REDD+ ACADEMY – LEARNING JOURNAL

1. FOREST, CARBON SEQUESTRATION AND CLIMATE CHANGE

CONTENTS
REDD+ Academy – Learning Journal ........................................................................................................ 1
1. Forest, Carbon Sequestration and Climate Change ............................................................................. 1
Key Messages ........................................................................................................................................... 2
Introduction ............................................................................................................................................... 3
What is causing climate change? ............................................................................................................. 5
The Greenhouse Effect .............................................................................................................................. 5
How does climate change link to the carbon cycle and forests? ........................................................... 7
Expected changes in the future .................................................................................................................. 8
Emissions from forest carbon stocks ..................................................................................................... 10
Carbon sequestration potential of forests .............................................................................................. 12
Forests and climate change mitigation ................................................................................................... 13
Case study ............................................................................................................................................... 14
Exercises ............................................................................................................................................... 14
KEY MESSAGES

- There is increasing evidence from around the world that the Earth’s climate is changing and human activity is the most likely cause;
- The carbon cycle means that vegetation (including forests), soils, oceans and the atmosphere are connected, and it is important to consider the role vegetation and changes in vegetation cover play in controlling overall greenhouse gas emissions and hence climate change;
- As forests contain substantial stores of carbon, their degradation and or conversion to other land cover causes the release of some of the carbon stored within them, conversely their restoration can act as a sink for atmospheric carbon;
- The UNFCC developed REDD+, reducing emissions from deforestation and forest degradation plus the conservation of forest carbon stocks, sustainable management of forests and enhancement of forest carbon stocks, recognizing the potential role of forests in contributing to climate change mitigation.
INTRODUCTION

This module shows evidence that the climate is changing and shows a clear link with human activity. It then presents the role of forests regarding climate regulation.

The module includes explanations about:

- Evidence of human induced climate change and factors influencing the climate;
- The regulatory role of forests;
- How human activity impacts the climate related function of forests.

There is increasing evidence from around the world that the Earth’s climate is changing and human activity is the most likely cause. As the IPCC 2015 AR5 summary report\(^1\) notes: "It is extremely likely that we are the dominant cause of warming since the mid-20th century".

These changes are most obviously seen by increasing average temperatures and rising sea levels. Figure 1.1 shows the average changes in temperature around the world between 1901 and 2012. As can be seen, apart from a couple of light blue areas which represent falling average temperatures, most of the world has experienced an increase in average temperatures represented by the orange/red and purple areas. The global average temperature increase over the period 1880 to 2012 period is 0.85°C.

**Figure 1.1 Map of the observed surface temperature change from 1901 to 2012**

Source: IPCC, 2013

**Reflection Point**

On average have temperatures in your region increased or decreased?

Figure 1.2 shows how temperatures have varied, between 1850 and 2010, in comparison to the average temperature of 1961-1990. The graph shows, for example, that in 1850, the average temperature was 0.4 degrees cooler than the average temperature between 1961 and 1990. The top part of the graph presents the annual averages, while the bottom one shows the average for decadal periods.

**Figure 1.2 Observed Global Mean Combined Land and Ocean Surface Temperature Anomalies**

![Graph showing temperature anomalies from 1850 to 2000.](image)

Source: IPCC, 2013

Figure 1.2 clearly shows that over this period, average temperatures have been increasing, and that the three last decades have been the hottest; each successively warmer at the Earth’s surface than any preceding decade since 1850.

The rise in temperature is not the only evidence of a changing climate: Figure 1.3 illustrates the changes measured in several other ways.

**Figure 1.3 Multiple Observed Indicators of a Changing Global Climate**

![Graphs showing various climate indicators from 1800 to 2000.](image)

Source: IPCC, 2013
Figure 1.3(b) shows that Northern Hemisphere snow cover and Arctic summer ice are falling, particularly since 1960. The melting snow and ice ends up in the oceans, which contributes to higher average sea levels (around 15 cm already over the observed period). In spite of the melting ice water, global upper water layers have warmed since 1950, when the measurements started.

