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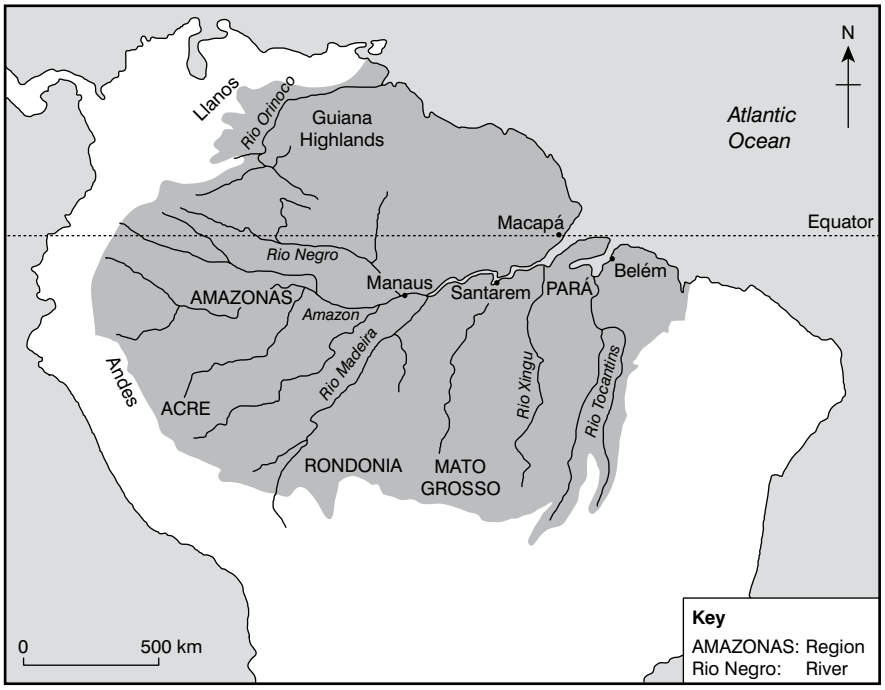
CASE STUDY OF A RAINFOREST ZONE: AMAZONIA

Location

Amazonia is located either side of the equator in South America and stretches from the eastern slopes of the Andes Mountains to the Atlantic Ocean. It occupies 68% of Brazil, and smaller parts of Peru, Bolivia, Colombia, Ecuador, Venezuela, Guyana, Suriname and the overseas territory of French Guiana (Figure 1). The size of the biome varies according to how the area is defined, but a reasonable view is that it covers 7.3 million sq km. The forested area extends beyond the boundaries of the Amazon River basin, especially on its northern and southern edges.

Figure 1: Map showing location of Amazonia



Biome characteristics

1. Climate

The Amazonian climate is hot and wet; for example, at Uaupes in Brazil on the equator, mean monthly temperatures range between 25 and 27°C and rainfall averages 2677mm per annum. Most precipitation occurs as heavy convectional storms, and skies are usually cloudy. Rainfall is well-distributed throughout the year in the western part of Amazonia, but southern and eastern areas experience a short dry season, although precipitation is still sufficient for rainforest.

2. Flora and fauna

Primary productivity is very high; the biome is the most biologically diverse ecosystem in the world. Although estimates vary, there are about 1300 bird, 428 amphibian, 427 mammal and 378 reptile species, and 3000 types of fish. Species typically associated with the biome are shown in Figure 2. Birds, bats, bees and butterflies are particularly prolific and some animals, such as the jaguar and sloth, are endemic. Intense competition ensures that few species dominate. Species diversity is high because:

- the rainforest has developed over a long period of time; which has encouraged complex food webs to develop
- constant, warm temperatures permit reproduction all year round, which means that natural selection and evolution take place relatively rapidly
- growth is not restricted by water supply

