22nd International Geography Olympiad

Istanbul, Türkiye

11 – 17 August 2026

WRITTEN RESPONSE TEST

Marking Scheme

Instructions for Markers

1. **Check if the iGeo student numbers are on each sheet (on odd pages) before dividing up the Test**.

2. This test consists of 6 sections.

3. The maximum total mark is 90.
   The mark for each question is given in the left-hand margin at the beginning of the question.
   There is a maximum of 15 marks for each section.

4. One whole section will be assigned to a pair of markers.
   Some lengthy (more than 2 pages) sections may be divided for two marker-pairs.

5. Get the hang of the full range of answers by reading through a few papers with your co-marker before you start your marking.
   You can mark together (especially for level marking), or after establishing a consensus on how to mark for thoroughness and consistency, act as each other's double-checkers by marking half of the test and then swapping the pile.
   We strongly recommend whenever in doubt, consult your marking partner and, if appropriate, the designated moderator(s).

6. Please develop your own marking/correcting notation system (using +/-, x/0, √ marks), underlining, comments etc. to ease double-checking and sample marking.

7. **These answers here are not exhaustive. Credit any relevant answer.**

8. Check whether the answer continues outside the designated area, in the margins or as clearly marked on blank pages.
   No credits will be given to answers in the Resource Booklet.

9. The test uses two marking systems: point and level marking.

10. Mark only the required number of answers (reasons, examples etc.).
    For instance, if the question asks for 2 reasons and there is more than 2, only the first 2 reasons should be marked.

11. Put your final mark next to the question number in the column on the left – it eases the work of the person who has to put the numbers into MS Excel.
    Please write your numbers clearly.

12. Please write down any inconsistencies of the Marking Scheme, revisions and additional answers or answers not accepted on the Notes page at the end of the Booklet (e-mail is preferred) and hand them in after marking to improve the final Marking Scheme that will be uploaded to show the actual marking.

13. The moderator(s) will sample the marking of all teams.

Command Terms for use in Written Response Test

Terms	Meaning
Analyse	break down the content of a topic, or issue, into its constituent parts in order to provide an account of it
Annotate	add labels with short comments to a diagram, map or photograph in order to describe or explain
Describe	give a factual statement of the distinctive features of something, e.g. for a landform, its shape, dimensions, composition, location (do not explain)
Discuss	give a thorough account from different points of view
Draw	make a clearly defined diagram, flowchart or map, and include labels
Elaborate	give further detail
Estimate	approximately calculate the number
Explain	give a reason, a cause, an effect, a consequence for why or how something happens
Evaluate	consider several arguments or options and come to a conclusion about their importance or success
Forecast	predict or estimate (a future event or trend)
Identify	name, select, point out something
Justify	provide sound reasons or evidence on which your response is based
Label	add names to a map, diagram, sketch or table
Match	put something together with something else that is appropriate or related
Name	state or specify, using a word or words by which something is known
Outline	give the main points or general principles of something, omitting minor details, and usually emphasizing structure and relationships
Specify	identify clearly
Study	look closely at the details in
Suggest	put forward an idea or a reason
With the help of the information provided	base answer partly on information provided (refer to this material) and partly on own knowledge

In level marking in order to credit higher marks the response has to cover a multi-perspective view with a range of factors/impacts from different spatial and temporal scales forming a thorough and well-elaborated account.

Section A: Pluvial flooding in urban areas

Resource Booklet: Table A1 provides data on rainfall and discharge for two storm events in Dardenne Creek Basin, Missouri, USA in 1982 (pre-urbanisation) and 2003 (post-urbanisation).
Resource Booklet: Figure A1 shows the hydrological cycle.
Resource Booklet: Figure A2 shows individual elements that constitute a sponge city.
Resource Booklet: Figure A3 shows types of sustainable drainage systems.

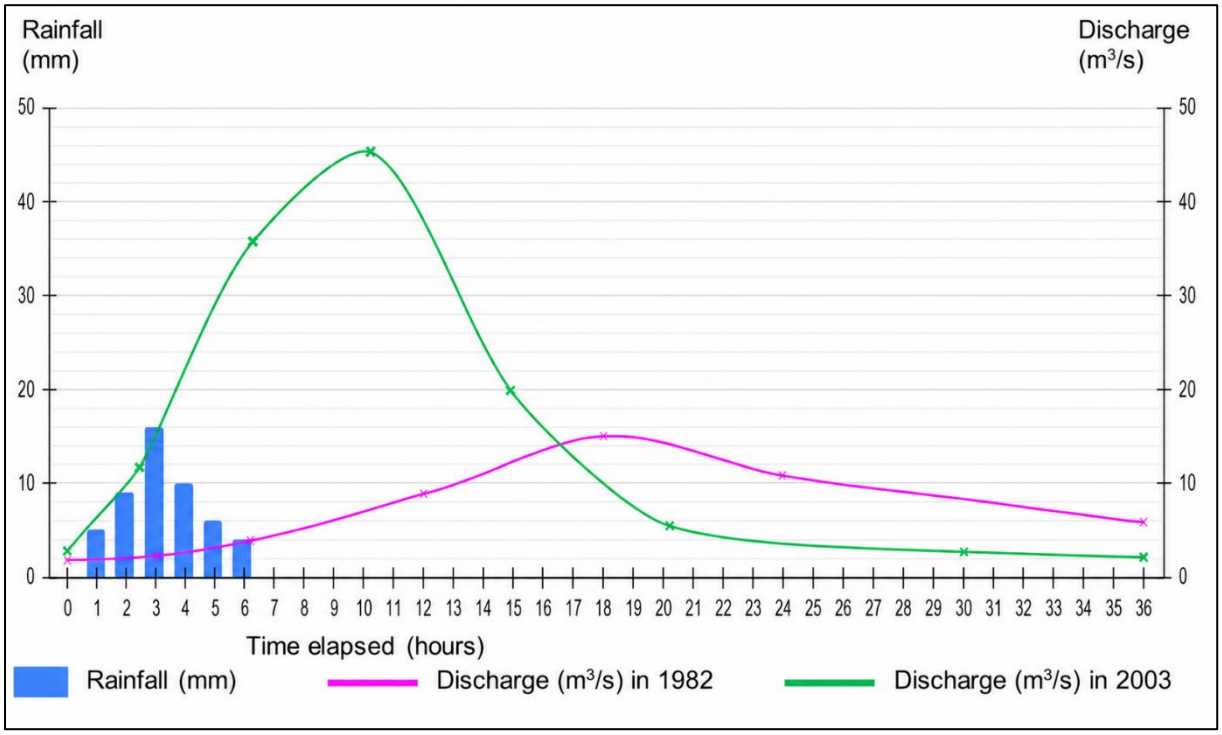
5 m

1. For this question, refer to **Resource Booklet: Table A1**. The two data series compare storm events with 50 mm of rainfall over six hours **before** and **after** urbanisation of the basin.

   Draw a **hydrograph** that combines the precipitation and discharge data for both storm events into a **single diagram**. Label your diagram appropriately.

   Point marking.

   Suggested answer:



   Award **2 marks** for an appropriate diagram (hydrograph) that displays data on both water discharges on one combined axis and data on precipitation on the other axis. Rainfall data must be shown with columns and discharge data with lines.

