Edexcel Geography GCSE

Forests Under Threat

Detailed Notes

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Forest Biomes

Forest biomes are **very important ecosystems** on Earth. They **absorb and store** huge levels of carbon, release **oxygen** into the atmosphere, and provide **habitats** for many plants and animals. However, some forest biomes, especially **tropical rainforests** and **taiga (boreal/coniferous forest)** biomes are increasingly under threat from **human activities**.

Tropical Rainforest Biome
(Source: © Ippei Naoi)

Taiga Biome
(Source: tass.com/society/1116379)

Tropical Rainforests

What is a Tropical Rainforest?

A **tropical rainforest** is a **warm, wet ecosystem** located within the **Tropics** (between the Tropic of Cancer and the Tropic of Capricorn).

The photo to the right was taken in the **Amazon Rainforest**, the world's **largest rainforest**. The **lush, dense vegetation** seen here is extremely typical of rainforests.

(Source: Pete Oxford / Corbis)

Examples of tropical rainforests include:

- Amazon Rainforest, South America
- Congolian Rainforests, Central Africa
- Daintree Rainforest, Australia
- South-East Asian Rainforests, Asia

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Tropical Rainforest Characteristics

Like all **global-scale ecosystems**, tropical rainforests around the world have similar environmental characteristics, including their **climate, soil type, and plant and animal life**.

Climate Characteristics

Rainfall

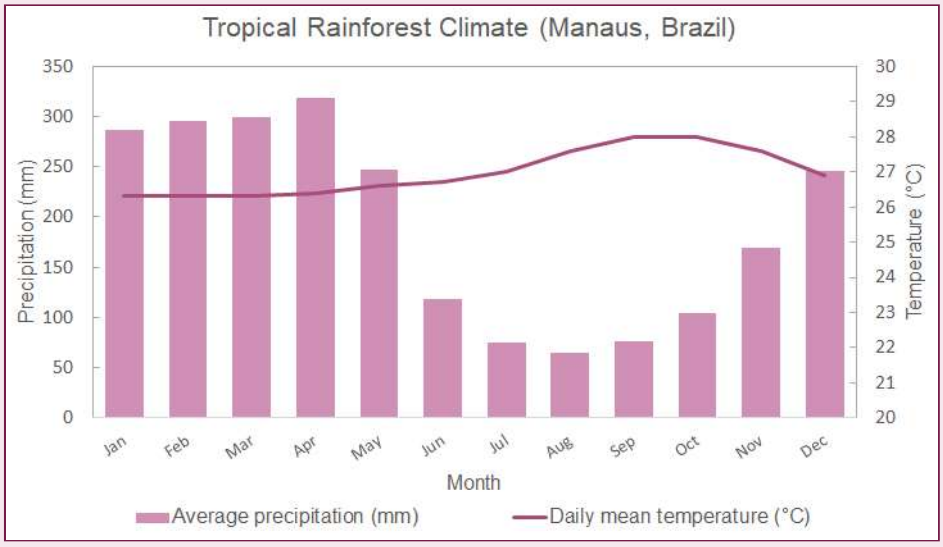
- Tropical rainforests are characterised by **extremely high rainfall**. In fact, tropical rainforests are some of the **wettest biomes in the world**.
- Annually, rainfall exceeds **2000mm per year**, which is over **double** the amount of rainfall the UK receives!
- Rainfall is usually **seasonal**, with a distinct **wet season** where monthly rainfall can exceed **well over 200mm of rain**. All of this rain also means tropical rainforests are **very humid**.

Research

(Source: Center for International Forestry

Temperature

- Temperatures in tropical rainforests are **high**, at around 26-27°C.
- Temperatures stay **consistent throughout the year**, with little variation seasonally.
- Temperatures are **high** and **consistent** due to the sun shining **directly on the equator** throughout the year. These patterns of temperature can be seen on the **climate graph** for Manaus in Brazil below.



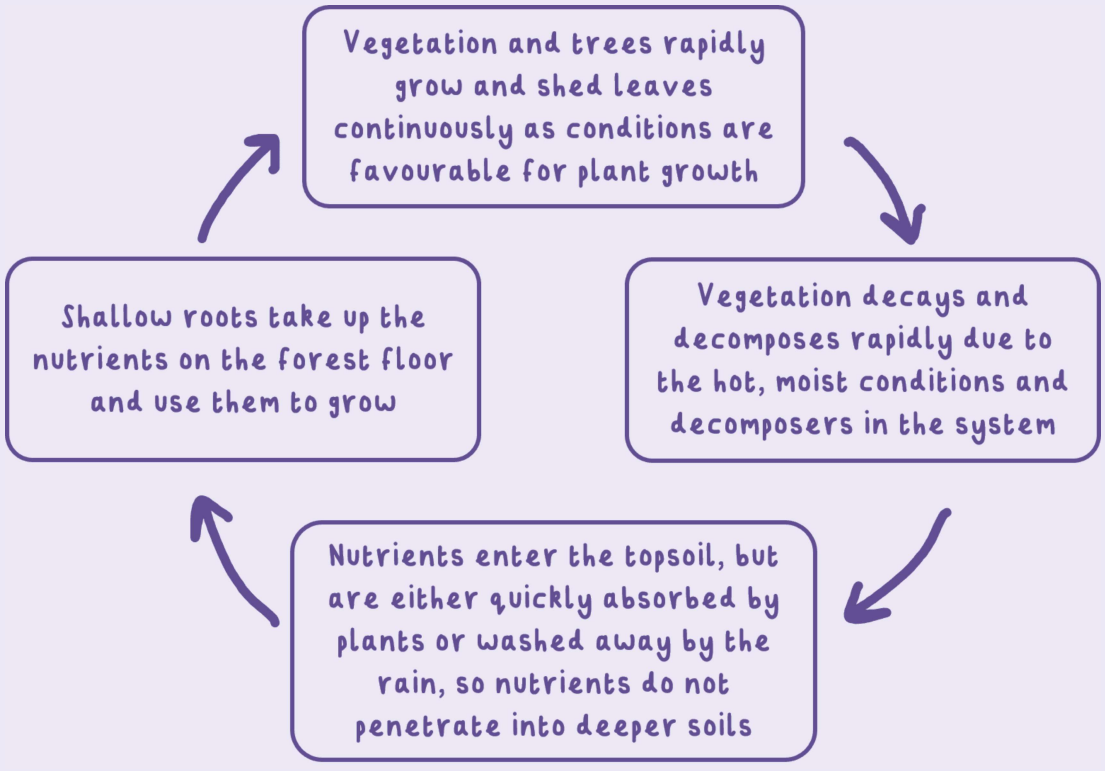
Soil Characteristics

- Despite the **lush vegetation** in tropical rainforests, the soils are actually **extremely nutrient deprived** and **infertile**. This is because nutrients are **washed away and dissolved very quickly** by the intense and continuous rainfall in a process known as **leaching**. This leaves an infertile, iron-rich soil called a **latosol**.
- Plants get their nutrients from the layer of **decomposing organic matter** that sits on the top of the **nutrient poor soil**. Dead plants and animals fall here and are **broken down by decomposers**, sped up by the **hot and humid conditions**. The nutrients released by decomposition are then rapidly absorbed by roots and put back into the living ecosystem.

(Source: earthobservatory.nasa.gov/features/Deforestation)

The **nutrient cycle** in tropical rainforests is very **quick**, which means the nutrients are transported from vegetation (and animals when they eat the vegetation), to the soils, back to vegetation relatively **rapidly**.

Nutrient Cycling in Tropical Rainforests:



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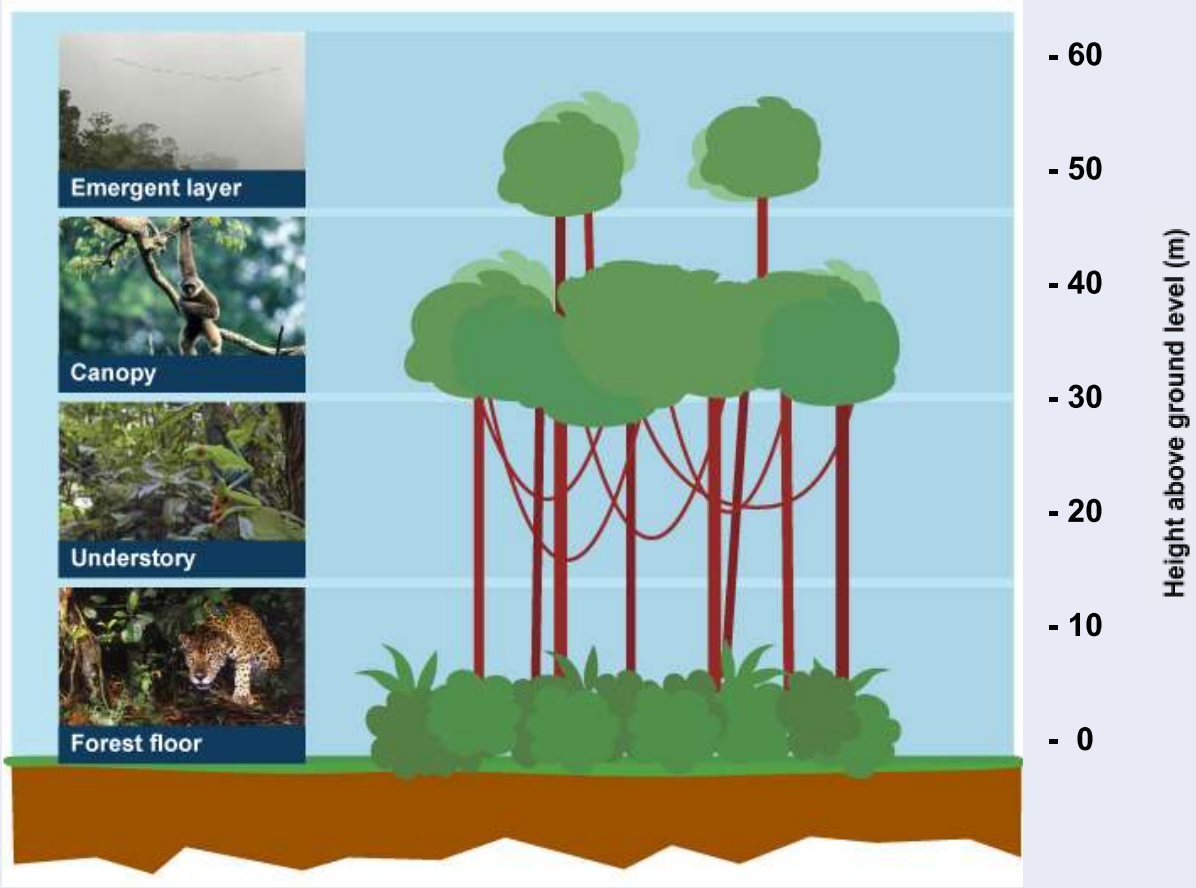
Plant and Animal Characteristics

