Cambridge AS & A Level · Geography 9696 · Notes

Tropical environments A2

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Read first: **Atmosphere and weather**, **Rocks and weathering**

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What you need to know

By the end of this topic you should be able to:

1. **Describe where humid tropical and seasonally humid tropical climates are found**, and their **climatic characteristics**, and explain them using the **intertropical convergence zone (ITCZ)**, the **subtropical anticyclones** and the **monsoons**.
2. **Describe and explain the temperature and rainfall** of both climates, including how they vary **through the year (annual)** and **through the day (diurnal)**.
3. **Explain how the typical landforms of tropical environments form**: on **granite**, deep weathering profiles, **tors**, **inselbergs** and **bornhardts**; on **limestone**, **tropical karst**: **cone karst**, **tower karst** and **cockpit karst**.
4. **Explain how plant communities develop** in rainforest and savanna ecosystems: **climax**, **subclimax** and **plagioclimax** communities.
5. **Describe and explain the vegetation characteristics** of both ecosystems.
6. **Explain nutrient cycling** with **Gersmehl diagrams**, and **soil fertility**, **energy flows** and **trophic levels**.
7. **Explain how tropical soils form**: the soil-forming processes, the soil types and their profiles (**oxisols/latosols**, **tropical red earths** and **tropical brown earths**).
8. **Know a case study of an area within either the rainforest or the savanna ecosystem**: the threats to it from exploitation, the problems of managing it sustainably, and an **evaluation of the attempted solutions**.

It is one of the options in Paper 3 (Advanced physical geography options), where you answer two options. For this option you answer Question 1 (10 marks: a 4-mark describe part and a 6-mark explain part, built on a figure) and one essay, Question 2 or Question 3 (20 marks). Read the notes on atmosphere and weather (pressure belts, the Hadley cell) and on rocks and weathering (hydrolysis, carbonation) first.

Understand it

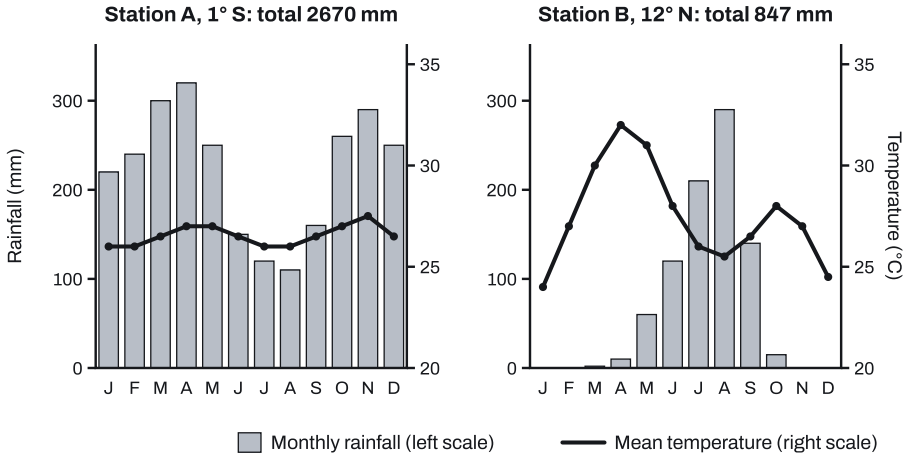
Where the tropical climates are

The tropics lie between the **Tropic of Cancer (23.5° N)** and the **Tropic of Capricorn (23.5° S)**, the limits of the overhead midday sun.

- **Humid tropical** (equatorial, rainforest) climates lie roughly **within 5–10° of the equator**: the Amazon Basin, the Congo Basin and South-east Asia (Indonesia, Malaysia, Papua New Guinea), with smaller areas on **east-facing coasts** further from the equator where moist trade winds blow onshore (eastern Central America, south-east Brazil, eastern Madagascar). The band is broken: East Africa is mostly too high and too dry.
- **Seasonally humid tropical** (savanna, tropical wet-and-dry) climates lie **between about 5° and 20° N and S**, on the poleward side of the rainforest: the Sahel and Sudan belt of West Africa, East and southern Africa, the Brazilian Cerrado, the Llanos of Venezuela and northern Australia. They grade into hot desert on their poleward edge.
- **Monsoon** climates are a seasonally humid type with a very wet summer: South and South-east Asia, where the ITCZ swings furthest from the equator.

Climatic characteristics

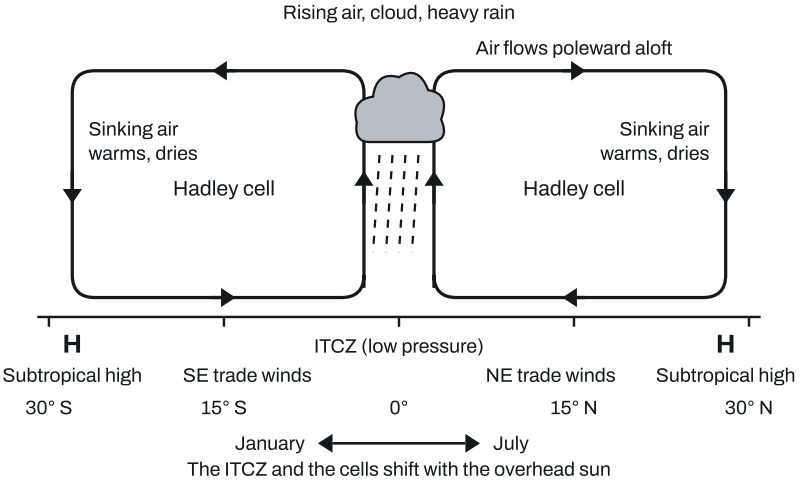
	Humid tropical	Seasonally humid tropical
Mean monthly temperature	26–28 °C all year	20–32 °C; hottest just **before** the rains
Annual temperature range	Very small, 1–3 °C	Larger, about 5–12 °C, growing away from the equator
Diurnal temperature range	About 7–10 °C, **larger than the annual range**	Similar in the wet season; up to 15–20 °C in the dry season
Annual rainfall	Over 1500 mm, often 2000–3000 mm	About 500–1500 mm, falling away from the equator
Seasonality of rain	Rain in every month; often **two maxima** near the equinoxes	**One wet season** (summer) and a **dry season** of 3–8 months
Humidity and cloud	High all year; afternoon cumulonimbus	High in the wet season; low, clear skies in the dry season



The ITCZ and the Hadley cell

The **ITCZ** is the belt of **low pressure** near the equator where the **north-east and south-east trade winds converge**. It lies under the zone of strongest heating, the **thermal equator**.

1. The high, often overhead, sun heats the ground strongly. Air in contact with it warms, becomes less dense and **rises by convection**; the trades converging at the surface force more air upward.
2. The air is very moist, from evaporation off warm seas and **transpiration** from the forest. As it rises it **cools** (adiabatically), its water vapour **condenses** and towering **cumulonimbus** clouds form, giving heavy **convectional rain** and thunderstorms.
3. At the top of the troposphere the air spreads **poleward**, cools by radiating heat, and **sinks** at about **25–30° N and S**, forming the **subtropical anticyclones** (high pressure). Sinking air warms and dries, so these are the zones of hot deserts.
4. From the subtropical highs, surface air flows back to the ITCZ as the **trade winds**, deflected by the Coriolis force into north-easterlies and south-easterlies. This loop is the **Hadley cell**.



The ITCZ moves with the seasons. It follows the overhead sun, about a month behind it, moving north in the northern summer and south in the northern winter. It moves **much further over the continents** (which heat and cool quickly) than over the oceans: over Africa it reaches about 15–20° N in July, over South Asia 20–25° N, while over the Atlantic it stays within a few degrees of the equator.

- Near the equator the ITCZ is **overhead or close by all year**, and passes over **twice** a year, so there is no dry season and rain peaks twice, a little after the equinoxes (March–April and October–November). This explains Station A.
- Further from the equator the ITCZ arrives **once**, in summer, bringing the wet season; for the rest of the year the **subtropical anticyclone** moves over, bringing sinking, dry air, clear skies and the **dry season**. This explains Station B.

Subtropical anticyclones

Subtropical anticyclones are large cells of **high pressure** centred near 25–30° N and S, such as the one over Australia in the southern winter or the Azores and South Atlantic highs. Their air **descends, warms adiabatically and dries**, which stops clouds forming (a **stable** atmosphere, often with a temperature inversion aloft). Their roles in tropical climates:

- they **bring the dry season** to the savanna when they shift towards the equator in winter, and the hot deserts on their poleward side;
- they are the **source of the trade winds**, which feed the ITCZ; when the winds blow over warm ocean they pick up moisture, and where they meet east-facing coasts they bring rain all year (eastern Madagascar, eastern Brazil);
- over land in winter they send out **dry, dusty continental air** such as the **Harmattan**, a north-easterly wind from the Sahara over West Africa (December–February);
- they move with the seasons, so their position, together with the ITCZ's, decides how long the dry season lasts at any place.

