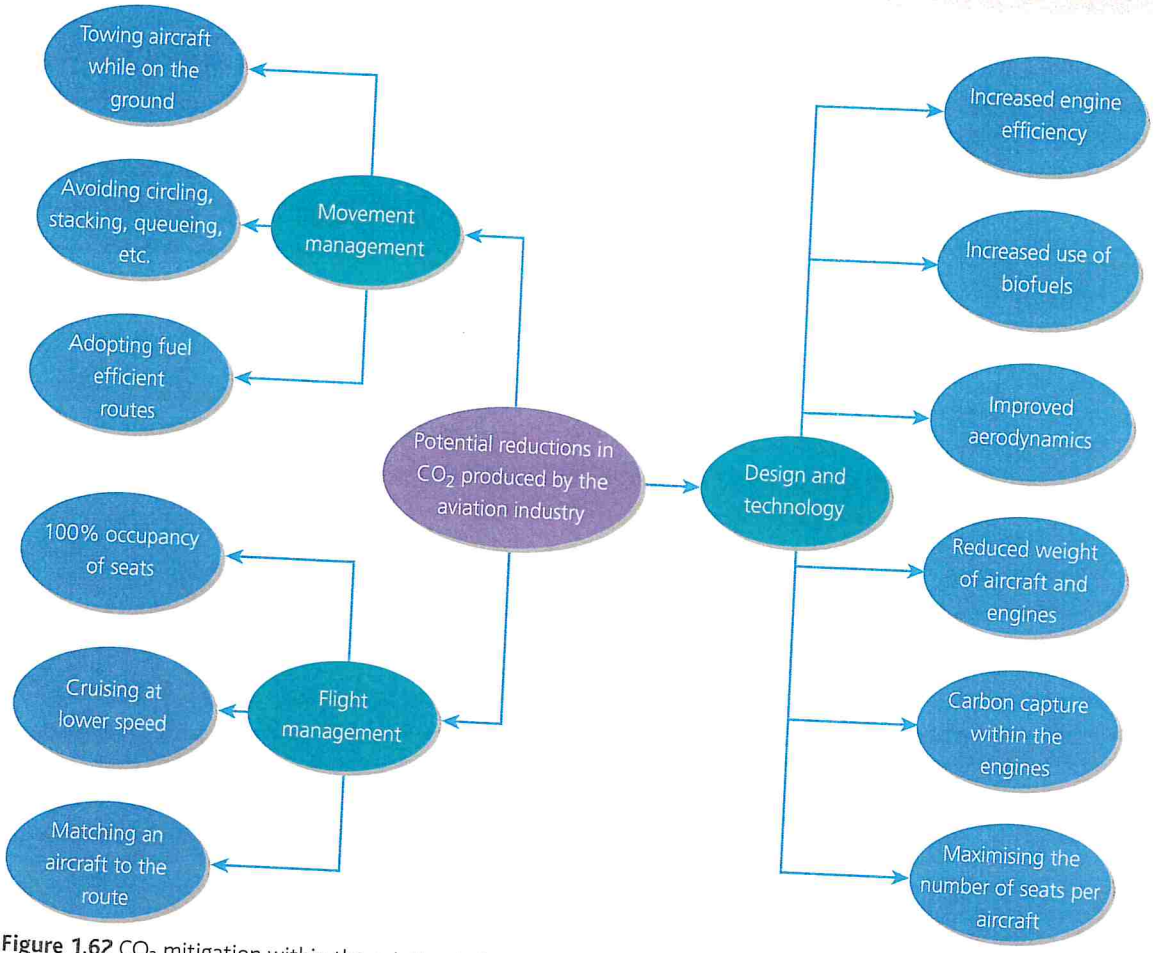

Figure 1.62 CO_2 mitigation within the aviation industry

Case study of a tropical rainforest setting: Water and carbon in the Amazon

The Amazon Basin is the world's largest rainforest and one of the most biodiverse. Its 300 billion trees and 15,000 species store one-fifth of all the carbon in the planet's biomass. Tropical forests have been present in South America for millions of years and were at one point spread over most of the continent. In the past the forest has shrunk back and then advanced again as ice ages came and went. Today's Amazon rainforest covers around 5.5 million km² and is spread across nine countries.