**Reflection Point**

Have you already noticed impacts of climate change? (e.g. changing in the timing of the seasons, species movements, changes in the frequency of extreme events).

Are you aware of any changes within your country that have been attributed to climate change?

Are you aware of the predicted threats from a warming planet on your country or region?

**What is Causing Climate Change?**

As mentioned previously, humans are the most likely cause of recent changes in the earth’s climate, but the climate system is complex, and is influenced by several natural effects such as variations in solar radiation, the natural greenhouse gas effect, naturally occurring aerosols, water currents, etc.

**The Greenhouse Effect**

The greenhouse effect is a natural phenomena through which carbon dioxide in the atmosphere (and a few other Greenhouse Gases (GHGs) including methane and nitrous oxide) keep the solar rays that hit the earth surface from reflecting back into the outer space, thus heating the earth’s atmosphere. Figure 1.4 illustrates the greenhouse effect and how it operates and how GHGs contribute. The GHGs absorb some of the reflected radiation and then re-emit it, including back down to the earth’s surface, heating the atmosphere. There are several GHGs and their impact depends on their ‘global warming potential’, as well as the amount of the gas in the atmosphere. The global warming potential is a factor of:

- The radiative forcing (the net downward flux) due to a pulse emission of the compound (gas);
- How long the compound remains in the atmosphere.

The global warming potential of methane and nitrous oxide are much larger than that of carbon dioxide but a far larger amount of carbon dioxide is emitted into the atmosphere.

In principle, the greenhouse effect is a good thing, as otherwise the planet would be too cold for humans to survive, but the increase in greenhouse gases has led to an increase in the “warming potential” of the atmosphere, and this is related to the changes in the climate observed. Mankind is, in effect, putting an extra blanket around the earth.
There is now a consensus amongst the scientific community that the cause of actual (and future) climate change is anthropogenic (from humans), mainly by the intensification of the greenhouse effect caused by the emission of greenhouse gases in the atmosphere.

The warming of the climate system is unequivocal, and the largest contribution comes from the increase in the atmospheric concentration of carbon dioxide (CO₂), which is man-made. The IPCC states it clearly: it is extremely likely (95%) that human influence has been the dominant cause of the observed warming since the mid-20th century. The figure 1.5 shows how the concentration of atmospheric CO₂, methane (CH₄) and Nitrous oxide (N₂O) have increased in the recent past.

**Reflection Point**

Are the following statements True or False?

Without the greenhouse effect the planet would be too cold to live on.

Climate change is a result of an increase in the concentration of these greenhouse gases mostly from anthropogenic sources, such as the burning of fossil fuels, agriculture and deforestation.
**HOW DOES CLIMATE CHANGE LINK TO THE CARBON CYCLE AND FORESTS?**

Carbon can be found in a variety of different forms and locations. These include in living organisms (including trees and other plants), fossil fuels (coal, oil and gas) and carbon dioxide within the atmosphere. The absolute quantity held within these different locations at a specified time is called the stock, and changes in these stocks are referred to as fluxes. Carbon flows between these stocks through a number of processes collectively known as the “carbon cycle”. The fluxes include natural processes such as plant growth and respiration, and human interventions such as the burning of fossil fuels and destruction of forests. Figure 1.6 below illustrates the global carbon cycle with its stocks and flows, which are shown in two ways:

1. How they were before large human intervention (roughly before 1750 – black figures and arrows);
2. How they were changed with human intervention since the industrial revolution (red figures and arrows).

The ‘historical’ fluxes were generally in equilibrium, the amount going into and out of each stock being about the same. Human actions, such as the burning of fossil fuels, cement production and land use change are creating disequilibrium, through increasing emissions. But these bigger fluxes from ‘sources’ (stocks producing carbon (C) output to the atmosphere) are compensated partly by bigger fluxes from the atmosphere into ‘sinks’ (processes or mechanisms that remove carbon dioxide from the atmosphere), particularly the ocean and the land sinks (this will be revisited later).