Air masses

An **air mass** is a huge body of air with similar temperature and humidity, taken from the region it formed over. Two dominate the tropics:

- **tropical maritime (mT)**: warm and moist, from the oceans, unstable when heated over land, bringing the rains;
- **tropical continental (cT)**: hot and dry, from deserts and the subtropical highs, bringing the dry season and dust.

In West Africa the boundary between them, the **Intertropical Discontinuity**, moves north in summer as moist south-westerly air from the Gulf of Guinea pushes inland, and south in winter as the Harmattan (cT) takes over. The length of the wet season at any place depends on how long it lies under the moist air.

Monsoons

A **monsoon** is a **seasonal reversal of the prevailing winds**, bringing a very wet season and a dry season. The South Asian monsoon is the strongest.

1. **Summer (June–September)**: the land of South Asia heats up far faster than the Indian Ocean, so **low pressure** forms over northern India and Pakistan. The ITCZ moves north to about 20–25° N. The south-east trades cross the equator and are **deflected by the Coriolis force** into **south-west winds**, carrying moist mT air over the warm ocean onto the land. Convection, convergence and **orographic uplift** (the Western Ghats, the hills of north-east India and the Himalayas) give heavy rain.
2. **The jet streams**: in early summer the **subtropical westerly jet** moves north of the Himalayas and a **tropical easterly jet** forms over India, helping the air to rise; the monsoon "bursts" suddenly, reaching Kerala in the south around 1 June and covering the country by early July.
3. **Winter (December–February)**: the land cools, **high pressure** builds over the cold interior of Asia, and **dry north-east winds** blow from land to sea. Most of India is dry, except where these winds cross the Bay of Bengal (south-east India gets winter rain).

El Niño years tend to weaken the South Asian monsoon and bring drought to parts of South-east Asia and Australia, while **La Niña** tends to strengthen it.

Annual and diurnal variations

Annual temperature. In humid tropical places the noon sun is high all year and day length hardly changes, so mean monthly temperatures stay near 27 °C and the annual range is only 1–3 °C. Cloud also limits the maximum: temperatures rarely exceed 33 °C. In seasonally humid places the sun's noon angle and day length change more, so the range is larger. The **hottest month comes just before the rains**, when the sun is high and the skies are still clear; once the wet season starts, cloud and evaporation cool the days, which is why Station B's temperature dips in July–August and rises again in October.

Real stations. Use named places with figures in essays. Mean values for 1991–2020:

Station	Climate	Annual temperature range	Diurnal range	Annual rainfall
Belém, Brazil (1° S)	Humid tropical	1.3 °C (26.1 °C in February to 27.4 °C in November)	8.4 °C in January, 10.3 °C in September	3308 mm; every month over 120 mm, wettest in March (506 mm)
Singapore (1° N)	Humid tropical	1.8 °C (26.8 °C in December and January to 28.6 °C in May)	6.6 °C (mean daily maximum 31.6 °C, minimum 25.0 °C)	2113 mm, spread through the year

Station	Climate	Annual temperature range	Diurnal range	Annual rainfall
Kano, Nigeria (12° N)	Seasonally humid (savanna)	10.7 °C (21.3 °C in January to 32.0 °C in April)	16.2 °C in January (dry season), 8.8 °C in August (wet season)	1149 mm; 91% in June–September, none in November–February
Mumbai, India (19° N; temperatures Colaba, rain Santacruz)	Monsoon	5.8 °C (24.9 °C in January to 30.7 °C in May)		2502 mm; 96% in June–September

The humid stations have tiny annual ranges and diurnal ranges several times larger; Kano's annual range is eight times Belém's, and its diurnal range nearly doubles in the dry season; Mumbai has more rain than Singapore but almost all of it in four monsoon months, with its hottest month, May, just before the rains.

Diurnal temperature. "Diurnal" means within a day (24 hours).

- **Humid tropical**: the **diurnal range (about 7–10 °C) is larger than the annual range**, so the "night is the winter of the tropics". After sunrise, temperatures climb steeply (for example from about 23 °C at dawn to about 31 °C by early afternoon). Cloud building from late morning cuts the sunshine, so the maximum is held down. At night the moist air and the cloud **absorb and re-radiate** outgoing long-wave radiation back to the ground, so temperatures fall only slowly and nights stay warm.
- **Seasonally humid**: in the wet season the pattern is like the rainforest's. In the **dry season**, the dry air and **clear skies** let strong sunshine heat the ground by day and let heat **radiate away** at night, so the range is much larger (for example from about 14 °C at night to about 33 °C in the day).

Diurnal rainfall. Rain in the humid tropics follows the daily heating: clear or misty mornings; cumulus building as convection strengthens; cumulonimbus and torrential **afternoon thunderstorms**, often between about 2 pm and 5 pm; clearing in the evening. Around coasts and large lakes, sea breezes by day and land breezes at night shift the timing (night or early-morning rain offshore and on coasts); over mountains, storms come earliest in the afternoon. In the seasonally humid tropics this daily pattern happens only in the wet season.

Granite landforms

Granite is a coarse igneous rock of **feldspar**, **quartz** and **mica**, cut by **joints**: vertical ones from cooling, and horizontal **sheeting** (pressure-release) joints that open as overlying rock is eroded. In the hot, wet tropics, **hydrolysis** rots the feldspar into kaolinite clay, leaving loose quartz grains (see the rocks and weathering note):

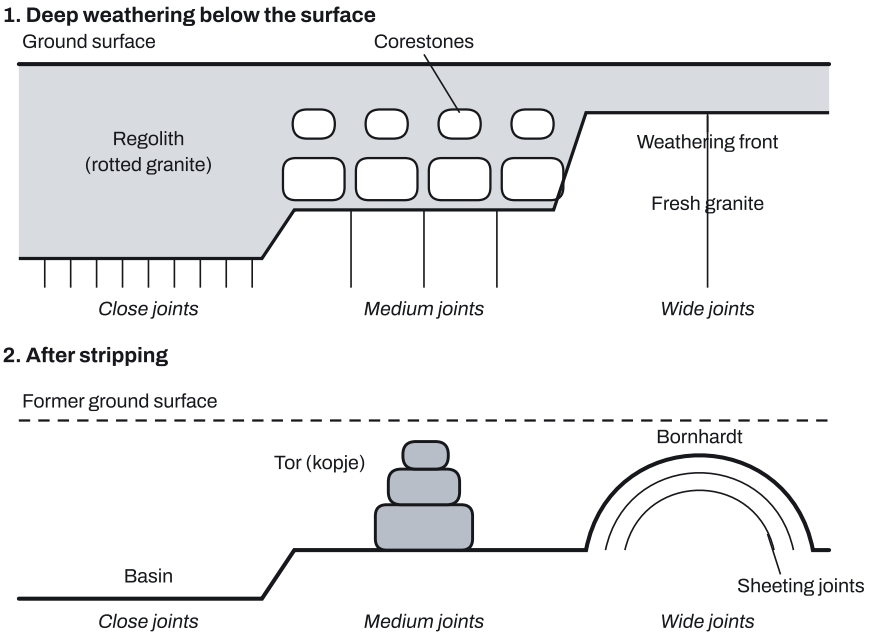
$$2\,\mathrm{KAlSi_3O_8} + 2\,\mathrm{H^+} + 9\,\mathrm{H_2O} \rightarrow \mathrm{Al_2Si_2O_5(OH)_4} + 4\,\mathrm{H_4SiO_4} + 2\,\mathrm{K^+}$$

Mica alters too, by hydrolysis and oxidation. Warmth speeds the reactions, water is plentiful all year, humic acids from decaying plants add hydrogen ions, and the rock is attacked along every joint.

Deep weathering profiles. Weathering works down the joints far below the surface, producing a layer of rotted rock (**regolith** or **saprolite**, sandy **grus** and clay) that can be **30 m deep or more**, in places over 100 m. Its base, where rotted rock meets fresh rock, is the **weathering front** (basal surface of weathering). The front is **irregular**: it goes deepest where joints are **closely spaced** (water gets in everywhere) and stays high where joints are **widely spaced**. Blocks between joints are attacked from their edges and corners first, so they are rounded into **corestones** (spheroidal weathering) sitting in the rotted rock.

The two-stage (etchplanation) model.

1. **Deep weathering** under a hot, wet climate and forest produces the regolith and the uneven weathering front.
2. **Stripping (exhumation)**: the loose regolith is washed away, for example after **uplift** (which makes rivers cut down) or a **change to a drier climate** (thinner vegetation, more surface wash). The weathering front is exposed, and the unweathered rock that stood up from it becomes the landforms. Surfaces lowered this way are **etchplains**.