- The nutrient rich soils and hot, moist climate supports huge levels of **biodiversity** within tropical rainforests. Over half of **all of the world's plant and animal species** are found within this ecosystem.
- The tropical rainforest ecosystem is separated into **layers**, which can be seen in the diagram below.
    - **Birds** and **flowers** live amongst **very tall** fast-growing **trees** in the **upper canopy**.
    - Mammals such as monkeys and sloths live in the **canopy**.
    - Insects, snakes, frogs, and other animals live in the **understory** beneath the canopy, away from predators on the forest floor. Some predators also hunt in the understory, like jaguars.
    - Rodents, larger mammals and **decomposers** (like fungi) live on the forest floor within the decaying organic matter.

Typical Structure of A Tropical Rainforest Ecosystem



(Source:www.bbc.co.uk/bitesize/guides/zpmnb9q/revision/1)

Plant Adaptations

Plants have adapted to the tropical rainforest climate and soils in different ways:

Buttress roots

- These are large, above ground roots that look like **ridges** at the bases of large tropical trees.
- Some trees have adapted to the **nutrient deprived**, waterlogged soils by growing large roots above ground.
- Buttress roots ensure tall trees are kept **stable** without growing roots **far down into the soil**. Having the roots above ground also ensures the roots receive enough **air**.

(Source: https://flic.kr/p/2G6GLW)

Leaf structure

- Some leaves have adapted to the **heavy and consistent rainfall** in tropical rainforests by developing **'drip-tips'**.
- A drip-tip is a **tapered end** of a leaf that allows excess rainfall to quickly drip off the leaf, ensuring plants are not left **too wet**, which can cause rotting.
- Many leaves also have **'flexible'** stems that move to find light, which is important as the **dense canopy blocks light** from reaching lower levels of the rainforest.

(Source:https://flic.kr/p/7ReuBn)

Lianas

- Lianas are **woody vines** that have adapted to the **dark** lower levels of tropical rainforests.
- Lianas have roots that grow **in the ground**, but their vines grow **high up** into the canopy by climbing and wrapping around trees.
- This means lianas can access the nutrients on the forest floor, but can access the light in the canopy.

Epiphytes

- Epiphytes are plants that live on the **surface of other plants**, receiving their nutrients from these plants.
- They have adapted to **growing on trees** high up in the canopy so they receive more **sunlight**, as the forest floor is so dark.

(Source:/Flickr_-_ggallice_-_Bromeliads.jpg)

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Animal Adaptations

Animals in tropical rainforests have had to adapt to the **physical conditions**, as well as **threats from predators** and **competition for resources** as there are **so many different animals** living in this ecosystem. The **high biodiversity** in this ecosystem means there is a lot of competition.

Poisons and venoms

- Animals have adapted to the threat of **being eaten** by the thousands of predators in rainforests by developing **poisons** or carrying **venoms**.
- Many ants, spiders, snakes and frogs can **paralyse** and **kill** other animals. Some animals sting or bite if they feel **threatened**, whereas others are **poisonous to eat**. The photo to the right is a **golden poison frog**, which holds enough poison to kill 10 people!

(Source: Dirk Ercken/Shutterstock

Physical characteristics

- Animals that **live in trees** have developed adaptations to help them move around and find food.
- **Primates** such as the spider monkey have adapted by developing very **long limbs** and long, **strong tails** to help them swing between trees and avoid predators.
- Some animals have **strong claws** to assist with climbing trees. Geckos have special pads that 'stick' to **leaves and trees** to assist with climbing.

Camouflage

- To hide from **predators**, some animals **camouflage** by blending in with sticks and vegetation. Leaf-tailed geckos have a tail that looks like a **leaf** to camouflage from predators. Look how difficult it is to spot in this image!

(Source:Thomas Marent/Minden Pictures)

Size

- To ensure animals can move through the **dense vegetation**, many have adapted to be a smaller size so they can **move through the growth** easily.
- **Jaguars** found in tropical rainforests are **significantly smaller** than jaguars found elsewhere in the world. The smaller size is advantageous for moving through the dense forest. They usually do not exceed 6 foot in length.

(Source:Getty Images/iStockphoto)

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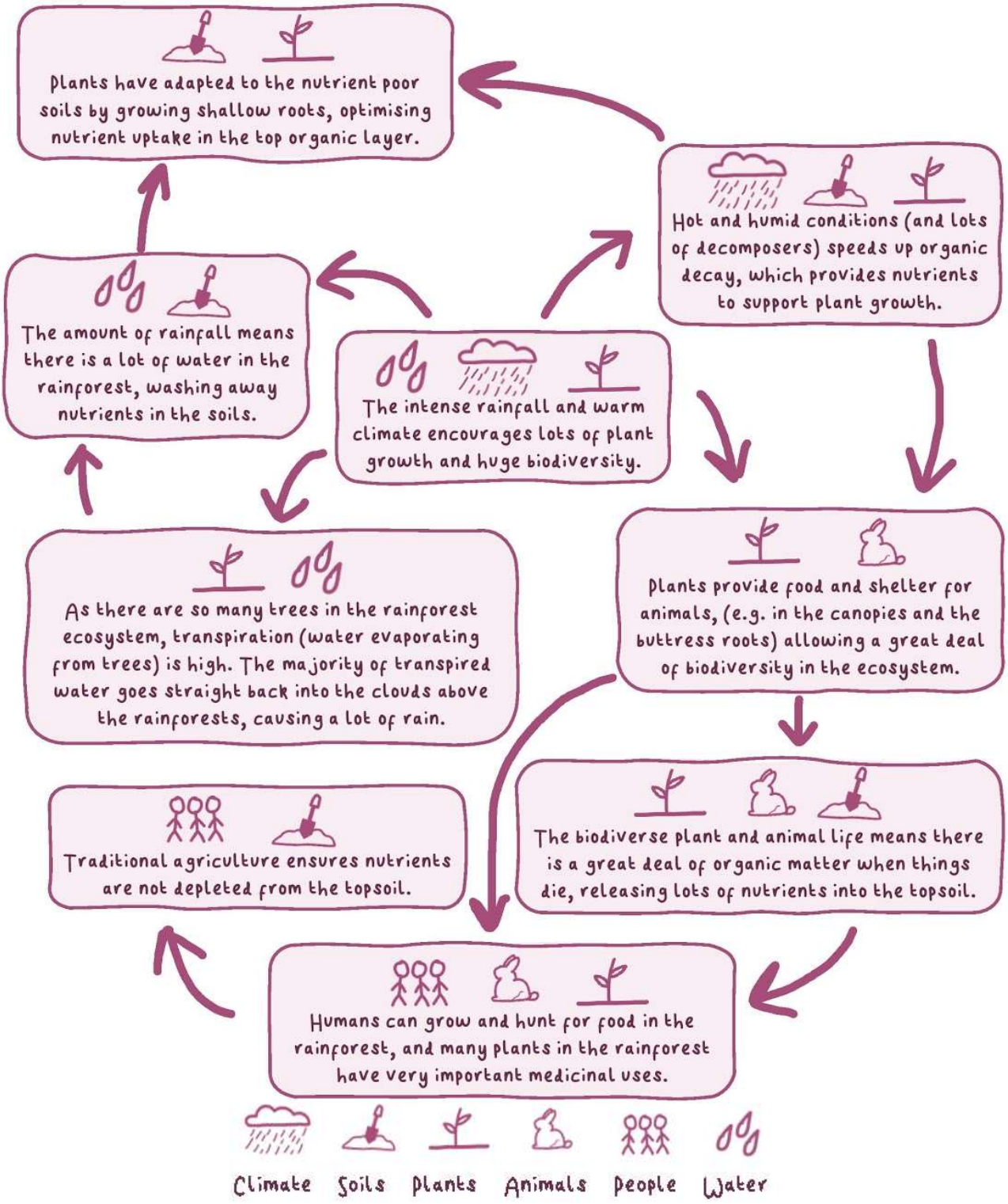
Interdependence in Tropical Rainforests

Within tropical rainforests, the **abiotic** (non-living) and **biotic** (living) factors of the ecosystem **interact with and influence each other**. These complex interactions are important to keep the rainforest ecosystem in a delicate balance.

There are many **examples of interdependence** within tropical rainforests; some examples of the interactions between physical and biological aspects of the ecosystem are outlined below. The arrows show the interactions between different components of the ecosystem.