**Figure 1.6 Global carbon cycle for the 1990s**

![Global Carbon Cycle Diagram](source: IPCC, 2015)

The carbon cycle means that vegetation (including forests), soils, oceans and the atmosphere are connected, and it is important to consider the role vegetation and changes in vegetation cover play in controlling overall greenhouse gas emissions and hence climate change. Overall, the most recent assessments by the IPCC...
estimate that anthropogenic net CO\textsubscript{2} emissions from land use change represent about 10% of the total anthropogenic emissions (IPCC AR5 WGI\textsuperscript{2}).

**EXPECTED CHANGES IN THE FUTURE**

There is little doubt that climate change is happening, and that it is being caused by human activity through the enhancing of the greenhouse effect by increasing greenhouse gas emissions. Several scenarios have been produced to provide an idea of what the future climate could look like. The scientific community has produced Representative Concentration Pathways (RCP), which are projections based on emission scenarios until 2100. These projections are based on scenarios which describe several ways in which emissions could fluctuate in the future. RCP 8.5 presents a continuous growth of emissions, RCP 6 and RCP 4.5 present intermediate situations, and RCP 2.6 present projection with a scenario of sharp emission reductions. These projections are useful for informing decisions related to future climate. The projections for change in temperature are shown in Figure 1.7.

![Figure 1.7 Simulated time series from 1950 to 2100](image)

Source: [IPCC, 2013](http://www.ipcc.ch/report/ar5/wg1/)

Figure 1.7 shows that unless important action is taken to reduce emissions; there will be drastic changes in the climate which will strongly affect the environment.
Current international agreements have set a goal that the rise in average world temperature should not go higher than 2°C above pre-industrial levels. The link between emissions since the 1850s and temperature increases means that emissions need to be capped at a certain level of cumulative emissions (the level that corresponds to the 2°C increase). If emission rates stay at the current levels, the remaining budget ‘quota’ would be used up in about 30 years.

In other words, unless strong mitigation actions are urgently adopted, the limit of a 2°C temperature rise will quickly be passed and a much more uncertain climate future awaits.

**Reflection Point**
What do the initials ‘RCP’ stand? Why are RCPs so important?

**The extent of forests and forest carbon stocks**

Globally, forests cover about 4 billion ha or 31% of the world’s land surface (relative to a pre-industrial area of 5.9 billion hectares of forests). Most forests occur in the tropics and in large areas of the Northern hemisphere in Canada, the US, Europe, Siberia and China, as shown in Figure 1.8.

The different forest (and other) biomes contain varying amounts of carbon, as presented in Figure 1.8. At a global scale tropical forests contain the largest carbon stock (547.8 million tonnes C in tropical and subtropical forests). There are also differences within tropical areas, with mangrove forests and swamp forests containing particularly high levels of biomass in their vegetation cover and soils.

**Figure 1.8 Forest cover in 2010**

---

3 Biomass is the total mass of living organisms in a given area or volume; dead plant material can be included as dead biomass.

The quantity of carbon contained in biomass varies slightly between vegetation types but on average, a ton of biomass equates to half a ton of carbon.
1. Forest, Carbon Sequestration and Climate Change

**Figure 1.9 Carbon Storage by Ecosystem**

Source: Kapos, V., Ravilious, C., Leng, C., Bertzky, M., Osti, M., Clements, T., Dickson, B. (2010)

**Reflection Point**

Referring to figure 1.9, what different ecosystem types are there in your country?

How much forest is there and where is it situated? Are there different types of forested habitat (e.g. mangroves, swamp-forests)?

**Emissions from forest carbon stocks**

As forests contain substantial stores of carbon, their degradation and or conversion to other land cover causes the release of some of the carbon stored within them. Forest degradation is defined as human activities negatively impacting on the forest, causing the partial removal and loss of ecosystem function, but where some forest cover remains, for example through damage from selective logging. The level of emissions depends on the amount of carbon stored in the forest, the extent to which the vegetation cover and soil structure is damaged or destroyed, as well as what happens to the land afterwards. Particularly high emissions will result if the vegetation is completely destroyed and then the area is burned afterwards, as is carried out during slash and burn agriculture in some parts of the developing world.