Figure 1.63 The location of the Amazon rainforest

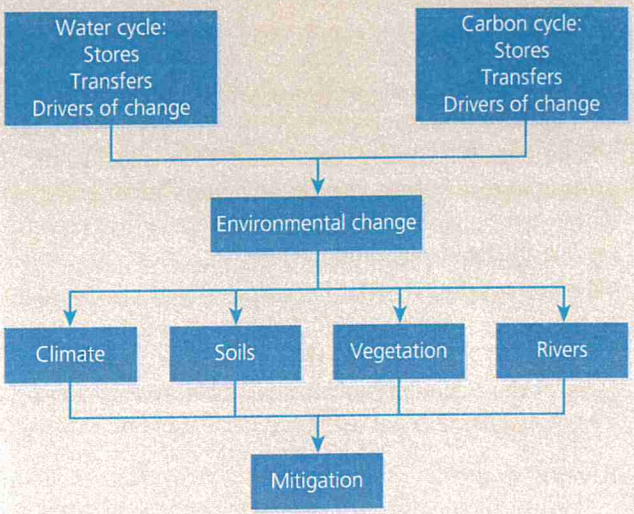

Figure 1.64 Key themes shown in this study

Carbon

The Amazon is estimated to store between 80 and 120 billion tons of carbon. Along with other tropical rainforests around the globe it forms a carbon sink of 1-3 GtC/year. Studies have shown that these forests have been increasing in above-ground biomass by 0.3–0.5 per cent per year and that the rising productivity of tropical forests is due to sequestering of increased CO_2 concentrations in the atmosphere (see Figure 1.4). This negative feedback seems to have offset rising atmospheric levels of CO_2.

Despite this, a study completed in 2015 has revealed that the Amazon forest is losing its capacity to absorb CO_2 from the atmosphere. From a peak of two billion tonnes of CO_2 each year in the 1990s, the net uptake by the forest has halved and now, for the first time, has been overtaken by fossil fuel emissions in Latin America.

It appears that for the Amazon basin, an increase in atmospheric CO_2 led to a growth spurt for the Amazon's trees; in time however, the growth stimulation feeds through the system, causing trees to live faster, and so die younger. This has led to a surge in the rate of trees dying across the Amazon.

Water

The average discharge of water into the Atlantic Ocean by the Amazon is approximately 175,000 m^3/s, or around 15 per cent of the fresh water entering the oceans each day.

The Rio Negro, a tributary of the Amazon, is the second largest river in the world in terms of water flow, and is 100 m deep and 14 km wide near its mouth at Manaus, Brazil.

Average rainfall across the whole Amazon basin is approximately 2,300 mm annually. In some areas of the northwest portion of the Amazon basin, it can exceed 6,000 mm. Up to half of this rainfall may never reach the ground. It is intercepted by the forest canopy and re-evaporated into the atmosphere. Additional water evaporates from the ground and rivers or is released into the atmosphere by transpiration from plant leaves. Of the rainfall that is evapotranspired back into the atmosphere, about 48 per cent falls again as rain. Only about 30 per cent of the rainfall actually reaches the sea. The rest is caught up in this constant closed system loop.

Drivers of change

- Between 2000 and 2007, the Brazilian Amazon was deforested at a rate of 19,368 km^2 per year. During this time, an area of forest larger than Greece was destroyed.
- Brazil is the world's fourth largest climate polluter, with 75 per cent of their greenhouse gas emissions attributed to deforestation and land use change; 59 per cent of this is from loss of forest and burning in the Amazon.
- The removal of forest was done using slash and burn techniques which:
  - reduces the retention of humidity in the soil's top layer down to a depth of one metre
  - facilitates sudden evaporation of water previously retained in the forest canopy
  - increases albedo (reflectiveness) and temperature
  - reduces porosity of soil, causing faster rainfall drainage, erosion and silting of rivers and lakes.
- Any moisture that evaporates from deforested areas forms shallow cumulous clouds which usually do not produce rain.
- Forests emit salts and organic fibres along with water when they transpire. These act as condensation nuclei and assist in cloud and rain formation. Their loss inhibits the formation of cloud and reduces rainfall.
- If destroyed, the vast carbon store will be released into the atmosphere.
- There are a range of differences between tropical rainforest and the pasture land it is generally replaced with.
  - Forests absorb approximately 11 per cent more solar radiation.
  - The average temperature in the rainforest is approximately 24.1°C; in pastures it is 33°C.
  - The daily temperature variation of Amazon forest soils at 20 cm did not exceed 2.8°C, though under pastures it was 8°C.
  - The moisture content in the upper one metre of pasture soil is about 15 per cent less than under nearby forest.
  - Deeper forest roots can pump more soil moisture to the surface, producing 20–30 per cent more air humidity and consequently 5–20 per cent more precipitation than pastures.