Landform	What it is like	How it forms
Tor (in Africa, **kopje**)	A small pile of rounded or blocky **corestones**, a few metres to tens of metres high, on a hill top or slope	Medium-spaced joints: corestones left in place when the regolith is stripped; **block disintegration** may later split and topple them (the Matobo Hills, Zimbabwe, have famous kopjes and balancing rocks)
Bornhardt	A large, **dome-shaped**, bare rock hill with steep, smooth sides, rising abruptly from a plain	Massive granite with **widely spaced joints** resists deep weathering; once exposed, unloading opens **sheeting joints** parallel to the surface, and slabs peel off (**exfoliation**), keeping it dome-shaped

Landform	What it is like	How it forms
Inselberg ("island mountain")	Any steep-sided isolated hill rising sharply from a plain; a bornhardt is a domed inselberg; some are angular or flat-topped (Spitzkoppe, Namibia)	Either exhumed from the weathering front (above), or left behind by **parallel slope retreat** (**pediplanation**): in a drier climate, slopes retreat back across the land, leaving a gently sloping **pediment** and the last remnant as an inselberg

Two theories of inselbergs, and the role of climate change:

- **Etchplanation** (deep weathering, then stripping) needs a **humid** phase followed by a phase of stripping, often **drier**.
- **Pediplanation** (L. C. King's idea) needs **semi-arid** slope retreat; deep weathering plays little part.
- Many tropical regions have swung between wetter and drier climates over millions of years, so both may have worked, and many landforms are **relict**: formed under past climates over very long timescales.

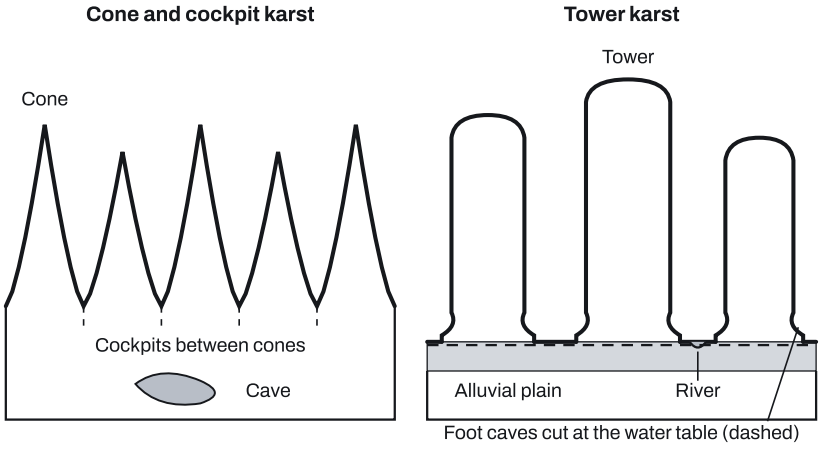
What controls the landforms, weighed: **rock structure**, especially the **spacing of joints** (vertical and horizontal), decides where weathering goes deep and what shape survives, so it is usually judged the most important factor; **climate**, present and past, drives deep weathering and then stripping; **uplift** and base-level fall allow stripping and unloading; **vegetation** supplies humic acids and holds the regolith in place until it is removed; **time** (millions of years) is needed for both stages.

Tropical karst

Karst is the landscape of soluble rock, usually limestone. Limestone is weathered by **carbonation**:

$$\mathrm{CaCO_3 + H_2O + CO_2 \rightarrow Ca(HCO_3)_2}$$

Calcium bicarbonate is soluble and is carried away in solution. Warm water holds **less** carbon dioxide than cold, but tropical karst is weathered **faster** because of **heavy rainfall** (more water passing through), **very high carbon dioxide in the soil** from rapid decay of plant litter and from roots and microbes, and **organic (humic) acids**. Limestone that is **thick, pure, hard and well jointed** gives the most dramatic landforms, because water is guided down joints and the rock can stand in steep faces.



- **Cockpit karst**: many enclosed hollows (**cockpits**), star-shaped in plan, separated by rounded, cone-shaped hills. It forms where **dolines** (solution hollows) grow at joint intersections, deepen and widen until their edges meet, leaving the hills between them. Cockpit Country, Jamaica, is the type example.
- **Cone karst** (Kegelkarst): the same landscape seen in terms of its hills, steep-sided cones about as wide as they are high, standing among the hollows; its form is guided by the joint pattern. Examples are in Jamaica, Puerto Rico and southern China.
- **Tower karst** (Turmkarst): isolated **towers** with **near-vertical sides**, tens to hundreds of metres high, standing on a **flat alluvial plain** (Guilin and Yangshuo, Guangxi, China; Hạ Long Bay in Vietnam is tower karst drowned by the sea). It forms where the land has been **uplifted** or a river has cut down, so that the surface between the hills is at or near the **water table**: swamps and rivers there attack the hills' bases sideways (**lateral undercutting**), cutting **foot caves** and notches; the overhangs collapse, and the sides retreat while staying steep. Rivers spread **alluvium** that floors the plain, and the collapse of cave systems inside the hills adds to their retreat. Many towers are thought to develop **from cone karst** as the hollows are lowered to the water table.

Factors to weigh in karst essays: **geology** (purity, thickness, joint spacing and pattern, bedding: without these, carbonation can't produce the landforms); **climate** (high rainfall and warmth, biogenic carbon dioxide); **tectonics** (uplift and base-level change, which separate cone from tower karst); **hydrology** (the height of the water table and rivers); **vegetation** (humic acids); and **time**.

Plant communities: climax, subclimax and plagioclimax

A **plant succession** is the sequence of communities that colonise a site, each changing conditions (adding soil, shade and nutrients) so that the next can replace it.

- **Climatic climax**: the final, stable community in balance with the **climate**, reached when succession runs its full course. The **tropical rainforest** is usually regarded as a climatic climax: its climate has been hot and wet, with no frosts, for a very long time (although some areas were drier in glacial periods), so the forest has had millions of years to develop its huge diversity, and its layered structure is similar across the Amazon, Congo and South-east Asia.
- **Subclimax**: a community in which succession has been halted by a **natural** factor other than climate, such as poor or waterlogged soil (an edaphic subclimax), relief, natural fires from lightning, or grazing by wild animals.
- **Plagioclimax**: a community in which succession has been **halted or deflected by human activity**: repeated **burning**, **grazing** of livestock, clearing and cultivation. When the activity stops, succession resumes towards the climax.

Is the savanna a climatic climax?

- **Climatic case**: rainfall decreases and the dry season lengthens away from the equator, and the vegetation changes with it from woodland to grassland; trees need more water than grasses, so a long dry season favours grass.
- **Subclimax case**: lateritic crusts and waterlogged clays in some areas stop trees rooting; elephants and other wild grazers break and eat trees; lightning starts fires in the dry season.

- **Plagioclimax case**: people have burnt the savanna for tens of thousands of years, to clear land, improve grazing (new grass grows after fire) and drive game; herds of cattle and goats graze it, and trees are cut for fuel. The evidence: vegetation type **does not match rainfall closely**; boundaries between woodland and grassland are often **sharp** (fire or grazing lines), not gradual; and where burning and grazing are stopped, **woody plants and woodland return**. In Kruger National Park, South Africa, plots burnt at different intervals since 1954 show that keeping fire out raises the number of trees and shrubs, though in the driest parts the change is small, so rainfall still limits trees there.
- **Overall**: most of the savanna is probably a **plagioclimax or fire subclimax** on a climatic base: climate sets the possible range from grassland to dry forest, and fire, grazing and people decide where within that range a place lies. The **rainforest**, in its natural state a climatic climax, is now often a **plagioclimax** too: cleared areas regrow as **secondary forest**, lower and less diverse, and where soils have been degraded the forest may not return at all. Shifting cultivation with long fallows let the forest regrow, but shorter fallows and permanent clearance do not.

Vegetation characteristics

Rainforest (humid tropical)

- **Structure in layers**: **emergents** up to 50–60 m, with **buttress roots** for support in shallow soil; a closed **canopy** at about 30–40 m that intercepts most of the light; an **under-canopy** of young trees; a sparse **shrub layer**; and a dark **ground layer**, where only about 1–2% of the light arrives, so the forest floor is fairly open.
- **Adaptations**: broad, dark-green, **evergreen** leaves with **drip tips** and waxy surfaces to shed the heavy rain; thin, smooth bark (no need to protect against cold or fire); **shallow roots** spreading wide, because nutrients are near the surface; **lianas** climbing to the light; **epiphytes** (orchids, bromeliads) growing on branches; flowers and fruit on trunks.
- **Very high biodiversity**: a single hectare can hold 100–300 tree species, and few trees of the same species grow close together. Growth is continuous (no cold or dry season), and **net primary productivity** is the highest of any land ecosystem, about 2200 g of dry matter per m^2 per year.
- **Variation**: along rivers (flooded forest), on mountains (lower, mossy cloud forest) and in gaps where trees fall.

