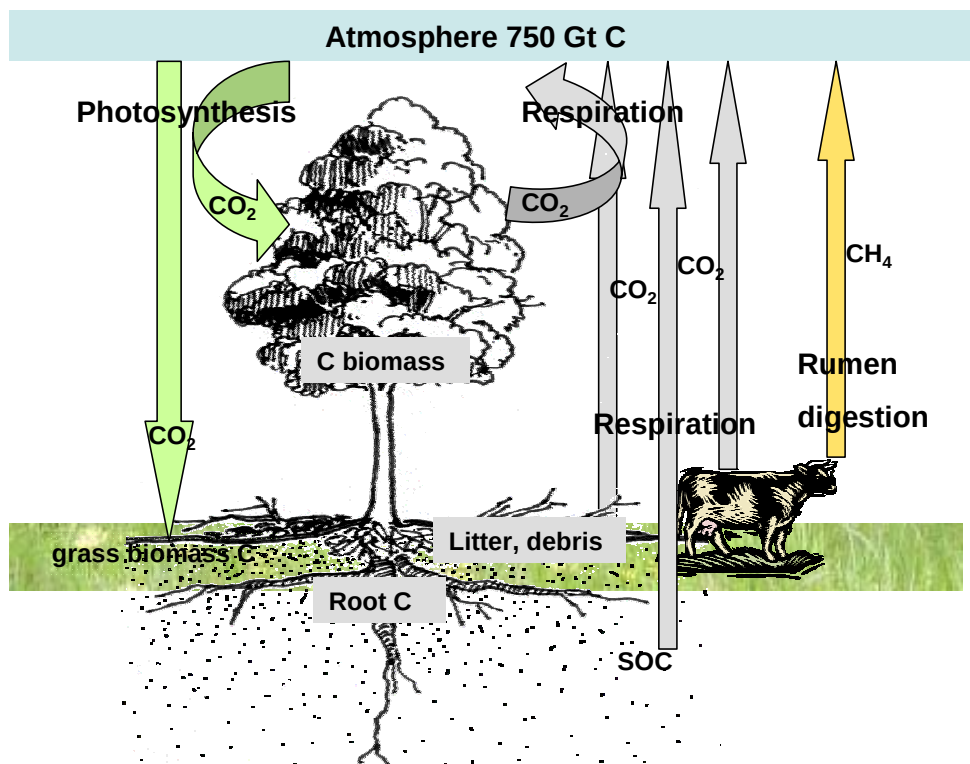


Figure 3: Adding ruminant livestock increases greenhouse gas emissions because methane (CH<sub>4</sub>) has a global warming impact 25 times that of carbon dioxide (CO<sub>2</sub>).

## How farmers can help the carbon cycle

Land that is in good condition generally stores more carbon in the soil than degraded land with less vegetation cover. It is also usually more productive for cropping or grazing. So it is good practice to maintain or increase the amount of carbon stored in landscapes and the condition of agricultural land, as this will have a range of environmental and productivity benefits.

Carbon stores on farms can be increased by planting trees, which store carbon dioxide during growth. Carbon is stored in the living parts of plants (stems, branches, leaves and roots), in leaf litter and woody debris that collect on the ground, and in soil organic matter. The amount of extra carbon removed from the atmosphere by growing trees depends on the climate, soil type, and condition and species of tree.

## Measuring changes in the carbon cycle

It is difficult to measure the human-induced impacts on the natural, very large exchanges of carbon between the Earth and the atmosphere. The changes are relatively small and occur over time periods that vary between less than a day and more than a century. For example, if a tree is cut down and burnt, the rate at which carbon returns to the atmosphere depends on the conditions of burning and the temperature and moisture conditions in which unburnt litter, debris and roots continue to decompose.

The Department of Climate Change has produced an accounting tool based on remote sensing, climate and soils data, and modelling to estimate the carbon stored in Australian forests.

### Sources

The information presented here is sourced from:

- Australian Government Department of Climate Change:  
<http://www.climatechange.gov.au>
- Intergovernmental Panel on Climate Change: <http://www.ipcc.ch>

### Further information

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