Nutrient Cycling in Tropical Rainforests

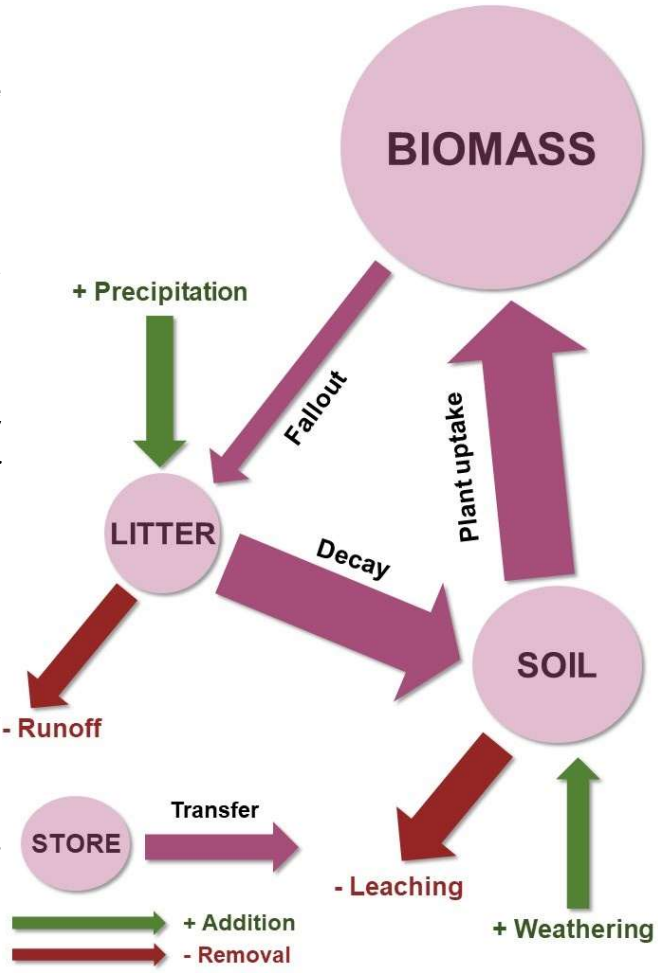
As previously mentioned, there is a **very quick nutrient cycle in tropical rainforests**. This means that nutrients that are very important for the **growth of plants and animals** (like phosphates, potassium, magnesium, and nitrogen) are transferred through the system **rapidly**.

The **rapid rate** of the tropical rainforest nutrient cycle means there are always plenty of nutrients readily available for plants and animals to use, supporting **high levels of biodiversity**.

The **interactions** within tropical rainforest nutrient cycles and the **reasons why** the nutrient cycle is fast can be illustrated using a nutrient cycle diagram:

Stores and Transfers

- Very large **biomass store** due to the dense, layered vegetation, large trees and high biodiversity.
- Fallout (e.g. dead animals, faeces, leaves, dead plants) is constant, continually adding **nutrients to the litter store**.
- Litter store is small as **decay is so rapid** in **hot, moist conditions**, meaning any litter is **very quickly decomposed** or washed away.
- The majority of nutrients are stored in the **topsoil**, and the rest of the soils are nutrient deprived and heavily leached.
- Plant uptake is **large** as **plants grow continuously** throughout the year in the hot, moist, sunny conditions. Nutrients are transferred from soil to biomass quickly as there are many plants absorbing nutrients, and growth is accelerated by the climate.



Nutrient Additions

- There are high levels of **precipitation** due to high rainfall levels, **adding nutrients** that are **dissolved in rainwater**.
- **Chemical weathering** is greater due to hot, wet conditions, **releasing nutrients from the rocks** into soils.

Nutrient Removals

- High rainfall means a lot of **litter is washed away** by the rain into rivers.
- Heavy rainfall washes **water-soluble nutrients** from the **soil** in a process known as **leaching**.

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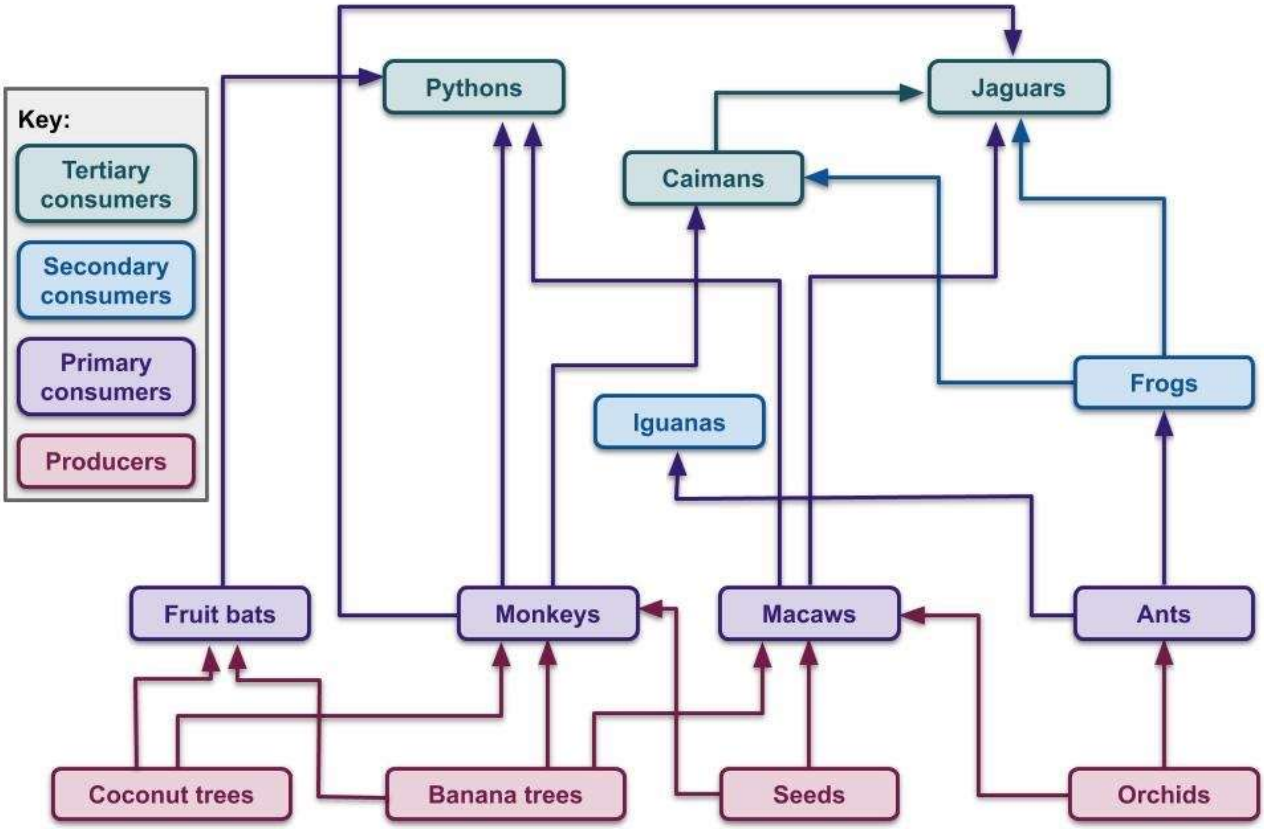
Food Webs in Tropical Rainforests

Food webs show how energy is transferred through an ecosystem, from **producers** to the top **consumers**.

In tropical rainforests, food webs are very complex as there are **thousands of species interacting with each other** in this biodiverse ecosystem.

Some plants and animals are **highly adapted to their environment**, meaning only certain animals are able to eat these species (e.g. a snake could have a natural resistance to a frog's poison), making the food webs even more complex.

The food web below shows how some species interact with each other in a typical tropical rainforest:

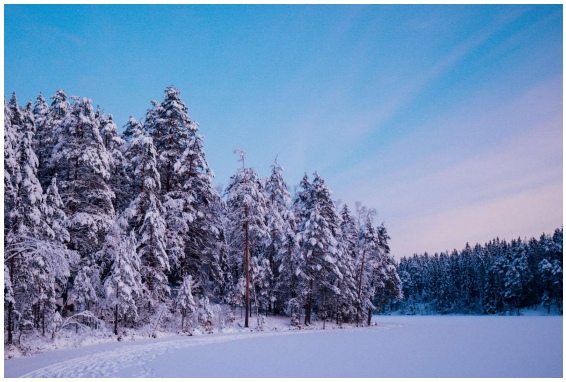


Taiga

Taiga biomes are **cold, forest ecosystems** located at **high latitudes (between 50° - 70°)**, mostly in the northern hemisphere. Taiga covers a **huge area of the Earth** (it is the largest biome), accounting for **30%** of the entire world's remaining forest.

They are characterised by **very cold, long winters** and mild, short summers with a **short growing season**. The milder temperatures allow **coniferous trees** to grow and dominate in this region.

Coniferous trees (seen in the image to the right) are **evergreen**, meaning they do not lose their leaves in the winter, which helps with **maximising photosynthesis** throughout the year.

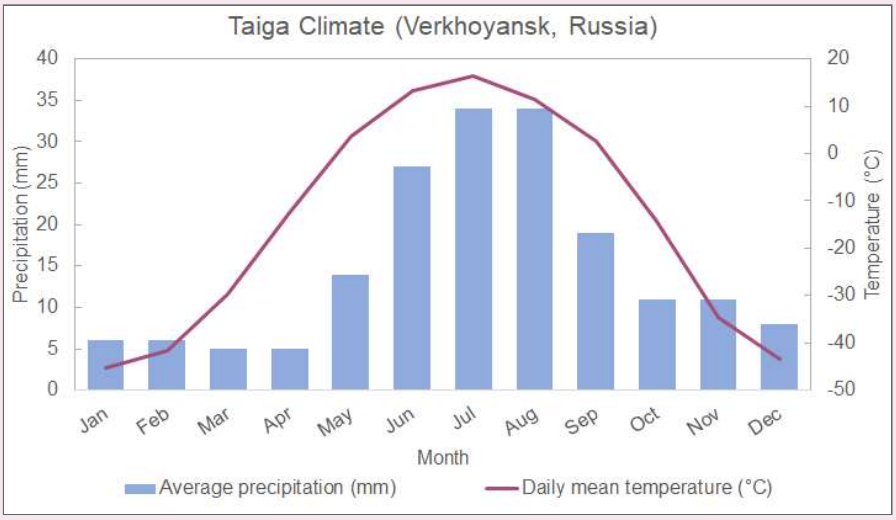


A Scandanavian forest (Source: reddit)

Taiga biomes are located in places around the world:

- Canada
- Central Russia
- Central Norway/Sweden

Climate Characteristics



The climate in taiga regions is **highly seasonal**, meaning it **varies** a lot between **winter and summer months**.