   - 0.5 mark is subtracted if the precipitation bars are drawn separately for each year.
   - 0.5 mark is subtracted if values are not plotted accurately. Allow some rounding to adjust the scale, especially for small values.
   - 0.5 mark is subtracted if there is empty space without values on the x- or y-axis (i.e. if the axis is longer than necessary).
   - 1 mark is subtracted if the diagram is not drawn using a ruler or very precisely by hand.
   - 1 mark (0.5 mark for each axis) is subtracted if the y-axis does not start from 0.

Do not award marks for any other type of diagram, as it is not the most appropriate for the data and a key skill is for students to select the most appropriate type for the data.

Award **3 marks** for the following elements – **0.5 mark** for element that has been drawn correctly:

- **0.5 mark** for a suitable title that refers to discharge in Dardenne Creek Basin, Missouri (location) in 1982 and 2003 (time reference).
- **1 mark** for the labels on the axes (0.5 mark for the x-axis and 0.5 mark for the y-axes):
  - The x-axis is labelled with hours numerically (0, 1, 2, etc.).
  - One y-axis is labelled as precipitation or rainfall in millimetres (mm).
  - The other y-axis is labelled as discharge in m^3/s.
- **1 mark** for bars representing precipitation in both years and lines representing 1982 and 2003 differently (0.5 mark for precipitation and 0.5 mark for discharge):
  - Precipitation bars must be drawn for each hour (hourly precipitation in both storms is the same).
  - Discharge lines must be drawn in different colours or line types (e.g., solid line, dotted line etc.)
- **0.5 mark** for a clear legend explaining the colours used for the precipitation bars and discharge lines in both years.

Accept any other relevant and correct answer.

2. For this question, refer to **Resource Booklet: Table A1** and the diagram in the previous question.

1 m a) Calculate the **lag time** between peak rainfall and peak discharge for each of the two storm events (pre- and post-urbanisation).

Suggested answers:

- Lag time in 1982: 15 hours
- Lag time in 2003: 7 hours

Award **0.5 mark** for each correct answer.

0.5 m b) How many **hours earlier** does the lag time occur after urbanisation?

Suggested answer:

- 8 hours earlier/sooner

Award **0.5 mark** for a correct answer.

0.5 m c) How many times larger is the **peak discharge** after urbanisation?

Suggested answer:

- 3 times larger

Award **0.5 mark** for a correct answer.

Note: accept the total amount (45 m^3/s) only if the answer mentions also the peak discharge before urbanization (15 m^3/s).

4 m

3. For this question, refer to **Resource Booklet: Table A1** and **Figure A1**.

Identify **two changes in the hydrological cycle** caused by urbanisation within the drainage basin. Explain these changes using specific evidence and refer to how they have contributed to the discharge patterns shown in the hydrograph.

Point marking.

Suggested answers:

- **Percolation/Infiltration:** The introduction of concrete, asphalt, and buildings has reduced the land's ability to absorb and store water in the ground. As a result, water is no longer stored and released slowly, unlike in the pre-urban hydrograph, which showed a lower peak discharge of 15 m^3/s occurring 15 hours after peak rainfall. The post-urbanisation hydrograph displays a much steeper and higher peak. Alternatively, the base flow is lower at the start of the storm in the post-urbanisation graph, as there is less throughflow when there has been no rain due to impervious surfaces (1.5 vs 2 m^3/s).
- **Surface runoff:** Impermeable surfaces such as roads, roofs, and buildings prevent water from infiltrating the ground, so surface runoff increases significantly and reaches the river more quickly, leading to flooding. The lag time was reduced by 8 hours after urbanisation, and discharge was three times higher than pre-urbanisation values.
- **Interception/Transpiration:** After urbanisation, the reduction in vegetation means that water is not intercepted by trees and plants, which can store water and return it directly to the atmosphere without it entering the stream or river. This results in more rapid runoff and a higher peak discharge, with a steep rising limb to 45 m^3/s in 7 hours.

Award a maximum of two identified and explained changes.
Award **4 marks** for two identified and explained changes.
Award **2 marks** for each fully developed answer with supporting evidence:

- Award **0.5 mark** for an identified change.
- Award **1 mark** for a complete explanation of the change. If the explanation is not complete, subtract 0.5 mark.
- Award **0.5 mark** for a supporting evidence.

Accept any other relevant and correct answer, but watch for repetition of ideas and reduce marks accordingly, especially if they continually relate to runoff and do not explain other aspects of the hydrological cycle.

4. For this question, refer to **Resource Booklet: Figures A2** and **A3**.

2 m

a) Explain **two potential solutions** related to the problems of discharge in urban areas following a heavy rainfall. Be sure to refer to the images provided.

Point marking.

Exemplary answers:

- Sustainable drainage systems (SuDS) and sponge cities mitigate address flooding through attenuation and infiltration. Features like **permeable paving** and **swales** allow water to soak into the ground or be stored in detention basins. The water is released slowly or later. This reduces the peak discharge of a river's hydrograph, preventing the flash flooding that is typical of urban areas.
- **Green roofs**, **rain gardens** and **wetlands** intercept precipitation and increase evapotranspiration. By capturing rainfall at its source, these solutions reduce the total volume of water entering drainage networks during high-intensity storms.

Award a maximum of two explained solutions.
Award **2 marks** for two explained solutions.
Award **1 mark** for each fully explained solution that makes connections to aspects of the hydrological cycle.
Award **0.5 mark** for each basic, partially explained solution or a fully explained solution without reference to the hydrological cycle.

Accept any other relevant and correct answer

2 m

b) Evaluate how **effective** these solutions might be in the future, considering the impacts of climate change and more intense precipitation.

Level marking.

Exemplary answer:

- While these "soft" engineering solutions are highly effective for frequent, low-magnitude events, their future efficacy is limited. Climate change is projected to increase the frequency of extreme rainfall events and "1-in-100-year" floods **(0.5 mark** for initial valid point). In these scenarios, "sponge" infrastructure can become saturated, reaching maximum capacity and failing to prevent catastrophic flooding **(0.5 mark** for development of point). Therefore, while vital for urban resilience, they must be integrated with traditional "hard" engineering which can immediately address some of the excess volumes to help manage future climate extremes (**1 mark** for providing insight and balance within the evaluation).

A complete answer must:

- refer to the limited effectiveness of soft solutions during extreme rainfall events (**0.5 mark**)
- elaborate what happens with soft infrastructure under such conditions (**0.5 mark**)
- highlight the need to integrate traditional engineering with soft solutions (**0.5 mark**)
- confirm the necessity of using both hard and soft solutions rather than relying solely on one (**0.5 mark**)

Accept any other relevant and plausible answer.

Section B: Agriculture and soil degradation

Resource Booklet: Figure B1 shows the share of degraded land worldwide in 2019, by country.
Resource Booklet: Figure B2 shows the share of the population experiencing moderate or severe food insecurity, by country.
Resource Booklet: Figure B3 shows the environmental impacts of food and agriculture.

1. For this question refer to **Resource Booklet: Figures B1 and B2**.

2 m a) Outline two **natural processes** (besides climate change) that can cause soil degradation.

Point marking.

Suggested answers:

- **Strong winds:** Heavy winds remove dry, microscopic soil particles, a common problem in semi-arid areas, leading to desertification.
- **Rainfall and flooding:** Excessive rain washes away topsoil, while large raindrops impact and damage the field surface with forceful splashes. Floodwaters also cause soil erosion.
- **Wildfires:** Water runoff is slowed by trees and plants. When forests or buffer zones are burned by wildfires, water streams have no impediments.
- **Natural salinisation:** The accumulation of water-soluble salts in the soil, driven by naturally high evaporation rates and poor drainage, degrades soil structure.
- **Mass movement:** Landslides and soil creep naturally strip away topsoil on steep gradients and unstable slopes.