Figure 2: Typical Amazonian species

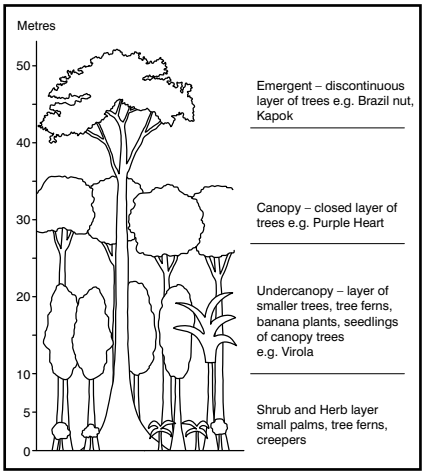
Birds:	toucan, macaw, harpy eagle
Insects:	blue morpho butterfly, leaf-cutter ants
Mammals:	spider monkey, howler monkey, sloth, jaguar, tapir, ant-eater, pink river dolphins, manatee, peccary, capybara
Reptiles:	black caiman, green anaconda
Amphibians:	poison dart frog, tree frog
Fish	piranaha, catfish

- forest stratification, discussed below, creates variations in temperature, humidity, light and soil conditions, producing a wide variety of ecological niches.

Flora as well as fauna are highly diverse. The vegetation is usually vertically stratified into four layers: emergent, canopy, undercanopy, and shrub and herb (Figure 3).

The forest appears to be evergreen because foliage is always present, but only the palm tree grows and sheds its leaves continually. Most trees instead have flushes of growth; for example the Brazil nut, a dry season deciduous tree,

Figure 3: Stratification of the rainforest



sheds its leaves well before bud break. Others, known as leaf exchangers, shed their leaves at the same time that buds break, while others lose their leaves after buds break.

3. Soils

Tropical soils or latosols are deep because warm, wet conditions encourage intense weathering of the bedrock. Heavy rainfall encourages intense leaching of soluble minerals which leaves the soil acidic. Moreover, leaching in removing soluble minerals, leaves behind a soil rich in iron and aluminium sesquioxides, giving it a red or yellow colour. Organic

matter is rapidly recycled by micro-organisms which thrive in warm, wet conditions, so a thick humus layer never develops.

Spatial variations

About 80% of Amazonia is rainforest; the rest is composed of seasonally flooded swamp forest and cleared, or cultivated, land. Variations in biodiversity reflect differences in regional climate, soils, geology, topography, drainage and past environmental histories.

- The western Amazon, which experiences no dry season, has higher species diversity and more epiphytes than forests in the drier south and east. The trees are also thinner and have smoother barks than their eastern and southern counterparts.
- Towards the Andes, lowland forest is replaced by cloud and montane forests. Trees here are smaller and more spread out than lowland forests and are prone to tree-falls on wet, slippery, steep soils.
- Swamp forests occur where rivers seasonally flood. Várzea swamp forests occur where land is inundated by muddy, nutrient-rich rivers, such as the Madeira which drains from the Andes. Igapó swamp forests develop in areas flooded by nutrient-poor rivers, such as the Rio Negro which flows from the Guiana Highlands. The trees here are lower, wider apart and less diverse than those in the várzea swamp forests.

Areas cleared for agriculture and later abandoned, or gaps created by natural tree-falls, are soon colonised by fast-growing, pioneer species such as cecropia. This plant has large leaves, a hollow stem and pale, low-density wood. Secondary communities germinating in the shade of the pioneers eventually overtop and out-compete them, leading to a vegetation succession.

Plant adaptations and ecological responses to climate

Amazonia, because of its equatorial position, receives high levels of solar energy throughout the year which leads to high rates of photosynthesis and lots of biomass. This together with a warm, wet climate encourages luxuriant growth. As a result of this, competition for sunlight is intense, which results in a vertically stratified forest.

Termites, fungi, bacteria, worms and ants all thrive in the warm, wet conditions and quickly decompose dead organic matter, releasing mineral nutrients which are rapidly recycled by tree roots. The activities of these organisms explain why the forest floor is not covered by a thick layer of litter.