The climate affects other components of the ecosystem, such as **nutrient cycling** and **plant and animal behaviour**.

Winter

- Temperatures are **consistently below freezing** for around **8-9 months** of the year. Lows can be anywhere from **-20 to -40°C** depending on the location.
- Winters are **very dry**, often with around **5-15mm** of precipitation monthly! The majority of precipitation falls as **snow**, which covers the ground for many months, only thawing when temperatures rise.

Summer

- Summers are **short** but mild-warm; temperatures may rise to 20°C.
- Much **more precipitation** falls in summer months, which helps with plant growth.
- **Ice, snow and frozen ground melts** in the summer, which can make soils waterlogged and boggy.

(Source: Dave McShaffrey)

Plant and Animal Characteristics

The taiga biome is a **harsh climate to live in**, especially during winter, which affects the biodiversity and characteristics of **biotic components** in this ecosystem.

Productivity

The taiga biome is characterised by **very low productivity**. Productivity refers to how much **new plant and animal growth** there is in a given time, usually measured in **grams per square metre per year** (i.e. how much biomass is added in a set area over the course of a year).

- If productivity is **high** in an ecosystem, this means **plants and animals grow a lot**, usually due to there being plenty of **sunlight**, high **temperatures**, sufficient **precipitation** and good **nutrient supply**.
- In the taiga, productivity is low due to the **low temperatures**, **frozen ground** and **dry weather** which limits plant growth. There are no **net biomass additions** for months during the long winters, affecting food supplies for animals.

Biodiversity

There is **low biodiversity** in the taiga biome for different reasons:

- **Low productivity** leads to a **reduced food supply** in winter, meaning only a **few animals** are able to survive.
- Only **highly adapted plants** can survive in the taiga biome (conifers, mosses, shrubs and lichens mainly) which only **certain herbivores** (plant-eaters) eat. This has a knock-on effect on the amount of **carnivores** (meat-eaters) in the ecosystem as their food supply is small.
- Many animals **migrate** in winter to warmer areas, removing chains of the **food web** that other animals depend on.

(Source: Ferenc Cegledi, iStockphoto)

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In order to survive in this harsh climate, plants and animals have had to **adapt** in special ways.

Plant Adaptations

Conifers are specially adapted to the winters in taiga forests in different ways.

- They are **conically (cone) shaped**, which **allows snow to slide off** rather than collect and weigh down the trees.
- Conifer branches are **flexible**, allowing them to bend downwards when snow becomes too heavy.
- Conifer leaves are **needle shaped**, which **reduces water loss** by lowering the **surface area**. They are also protected with a **waxy outer coating**, which retains water and reduces freezing.
- Seeds are stored in **cones**, protecting them from the weather.
- Roots are wide but **shallow**, stopping them from reaching the **frozen subsoil** below while still supporting the tree.
- Evergreen trees are **green all-year round**, allowing them to **photosynthesise** whenever light is available.

(Source: AdstockRF)

The taiga ecosystem is a difficult place for plants to live in, so only certain ferns, mosses, shrubs and lichens can survive through the cold conditions and acidic, nutrient deprived soils.

Animal Adaptations

Animals have also had to adapt to the cold environment and limited food supply:

Migration

There are many birds that live in the taiga biome in summer, feeding on insects and berries, and breeding. However, the vast majority of these species have adapted to **migrate south in winter** to avoid the harsh temperatures.

Hibernation

Many animals (bears, chipmunks, squirrels) sleep through the whole winter in an adaptation known as **hibernation**. Their breathing, heart rate and metabolism slows down, which conserves energy supplies until they wake up in spring.

Physical features

- **Thick, oily fur** to retain body heat.
- Large feet to be stable on icy/snowy ground.
- Winter coats that are thicker and may even be **white coloured** for **camouflage** (seen in the snowshoe hare to the right).

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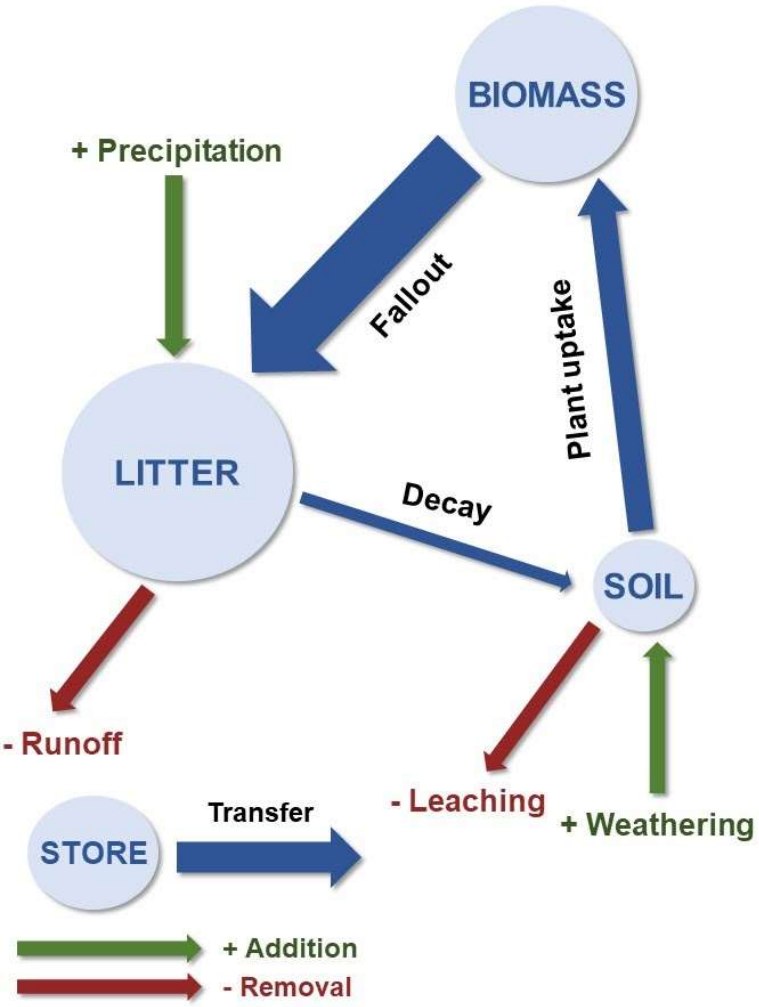
Nutrient Cycling in the Taiga

The nutrient cycle in the taiga is very slow due to the climate.

Stores and Transfers

- Small **biomass store** due to the **limited vegetation**, **limited growth** and **low biodiversity**, especially in winter.
- **Fallout** is large due to the needles falling off the trees, adding **nutrients to the litter store**.
- Litter store is larger as **decay is very slow** in cold conditions. Needles are left on the forest floor for months before decomposing.
- Soil is **nutrient deprived** as decay is limited.
- **Plant uptake is low** as there is low biodiversity and plants only grow when there is enough water available and it is warm enough (late spring).



Nutrient Additions

- Low **precipitation** levels mean little nutrients are added via precipitation.
- **Chemical weathering** is slower in cold, dry conditions.