Savanna (seasonally humid tropical)

- **A mixture of grasses, trees and shrubs** whose balance changes with rainfall and the length of the dry season, from the rainforest edge to the desert edge:

Type	Rainfall and dry season	Vegetation
Savanna woodland	About 1000–1500 mm; dry season 3–4 months	Trees forming a light, broken canopy, with tall grasses below
Tree savanna (parkland)	About 750–1000 mm	Tall grasses (elephant grass up to 3–5 m) with scattered trees

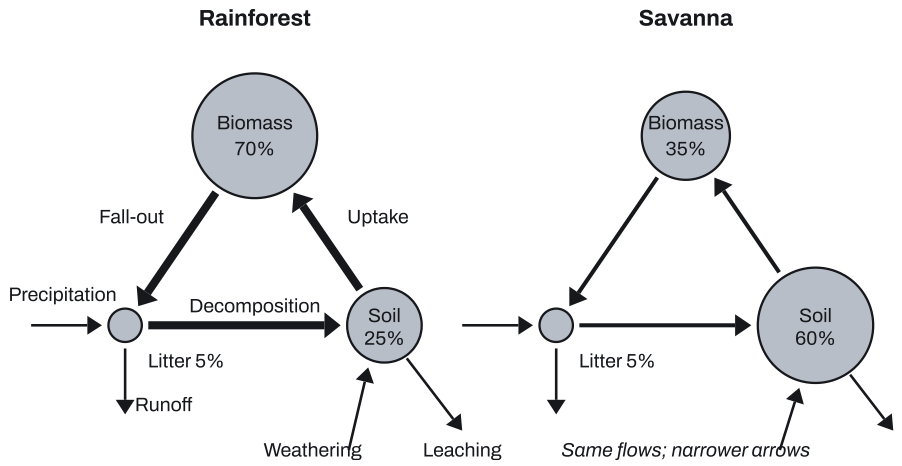
Type	Rainfall and dry season	Vegetation
Shrub savanna	About 500–750 mm	Shorter, tufted grasses with thorny shrubs and few trees
Grass savanna	Under about 500 mm; dry season 7–8 months	Short, tufted grasses with bare ground between, grading into semi-desert

- **Xerophytic** (drought) adaptations: the **baobab** stores water in its huge, swollen trunk and drops its leaves in the dry season; **acacias** have deep **tap roots** and wide lateral roots, small leaves (fewer stomata, less water loss), **thorns** against browsing, and a flat, **umbrella-shaped crown** that shades the ground around the roots; many trees are **deciduous** in the dry season.
- **Pyrophytic** (fire) adaptations: **thick, corky bark** that insulates the trunk; seeds that need heat to germinate; grasses that die back above ground in the dry season but survive as **roots, rhizomes and seeds**, then grow fast when the rains come.
- **Productivity** is lower than the rainforest's, about 900 g per m^2 per year, and seasonal.
- **Which is more varied?** The rainforest has far more **species** in any one place, but a fairly **uniform structure** everywhere. The savanna has fewer species but much more variation **across space** (from woodland to grassland), **through the year** (green in the wet season, brown and leafless in the dry) and with soil, relief, fire and grazing. So the answer depends on **scale** and on what "varied" measures.

Nutrient cycling: Gersmehl diagrams

Nutrients (calcium, potassium, nitrogen, phosphorus and others) are stored and moved within an ecosystem. **Gersmehl's model** shows three **stores**, drawn as circles whose size shows how much each holds, and **flows**, drawn as arrows whose width shows how much moves:

- **Stores**: **biomass** (B, living plants and animals), **litter** (L, dead leaves and wood on the ground) and **soil** (S).
- **Flows within the cycle**: **fall-out** (B to L, leaves and plants dying), **decomposition** (L to S, released by decomposers) and **uptake** (S to B, through roots).
- **Inputs**: nutrients **dissolved in precipitation** (to the litter) and released from rock by **weathering** (to the soil).
- **Outputs**: **runoff** (washing nutrients off the surface, from the litter) and **leaching** (dissolved nutrients carried down through the soil out of reach of roots).



Rainforest: the **biomass store is by far the largest** (most nutrients are locked in the trees); the **litter store is small** because heat, moisture and abundant decomposers (fungi, bacteria, termites) break litter down in weeks; the **soil store is small** because roots (helped by **mycorrhizal** fungi) take nutrients up as soon as they are released, and heavy rain **leaches** the rest; the **flows are large and fast**. The cycle is nearly **closed**: nutrients circulate rapidly between living plants and the thin topsoil.

Savanna: the **soil store is the largest**, because grasses die back and many trees drop their leaves at the start of the dry season, and decay and fire return nutrients to the soil, where less rain means **less leaching**; in the dry season water is even drawn **up** through the soil by evaporation. The **litter store is small** because **fire** burns it and termites and grazing animals remove it. The **biomass store is smaller** than the rainforest's because the growing season is short and the vegetation sparser. **Inputs** are small: rain is **lower (about 500–1000 mm)** and falls in only part of the year, and the weathered rock is often old and poor in nutrients. **Runoff** can be important in the wet season, because the ground cover is patchy and storms are intense. **Flows are smaller** and **seasonal**: rapid in the wet season, almost stopped in the dry.

Deforestation and the nutrient cycle. When rainforest is cleared:

- the **biomass store is removed**, taking most of the ecosystem's nutrients with it (as logs or smoke);
- **no new litter** falls, and the existing litter decomposes in weeks and is washed away, so the litter store **shrinks**;
- the bare soil is exposed to the heavy rain, so **leaching** and **runoff/soil erosion** rise sharply, and the soil store falls;
- **uptake** stops or falls, so the cycle is broken;
- if the vegetation is **burnt**, the **ash** briefly **adds nutrients** to the soil and fertility rises for a year or two, then they are leached away. This is why shifting cultivators move on after 2–3 years, and why cleared pasture soon degrades.

Soil fertility. Rainforest soils are **infertile** despite the luxuriant forest, because the nutrients are in the biomass, not the soil, and the clay (kaolinite and iron and aluminium oxides) holds few nutrient ions. Savanna soils are somewhat richer in bases but often short of water, and can be poor where crusts or old, leached rock lie underneath.

Energy flows and trophic levels

Energy enters the ecosystem as sunlight, fixed by **producers** (green plants) in photosynthesis. It passes along food chains through **trophic levels**: producers, then **primary consumers** (herbivores), **secondary consumers** (carnivores that eat herbivores) and **tertiary consumers** (top carnivores). **Decomposers** take energy from dead material at every level.

- At each transfer most energy is **lost**: used in respiration and released as heat, used in movement, or not eaten or digested. Only about **10%** passes on to the next level, so food chains are short (usually four or five levels) and there are far fewer carnivores than herbivores.
- A **pyramid of biomass** shows the mass of living material at each level: a broad base of producers narrowing upwards.
- **Rainforest**: very high productivity and biomass (about 45 kg per m^2, the largest of any land ecosystem); most primary consumers are **insects** and other small animals feeding in the canopy; many feed on fruit and leaves; energy flows quickly.
- **Savanna**: lower biomass (about 4 kg per m^2) mostly in the **grasses** and trees; but grasses regrow quickly after grazing, so the savanna supports the world's largest herds of large herbivores (wildebeest, zebra, gazelle in the Serengeti), and big predators (lions, cheetahs, hyenas), so the herbivore level is unusually large compared with the producers. Seasonal drought makes herds **migrate** to follow the rains and fresh grass.

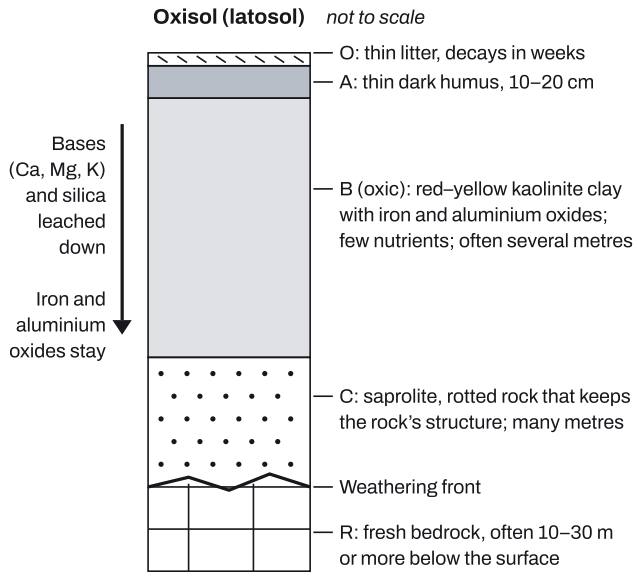
Tropical soils

Soil-forming factors: **climate** (heat and water drive weathering, decay and leaching), **parent material** (rock type gives minerals and texture), **vegetation and organisms** (litter, humus, roots, termites, earthworms), **relief** (slope and drainage), **time** (many tropical surfaces have been weathering for millions of years) and **people** (clearing, burning, ploughing, grazing, irrigation).