Award a maximum of **2 marks** for outlined natural processes.
Award **1 mark** for each identified and outlined/explained natural process that contributes to soil degradation. Students must briefly explain how that process contributes to soil degradation, not just name the process.
Award **0.5 mark** for each identified and partially outlined/explained natural process.

Accept any other relevant and complete answer.

2 m b) Describe two specific **socio-economic activities or land-use changes** that may contribute to soil degradation.

Point marking.

Suggested answers:

- **Mono-cropping:** Involves growing the same crop for multiple seasons, leading to field depletion and soil erosion.
- **Conventional tillage:** For example, mouldboard ploughing can cause erosion in fields, while no-till farming prevents it. It also causes soil compaction.
- **Excessive use of mineral fertilisers:** Can result in dehumidification and destruction of soil structure, making it more vulnerable to erosive processes.
- **Irrigation:** Especially surface irrigation, which removes nutrients and topsoil particles from uneven fields due to gravity.
- **Overgrazing:** Can destroy topsoil cover, but rotational grazing and cover crops can help prevent this.

- **Deforestation:** Any tree felling, whether for wood or to expand agricultural fields for oil palm production, might accelerate erosive processes.
- **Urban sprawl and land-use conversion:** The outward expansion of settlements often paves over the most fertile arable land, forcing agricultural activities into marginal, highly erodible environments.
- **Export-driven cash crop expansion:** Economic pressures to produce high-yield export commodities can lead to the over-exploitation of local soils without adequate rest periods.
- **Insecure land tenure:** Farmers lacking long-term land rights or ownership are disincentivised from investing in sustainable, long-term soil conservation practices.

Award a maximum of **2 marks** for described human activities.
Award **1 mark** for each identified and described/explained human activity that contributes to soil degradation. Students must briefly explain how the activity contributes to soil degradation, not just name the process.
Award **0.5 mark** for each identified and partially described/explained human activity.

Accept any other relevant and complete answer.

2 m

c) Suggest a practical **solution to mitigate** <u>one</u> of the human activities that you identified in the question 1b).

Point marking.

Suggested answers:

- **Mono-cropping:**
  - Practice **crop rotation** by alternating the types of crops grown in fields each season. This helps to break pest and disease cycles, enhances soil fertility, and reduces the risk of nutrient depletion.
  - Alternate crops using **strip cropping**. This strategy involves rotating crops from one strip to another annually to improve degradation management. Effective soil degradation solutions focus on strip-cropping rotations, where annual grasses and legumes are alternated with grain and row crops.
  - Plant **cover crops**, such as legumes or grasses, when the cash crop is not in season. Cover crops protect the land from degradation, reduce weed growth, improve soil structure, and increase organic matter content.
- **Conventional tillage:**
  - Apply **conservation tillage** techniques. Reduce or eliminate intensive tillage practices that disturb the soil structure and contribute to degradation. Conservation tillage methods, such as no-till or reduced tillage, help retain moisture, improve organic matter content, and minimise land degradation.
- **Excessive use of mineral fertilisers:**
  - Apply the **correct amount of fertiliser**. Variable rate application based on soil diagnostics and satellite imagery analytics can determine how much fertiliser is needed in each zone to achieve the desired yield without harming the land or the surrounding environment.
  - Aim for **organic farming**. To help prevent soil degradation, reduce the use of chemical fertilisers and consider organic alternatives. When managing pests, choose chemical-free IPM (integrated pest management) practices to avoid pesticide drift.
- **Irrigation:**
  - Adopt **contour farming**. By collecting precipitation behind the ridges, contour farming mitigates land degradation and water runoff.
  - Practise **terrace farming** on slopes. Agricultural terraces reduce the hillside gradient, minimising the potential for surface water flow to cause slope erosion.

- Avoid **over-irrigation**. Use efficient irrigation methods, such as drip irrigation, to prevent secondary salinisation and sodification (excessive sodium accumulation) of fields.

- **Overgrazing:**
  - Practice rotational grazing and introduce cover crops. Ensure the number of animals does not exceed the land's capacity. Provide supplemental feed to reduce pressure on pastures. Introduce restoration measures: re-seeding damaged areas, controlling invasive species.
- **Deforestation:**
  - Eliminate **tree felling**, whether for wood or to expand agricultural production, to reduce erosive processes.
  - Adopting **sustainable forestry practices** that prioritise the long-term health and productivity of forest ecosystems.
  - Reducing or eliminating **clearcut logging** – use selective logging if necessary.
  - Protecting primary and intact forests.
  - Implementing stricter deforestation regulations
  - Economic incentives for conservation

Award marks only for solutions related to the human activity described in 1b. Do not award marks if the solution is not related to one of the human activities provided by the student in 1b.
Award **2 marks** for a fully explained or developed solution.
Award **1 mark** for a solution that is not fully explained or developed.

Accept any other relevant and complete answer.

2 m d) Discuss the possible **limitations** of the solution you suggested in the question 1c).

Point marking.

Suggested answers:

- **Mono-cropping to multi-cropping:** Solutions are often less efficient in the short term regarding crop yields and may therefore be less attractive to farmers. Immediate economic factors can reduce the likelihood of switching from mono-cropping.
- **Conventional tillage to conservation tillage:** Challenges include increased reliance on herbicides due to reduced mechanical weeding, higher upfront costs for specialised equipment, and management difficulties in cold, wet soils. Key issues also include potential short-term yield reductions, increased pest and disease pressure, and complex nutrient management.
- **Excessive use of mineral fertilisers:** The main obstacles include the potential for reduced crop yields, high costs to farmers of alternatives, slow adoption of alternative methods, and the high nutrient demand of modern, high-intensity farming systems.
- **Irrigation:** Changing to water-efficient technologies is expensive and therefore a limiting factor. The risk of lower crop yields, reduced food security, and financial strain means that changes to irrigation practices are less likely to occur.
- **Overgrazing:** Factors limiting the shift to rotational grazing include significant investment in fencing, water systems, and feed bunkers. Moving animals frequently between pastures is labour-intensive. Effective rotational grazing requires careful planning, monitoring of grass growth, and understanding of rainfall patterns.
- **Deforestation:** Transitioning to sustainable agroforestry or restoring degraded land requires significant investment and often has lower immediate financial returns than destructive practices. Local communities often depend on forests for their livelihoods, and

restricting land access without providing alternative income either causes or fails to prevent deforestation. Protecting one area often shifts deforestation to other forests or non-forest ecosystems (e.g., grasslands), simply relocating the problem rather than solving it. Weak governance and enforcement limit the effectiveness of attempts to reduce deforestation.

Award marks only for limitations related to the solution explained in 1c. Do not award any marks if the limitation provided is not related to the solution the student gave in 1c.
Award **2 marks** for a discussion with that includes two limitations/arguments
Award **1 mark** for a discussion with one valid limitation/argument.

Accept any other relevant and complete answer.

2 m

2. For this question refer to **Resource Booklet: Figures B1 and B2**.

Identify two spatial patterns related to land degradation and food security shown on the maps. Provide specific data from the sources in your answer. You should refer to regions and/or multiple countries, not just individual countries.

Point marking.