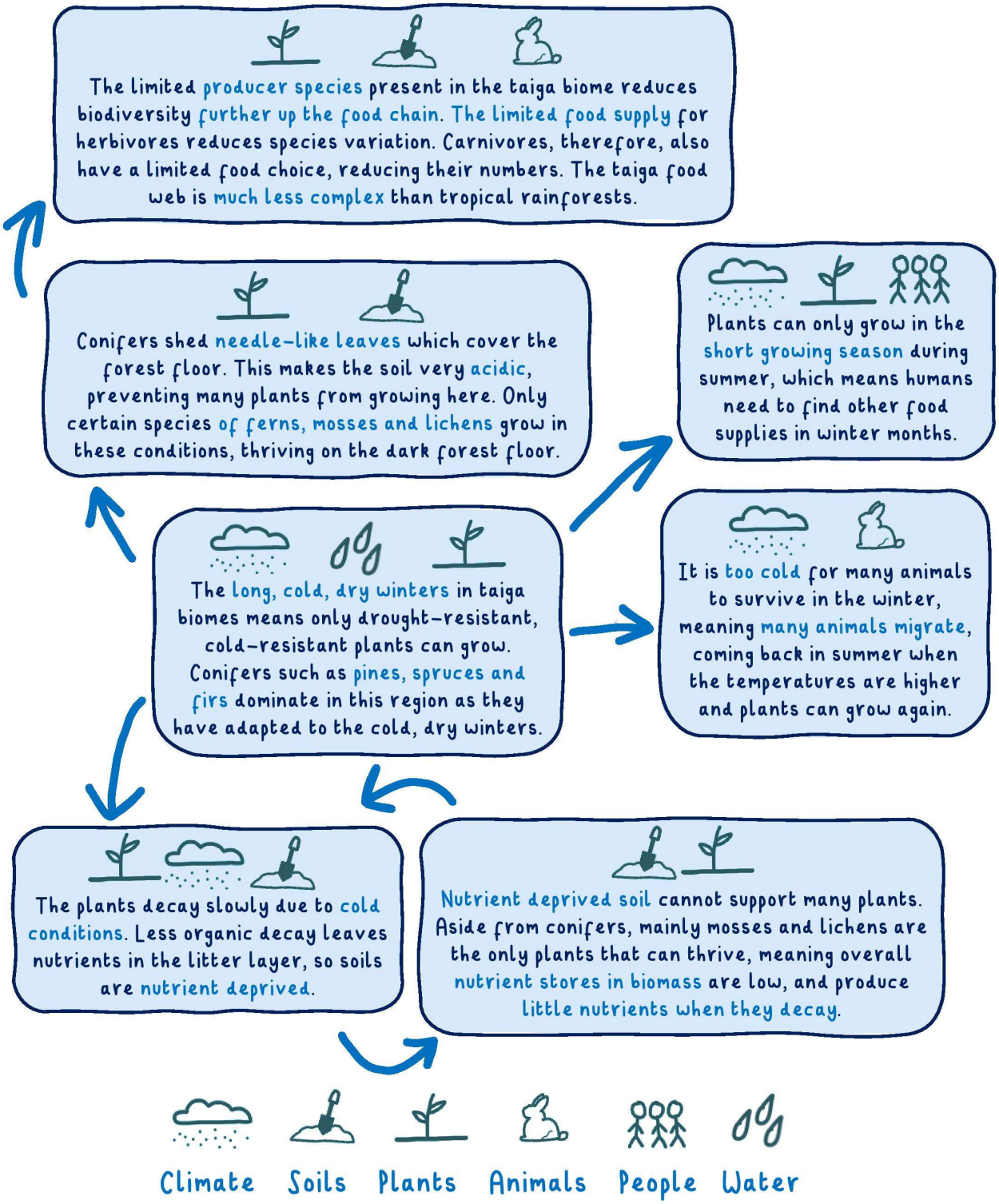
Nutrient Removals

- **Runoff** only washes away litter in spring, where there is high meltwater from the melting snow.
- **Leaching** is limited as there is little precipitation.

Notice how the **biomass store and the decay transfer** is much **smaller in the taiga nutrient cycle** compared to the **tropical rainforest ecosystem**. This shows there are much **less nutrients available** in the taiga nutrient cycle, and it is **slower** because decay rates are low.

Interdependence in the Taiga

Like tropical rainforests, the **abiotic and biotic components** of the taiga biome also interact and depend on each other.



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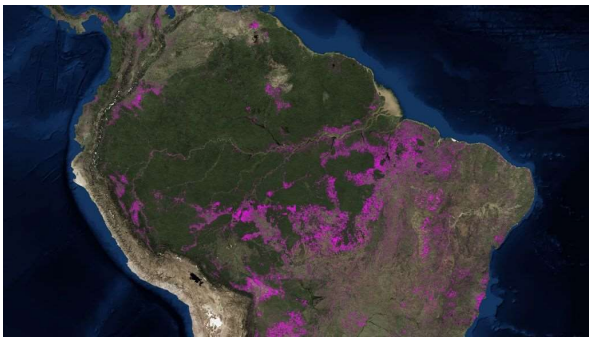
Deforestation in Tropical Rainforests

Deforestation is the **permanent** and usually **large-scale removal of trees**.

(Source: Mongabay)

Deforestation has been occurring on a **huge scale** in tropical rainforests all over the world, usually for timber or to clear land for agriculture. Deforestation is a major **direct threat** to the delicate **tropical rainforest ecosystem**.

It is estimated that overall global rainforest cover has reduced from **6 million square miles to 2.4 million square miles**. In 2019, a football pitch-size patch of tropical rainforest was lost every six seconds.


(Source: Global Forest Watch)

The Amazon Rainforest is estimated to have lost around **17% of forest cover in 50 years**. The majority of this deforestation is due to land clearing for **cattle ranching**, as well as **plantations**. The **purple** on the map to the left shows tree cover lost to deforestation in The Amazon.

Causes of Tropical Deforestation

There are many reasons why deforestation occurs on such a **huge scale** in tropical rainforests. Tropical deforestation has many environmental, social and economic impacts.

Subsistence Farming

Subsistence farming is where farmers only produce enough food for **themselves and their families to eat**, rather than growing **surplus** food for **profit**.

In tropical rainforests, subsistence farmers usually clear land using **slash-and-burn:**

- Farmers **cut down trees** and use the wood for building materials or to sell.
- The land is left to **dry out**.
- The **shrubbery** left behind is then purposefully **burnt**, as this clears the land quickly and **the ash releases nutrients into the soil**.
- After a **few years** of cultivation, the soil becomes **infertile**, so farmers leave the land to recover (usually from 20-100 years) and move to a different area.


(Source: KU Leuven - Pieter Moonen)

This traditional method has historically been **sustainable** as the land has been left to recover. However, with more people moving into rainforest areas, there is **less land available** and some are **not educated** in the subsistence farming practice. Less time is being left for the rainforest to **fully recover** (only 5-8 years) before burning again, permanently altering the ecology of the rainforest. Also, poorly controlled fires can grow out of control and lead to **wildfires**.

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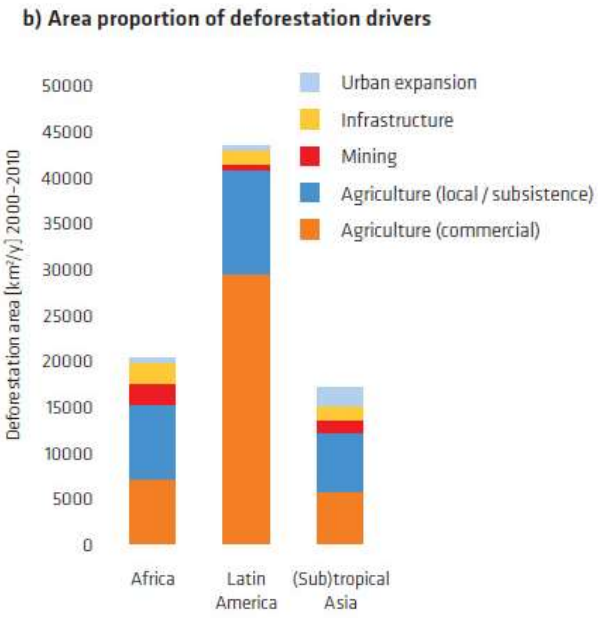
Commercial Farming

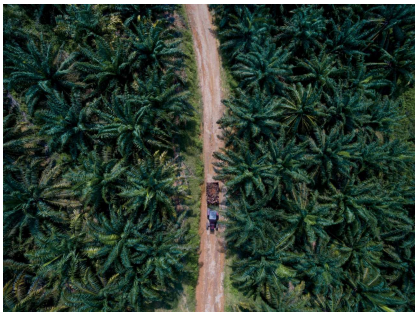


Unlike subsistence farming, **commercial farming** is agriculture with the direct intention of making **profit** from the produce.

Commercial farming is a massive contributor to tropical deforestation, as huge areas of land are cleared to make space for **plantations** (such as **soy** or **palm oil**) or **cattle ranches** for beef production.

Furthermore, a lot of deforestation for commercial agriculture is done **illegally**, often with little consideration for the **environmental impacts**.

(Source: https://news.mongabay.com)



Clearing land for palm oil plantations has accounted for **47% of all deforestation on Borneo since 2000.** This has huge environmental consequences, especially for the wildlife. Deforestation and hunting killed nearly **150,000 Bornean orangutans** from 1999 to 2015.

This article by National Geographic questions whether palm oil can ever be cultivated sustainably.
(www.nationalgeographic.com/magazine/2018/12/palm-oil-products-borneo-africa-environment-impact/)

Cattle ranching accounts for up to **80% of all deforestation in the Amazon.** A lot of cattle ranches are set up to satisfy the demand for beef in developed countries like the USA.

(Source: João Laet/The Guardian)

Fuel Wood

When **other sources of energy** are not available, **wood** is heavily relied upon as a source of energy for cooking and heating.

In **tropical rainforests** where gas and electricity may not be available, communities have cut down large amounts of trees to either use the wood for burning directly, or to process into **charcoal**. Wood as a source of energy accounts for over **90% of rural communities' fuel** in some countries.

Logging

Logging is the process of **cutting down trees for wood**, which is then sold as timber or processed into other products. Logging occurs in rainforests as **tropical hardwoods** are very popular woods and can sell for **high prices**.

Clear felling (or clear cutting) is a form of logging where **all the trees in an area** are cut down, including young trees. This method is more **profitable** as it can be done quickly.

(Source: Romeo Gacad/AFP/Getty Images)

However, there are obviously **huge environmental effects** with this method of logging. **Habitats** are **completely destroyed**, other vegetation is usually severely disrupted and animals are displaced. Also, leaving the land bare exposes the soil to the heavy rainfall, causing **soil erosion**.

Biofuels

Biofuels are fuels produced from **biomass** (i.e. organic matter). Biofuels are increasingly being used as a fuel source across the world as they can **substitute fossil fuels** (coal, oil and gas).

(Source: © shutterstock.com)

However, huge areas of **land need to be cleared** to make space for crops like oil palm, soy and sugar cane that are eventually processed into biofuels.

Mineral Extraction

Some areas of tropical rainforests have vast reserves in **metals, gemstones** and **fossil fuels** which are extracted by **mining** and **drilling**.

Large areas of land need to be cleared for **roads and mines**, which causes severe environmental degradation. The rainforest ecosystem is unlikely to recover from this level of damage and deforestation, leaving vast areas of tropical rainforest bare for hundreds of years.

Energy Development

Hydroelectric power is a rapidly growing form of **energy production** in **tropical rainforests** (**80%** of Brazil's energy comes from hydroelectric power!) as the large rivers and huge drainage basins generate a lot of **water movement**. In order to **harness this energy**, **huge dams** have been constructed in tropical rainforests throughout the world, with many more planned.