Soil-forming processes in the tropics:

- **Deep chemical weathering** (hydrolysis, oxidation): rock rots to great depth, producing clay (kaolinite).
- **Leaching**: heavy rain carries soluble **bases** (calcium, magnesium, potassium, sodium) down and out of the soil, making it acidic and infertile.
- **Ferralitisation (laterisation)**: in the hot, wet climate, even **silica** is dissolved and removed (desilication), so **iron and aluminium oxides (sesquioxides)**, which do not dissolve, build up. The iron oxides colour the soil **red** (or yellow where the soil is wetter).
- **Humification**: dead plant material becomes humus, rapidly in the tropics, so the humus layer stays thin.
- **Eluviation and illuviation**: clay and sesquioxides washed out of upper horizons and deposited lower down.
- **Capillary rise** in the dry season: water drawn up by evaporation brings iron in solution to near the surface, where it hardens into concretions or a crust (**laterite**, **duricrust**).

Oxisols (latosols): the soils of the humid tropics.



- **Very deep** (often over 10 m to the bedrock); **red or yellow**; **little horizon differentiation** (colour changes gradually with depth); a **thin litter and humus layer**; a **clay-rich B horizon** with iron and aluminium oxides; **acidic** and **low in nutrients**, because bases are leached and the clay holds few nutrients; but often **well drained and crumbly**, because the oxides bind the clay into granules.
- **Climate's role**: high temperatures and rain all year give **deep, fast chemical weathering**, **intense leaching** and **rapid decay** (thin humus); continuous downward water movement removes bases and silica.
- **If the forest is cleared**, the soil loses its supply of litter and is exposed to rain and sun; in some areas iron-rich horizons exposed at the surface **harden irreversibly** into laterite crusts that roots cannot penetrate.

Tropical red earths (ferruginous soils): in the wetter savanna. Less deeply weathered and **less leached** than oxisols, because rain falls only in part of the year; still red from iron oxides; more **bases** remain; **seasonal processes**: leaching downward in the wet season, **capillary rise** in the dry season, which may form **iron concretions** or a **lateritic crust** near the surface. A thicker, grassy humus layer than oxisols.

Tropical brown earths: in the drier savanna. Less weathered and less leached again, so they are **richer in bases** and less acidic; browner, because there is more humus from the **grass roots** and less iron oxide; shallower. They are often among the more fertile tropical soils, but they are short of water for much of the year and erode easily when the grass cover is lost.

What matters most? Climate decides the processes (weathering, leaching, laterisation) and so the broad zones of soil types; **parent material** matters locally (granite gives sandy, acid soils; basalt gives deep, richer clays); **relief** gives a **catena**, with thin, well-drained red soils on hilltops and darker, heavier, poorly drained soils in valleys; **vegetation** controls the humus and the nutrient supply; **time** explains the extraordinary depth of oxisols on ancient, stable surfaces; **people** change soils fastest today.

Case study: sustainable management of the Brazilian Amazon rainforest

The area. About 60% of the Amazon rainforest is in Brazil, within the **Legal Amazon**, an administrative region of about 5 million km² covering nine states. The forest stores huge amounts of carbon, holds perhaps a tenth of the world's known species, recycles much of its own rainfall through transpiration, and is home to hundreds of Indigenous peoples and millions of other people, many of them poor.

Threats from exploitation:

- **Cattle ranching**: the main cause of clearance; forest is cut and burnt and sown with grass. Beef is exported and sold across Brazil.
- **Soy farming**: mostly on land already cleared for pasture, which pushes ranchers deeper into the forest.
- **Logging**, much of it illegal and selective, which opens roads into the forest for settlers to follow.
- **Mining**: legal mines such as the huge Carajás iron ore mine in Pará, and illegal gold mining (**garimpo**) that pollutes rivers with mercury; in the Yanomami Indigenous Territory, mining contributed to a health emergency declared in January 2023.
- **Roads and dams**: highways such as the Trans-Amazonian Highway (from the 1970s) and BR-163 open land to settlement; the **Belo Monte** hydroelectric dam on the Xingu River (completed in 2019, about 11 000 MW) flooded land and displaced people.
- **Fire**, set to clear land, escaping into standing forest, especially in drought years.
- **Climate change**: higher temperatures and more severe droughts (2005, 2010, 2023 and 2024, when the Rio Negro at Manaus fell to record lows) dry the forest out and could push parts of it towards savanna.

Problems of managing it sustainably:

- **Size and remoteness**: an area larger than the whole European Union cannot be patrolled on the ground.
- **Poverty and jobs**: clearing land is often the quickest way for poor settlers to make a living, and ranching and mining bring income and taxes to local states.
- **Land tenure**: unclear land titles let land grabbers clear public forest and claim it (**grilagem**).
- **Weak enforcement, corruption and politics**: fines go unpaid; policy changes with each government (enforcement was cut back in 2019–2022, then restored from 2023).
- **Global demand** for beef, soy, timber, gold and iron ore.
- **The soils**: once the forest and its nutrient cycle are gone, the infertile oxisols lose fertility within a few years, so farmers clear more forest instead of improving the old land.

Attempted solutions and their evaluation:

1. **Satellite monitoring and enforcement (PPCDAm, from 2004)**. Brazil's action plan against deforestation combined near-real-time satellite alerts (**DETER**) with raids by the environment agency (IBAMA), a blacklist of the worst municipalities, and from 2008 a rule that farmers must comply with environmental law to get rural credit. Annual clearance (measured by the PRODES satellite survey) fell from about **27 800 km² in 2004 to about 4600 km² in 2012, a fall of over 80%**. But it depends on political will: when enforcement was weakened it rose again to about **13 000 km² in 2021**, before falling to about **6300 km² in 2024** once enforcement returned. Highly effective, but not permanent unless governments sustain it.

2. **Protected areas and Indigenous territories**: national parks, reserves and the ARPA programme (from 2002) protect large blocks of forest, and Indigenous territories cover about a fifth of the Brazilian Amazon. Deforestation inside them is much lower than outside, and they protect Indigenous peoples' rights and cultures. But some are "paper parks" with few guards, invaded by miners and loggers, and they move clearance to unprotected land rather than stopping it.
3. **Sustainable use by local communities**: **extractive reserves** such as the Chico Mendes Extractive Reserve in Acre (1990), where rubber tappers harvest latex and Brazil nuts without clearing the forest; **agroforestry**, growing crops such as cocoa, açaí and fruit trees under or among forest trees, which keeps a tree cover and a nutrient cycle; the **Mamirauá** Sustainable Development Reserve (1996), where communities manage fishing of the giant pirarucu with **quotas** set from their own counts, which brought the fish back from overfishing and earns them an income. These are **bottom-up**, keep people on the land and earn money from standing forest, but they are small in scale and incomes are modest compared with ranching.
4. **Supply-chain agreements**: under the **Soy Moratorium (2006)**, the big traders agreed not to buy soy grown on newly cleared Amazon land. Very little new soy now comes from recently cleared forest, but clearing shifted to cattle and to the neighbouring Cerrado savanna (**leakage**), and cattle supply chains are much harder to trace.
5. **International funding**: the **Amazon Fund (2008)**, paid mainly by Norway and Germany for **results** (reduced deforestation), finances monitoring, sustainable businesses and land registration. It was frozen in 2019 and revived in 2023, showing how international money also depends on national politics.
6. **Socially responsible logging and ecotourism**: under the Public Forest Management Law (2006), companies get concessions in public forests to log selectively with **reduced-impact** methods, certified to international standards; community-run **ecotourism** lodges (such as Mamirauá's floating lodge) earn income from visitors. Both make the forest worth more standing, but only cover a small area, and certified timber costs more.
7. **Education and NGOs**: Brazilian and international organisations train farmers, map Indigenous lands, publish independent deforestation data, and help communities defend their territories in court.

Judgement. Judged by the **environment**, government enforcement (1) did the most, the fastest, but it rises and falls with politics; judged over the **long term**, the most lasting solutions are those that give local people secure land and an **income from standing forest** (2, 3 and 6), but they are small. **Economic** growth from ranching still competes with every scheme. The best results come when several solutions work together: enforcement to stop illegal clearance now, protected areas and land rights to fix where clearance cannot happen, and sustainable incomes to remove the reason to clear. No solution has yet stopped deforestation altogether, so management is improving but not yet **sustainable**.

Key facts and formulas

There is no formula list in Paper 3, so learn all of these.