Suggested answers:

- Countries with a **high percentage of degraded land** also tend to have higher levels of food insecurity.
- Sub-Saharan Africa, South America, and Southeast Asia experience the **highest rates of soil degradation**, largely driven by agricultural expansion, deforestation, and high rainfall erosivity.
- The highest levels of food insecurity are concentrated in the Global South, highlighting a distinct macro-regional divide compared to the Global North.
- There is a distinct **latitudinal pattern**, with countries in tropical and semi-arid zones facing compounded challenges of both high soil degradation and elevated food insecurity.
- Most countries with high levels of food insecurity are in **less developed countries (LDCs)**, indicating a correlation between economic development and vulnerability to degradation.

A complete answer may refer to data from sources in a descriptive way (e.g. greater percentage of the regions has soil degradation or food insecurity) or in a quantitative way (e.g. more than 40% of the land is degraded or more than 80% of people experience food insecurity).

Award a maximum of **2 marks** for two analysed patterns.
Award **1 mark** for each pattern analysed with a reference to data from sources.
Award **0.5 mark** for each pattern analysed pattern without reference to data from sources.
Do not award patterns identified without analysis.

Accept any other relevant and complete answer.

2 m

3. Explain two impacts of soil degradation on **food security**.

Point marking.

Suggested answers:

- **Reduced food availability:** Soil erosion (by water and wind) removes fertile topsoil, drastically reducing crop yields. Soil compaction from machinery hinders root growth and water infiltration, lowering production capacity.
- **Lower nutritional quality:** Depleted soils, lacking vital nutrients, produce food with significantly reduced vitamins and minerals (e.g., lower magnesium, calcium, and protein), resulting in widespread malnutrition.
- **Increased food prices:** As productive land becomes scarce or infertile due to salinisation and desertification, the cost of food production rises, resulting in higher food prices and reduced access for vulnerable populations.
- **Rural-to-urban migration:** The loss of viable agricultural livelihoods forces rural populations to migrate, straining urban food distribution networks and exacerbating urban food insecurity.
- **Vulnerability of subsistence farmers:** Populations relying on small-scale, subsistence farming are disproportionately affected by soil degradation, widening economic inequalities and deepening localised famine risks.
- **Long-term agricultural decline:** The slow rate of soil regeneration (taking up to 1,000 years for significant topsoil recovery) means that once land is degraded, it may not be usable for future generations.
- **Environmental vulnerability:** Loss of organic matter weakens the soil's ability to retain water, leading to increased runoff and making agricultural systems less resilient to environmental shocks.

Award a maximum of **2 marks** for two explained impacts.
Award **1 mark** for each fully explained impact.
Award **0.5 mark** for each partially explained impact.
Do not award answers that only name impacts and without explanation.

Accept any other relevant and complete answer.

3 m

4. For this question refer to **Resource Booklet: Figures B1, B2** and **B3**.

Evaluate this statement: "***Food lies at the heart of the world's environmental issues*.**" Use specific evidence from the data provided to support your answer.

Level marking.

Exemplary answer:

Maps show a **high correlation** between areas experiencing extensive soil degradation (a major global environmental concern) and regions with high rates of moderate to severe food insecurity.

Food and agriculture have a significant **global impact on the environment**, as shown in image B3. Food production accounts for over a quarter (26%) of global greenhouse gas emissions. Half of the world's habitable (ice- and desert-free) land is used for agriculture. Seventy per cent of global freshwater withdrawals are used for agriculture. Seventy-eight per cent of global ocean and freshwater eutrophication (the pollution of waterways with nutrient-

rich pollutants) is caused by agriculture. Ninety-four per cent of mammal biomass (excluding humans) is livestock. This means livestock outweigh wild mammals by a factor of 15 to 1.3.

Food, therefore, lies at the **heart of efforts to tackle** climate change, reduce water stress and pollution, restore land to forests or grasslands, and protect the world's wildlife.

A complete answer must include the following **elements**:

- reference to relationship between **land degradation and food security** as shown in maps
- provide arguments and specific evidence regarding the use of **resources for agriculture** (as shown in image B3)
- highlight the importance of agriculture in **environmental changes**

Award **3 marks** for a thorough evaluation with specific reference to all three elements. Data from the graphics should be explained not just listed.
Award **2 marks** for a limited evaluation with specific reference to two elements. Data from the graphics should be explained not just listed.
Award **1 mark** for an answer that is limited in evidence and evaluation of the statement.

Accept any other relevant and complete answer.

Section C: Natural resources

Resource Booklet: Figure C1 shows the average natural resource rent as a percentage of GDP and the average GDP per capita growth rate (1995–2019) worldwide, by country. **Resource Booklet: Figure C2** presents global bauxite mining, aluminium smelting and refining (2024), as well as information on lateritic bauxite deposits.

1. For this question, refer to **Resource Booklet**: **Figure C1**.

2 m a) Analyse the **relationship** between average natural resource rent as a percentage of GDP and average GDP per capita growth rate (1995-2019). Justify your arguments using **specific evidences**.

Point marking.

Suggested answer:

- Natural resources rent and average GDP growth per capita have an inverse relationship (**0.5 mark**). The higher the proportion of natural resource rent in GDP, the lower the GDP per capita growth rate tends to be (**0.5 mark**).
- Example 1: South Korea has 0% of its GDP from natural resource rent and recorded one of the highest GDP per capita growth rates, at about 4.1% (**0.5 mark**). In contrast, the Democratic Republic of Congo (DRC) has the highest natural resource rent at approximately 47% of GDP and one of the lowest GDP per capita growth rates, close to 1%. (**0.5 mark**).
- Example 2: Although the DR Congo has about 5% higher natural resource rent than Saudi Arabia, its GDP per capita growth rate is lower by about 1% (**0.5 mark**). Saudi Arabia, with a high resource rent of around 42% of GDP, also has a low GDP per capita growth rate, near 1% (**0.5 mark**).
- Other anomalies include Cote d'Ivoire and South Africa. Despite having a low natural resource rent percentage (less than 8%), their GDP per capita growth rates are about 1% or less (**0.5 mark**).

Elements for marking:

- Explanation of inverse relationship between natural resources rent and average GDP growth per capita. Award **1 mark** for the explanation. Award **0.5 mark** for mentioning inverse relationship without an explanation.
- Description of one country with a low natural resource rent and a higher average GDP growth rate per capita with specific evidences (percentage). Award **0.5 mark** for a full description and evidences.
- Description of one country with a high natural resource rent and a lower average GDP growth rate per capita with specific evidences (percentage). Award **0.5 mark** for a full description and evidences.
- One previously mentioned type of example can be replaced by an example of anomaly with adequate evidences.

Accept any other relevant and complete answer.

0.5 m b) Identify the **concept/phenomenon** shown in Figure C1.

Point marking.

Answer:
- Resource curse or paradox of plenty

Award **0.5 mark** for a correct term.

Accept any other correct similar term.

2 m c) Explain two impacts of **high dependence on natural resources** on national economies.

Point marking.

Suggested answers:
- **Volatility of commodity prices:** Volatile commodity prices create boom-and-bust cycles that encourage short-term spending during booms, often on unsustainable projects or consumption. When prices crash, governments that have failed to save face severe fiscal crises without reserves to cushion the blow, leading to economic instability and social unrest.
- **Failure to diversify the economy:** Heavy reliance on resource extraction leads countries to neglect other productive sectors such as manufacturing and agriculture. When resource prices fall, the economy lacks alternative sectors to sustain growth and employment, leaving it vulnerable to collapse.
- **Dutch disease**: When a resource boom causes currency appreciation, it makes other exports uncompetitive internationally. Resources then flow into extraction while other productive sectors shrink, leaving the economy dependent on a single volatile commodity.
- **Reliance on foreign labour / companies**: Reliance on expatriate specialists means high-value employment and expertise do not build domestic human capital, while revenues earned by expatriate workers are repatriated abroad rather than circulating locally. This economic leakage reduces the multiplier effects of resource wealth and prevents the development of local skills and industries.
- **Corruption:** Corrupt political elites capture resource revenues for personal gain rather than investing them in public goods such as infrastructure, education, and healthcare. This misallocation of wealth undermines economic development, weakens institutions, and perpetuates inequality while eroding public trust in government.