Trees are adapted to the environment in the following ways:

- Canopy trees have umbrella-shaped crowns to maximise exposure to sunlight. They also have straight trunks and only begin to branch near their crowns, in order to conserve energy while growing tall. Understorey trees occupy gaps beneath the canopy and have crowns which are narrow in comparison to their height, ie they are conical-shaped.
- Leaves in the canopy, and especially those in the understorey, where light levels are lower, are large to maximise photosynthesis. Emergent trees have smaller leaves than those in the canopy and understorey in order to reduce transpiration because of their exposure to wind and strong sunshine. Leaves are dark green in colour and have a thick cuticle and waxy surface to help shed rainfall and provide protection against strong solar rays.
- Understorey leaves have extended apical ends or 'drip tips'. Originally it was thought that drip-tips shed heavy rainfall to discourage bryophytes and epiphyllous algae becoming established and impeding transpiration and photosynthesis. Experiments have, however, revealed this is not the case and it is now believed that the main function of the tip is to remove water from the leaf surface so that transpiration can proceed unhindered. This idea is supported by the fact that drip-tips are particularly common in the understorey layer, where lack of wind and high humidity reduce transpiration rates.
- Tree bark is thin (1–2mm) because protection is not needed against low temperatures or high water loss. Many species also have smooth barks to shed rainfall, which discourages algae and epiphytes growing on their surfaces. Fast-growing, light-seeking, pioneer species such as balsa have pale-coloured, low-density wood, whereas understorey trees, which grow more slowly, have darker, denser wood, which is often also impregnated with chemicals that repel insect attack.
- Understorey trees, such as the cocoa, produce fruit and flowers directly on the trunk, ie cauliflory, or on large branches, ie ramiflory. The reason for these growth habits relates to germination and pollination. Plants with large seeds surrounded by copious fruit reserves have a better chance of supporting a seedling germinating in the gloom of the forest floor than small seeds. Trunks and large branches provide good support for large seeds. Moreover, in the gloom of the under-storey, pollinators find it easier to locate flowers and seeds growing on trunks than within foliage.
- A broad, woody flange, or plank buttress occurs at the base of the trunk of species such as the kapok. Other species sometimes have stilt-like projections near their bases. Several theories have been advanced to explain plank buttresses and stilt-like projections, although a commonly held view is that they are tensional structures designed to support the trees.
- Tree-roots tend to be shallow because mineral nutrients are rapidly recycled and plants have no need to seek moisture. Some trees have tap roots; others have sinkers which descend vertically from spreading roots or buttresses.

Other plants adapted to the rainforest environment include epiphytes, lianas and parasites.

Epiphytes are plants that use tree branches for support, but do not feed off their hosts. Instead their aerial roots extract moisture from the air and trap dead leaves and insects. Such plants typically include orchids, bromeliads and bird's-nest ferns. Sun-dwelling epiphytes live high in the canopy and have leathery leaves and thick cuticles, whereas shade epiphytes occur in the understorey and have thinner leaves.

Lianas are large, rooted, woody vines which use trees to gain access to sunlight and produce fruit and flowers in the canopy. The plants

bind themselves to trees using hooks, thorns and tendrils; many hang freely by attachments to the canopy. Examples include philodendron, a vine which coils itself around the tree, and monsteras, which is common alongside roads and rivers. It should be noted that 'liana' is not a taxonomic term, but a description of the way the plants grow.

Parasitic plants which live on other living organisms occur on the floor of the rainforest, where low light levels limit photosynthesis. Lack of sunlight here also explains why, contrary to popular opinion, the ground/field layer is more or less bare except for mosses, liverworts and fungi.