Itaipu dam on the Brazil–Paraguay border

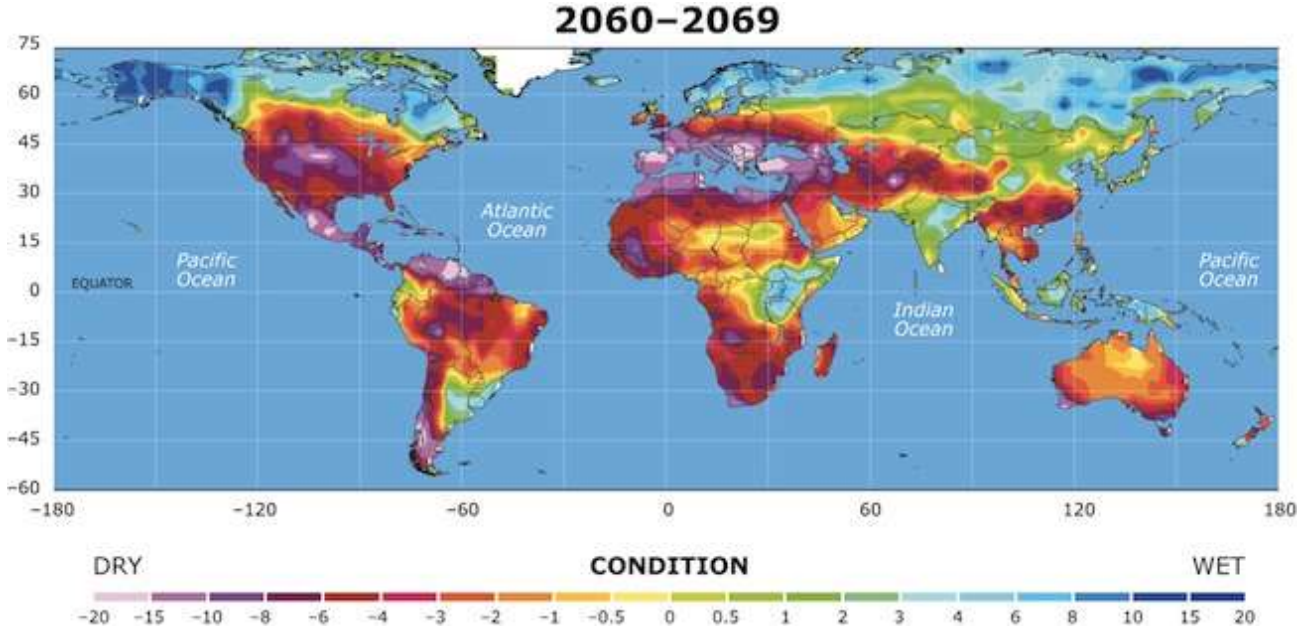
(Source: Ember Stefano/Agefotostock)

Dam construction causes deforestation as **large areas of land need to be flooded** to make reservoirs. As tropical rainforests are very **flat**, a lot more land is flooded than necessary, completely destroying **terrestrial habitats** and **displacing indigenous communities**.

Climate Change and Tropical Rainforests

Although **direct threats** to tropical rainforests (**deforestation**) are very serious, **indirect threats** are harder to manage, which makes them potentially more dangerous. The effects of **human-caused climate change** are predicted to **alter tropical rainforest ecosystems** all over the world, and are already having negative effects.

Temperature and precipitation patterns are projected to change in tropical regions. By the middle of the 21st century, temperatures in tropical rainforests may rise by between 2-3°C.
Tropical regions are predicted to become more dry, with **droughts** potentially becoming more severe and prolonged.
The map below shows how tropical biomes are expected to become drier, especially the Amazon.



Changing patterns of **precipitation and temperature** can alter the complex ecosystem, putting stress on different components. For example:

- Prolonged droughts can **dry out the forest floor**, killing **decomposers** and altering the **nutrient cycle**.
- Lack of water can have **severe effects on trees**. **Leaves fall off trees** when they are **dehydrated**, creating gaps in the canopy and thus changing the behaviour of plants and animals that are adapted to the **dark** understory. The **tallest trees** suffer the most, as they cannot transport water high enough when it is dry. This causes the tallest trees to die, fall over, and leave **huge gaps in the canopy**.

(Source: TUM/ Rammig)

- **Flowering and fruiting patterns may alter**, which affects species that rely on these plants, and carnivores that rely on those species.
- **Aquatic habitats** like streams and rivers can **dry out**, having serious consequences on the plants and animals that depend on these areas.
- Droughts can create **forest fire conditions**, which **ravage through areas of tropical rainforests**. The frequency of severe droughts is thought to have increased in recent years; severe droughts have hit the Amazon in 1997-98, 2005, 2010 and 2015-2016, all having devastating forest fires as a result.

(Source: https://rainforestpartnership.org/amazon-wildfires/)

Direct Threats to the Taiga

Taiga biomes are also under threat from human activities, especially **commercial activities** that have exploited this ecosystem.

Logging

Taiga forests are deforested on a huge scale for **softwood** and **paper production**. Canada and Russia (which both contain taiga forests) accounted for **40% of the world's deforestation** between 2000-2013, and **8% of taiga** has been lost overall.

Softwood is harvested as it has many uses, for example:

- Doors, beams, frames etc.
- Furniture
- Panels for flooring, decking etc.
- Fences
- Boats
- Paper

Pulp and Paper Production

Around **400 million tonnes of paper** is used each year, the majority of which come from **softwoods grown in taiga forests**.

In the pulp-and-paper process, softwood is turned into pulp and then spread thinly to make paper. Although thousands of sheets of paper can be made from one tree, **global demand for paper** is a major cause of deforestation in taiga forests.

(Source: /www.papnews.com)

Indirect Threats to the Taiga

As well as **physical deforestation**, there are other human activities that are **indirectly** causing damage to taiga biomes. Threats include:

- The exploitation of **mineral resources**
- Extraction of **fossil fuels**
- Development of **hydroelectric power**

Mineral Resources

Mining for mineral resources has been common in taiga forests for hundreds of years, as these areas contain mineral deposits of iron, silver, gold and diamond.

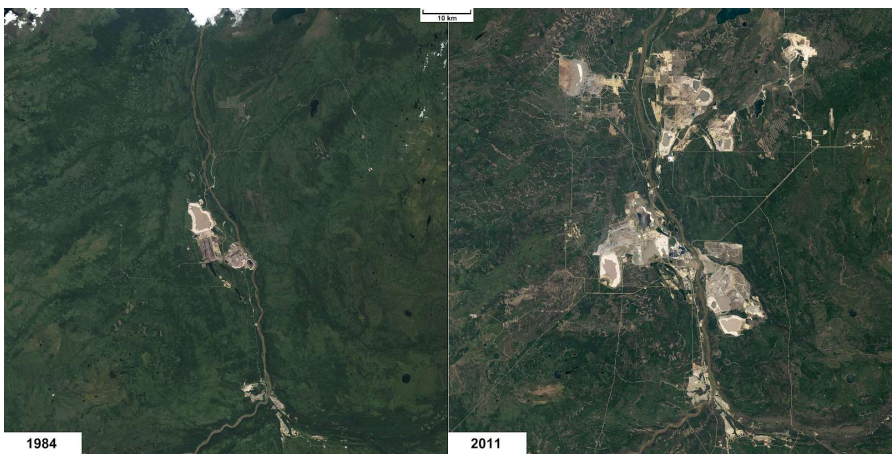
However, past mining efforts were conducted with very little consideration for the environment. In the Canadian coniferous forests, **over 7,000 abandoned mines can be found**, many of which are close to **rivers and lakes**. This means **harmful chemicals** are washed into river ecosystems, disrupting the wildlife.

Furthermore, in order to build mines **large areas of forest** must be cleared, and **roads** may be built to provide access to these sites.

Fossil Fuel Extraction

Tar sands (also known as oil sands) are **natural deposits of oil** mixed with sediments and water. The oil (in the form of **bitumen**) can be extracted in a process known as **open-cast mining**, where the surface of an area is cleared and then mined, rather than mining underground.

There are **very large tar sand deposits** found in Canada and Russia's boreal forests, of which hundreds of kilometres have been mined already. The extraction of oil in tar sands produces **toxic waste**, uses huge amounts of **water**, and of course requires the **clearing of large areas of forest** which disrupts the fragile ecosystem and displaces wildlife. Below are two satellite images of tar sand exploitation in Canada, taken in 1984 and 2011. Notice the scale of the forest destruction.



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Hydroelectric Power

Although taiga biomes have low precipitation, there is a lot of **water** in these ecosystems, especially during spring when the winter's snow and ice melts. Some areas have decided to **harness the energy generated by this water** in the form of hydroelectric power (HEP).

Huge areas of land need to be flooded in order to create **reservoirs** behind **dams**, which aid in the **generation of HEP**. In Canada alone, more than 52,000 km^2 of forest and land has been flooded for hydroelectric power generation. This obviously has major consequences on the plants and animals that depend on this ecosystem, especially the disruption of **fish migration patterns** (as dams block their routes).

Threats to Taiga Biodiversity

Environmental conditions in the taiga may also have damaging effects on the **biodiversity** of the biome.

Acid Precipitation

Acid rain affects taiga forests by **weakening trees**, damaging **needles** and **reacting with soils** to form harmful compounds.

Acid rain forms when **chemicals** such as **sulfur dioxide and nitrous oxides** are **released from burning fossil fuels**. These chemicals then react with water in rain clouds to form acidic compounds (nitric acid and sulfuric acid) which then fall in the rain.

The acids do not kill trees directly, but the effects they have on the environment can result in **trees dying** if they cannot cope with the stress. This can alter biodiversity by **affecting biotic components that rely on these trees**, and increasing **acid-tolerant plants** (and **animals** that eat these plants) which may disrupt the delicate food web.