A complete explanation of an impact must refer to the present situation in the national economy and the potential short- or long-term impact on the economy.

Award a maximum of **2 marks** for two explained impacts.
Award **1 mark** for each explained impact that includes a reference to the present situation and short- or long-term impact on the economy.
Award **0.5 mark** for a partially explained impact that includes either a reference to the present situation or short- or long-term impact on the economy.
Do not award marks for impacts listed without a proper explanation.

Accept any other relevant and complete answer.

2. For this question, refer to **Resource Booklet**: **Figure C2.**

2 m a) Identify **two** examples of negative **environmental impacts** associated with lateritic bauxite mining.

Point marking.

Suggested answers:
- Sedimentation of local waterways due to runoff of tailings ("red mud") released from disturbing lateritic soils, which can destroy aquatic habitats and fisheries.
- Deforestation and habitat destruction, as many bauxite deposits are located beneath tropical rainforests. Examples include Brazil and Guinea.
- Air pollution from dust emitted during mining or transportation.
- Increased water use during mining.
- CO^2 emissions related from mine operations.

Award a maximum of **two** environmental harms.
Award **1 mark** for each identified environmental harm associated specifically with mining.
Do not award marks for general answers that mention environmental issues without a reference to mining.

Accept any other relevant and complete answer.

2 m b) Explain **two socio-economic impacts** associated with lateritic bauxite mining in **developing** countries.

Point marking.

Suggested answers:
- **Economic development:** Job creation, business growth to support mine development and operations, and small businesses serving mine workers.
- **Economic vulnerability:** Aluminium is a boom-bust commodity. Countries heavily reliant on aluminium exports may struggle to diversify their economies before the next downturn, resulting in low job security and ripple effects throughout the economy.
- **Food insecurity:** Dust from bauxite mines can damage crops and reduce yields.
- **Competitiveness of agriculture:** Growth of a country's resource sector increases the value of its currency, reducing the competitiveness of agricultural exports on the global market.
- **Land-use changes:** Many landholders may lease their land for bauxite mining rather than farming, decreasing local food production and leading to food scarcity and higher prices.
- **Political impacts:** "Resource curse": While aluminium is not as lucrative as other conflict minerals, resource-based economies lacking strong government institutions tend to develop slowly due to government corruption. This affects access to healthcare, education, and the economic prosperity of the working class.
- **Gender inequality:** Mine employees are predominantly men, reducing women's economic independence
- **Health issues:** Airborne dust and other contaminants from bauxite mining may cause air pollution. There are occupational hazards at the mine site. Tax revenues from mining can help improve local healthcare infrastructure.

Award a maximum of **2 marks** for two explained impacts.
Award **1 mark** for each fully explained impact.
Award **0.5 mark** for each partially explained impact.

Do not award answers that only list impacts and without explanation.
Accept any other relevant and complete answer.

3 m

3. For this question, refer to **Resource Booklet: Figure C2**.

Four to five kilograms of bauxite ore are required to produce one kilogram of aluminium, making it a **bulk-reducing industry**. However, many aluminium smelters and refineries are located in countries that are not major bauxite producers.

Outline **three reasons** why this may be the case.

Point marking.

Suggested answers:

- Aluminium smelting and refining are very energy intensive. Smelters and refineries are located in countries that provide consistent, cheap electricity. Examples include Canada and Norway (hydroelectric power), Arabian Gulf states (natural gas), and Iceland (hydroelectric and geothermal power).
- Major companies prefer to locate these expensive assets in politically stable areas.
- Easier access to large, industrialised markets.
- Access to capital for developing refineries.
- Government subsidies for building smelters and refineries.
- Low ocean bulk shipping costs to coastal refineries.

Award a maximum of **three** reasons why many aluminium smelters or refineries are located in countries that are not major bauxite producers.
Award **1 mark** for each outlined reason.
Award **0.5 mark** for each identified reason without an explanation.
Accept any other relevant and complete answer.

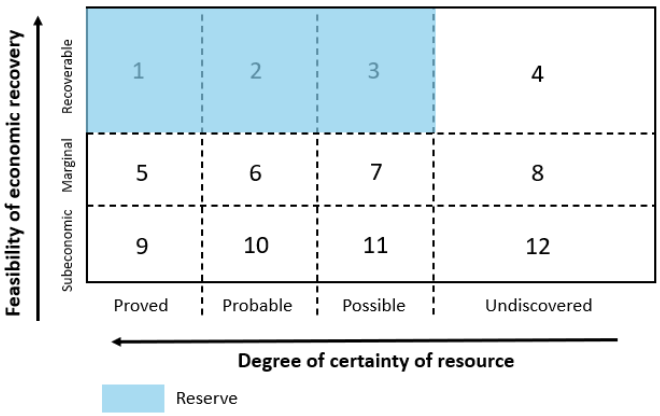
0.5 m

4. The image below presents the **McKelvey Diagram**, which is used to illustrate the difference between resources and reserves based on geological certainty and economic feasibility.

Complete the diagram by **shading relevant box(es)** to show the **'reserves'** category.

Point marking.

Answer:



Award **0.5 marks** for correct shading of reserves category.
Do not award any other combinations of shaded boxes.

3 m

5. For this question, refer to **Resource Booklet: Figure C2** and the **McKelvey Diagram in the question 4**.

Discuss **three potential ways** the reserves category could be expanded.

Point marking.

Suggested answers:

- **Economic aspects:**
  - Rising commodity prices can shift resources from the "subeconomic" category into reserves by making extraction profitable.
  - Lower extraction costs through operational efficiencies, automation, or economies of scale.
- **Technological aspects:**
  - Improved exploration technologies such as advanced geophysical surveys and remote sensing can identify new deposits or better define existing ones.
  - New extraction technologies can make previously uneconomic deposits viable by reducing extraction costs or enabling access to difficult-to-reach resources.
- **Political aspects:**
  - Favourable government policies, tax incentives, or streamlined permitting processes can improve project economics.
  - Environmental regulations may also change to allow previously restricted areas to be developed.

Award a maximum of **three** discussed ways in which the resource reserves category can potentially be expanded.
Award **3 marks** for three listed and explained ways.
Award **1 mark** for each listed and explained reason for the potential expansion of resource reserves. Reasons may be in the same or different categories.
Award **0.5 mark** for a suggested reason without an explanation.

Accept any other relevant and correct answer.