The extent of forest destruction is very high in some areas. For example, a recently published study on deforestation in Borneo shows that deforestation has reduced the once large forest cover on Borneo (75.7%) by one third, as shown in figure 1.10.
Historically, deforestation was largely in the US, Europe and Eastern Europe. Today, the largest deforestation rates are observed in tropical rain forest regions. Figure 1.11 shows that the USA and Europe have reversed the trend and are now increasing their forest cover. This highlights an important issue, that although the destruction of forests causes the release of carbon dioxide, their restoration can act as a sink for atmospheric carbon. As mentioned previously, the net contribution of land use change to global emissions is about 10% (0.9 PgC/yr). This contribution is calculated by combining both emissions due to deforestation and the sequestration of carbon due to forest recovery. The gross emissions from deforestation and degradation are larger than the net emissions (about 2.8 ± 0.5 PgC/yr for the 2000s, IPCC AR5 WGI, 2013) because of the significant regrowth that compensates for the gross emissions.

There are several causes for deforestation and forest degradation, which are addressed more in depth in Module 3: Drivers of Forest Degradation and Deforestation.

Source: Gaveau et al., 2014

Why is it so important to understand the link between deforestation and degradation in addressing the issues of climate change?

**CARBON SEQUESTRATION POTENTIAL OF FORESTS**

Forests are not only potential sources of carbon emissions to the atmosphere; they can also act as carbon sinks, sequestering carbon both as they grow when they are being restored to the biomass sink and as part of the terrestrial carbon sink.

More than two billion hectares worldwide may offer some form of opportunities for restoration. In areas that were deforested but that are not currently densely populated or cultivated, it may be possible to undertake some form of restoration, ranging from complete reforestation of closed canopy cover to more mosaic restoration that includes restored forest areas interspersed with other land uses including agroforestry, small scale agriculture and settlements. Such restoration sequesters carbon, with the level of sequestration depending on the extent of recovery of plant biomass and soil carbon. This potential is illustrated in figure 1.12.
The observed increases in atmospheric carbon dioxide are lower than would be expected if anthropogenic emissions were considered alone, due to the combined action of natural land and ocean sinks of carbon dioxide which removed an average 55% of the total anthropogenic emissions every year during the period 1958–2011 (IPCC 2013, AR5 WGI). The increased storage of carbon in terrestrial ecosystems not affected by land use change is partially caused by enhanced photosynthesis at higher carbon dioxide levels, and it means that intact forests are helping to act as a buffer against anthropogenic carbon dioxide emissions.

**FORESTS AND CLIMATE CHANGE MITIGATION**

The links between forests and the carbon cycle mean that actions that affect the forest sector can have a large impact on greenhouse gas emissions and so on climate change. The total amount of carbon dioxide in the atmosphere can be reduced by decreasing emissions from both deforestation and forest degradation. Maintaining standing forests can preserve their role in the terrestrial carbon sink and restoring forests can increase the sequestration of carbon by forests thereby decreasing the overall levels of carbon dioxide in the atmosphere.

Recognizing the potential role of forests in contributing to climate change mitigation, the UNFCC developed REDD+, reducing emissions from deforestation and forest degradation plus the conservation of forest carbon stocks, sustainable management of forests and enhancement of forest carbon stocks. Module 2 presents the basis of REDD+ and the UN-REDD Programme.

REDD+ is a potentially important way to reduce total GHG emissions and thus mitigate climate change as illustrated by figure 1.13.
Figure 1.13 REDD = Reducing emissions from deforestation and forest degradation

**CASE STUDY**

**EXERCISES**

1. Match the correct definition with each word:
   - deforestation
   - forest degradation?

   - **is the total removal of forest cover**
   - **is the part removal and loss of ecosystem function**

Source: UN-REDD Programme
2. Below is the recent IPCC estimate of the fluxes in the Carbon cycle expressed in Petagrammes Carbon per year (1 Petagramme = Gigatonne Carbon per year).

List the numbers in the figure below associated with the following fluxes:

- Atmosphere
- Net Ocean
- Net land use change
- Fossil fuels (coal, Oil, gas), cement production.

Source: IPCC, 2015