Climate change

Studies investigating all tropical rainforest regions found a mean temperature increase of 0.26°C ± 0.05° every ten years since the mid-1970s and predict that by the year 2050, temperatures in the Amazon will increase by 2–3°C. There has also been evidence of more frequent and increased extremes in temperature.

Amazonia experienced falling amounts of rainfall between the 1920s and the 1970s but since then it appears there has been no significant change.

Vegetation change

There has been a massive net loss of forests in the Amazon Basin, about 3.6 million hectares per year between 2000 and 2010. Although most of this has been caused by deliberate deforestation, a significant amount has been as a result of climate change. Some species are limited by their tolerance to temperature change, drought and seasonality. Climate change can affect species sustainability by directly altering the conditions needed to grow and survive. Droughts and unusually high temperatures in the Amazon in recent years may also be playing a role in killing millions of trees although the tree mortality increases began well before an intense drought in 2005.

A 2009 study concluded that a 2°C temperature rise above pre-industrial levels would see 20–40 per cent of the Amazon die off within 100 years. A 3°C rise would see 75 per cent of the forest destroyed by drought over the following century, while a 4°C rise would kill 85 per cent.

Soil

Amazonian soils contain from 4 to 9 kg of carbon in the upper 50 cm of the soil layer, while pasturelands contain only about one kg/m^2. When forests are cleared and burned, 30–60 per cent of the carbon is lost to the atmosphere; unburned vegetation decays and is lost within ten years. The soil fungi and bacteria that used to recycle the dead vegetation die off.

When forest clearance first occurs, the soils are exposed to the heavy tropical rainfall. This rapidly washes away the topsoil and attacks the deep weathered layer below. Most of the soil is washed into rivers before the forest clearance has caused a reduction in the rainfall.

Rivers

Changes in total precipitation, extreme rainfall events and seasonality may:

- lead to an overall reduction in river discharge
- cause an increase in silt washed into the rivers, which could disrupt river transport routes
- lead to flash flooding
- destroy freshwater ecosystems; this could remove a source of protein and income to local inhabitants
- destroy water supply which fulfils the needs of Amazonian peoples.

Warming water temperatures may:

- kill off temperature dependent species
- change the biodiversity of the river system by introducing new species and killing others
- reduce water-dissolved oxygen concentrations, which could destroy eggs and larvae, which rely on dissolved oxygen for survival.

Mitigation

Figure 1.65 describes some of the strategies to reduce the effects of environmental change in Amazonia.

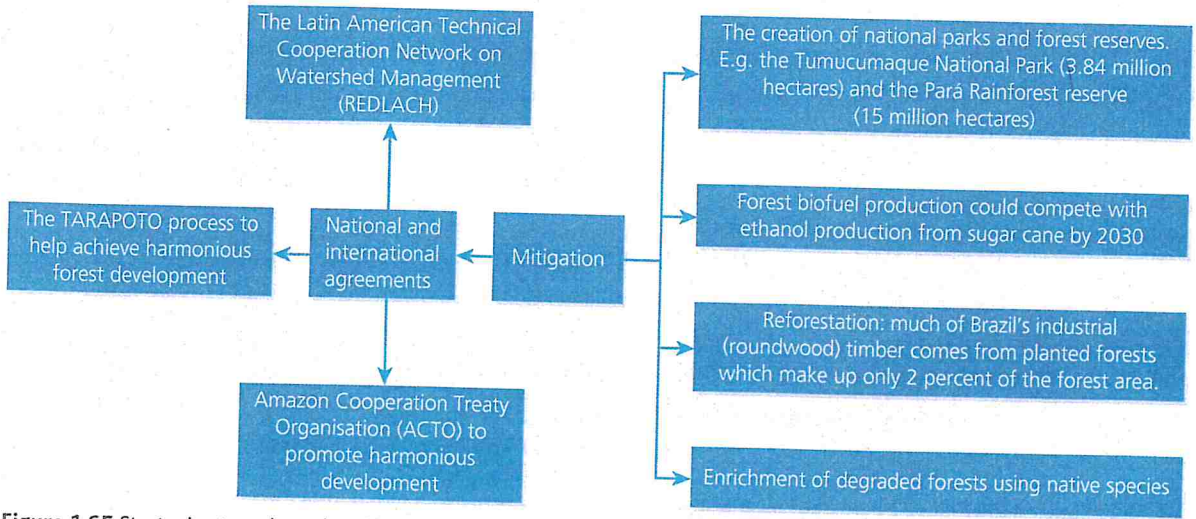

Figure 1.65 Strategies to reduce the effects of environmental change in Amazonia