Section D: Arctic ice

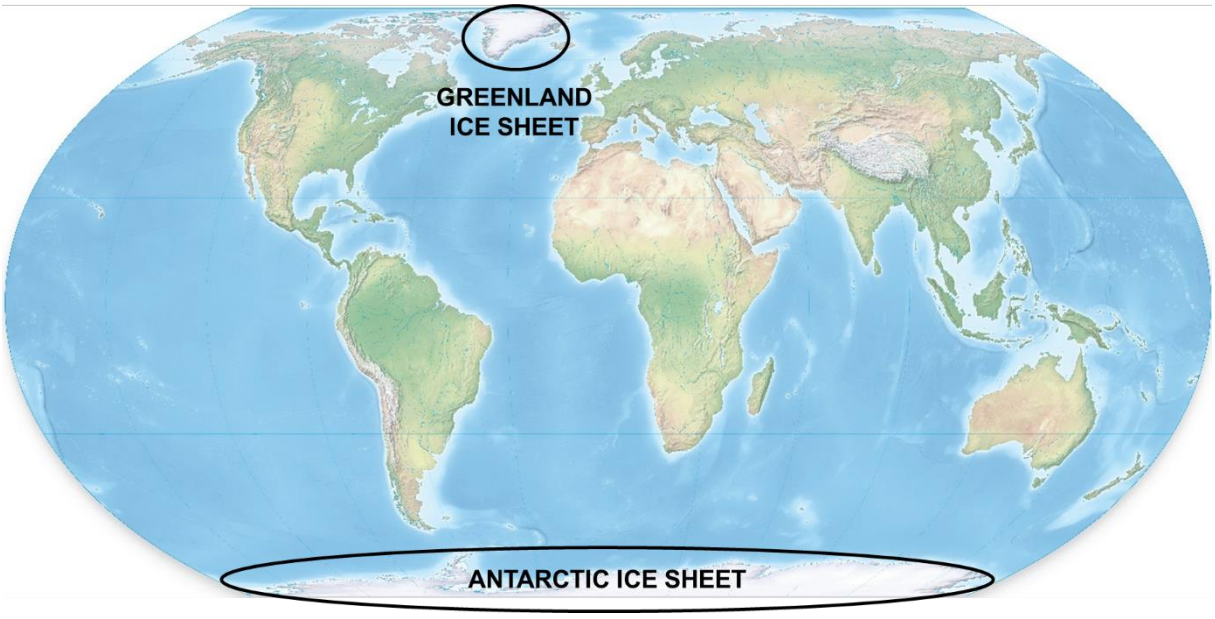
Resource Booklet: Table D1 shows the average temperatures and precipitation for Camp Summit, Greenland (72.38°N, 38.45°W, elevation: 3216 m)
Resource Booklet: Figure D1 illustrates the transformation of snow into ice.
Resource Booklet: Figure D2 shows the decline of Arctic sea ice from 1979 to 2015, with projections to 2050 (maps are for September, when there is the least ice).
Resource Booklet: Table D2 shows the number of ships by type in the Arctic region from 2013 to 2024.

1. For this question, use the following **physical map** of the world.

1 m a) On the map provided, mark one the largest **ice sheets** using solid lines and name it.

Point marking.

Answers (see the map below):
- Antarctic ice sheet
- Greenland ice sheet



Award a maximum of **one** marked and named ice sheets.
Award **0.5 mark** for a correctly marked ice sheet.
Award **0.5 mark** for a correctly named ice sheet (the name may be placed next to the area or included in a legend).

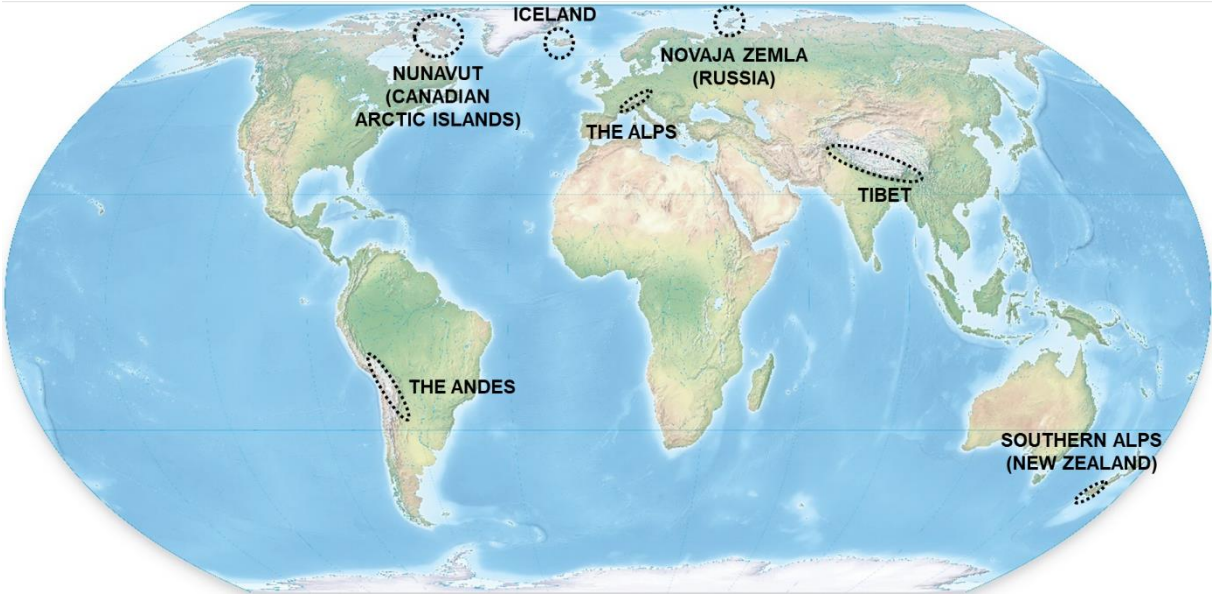
Accept any other relevant and correct answer.

2 m b) On the map provided, mark two areas with major **ice caps** using dotted lines and name each.

Point marking.

Answers (see the map below):
- Iceland (e.g. Vatnajökull)

- The Canadian Arctic, especially on islands in Nunavut
- Svalbard
- Parts of Russia, such as Novaya Zemlya
- Tibet
- The Andes Mountains
- The European Alps
- The Southern Alps of New Zealand



Award a maximum of **two** marked areas.
Award **1 mark** for each correctly marked and named ice cap.

- Award **0.5 mark** for a correctly marked ice cap.
- Award **0.5 mark** for a correctly named ice cap (the name may be placed next to the area or provided in a legend).

Accept any other relevant and correct answer.

1 m

2. Describe **two differences** between ice sheets and ice caps.

Point marking.

Suggested answers:

- An ice sheet is a mass of glacial land ice extending more than 50,000 square kilometres. An ice cap covers less than 50,000 square kilometres.
- Ice caps are much more localized and typically cover high mountain regions or high latitude areas.
- Ice sheets are so large that they bury the underlying landscape (including entire valleys and mountain ranges). Ice caps, being smaller, are heavily influenced by the underlying topography and often leave mountain peaks exposed.
- Ice sheets can be several thousand meters thick. Ice caps are thinner, generally reaching only several hundred meters in depth.
- Like ice sheets, ice caps tend to spread out in dome-like shapes as opposed to flowing down slopes.

Award a maximum of two described differences.
Award **1 mark** for a complete answer that includes two described differences.
Award **0.5 mark** for each described difference.

Accept any other relevant and correct answer.

2 m

3. Identify and explain **two processes** by which ice sheets lose mass in the **ablation zone**.

Point marking.

Suggested answers:

- **Meltwater**: Summer temperatures melt the ice, producing meltwater that flows as rivers either on the surface of the ice or through cracks, running into and beneath the ice along the bedrock to the sea.
- **Icebergs**: Glaciers that terminate at the sea calve, forming icebergs which break off and drift further out to sea.
- **Evaporation**: Meltwater formed on the ice absorbs energy and evaporates into the air.
- **Sublimation**: Ice can transform directly from a solid state to water vapour.