(Source: www.gizmodo.com)

Pests and Diseases

Pests and diseases **reduce biodiversity in taiga biomes** by **killing large amounts of trees**, which reduces food supplies for animals that depend on these trees and their seeds, having knock-on effects further up the food chain.

As the taiga ecosystem already has **low biodiversity**, it has a **low tolerance** for pests and diseases.

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In a **biodiverse forest**, the spread of a disease or pest may be **slowed down** by the presence of **different species** with resistance to the disease, or animals that eat the pests. However, the **low biodiversity of the taiga forest** means many of the **same species of tree** grow **very close together**, so a disease or pest can **quickly ravage** through an area with little to stop it.

(Source:https://www.fs.usda.gov)

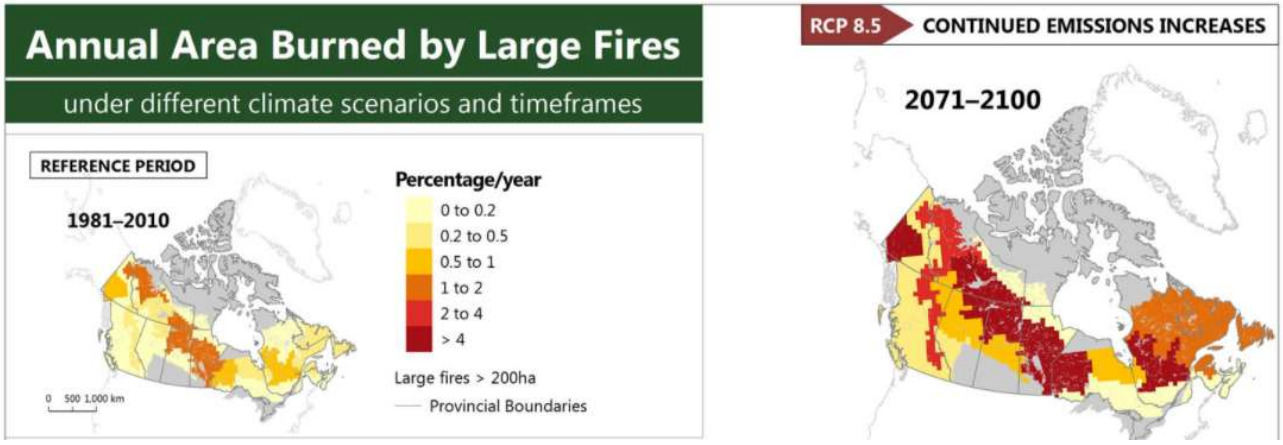
The effects of pests can be seen in this North American forest ravaged by the **mountain pine beetle** (pictured below). The mountain pine beetle is responsible for destroying **16 million hectares of taiga forest** in British Columbia, Canada.

(Source: Black Press Media)

Pests and diseases are usually **killed off by the cold winters**, but global warming may be affecting this. Larvae of some pests are not dying in winter, which can cause consistent devastation to the forest for years.

Forest Fires

Forest fires are a **natural process in the world's taiga forests**, and the biome is adapted to cope with the effects of fires. However, climate change is altering the **pattern of wildfires**, specifically their **range**, **intensity** and **time between fires**. The map below shows how forest fires may potentially affect the taiga forests of North America if carbon dioxide emissions continue.



(Source:www.nrcan.gc.ca)

If sufficient time does not pass between wildfires, biodiversity can be majorly affected:

- The forest **may not have time to regenerate**, meaning less tolerant species of trees may die out, which **cuts off a food supply for many animals**, and affects the animals that eat them.
- **Fire-tolerant vegetation** may become more **dominant**, especially shrubs. As the ecosystem is not adapted to this vegetation, there may be few herbivores to **control it**. Only animals that eat this vegetation can survive in the ecosystem.

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Conservation of Tropical Rainforests

As tropical rainforests are **under threat from human activities**, it is important that they are protected and conserved so that their **goods and services** to **people** and the **ecosystem** are available for **future generations**.

CITES

The Convention on International Trade in Endangered Species of Wild Fauna & Flora (**CITES**) is an **international agreement** adopted by 183 **member parties** that works to protect **threatened wildlife** from **exploitation**.

©

CITES aims to regulate the **international trade of wildlife and wildlife products** (e.g. leather, ivory, food products, fur) as current trading patterns are **unsustainable** and are threatening **vulnerable and endangered** species.

CITES lists over **38,700 species** of animals (around 5,950) and plants (around 32,800) that are **under protected status**, encouraging countries to take action against the **unsustainable trading** of these species. A great deal of **wildlife native to tropical rainforests** are under protection from CITES, including:

Ring-tailed Lemur

(Source:© Peter Dollinger)

Channel-billed Toucan

(Source: © Peter Dollinger)

Lilac-crowned Amazon

(Source: Katherine Renton)

CITES has its **advantages and disadvantages** as an international treaty:

Advantages	Disadvantages
Many countries are part of the agreement, which allows **international collaboration**. This is useful for controlling **international trade** and **border control strategies** between countries.	Each party is **in control of their own management** and **laws** against international trade, meaning they could technically **break their own rules** with no consequences.
CITES has had **successes in tropical conservation**, such as their partnerships with other organisations to ensure **sustainable tree harvesting and trade**. Watch this video to see what CITES has done for tropical rainforest management all over the world.	**Low income countries** (where many tropical rainforests are) may not have the **finances available** to implement management strategies. Wildlife and wildlife product trading can often be the only reliable **source of income** for some people, meaning it is difficult to ban entirely.
Meetings, research and reports spread awareness to **country leaders** and **decision makers**, allowing them to take action.	The agreement focuses on **species** rather than **habitats**, which are also **under threat**. Habitat loss is also a major threat to tropical species.

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REDD+ and UN-REDD

REDD+ (Reducing emissions from deforestation and forest degradation) is a scheme created by the **United Nations** that aims to **reduce emissions caused as a result of forest degradation** by **conserving** and **sustainably managing** forests.

UN-REDD PROGRAMME

Food and Agriculture Organization of the United Nations

UNDP Empowered lives. Resilient nations.

UNEP

REDD+ recognises the role forests play as a **carbon store**, and how **forest degradation is reducing** the effectiveness of this store, which is contributing to climate change (e.g. burning and deforestation).

The way that REDD+ operates is it **offers financial incentives** to **developing countries** for conserving their forests and **offsetting carbon emissions**. The countries receive payments when they prove they have successfully **reduced emissions from forests**.

The **UN-REDD programme** assists countries in reaching their goals. For example, UN-REDD works to **educate farmers** and other workers on sustainable practises, creates **action plans**, and provides **resources** for small-scale camps and bases with **special equipment** to help with monitoring and conservation.
The image to the right shows two camp workers travelling to a **bird watching station** in Kupiano, Papua New Guinea. Biodiversity monitoring and management is a major aspect of the REDD schemes.

(Source:UN-REDD)

Advantages	Disadvantages
Countries are more likely to take direct action if they get a **financial reward**, as opposed to doing it simply for the **environmental benefits**.	The scheme has been criticised for **putting an economic value** on forests, rather than realising the value they have to their communities.
There are **monitoring, reporting and verification systems** in place to ensure countries are doing their bit. Technology such as **satellites** are even used for monitoring purposes. This means action **has to be taken** for the financial incentive to be rewarded.	**The scheme focuses on low income countries**, which may shift blame onto them rather than the **developed countries** who often are driving deforestation through their demands for **wood**, **beef** and **tropical products**.
The UN-REDD programme also helps **other aspects of tropical rainforests** by **including communities** into conservation efforts. This can **create jobs** and ensure the community voices are **considered** in the schemes.	Some argue that these schemes **do not actually reduce emissions**, only offset them, meaning countries can theoretically **still emit high amounts of greenhouse gases** and still be rewarded for offsetting their carbon emissions from forest degradation.

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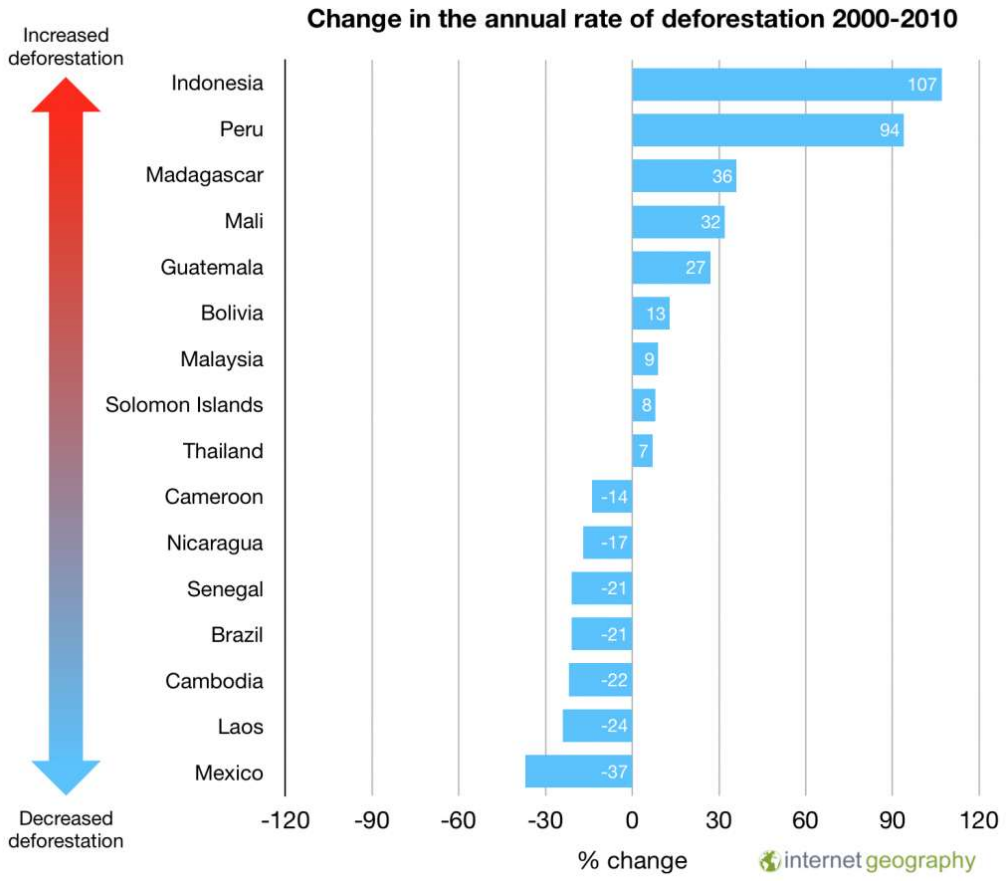
Rates of Deforestation in Tropical Rainforests

Although deforestation continues to be a serious ecological issue all over the world, **annual rates of deforestation are decreasing globally**.