Formula	Status
Annual temperature range = highest mean monthly temperature – lowest mean monthly temperature	Learn it
Diurnal temperature range = highest temperature – lowest temperature in the same 24 hours	Learn it
Annual rainfall total = sum of the 12 monthly totals	Learn it
Percentage of the year's rain in a period = rain in the period ÷ annual total × 100	Learn it
Percentage change = (new – old) ÷ old × 100 (negative for a fall)	Learn it
Energy passed to the next trophic level ≈ 10% of the level below	Learn it
Carbonation: $\mathrm{CaCO_3 + H_2O + CO_2 \rightarrow Ca(HCO_3)_2}$ (soluble calcium bicarbonate)	Learn it
Hydrolysis of feldspar: feldspar + water (hydrogen ions) → kaolinite clay + silica and potassium in solution; quartz is left	Learn it

Term and meaning	Status
Intertropical convergence zone (ITCZ): the low-pressure belt near the equator where the trade winds converge and air rises, bringing heavy rain; it moves with the overhead sun	Learn it
Subtropical anticyclone: a high-pressure cell at about 25–30° N or S, with sinking, warming, dry air and clear skies	Learn it
Hadley cell: the circulation of air rising at the ITCZ, flowing poleward aloft, sinking at the subtropical highs and returning as the trade winds	Learn it
Monsoon: a seasonal reversal of the prevailing winds, giving a very wet season and a dry season	Learn it
Diurnal: within a day (24 hours); **annual** variation is through the year	Learn it
Deep weathering: chemical weathering (mainly hydrolysis) of rock to tens of metres below the surface	Learn it
Weathering front: the boundary between weathered regolith and fresh rock below	Learn it
Etchplanation: lowering of the land by deep weathering followed by stripping of the regolith	Learn it
Tor (kopje): a pile of rounded corestones on a hill, exposed by stripping of weathered granite	Learn it

Term and meaning	Status
Bornhardt: a large, bare, dome-shaped rock hill bounded by curved sheeting joints	Learn it
Inselberg: an isolated, steep-sided hill rising abruptly from a plain	Learn it
Cockpit karst: enclosed, star-shaped hollows (cockpits) between rounded hills	Learn it
Cone karst: steep, cone-shaped limestone hills among closed hollows	Learn it
Tower karst: steep, isolated limestone towers rising from a flat alluvial plain	Learn it
Climatic climax: the final, stable plant community in balance with the climate	Learn it
Subclimax: a community whose succession is halted by a natural factor other than climate (soil, relief, natural fire)	Learn it
Plagioclimax: a community whose succession is halted or deflected by human activity (burning, grazing, clearing)	Learn it
Trophic level: a feeding level in a food chain (producers, primary, secondary and tertiary consumers)	Learn it
Leaching: the removal of soluble nutrients down through the soil by water	Learn it
Ferralitisation (laterisation): the removal of silica and bases, leaving iron and aluminium oxides, under hot, wet conditions	Learn it
Oxisol (latosol): a deep, red, leached, infertile soil of the humid tropics, rich in iron and aluminium oxides	Learn it
Sustainable management: using an ecosystem to meet people's needs today without destroying it for the future, balancing economic, social and environmental aims	Learn it

How to do it

We have tagged 87 questions for this topic (2021–2025, all Paper 3), 60 different (the variants 31, 32 and 33 often share questions). Every Question 1 (29 of them) has a describe part (a) and an explain part (b), so it counts under both types and the counts add up to 116.

Question type	Questions
Describe or compare a figure	29
Explain a pattern, process or the figure's features	29

Question type	Questions
Essay: tropical climates	13
Essay: vegetation and plant communities	13
Essay: sustainable management case study	13
Essay: granite landforms	9
Essay: tropical karst landforms	5
Essay: tropical soils	4
Essay: nutrient cycle	1

Marking: Question 1(a) gives **1 mark for each accurate point** (3 or 4 marks), with a mark kept for **data**; without figures or place names the cap is usually 3. Question 1(b) (6 or 7 marks) is marked in **three levels** (Level 3, 5–6 marks: clear explanation, tied to the figure or the ecosystem). The 20-mark essays are marked in **four levels** (Level 4, 16–20 marks: sustained evaluation and a sound conclusion), with a **maximum of 8 without examples**.

1. Describe or compare a figure (29 questions)

Figures: distribution maps (tree-cover loss, humid tropical climates, oxisols, savanna in Africa, the advance of the monsoon, a pressure chart), climate and temperature graphs, nutrient-cycle and biomass diagrams, a soil profile, and photographs (savanna, rainforest, tower karst, a granite landscape).

1. **Give the overall pattern first**, then the detail, then **anomalies**.
2. **Quote data**: values with units, months, places, latitudes, compass directions. One point per mark, and one mark is kept for data.
3. **Describe only**: no explanations, and for photographs, **physical features only** (human features score nothing).

Variants:

- **Distribution maps**: in relation to the **equator and tropics** (a band, continuous or broken), **continents and named regions**, coasts against interiors, the **largest areas** and the **gaps**, and differences north and south of the equator.
- **Climate graphs**: annual total and range, wettest and driest months, the number of dry months, one or two rainfall maxima, the hottest month and its timing relative to the rain.
- **"Compare"**: every sentence links the two ("Station A has rain in every month, **whereas** B has five months with none"); include both temperature and rainfall (answers on only one are capped at 3).
- **A Gersmehl diagram**: the largest and smallest stores, the largest and smallest flows, which flows are equal, inputs against outputs (do they **balance**?), which input or output is larger, and which store has the most flows in or out.
- **A pyramid of biomass**: the size of each level and how fast it narrows (producers far larger than herbivores, herbivores larger than carnivores), with values.

- **A soil profile**: depth ("very deep", not just the number), the thickness of each horizon, **colours**, the organic layer at the top, where the clay and the iron are, and the boundary with weathered and fresh rock.
- **A pattern over time** (for example deforestation, 1988–2019): the overall trend, the peaks and troughs with years and values, and the size of change; don't go year by year.
- **Photographs**: of **vegetation** (density, height, layers, tree shapes, trunks, bark, leaves, colours, ground cover); of **landforms** (shape, steepness, height relative to the surroundings, bare rock, joints, rounded blocks, the flat plain around them, vegetation, a river).
- **Diurnal temperature graph**: the time and value of the minimum (around dawn) and maximum (early afternoon), the steep morning rise and slow night-time fall, any steady periods, and the **diurnal range**.

2. Explain a pattern, process or the figure's features (29 questions)

1. **Explain the pattern or features you described**, with **processes** (the ITCZ, the overhead sun, convection, water stress, fire, joints, leaching, decomposition), linking cause and effect.
2. **Refer to the figure** and to the ecosystem or climate named; answers that don't are capped at Level 2.
3. "**Suggest two reasons**" or "**explain two**": develop **both** reasons fully, each with its process and its effect on the figure.
4. A **labelled diagram** (a Gersmehl diagram, a soil profile, an ITCZ cross-section) is credited.

The common ones, with what to explain (all taught in "Understand it"):

- **A humid tropical climate**: high sun angle all year, convection, converging trades and the ITCZ, double maxima as the ITCZ crosses the equator twice.
- **A monsoon or seasonally humid station** (for example Chittagong in Bangladesh): the ITCZ arriving in summer with south-west winds and orographic rain; the dry winter under high pressure; the hottest month before the rains, when the sun is high and skies clear.
- **Different rainfall patterns at two stations**: latitude, how long the ITCZ stays over each, prevailing winds and air masses; don't overplay altitude.
- **Subtropical anticyclones**: sinking, stable air, the dry season and deserts, the source of the trade winds, their seasonal movement.
- **Savanna or rainforest vegetation**: each feature linked to the climate (the dry season, drought, fire, light, heavy rain).
- **A nutrient cycle** (rainforest or savanna), or **how deforestation affects it**: each store and flow explained by the climate, decomposition, fire and leaching; for deforestation, what happens to each store and flow, and why.
- **A pyramid of biomass**: energy lost at each level (respiration, heat, movement, undigested material), so only about 10% passes on.
- **Tower karst, a granite landform or the depth of weathering**: joints, chemical weathering below the surface, stripping, undercutting at the water table, and local factors such as relief, drainage and rock composition.
- **Oxisol formation or climate's effect on a profile**: deep weathering, leaching of bases and silica, accumulation of iron and aluminium oxides, rapid decay giving a thin humus layer.

3. Essay: tropical climates (13 questions)

Two kinds: **weigh one factor against the others** ("mainly caused by the ITCZ", "atmospheric pressure is the most important factor", "air masses", "latitude") and **compare the two climates** (annual rainfall, annual and diurnal variations of temperature and rainfall).

1. **Define** the climates and the factor in the question.
2. **The case for the factor**: for the ITCZ, its position and seasonal movement following the overhead sun, convergence and uplift, convection, condensation and heavy rain, two passes a year near the equator, one further away; humidity and cloud.
3. **The other factors**: **subtropical anticyclones** (the dry season), **air masses** (mT and cT), **monsoons** (land–sea heating contrasts, jet streams), **ocean currents** (warm currents add moisture, cold ones cool and dry coasts), **land and sea breezes**, **altitude and relief** (cooler, and orographic rain), **El Niño and La Niña** (year-to-year swings), and **vegetation** (transpiration recycles moisture into rain). Show they are **linked**: latitude sets the sun angle, which drives the ITCZ and pressure belts.
4. **Use named stations** from the table in "Annual and diurnal variations" (Belém or Singapore against Kano or Mumbai), with their ranges and rainfall; Level 4 needs detailed, located examples.
5. **For comparisons**, cover **all the strands asked** (annual and diurnal, temperature and rainfall, in both climates), with real or typical figures, and say **where and when** they are similar (the wet season) and different (the dry season).
6. **Conclude**: for example, the ITCZ is the key control because it sets the timing and amount of rain, but latitude underlies it, and other factors explain regional and year-to-year variation.