Award a maximum of **two** identified and explained processes.
Award **1 mark** for each correctly identified and fully explained process.
Award **0.5 mark** for each correctly identified and partially explained process.
Do not award marks for naming the process without an explanation.

Accept any other relevant and correct answer.

4. For this question, refer to **Resource Booklet: Table D1** and **Figure D1**.

1 m

a) Calculate the **annual precipitation** in Camp Summit in **millimetres** and convert it into the **annual snowfall** in **centimetres**.

Point marking.

Answers:

- Annual precipitation: 78 mm
- Annual snowfall: 78 cm

Award **0.5 mark** for correct annual precipitation.
Award **0.5 mark** for correct annual snowfall.
Do not award marks for other answers, as the calculation must be precise.

2 m

b) Explain why the **depth of ice** in Camp Summit is not increasing despite the annual snowfall.

Level marking.

Exemplary answer:

- New snow accumulates on top of previous layers each year, compressing the lower layers and making them denser through firnification. As the snow compacts, air is expelled, causing the overall height of the ice to decrease even as new snow falls. Additionally, the annual snowfall of only 78 cm is not enough to increase the depth of the ice.

A complete answer must include a thorough explanation of how snow compacts and transforms into firn.
Award **2 marks** for a complete explanation the process.
Award **1 mark** for a partial explanation of the process.

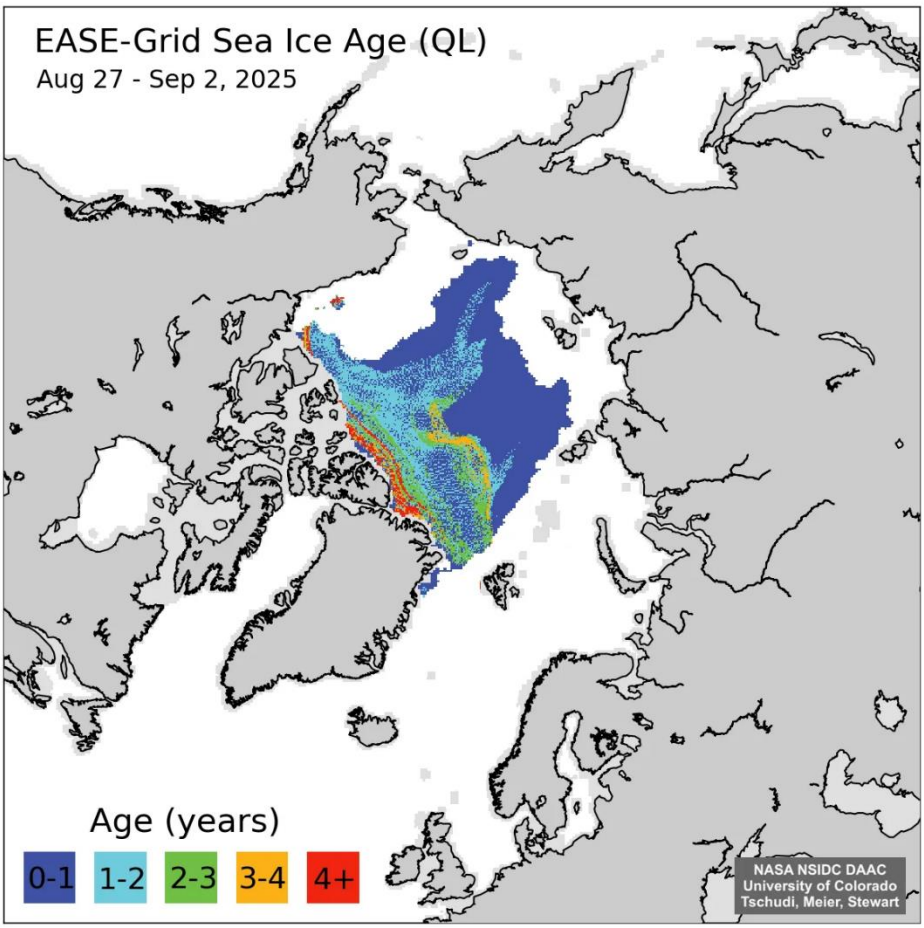
Accept any other relevant and correct answer.

5. For this question, refer to **Resource Booklet: Figure D2**.

1 m a) Estimate the **extent of Arctic sea ice** in September 2025 based on Figure D2. Draw the estimated extent of Arctic sea ice **on the map of the Arctic below**.

Point marking.

Suggested answer: see the map below.



Explanation:

- September 2025 had a greater extent of Arctic ice than in previous years. The ice covered the polar region and extended to the Canadian Arctic islands. The area north of Russia, Alaska, and Scandinavia was ice-free.
- Students may draw a similar or smaller area, as shown on the map (the presence of one-year-old ice in the eastern part suggests that the extent of ice varies in that region). The drawn extent of ice must cover the polar region and the area adjacent to Greenland and the Canadian Arctic islands. Allow some variation in the extent of ice.

Award **1 mark** for a marked area as shown in the image, which covers the polar area and the western and southern parts (towards Greenland and the Canadian Arctic islands).
Award **0.5 mark** for a marked area that is significantly larger or smaller than in the image, or does not extend to Greenland or the Canadian Arctic islands.
Do not award any marks for an area marked only around the North Pole.

Accept any other relevant and correct answer.

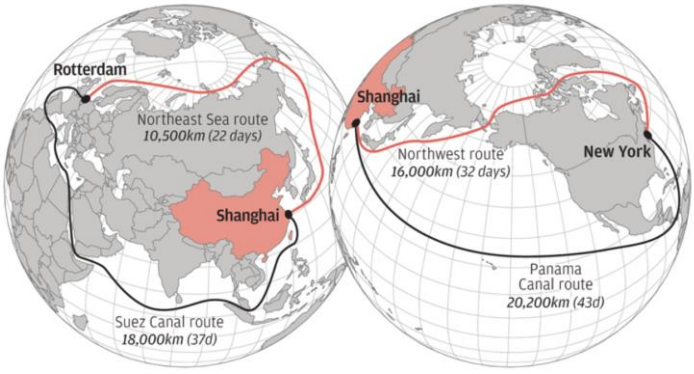
2 m b) Due to the smaller extent of sea ice, the Arctic is becoming an important sea transport route.

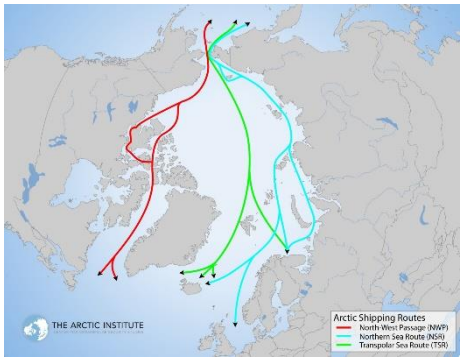
Draw two **Arctic shipping routes** on the map that could soon provide alternatives to major intercontinental maritime corridors, connecting key port regions in the Northern Hemisphere. Mark the routes in **different colours** and **annotate the regions** they connect.

Point marking.

Suggested answers: see the map below.

- **North-eastern route**: North-western Europe – (Barents Sea – along the northern coast of Russia – Bering Strait) – East Asia.
- **North-western route**: East Asia – (Bering Strait – along the northern coast of Alaska – Canadian Arctic islands – along the coast of New Foundland) – east coast of the USA and Canada





Award a maximum of **two** drawn and annotated routes.
Award **1 mark** for each correctly drawn route with annotated regions it connects.
Award **0.5 mark** for each precisely drawn route. Allow some variation in drawing of the route.
Award **0.5 mark** for each pair of annotated regions the route connects. Allow some variation in naming the regions.