Deforestation in Brazil has fallen by nearly **80% since 2004**, and this is similar in many other countries with tropical rainforests. However, deforestation rates are **not decreasing everywhere**. Indonesia especially is seeing **very high deforestation rates**.



There are reasons why some countries have falling rates, whereas others have rising rates:

Reasons for falling rates	Reasons for increasing rates
• **Forest protection laws**, with fines and prosecution for **illegal deforestation** and financial rewards for protection. • **Growing urban population** means less people rely on income from **tropical rainforest activities**, like agriculture. • Increasing use of **National Park** and **reserve** status, enforcing protection. • **Education and public awareness** encourages activism, donations and support for forest **protection**.	• **Urban poverty** forces people to move to cheaper rural areas where **job opportunities** are limited, often involving forest degradation (agriculture, logging). • **Conflict** and **war** limits protection efforts. • Low income countries do not have enough money to **invest in forest conservation**. • **Newly industrialised countries** have **high demand** for resources from tropical rainforests such as timber, energy sources and tradable resources.

Sustainable Management of Tropical Rainforests

To **preserve tropical rainforests** for years to come, sustainable management is necessary:

Selective logging & replanting

Selective logging is the **partial** felling of trees in an area, intended to reduce the **environmental impact of logging** as disturbances are limited. Usually, **only mature trees** are cut down; younger trees are **left in the ecosystem** to grow. Trees are also cut to **fall away from other trees** so they do not damage them, and trees are marked so **illegal logging can be traced**.

Replanting reduces environmental impacts further by preventing **soil erosion** and ensuring **carbon dioxide intake** is not lost. After many years, replanted trees can eventually be felled, meaning this is **a sustainable practice**.

Ecotourism

Ecotourism is a form of **sustainable** tourism that aims to have **reduced environmental impact** and support **conservation** efforts. **Tropical rainforest ecotourism** is becoming more common, as many people want to **visit rainforests** and take part in activities (bird watching, canoeing, wildlife photography etc.) in a sustainable way.

Ecotourism can also **provide income** to indigenous populations **and fund conservation efforts**. For example, The Chalalan ecolodge in Bolivia is ran by an **indigenous community** and is eco-friendly, attracting 1600 tourists a year.

Sustainable Management of Tropical Rainforests

International agreements

Debt-for-nature swaps are agreements where one country **cancels part of the debt owed by another country** in return for the owing country agreeing that they will **conserve and protect their environment**.

The **Tropical Forest Conservation Act** has enabled many debt-for-nature swaps. The US recently **cancelled $30 million of debt** owed by Indonesia in agreement that Indonesia would better protect Sumatra Island, for example.

International agreements are also useful ways to spread awareness of issues and collaborate with other countries to find solutions. **The 2006 International Tropical Timber Agreement** works to develop **sustainable sources of tropical hardwood** for trading. Tropical hardwoods are **valuable** as they are are in high demand, which has caused issues surrounding **unsustainable logging**.

Conservation & Education

Designating **protected status** to tropical rainforests **legally enforces protection** by making environmentally-damaging activities illegal. **National parks and nature reserves** are a sustainable way to **allow wildlife to live** undisturbed, and also encourage **tourism** (which is economically beneficial and can **support conservation**).

Educating **consumers** and **companies** on the **environmental impacts** of rainforest products (meat, palm oil etc.) reduces the demand for these products, and encourages brands to use more **sustainable products**.

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Protection of the Taiga Wilderness

Some areas of the taiga are classed as areas of **wilderness**, which means they are **untouched by humans** and therefore remain unaffected by human activity (aside from passive contributions like the influence of human-induced **climate change**).

With the threat of **over-exploitation** of the taiga from **human activities**, there is an increasing importance to sustainably **protect these areas** for future generations. However, conservation efforts are not straight forward and present **challenges** for those who create and maintain them.

Wilderness Areas and National Parks

Designating **protected status** to **taiga forests** can be a successful way of protecting an area from **human activities** through **restrictions** or **bans** of activities in the area. Wilderness areas are usually completely off-limits, whereas **National Parks** can be helpful for **research, education and tourism**.

Restrictions may include:

- Bans of **motorised transport** or **heavy vehicles**
- Restrictions on **recreational activities** (e.g. no wild camping, no campfires)
- Complete bans on **logging, mining, resource extraction** and **road building** in certain areas

The **USA's 1964 Wilderness Act** protects areas of taiga from human development by enforcing some of these restrictions. A designated area of wilderness in the US can be seen below.

(Source: Mason Cummings, The Wilderness Society)

Protected areas are also conserved by having **rangers** and **volunteers** who patrol the areas, as well as **scientists** periodically **monitoring biodiversity** levels and **species numbers**.

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Sustainable Forestry

Sustainable forestry is where forestry activities such as logging are carried out with **low environmental impact**, meaning these activities can continue in the future. Sustainable forestry practices can include many things, such as:

- **Limits** on the amount of trees allowed to be **cut down**, enforced by having **records** for **felled trees** so every tree is accounted for.
- **Selective logging** rather than clear-cutting.
- Tree **replanting** to balance deforestation.
- **Monitoring** of forestry businesses and practices, with regulations to abide by and professionals who conduct visits on businesses.

One example of sustainable forestry practices is the **Forest Certification scheme**. This is where businesses can be **certified** as a sustainable forestry business if they prove their practices are environmentally, socially and economically beneficial.

This can offer **economic benefits** (e.g. they stand out as a sustainable business during trade) which is especially helpful for **small-scale and family-run forestry businesses**, who account for the vast majority of logging in Nordic countries.

"Finnish forestry is often family forestry: private individuals and families own 60 percent of Finnish forests, and the average holding is only 23 ha" (Source: K. Salonen / FAO)

Although these protection efforts are helpful, their creation and maintenance present challenges:

- Taiga forests are **massive areas to monitor**, which requires huge amounts of **time, resources and money**. Some areas are simply too large to properly enforce restrictions.
- There can be **conflicts** between **land-owners and local businesses**, and **governments**. The introduction of new regulations may not go down well with those who have **lived and worked on the land their whole lives** without these rules.
- **Replanting is slow.** Trees take years to grow, especially in the unproductive taiga biome, which means it takes decades for forestry practices to be 'sustainable'.
- **Money and resources** are needed for all of these protection and conservation efforts.

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Conflicting Views on Protection in the Taiga

Different people and groups have different opinions on **whether taiga biomes should be protected** or **exploited**. This may be due to contrasting economic, cultural, social, religious or environmental beliefs. Below is a table of conflicting views of different groups.

Protection	Exploitation

Indigenous people Indigenous groups (those who are early settlers of the land) believe **taiga areas should not be exploited.** Many rely on the **goods and services** of the land to live (e.g. hunting, gathering, firewood). In indigenous culture, the forest is often viewed spiritually, and **degradation of the forest** goes against their spiritual **values, heritage** & **traditions.**	**Oil companies** Companies that extract oil from taiga forests see the **economic opportunity** as more beneficial than **environmental protection.** Some argue they are **benefiting the citizens** of the area by providing jobs to otherwise **remote areas** and boosting the country's GDP, which outweighs the **environmental damage.**	**Environmental groups** **Non-governmental organisations** and **conservation groups** like WWF and Greenpeace want to **protect these areas of wilderness from overexploitation. Endangered species** and the **vulnerable ecosystem** needs to be protected rather than exploited, and exploitation also contributes to **fossil fuel emissions** and **climate change.**	**Logging companies** Companies who **cut down trees** for wood or to make products argue that this practice is **sustainable** as trees are '**renewable**' and can be planted again. They believe logging should therefore be allowed as it brings economic benefits and **only affects a small area** of a vast biome.
HEP Companies Companies that specialise in **hydroelectric power development** argue that the **economic benefits** (jobs, national energy supply) outweighs the land degradation, especially as taiga areas are so large. HEP is also considered **renewable** so it is **sustainable.**	**Tourists** Some people want to visit the taiga for recreational activities, like **camping, birdwatching, hiking, and canoeing.** Visitors want the area to be **protected** from developments as they want to **enjoy the natural environment.** However, this does mean visitors do not want the forests to be **restricted** protected areas.	**Mining companies** In some areas, mining has been an **important income source** for many **rural communities**, so mining companies argue it is **important to protect worker jobs** in this industry. The benefits mining brings for the **economy** and **trade** agreements are also valuable internationally, nationally and regionally.	**Climate Scientists** Those who **study the taiga forests** understand their importance to the environment, especially as a **carbon sink and store.** Therefore, climate scientists argue for the **protection of the taiga biome**, agreeing the area should be protected and conserved for its benefits to the world.