4. Essay: vegetation and plant communities (13 questions)

Asks about **climax and plagioclimax** (rainforest a climatic climax, savanna a plagioclimax; savanna rarely reaching its climax), whether **savanna vegetation is more varied** than rainforest (or whether there is little variation in it), and **climate against human activity** as the influence.

1. **Define** climatic climax, subclimax and plagioclimax, and show **development** (succession), not just destruction: the examiners report many answers that only list human damage.
2. **Describe the actual vegetation** of each ecosystem (layers, adaptations, the savanna types from woodland to grassland) as evidence.
3. **Weigh the factors**: climate (rainfall, dry-season length), soils and drainage, relief, fire (natural and human), grazing (wild and domestic), clearing; and the evidence for plagioclimax (poor match with rainfall, sharp boundaries, woodland returning where fire and grazing stop).
4. **"It depends"**: on **scale** (species variety in one hectare against variation across a region), on **time** (how long people have burnt and grazed), and on **place** (protected areas against heavily used land).
5. **Conclude**, answering "how far".

5. Essay: sustainable management case study (13 questions)

Takes **one named area** of rainforest or savanna and asks you to judge either the **threats** or **problems** (their relative significance; whether the soil or the climate is the main problem) or the **attempted solutions**.

1. **Name and locate** the case study and give facts (area, dates, numbers). A specific area or scheme beats a whole country.
2. **Problems or threats**: explain each one's effect, then **rank** them: by scale, by how hard each is to manage (local against global), by whether it causes the others (poverty and demand drive clearance).
3. **Solutions**: say what each tried to do and **link it to the problem** it targets.
4. **Set criteria** for success: **economic, social and environmental** outcomes, **stakeholders** (who gained, who lost), **timescale** (short against long term), the **scale** of the area covered, and **how far** the problem was actually solved.
5. **Conclude** with which solution worked best and why, and whether management is truly **sustainable**.

For "is the soil (or the climate) the main problem?": soils (oxisols lose fertility fast after clearing, laterite crusts, erosion) and climate (heavy rain causing leaching and erosion, drought and fire, climate change) against human factors (poverty, demand, roads, weak law).

6. Essay: granite landforms (9 questions)

Asks about the role of **deep weathering**, of **climate**, of **all factors**, of **rock type**, or whether tors, inselbergs and bornhardts **differ only in size**.

1. **Name and describe** the three landforms (size and **shape**: blocky tors, smooth domed bornhardts, angular or domed inselbergs), with examples.
2. **The two-stage model**: hydrolysis below the surface, guided by joints; the irregular weathering front; corestones; stripping (etchplanation).
3. **Joint spacing** decides the form: close (basins), medium (tors), wide (bornhardts); sheeting joints keep domes rounded.
4. **The other view**: **parallel retreat** (pediplanation) under semi-arid conditions, especially for inselbergs; surface processes after exposure (block disintegration, exfoliation, granular disintegration).
5. **Climate and time**: present and past climates (a wet phase to weather, a drier phase to strip), uplift, millions of years.
6. **Conclude**: deep weathering starts most of them, but **rock structure** (joints) decides their shape, and surface processes finish them, so "the same processes" is only partly true.

One variant, **9696/31/M/J/22 Q2**, asks about the influence of **different rock types** on tropical landforms: write about **both** granite (hydrolysis, joints, tors and bornhardts) and limestone (carbonation, cone, cockpit and tower karst), and compare them.

7. Essay: tropical karst landforms (5 questions)

Weighs **processes** (carbonation, solution along joints, collapse, undercutting) or **conditions** (geology, climate, uplift, the water table) behind cockpit, cone and tower karst.

1. **Name and distinguish** the three landforms, with examples (Cockpit Country, Jamaica; Guilin, China).
2. **Carbonation**, and why it is intense in the tropics (rain, soil carbon dioxide, humic acids).
3. **Geology**: thick, pure, well-jointed limestone; joint spacing and pattern guide the dolines and hollows.
4. **Tectonics and hydrology**: uplift and base level, undercutting at the water table, alluvial plains, cave collapse; these separate tower karst from cone karst.
5. **Link factors to particular landforms**, not to tropical karst in general, and **conclude** (geology makes karst possible, climate sets the speed, uplift and water table explain which form develops). Don't write about granite, hydrolysis or etchplains in a karst-only essay: examiners report this mix-up. (A question on different rock types, such as 9696/31/M/J/22 Q2 in section 6, needs both.)

8. Essay: tropical soils (4 questions)

Weighs the **soil-forming factors** (or "rock type is the most important factor", or the role of climate in soil types and profiles).

1. **Name the soils** (oxisols/latosols, tropical red and brown earths) and describe their **profiles**.
2. **Explain the processes**: deep weathering, leaching, ferralitisation, humification, capillary rise and laterite.
3. **Weigh the factors**: climate (the zonal pattern) against parent rock (local texture and fertility), relief (the catena), vegetation and organisms, time and people.
4. **Conclude**, at different scales: climate dominates at the global scale, rock and relief at the local scale, and people over the short term.

9. Essay: nutrient cycle (1 question)

Asked once: the importance of **weathering** in the rainforest nutrient cycle. It is about the **cycle**, not weathering types (examiners saw long answers about freeze–thaw).

1. Draw and use a **Gersmehl diagram** for the rainforest.
2. **Weathering** as an input: deep, fast weathering, but of old, already-leached rock far below the root zone, so it adds little.
3. **Other inputs and stores**: precipitation input, the huge biomass store, rapid fall-out, decomposition and uptake (mycorrhizae), leaching and runoff outputs.
4. **Conclude**: the cycle depends mainly on **rapid recycling within the biomass**, not on weathering; weathering matters more on younger, richer rocks (volcanic soils).

Worked examples

Example 1

The climate graphs in "Understand it" show two model stations, Station A (1° S) and Station B (12° N).

(a) Compare the climates of Station A and Station B. **[4]**

(b) Explain the rainfall pattern at Station B. **[6]**

(a) One mark for each explicit comparison; one mark kept for data.

- Station A is much wetter: about 2670 mm a year, more than three times Station B's 847 mm **(1)**.
- Station A has rain in every month (at least 110 mm), whereas Station B has four months (November to February) with none and seven months under 60 mm **(1)**.
- Station A has two rainfall maxima (320 mm in April and 290 mm in November), whereas Station B has a single peak, 290 mm in August **(1)**.
- Station A's temperature hardly changes (26.0–27.5 °C, a range of 1.5 °C), whereas Station B's annual range is 8 °C (24–32 °C), with its maximum in April, before the rains **(1)**.

(b)

Station B lies at 12° N, so its rainfall is controlled by the seasonal movement of the ITCZ. The overhead sun crosses the equator northward at the March equinox and is overhead at 12° N by late April; the ITCZ follows about a month behind, reaching Station B in May, when its wet season starts. As the ITCZ moves over Station B, the trade winds converge and moist, unstable tropical maritime air from the south-west is drawn in; the strong heating of the ground makes it rise by convection, cool, condense and form cumulonimbus clouds, so heavy rain falls. The ITCZ reaches its most northerly position in July–August, which is why rainfall peaks in August (290 mm); about 90% of the year's rain falls from June to September.

The overhead sun crosses the equator southward in late September, so from October the ITCZ retreats towards the equator and the subtropical anticyclone moves over Station B. Its sinking, warming air is stable, so clouds cannot form, and dry north-easterly winds from the continent (continental air) blow over it, so there is no rain from November to February. The single wet season, rather than Station A's two, shows that Station B is far enough from the equator for the ITCZ to pass over only once a year.

Level 3 (5–6 marks): the wet and dry seasons are clearly explained by the movement of the ITCZ and the subtropical anticyclone, with processes and timing linked to the figure's months and values.

Example 2

Explain the formation of tors in tropical environments. **[6]**

Tors, called kopjes in Africa (for example in the Matobo Hills, Zimbabwe), are piles of rounded granite blocks that form in two stages.

First, deep weathering. Granite is cut by vertical and horizontal joints. Under the hot, wet tropical climate, water seeps down the joints and **hydrolysis** turns the feldspar into kaolinite clay, leaving the quartz as loose grains. Weathering attacks the blocks from every joint, fastest at their corners and edges, so they are rounded into **corestones** set in a rotted layer (regolith) that may be tens of metres deep. Where the joints are medium-spaced, some cores remain unweathered; where they are close together, the rock is rotted completely.

Second, stripping. When the land is uplifted or the climate becomes drier, the loose regolith is washed away and the irregular weathering front is exposed. The corestones that stood above it are left as a tor, the blocks resting on one another, while the surrounding closely jointed rock forms lower ground.

Once exposed, the tor is attacked by surface processes: block disintegration and pressure release widen the joints, and blocks may topple around its base.