Warm wet conditions encourage micro-organisms to thrive, and plants have developed defensive mechanisms for protection against predators. Some trees have spines, or, as mentioned earlier, contain chemicals to repel insects. Rubber trees produce latex which traps sap-sucking insects, whose mouth parts become gummed up. Some plants have developed special relationships with ants such that, in return for shelter and food, the ant protects the tree from predators. For example the hollow stem of the cecropia tree provides azteca ants with food and an egg nesting site. In return for this the ants defend the tree against predators such as caterpillars, beetles, leaf-cutter ants and mammals that eat the leaves. Only the three-toed sloth finds the tree approachable.

Animal adaptations

Many animals live and feed in the tree canopy, which is rich in fruits and seeds. Adaptations to living in this arboreal environment include:

- strong, large, lightweight bills to prise open fruit and crack seeds, eg the toucan (Figure 4)
- specially developed hands and feet which can cling to branches, eg the toucan has two backward-facing toes, while the sloth has an opposable thumb which allows it to hang upside down from branches. Tree frogs have sticky disc pads on their feet to enable them to hold onto wet leaves and branches,
- prehensile tails to facilitate easy movement through the canopy, eg spider monkey, tree porcupine, kinkajou and pygmy anteater.

Figure 4: Keel-billed Toucan with strong, large, lightweight bill

Photo: Donar Reiskoffer

Competition between species is intense, and many animals have developed ways of protecting themselves from predators, including:

- camouflage, eg the anaconda snake has green and black markings which blend in with the foliage
- mimicry, eg the false-leaf katydid looks like a leaf
- thick, scaly skin, eg the armadillo
- bright colours, eg the poison dart frog is bright red, or yellow, or blue, to warn predators it is highly toxic
- nocturnal habits, eg the kinkajou, which has large eyes for night vision.

Biome threats

Up to 1960, shifting subsistence cultivation by indigenous groups had little impact on the biome. In the late 1960s the Brazilian Government encouraged colonisation and sponsored large-scale projects to exploit resources. Road construction opened up large areas of previously inaccessible forest to activities such as logging. It is estimated that about 17% of the original forest has been lost, an area about the size of France.

The main causes of deforestation are:

- Cattle ranching – accounts for 80% of deforestation. Improvements in infrastructure, eradication of foot and mouth disease in Brazil and devaluation of the Brazilian currency against the dollar have all encouraged ranching to expand.
- Soya bean agriculture – especially in the Brazilian states of Pará and Mato Grosso. This has been encouraged by a new variety of soya which thrives in rainforest climates, rising demand for vegetable oils, interest in biofuels, road improvements and the construction of a grain outlet at Santarem.
- Colonisation – from overcrowded urban areas in Brazil, encouraged by government incentives.
- Hydroelectric power generation – large hydroelectric dams have been constructed on rivers such as the Rio Tocantins and have flooded large areas of rainforest. Early in 2010, the Brazilian government approved the construction of the highly controversial huge Belo Monte Dam on the Xingu River. The proposal is strongly opposed by environmental groups and indigenous people. The dam, potentially the third largest in the world, would flood 400 km^2 and displace 12,000 locals.
- Logging – loggers, often working in tandem with cattle farmers, take the best trees and clear and burn the rest, and then the land is sown with grass to raise cattle. Illegal logging is widespread. Outright deforestation for timber is, however, rare, because of the dispersed nature of valuable trees such as kapok.
- Oil and gas are extracted in western Amazonia in Colombia, Ecuador and Peru. Gold mining

occurs in the Brazilian state of Pará. Other minerals mined include manganese, iron and tin. The indigenous Achuar tribe in Peru oppose oil drilling, fearing loss of land and livelihoods and contamination of water supplies.

Other threats to the rainforest ecosystem include hunting and illegal trade in birds, reptiles and mammals. Parts of the Amazon basin experienced drought in 2005 and 2010. The 2010 event lowered the Río Negro upstream from Manaus, isolating local people who depended on the river for transport. Forest fires often occur as a result of drought.