Level 3 (5–6 marks): both stages clearly explained, with the role of the joints, the process of hydrolysis, and an example.

Example 3

'Savanna vegetation is mainly the result of human activity rather than climate.' How far do you agree with this statement? **[20]**

Introduction. Savanna is a mixture of grasses, trees and shrubs between the rainforest and the hot desert, in the seasonally humid tropics (about 5–20° N and S). If climate alone controlled it, it would be a **climatic climax**; if human activity (burning, grazing, clearing) holds it back from that climax, it is a **plagioclimax**.

The case for climate. The savanna's distribution matches the seasonal movement of the ITCZ: rainfall falls from about 1500 mm to 500 mm away from the equator, and the dry season lengthens from 3 to 8 months. The vegetation changes with it, from savanna woodland, through tree savanna and shrub savanna, to grass savanna, as in the belt across West Africa from the Guinea coast to the Sahel. The plants are adapted to drought: baobabs store water, acacias have deep roots and small leaves, and grasses die back in the dry season and regrow with the rains. These are signs of a climate that limits trees.

The case for human activity. People have burnt the savanna for tens of thousands of years, to clear land, drive game and bring fresh grass for herds, and today many areas burn every year or two. Fire kills young trees but not grass, whose roots survive. Herds of cattle and goats graze young trees, and trees are cut for firewood and charcoal around growing towns. The evidence that people matter is strong: the vegetation often **does not match rainfall closely**, with grassland in areas wet enough for woodland; boundaries between woodland and grassland are often **sharp**, following fire and grazing lines rather than gradual changes in rainfall; and where fire and grazing are stopped, **woody plants return**: in long-term plots in Kruger National Park, South Africa, burnt at set intervals since 1954, plots kept free of fire gained trees and shrubs.

Other factors. Not all the influences are human or climatic. Lightning starts natural fires in the dry season; elephants and other wild animals break and eat trees; and soils matter, since lateritic crusts and seasonally waterlogged clays stop trees rooting. Where these natural factors hold the vegetation back, it is a **subclimax**, not a plagioclimax.

It depends. On **place**: in the wetter savanna, near the rainforest edge, fire and clearing decide whether there is woodland or grassland, so human activity dominates; in the driest savanna, rainfall is so low that trees struggle even without fire, so climate dominates, and the Kruger plots showed little change there. On **time**: climate created the conditions over millions of years, while people have shaped the details over thousands. On **scale**: across the continent the broad zones follow climate; locally, the pattern follows fire, grazing and farming.

Conclusion. Climate sets the broad framework, the range from grassland to dry woodland that is possible at a place, and explains the adaptations of savanna plants. But within that framework, human burning and grazing decide much of the actual vegetation, especially in the wetter savanna, so much of it is a plagioclimax. I agree only partly: savanna vegetation is the result of climate **and** human activity together, with people most important where the climate would allow woodland.

Level 4 (16–20 marks): both sides weighed with evidence and located examples, other natural factors considered, variation by place, time and scale, and a judgement that answers "how far".

Common mistakes

- **Mixing up "diurnal" and "annual".** Diurnal is within one day; annual is through the year. In the humid tropics the diurnal range is larger than the annual range.
- **Saying the ITCZ is fixed at the equator.** It follows the overhead sun, lags behind it, and moves much further over land than over the oceans.
- **Describing the ITCZ without the processes**: explain convergence, rising air, cooling, condensation and rain, and link it to the timing of wet and dry seasons at named places.
- **Answering about the ITCZ when asked about air masses or anticyclones**; tie each factor to the climate it controls.
- **Mixing up granite and limestone.** Hydrolysis, deep weathering, etchplains, tors and bornhardts belong to granite; carbonation, dolines, cockpits, cones and towers belong to limestone.
- **Ignoring joints.** The spacing and pattern of joints explain why one granite landform differs from another, and guide the hollows in karst.
- **Forgetting that deep weathering happens below the surface**, and that the landforms appear only after the regolith is stripped.
- **Treating "plant communities" as "vegetation destroyed by people"**: the questions ask how communities **develop** (succession, climax, subclimax, plagioclimax).
- **Treating the savanna as uniform.** It ranges from woodland through parkland and shrubland to grassland.
- **Describing changes in a nutrient cycle without explaining them**, or writing about animals instead of nutrient stores and flows.
- **Copying phrases from a figure** ("5–10 m") instead of interpreting it ("very deep").
- **Not comparing in "compare" questions**: two separate descriptions earn little.
- **Explaining in a "describe" part**, and describing human features in a physical photograph.

- **A case study that is a whole country**, or threats and solutions listed without saying how significant each is or how well each worked.
- **Using "sustainable" without meaning it**: show the economic, social and environmental strands and the long term.

How to get the marks

- **Command words. Describe** = what the figure shows, with data, no reasons. **Compare** = linked similarities and differences ("whereas", "both"). **Explain** = reasons and processes, cause and effect. **Suggest** = apply what you know to the figure. **Assess**, **evaluate**, **how far**, **to what extent** = weigh both sides and reach a judgement.
- **Question 1(a)**: one point per mark; use the figure's values, places and months; give the overall pattern before detail.
- **Question 1(b)**: Level 3 needs clear explanation **linked to the figure or ecosystem**; "two reasons" needs both developed. A labelled diagram (Gersmehl, soil profile, ITCZ cross-section, a landform) is credited.
- **Essays**: an introduction that defines the terms; both sides, each point explained and backed by a **located example** (place, date, number); "it depends" on scale, time and place; a conclusion that answers the question directly. Without examples, the maximum is 8 of 20.
- **Cover every strand** of the question: annual **and** diurnal, temperature **and** rainfall, humid **and** seasonally humid.
- **Case studies**: one named area, with facts; problems ranked; each solution linked to a problem; criteria for evaluation (economic, social, environmental, stakeholders, timescale); a final judgement.
- **Time**: Question 1 is 10 marks and the essay 20, so spend about twice as long on the essay, and leave time for its conclusion.

Quick check

1. A station's mean monthly rainfall (mm), January to December, is: 5, 10, 30, 70, 150, 220, 260, 240, 160, 55, 15, 5. Calculate its annual total and the percentage that falls in the wettest four months. Count the months with under 60 mm, and state which tropical climate it has.
2. Producers in a savanna ecosystem fix 24 000 kJ of energy per m^2 per year. Assuming 10% is passed on at each transfer, how much reaches the secondary consumers and the tertiary consumers?
3. A model rainforest nutrient cycle holds 1400 units of nutrients in the biomass, 60 in the litter and 540 in the soil. What percentage is in the biomass, and why does this make the soil infertile after clearance?
4. Explain the difference between a subclimax and a plagioclimax community.
5. Explain why the diurnal temperature range in a humid tropical lowland is larger than its annual range.

Answers

1. Total $= 5 + 10 + 30 + 70 + 150 + 220 + 260 + 240 + 160 + 55 + 15 + 5 = 1220$ mm. Wettest four months (June to September) $= 220 + 260 + 240 + 160 = 880$ mm, which is $\frac{880}{1220} \times 100 = 72.1\%$. Six months have under 60 mm (January to March and October to December). One wet season and a long dry season with about 1200 mm: a **seasonally humid tropical (savanna)** climate, on its wetter side.
2. Primary consumers receive $24\,000 \times 0.1 = 2400$ kJ, secondary consumers $2400 \times 0.1 = 240$ kJ per m² per year, and tertiary consumers $240 \times 0.1 = 24$ kJ per m² per year, just 0.1% of what the producers fixed.
3. Total $= 1400 + 60 + 540 = 2000$, so the biomass holds $\frac{1400}{2000} \times 100 = 70\%$. When the forest is cleared, most of the nutrients go with the trees; the small litter store is not replaced and the thin soil store is leached by the heavy rain, so fertility falls within a few years.
4. Both are communities in which succession has stopped before the climatic climax. In a **subclimax** it is stopped by a **natural** factor other than climate, such as waterlogged or crusted soil, relief, or fires started by lightning. In a **plagioclimax** it is stopped by **human activity**, such as repeated burning, grazing by livestock, or clearing; if the activity stops, succession resumes.
5. The noon sun is high all year and day length hardly changes, so mean monthly temperatures vary by only 1–3 °C. But within each day, the sun heats the ground strongly from morning to early afternoon and there is no sunshine at night, so temperatures rise and fall by about 7–10 °C. Humid air and cloud hold the range down (cloud cuts the afternoon maximum, and water vapour traps heat at night), but not below the very small annual range.

Past questions to try

- **9696/33/O/N/24 Q1**: a photograph of tower karst, then how tropical tower karst forms.
- **9696/32/O/N/22 Q1**: a graph of Amazon deforestation, then how deforestation affects nutrient cycling.
- **9696/33/M/J/24 Q2**: essay on the factors that form granite landforms.
- **9696/33/M/J/25 Q3**: essay on the factors that influence tropical soil formation.