Ecological consequences of deforestation

Despite its high biodiversity, the Amazon rainforest is a fragile ecosystem, because a high proportion of its energy and nutrients are stored above the ground in the biomass, and therefore are vulnerable to disturbance. Plants are well-distributed in the primary forest and have relatively low seed production and dispersal capabilities. A consequence of this is that unless the seeds germinate almost immediately after dispersal, they are eaten or decompose very rapidly.

Complex and highly specialised relationships exist between rainforest species. The Brazil nut tree for example is dependent on several species for its survival. The agouti is the only animal that can open the tough outer pod of the Brazil nut, and, by storing the nuts in hoards, some of which he does not eat, is responsible for dispersing nuts throughout the forest. The female Euglossine, or orchid bee, is responsible for pollinating the flowers of the Brazil nut tree, while the male bee is reliant on the strong scent of the gongora orchid to attract female bees. A decline in bees, orchids or agoutis would have negative consequences for the Brazil nut tree.

A number of important seed-dispersing animals, such as monkeys and toucans, are pivotal in maintaining the ecosystem. Loss of these 'keystone species' would trigger a decline in many other species. Fish, in consuming fruit which often falls into rivers during the wet season, are also major seed dispersers. The fig tree, *Ficus insipida*, is also an important keystone species because it provides food for a wide range of other species.

The impacts of deforestation on biodiversity extend beyond the area which is directly cleared. Forest fragmentation creates small areas which are often unable to support viable populations. The length of the perimeter of the rainforest increases with fragmentation, which alters microclimates. Tall trees with their inflexible trunks are prone to wind throw, and circulating air currents dry out the soil.

The future

Ways of protecting the Amazonian rainforest in the future include:

- Establishing clear property rights over land – the Brazilian Government is keen to establish a land registry to reduce land grabbing and illegal logging and ranching.
- Paying owners not to cut down the trees. The main international effort to reduce forest clearance, known as REDD (reduced emissions from deforestation and forest degradation) is based on the idea that rich countries should pay poor countries not to cut down trees. $4.5 billion was pledged to support this idea following the Copenhagen climate talks in 2009 and a carbon tax offers another way of raising revenue.
- Encouraging markets to buy forest products from legally registered sources. The problem, however, is that the destination of many tropical commodities is often markets which are not eco-sensitive; for example much Amazon rainforest timber is sold in China and India, while Brazilian beef is exported to Russia, Iran and Egypt.
- Monitoring deforestation. Brazil has a sophisticated system of monitoring deforestation using satellites and aeroplanes which can detect large-scale illegal clearances.
- Expanding areas designated as National Parks or Indigenous Reserves.

Figure 5: A satellite image showing deforestation at Rondonia. The fish bone pattern of small clearings along new roads is the beginning of one of the common deforestation trajectories in the Amazon

Source: NASA Earth Observatory

- Ecotourism – this protects rainforests from hunting, logging and mining and provides local employment. The Posada Amazonas Lodge in the Peruvian Amazon, for example, is jointly run by an eco-tour operator and the local Ese'eja community.

Brazil obtains 40% of its energy from renewable resources and recognises that deforestation damages its reputation. The rainforest recycles 50% of its precipitation, while deforestation alters transpiration and albedo levels, which will lead to reduced precipitation. The Government knows that lower rainfall across Brazil will adversely affect agriculture, a major export-earner. On the other hand the global demand for commodities, including bio-fuels, along with rising food prices and populations, means the future of Amazonia is uncertain.

Further reading

Hemming, J. (2008) *Tree of Rivers. The Story of the Amazon*, Thames & Hudson, London.
Whitmore, T. C. (1998) *An Introduction to Tropical Rainforests.* Oxford University Press, Oxford.
www.amazon-rainforest.org
http://rainforests.mongabay.com/amazon

Focus Questions

1. Give reasons for the high biodiversity of the Amazon rainforest.

2. Why, despite its long history and apparent lush appearance, is the rainforest so fragile?

3. Suggest ways in which plants are structurally adapted to living in the Amazon rainforest.