Accept any other relevant and correct answer.

TEST DIRECTOR'S NOTE: Transpolar Route could also be considered

3 m

6. For this question, refer to **Resource Booklet: Table D2** and **the map in question 4.**

In areas where sea ice disappears completely or is present only in winter, more opportunities for economic activities emerge. Outline three such **economic activities** other than sea transport.

Point marking.

Suggested answers:

- Fishing in new maritime areas that were previously covered by sea ice.
- Exploration and extraction of mineral resources that were previously inaccessible become possible.
- Trade and shipping companies can save time and costs by transporting goods via shorter Arctic sea routes.
- Tour operators can offer Arctic trips for a longer period each year.
- Access is opened to vast natural resources (oil, gas, and minerals) whose extraction without maritime transport would be economically unviable.
- The development of the Arctic increases public awareness of climate change and the impact of human activities on the planet, creating conditions for better and more detailed scientific research in the Arctic.
- Harsh Arctic conditions encourage the development of new technologies, from icebreakers and autonomous vessels to resilient construction solutions and renewable energy technologies.

Award a maximum of **three** activities that result from reduced Arctic sea ice.
Award **1 mark** for each outlined activity.
Award **0.5 mark** for each identified activity without an explanation.
Accept any other relevant and complete answer.

Section E: Coral reefs and tourism management

A bay on a tropical island is a popular diving destination because of its diverse coral reefs. However, the increasing number of tourists, combined with environmental changes, has gradually led to the deterioration and bleaching of the corals. The Covid-19 pandemic, which affected the world between 2020 and 2021, caused a sharp decline in tourist numbers to the island. During this period, local accommodation operators renovated and built new facilities, hoping to provide a better travel experience in the future. After the pandemic, tourist numbers returned to pre-pandemic levels and are even expected to surpass the previous peak.

Resource Booklet: Figure E1 represents an aerial image of the bay on a tropical island in South East Asia.
Resource Booklet: Figure E2 provides various images of the bay on the same tropical island as on Figure E1.
Resource Booklet: Figure E3 shows a sea turtle swimming in a healthy coral reef and a sea turtle and a snorkel diver swimming in a compromised coral reef.
Resource Booklet: Figure E4 shows the sea surface temperature and monthly rainfall in the bay.
Resource Booklet: Figure E5 provides data on the number of visitors to the tropical bay from 2017 to 2025, the percentage of healthy and compromised coral colonies recorded in the bay during different periods, and substrate characterisation of the bay in different periods.

1. For this question, refer to **Resource Booklet: Figures E1 and E2**.

1 m a) Name **type of the coral** reef shown in the photos.

Point marking.

Suggested answer:
- Fringing reef

Award **1 mark** for a correct answer.

1 m b) Describe how this type of coral reef is formed.

Point marking.

Exemplary answer:
- Forms directly along the coastline of a landmass. It is formed in shallow water, often just offshore. Coral larvae settle on the shallow seabed and grow outward. There is no significant gap (lagoon) between the reef and the land.

A complete description must include at least two underlined elements.
Award **1 mark** for a complete description containing two elements.
Award **0.5 mark** for a partial description containing one element.

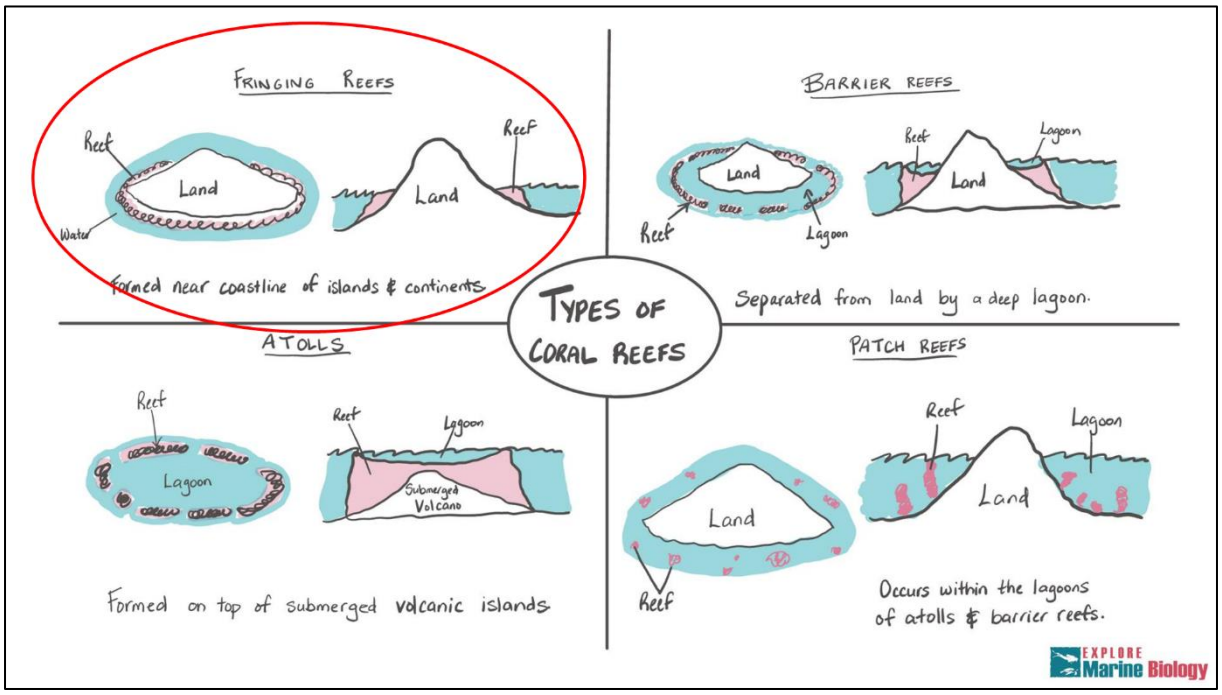
Accept any other relevant and correct answer.

2 m

c) Draw a **sketch** of the reef type defined in (a) and label the basic elements on the sketch.

Point marking.

Suggested answer: see the upper left part of the image below.



Suggested answer – elements of the sketch:

- land or island in the centre
- coral reef located next to the coastline or island
- no lagoon between the coastline and the reef
- labelled elements: land (or island), (coral) reef

Award **2 marks** for a complete sketch containing all four elements.
Award **0.5 mark** for each element included in the sketch.
Do not award marks for other types of coral reefs or for labelled elements without a sketch.

Accept any other relevant and correct answer.

2 m

2. For this question, refer to **Resource Booklet: Figure E1 and E2**.

Identify the **physical features** and **land uses** around the bay and label them in the boxes next to the aerial image.

Point marking.

Suggested answer: see image below.



Award one answer in each box.
Award **2 marks** for four correctly identified physical features and land uses in the text boxes.
Award **0.5 mark** for each correctly identified physical feature or land use in a text box.

Accept any other relevant and correct answer.

2 m

3. For this question, refer to **Resource Booklet: Figures E3 and E4**.

Some believe that "a short break in tourism could reverse the long-term disturbances to coral reef ecosystems caused by natural and anthropogenic stressors".

With the help of the information provided, state whether you **agree or disagree** with the statement. **Justify** your reasons using **specific evidence**.

Point marking.

Exemplary answer:

- Disagree. Although visitor numbers dropped drastically during the pandemic break (120,000 in 2020 and 30,000 in 2021), coral health declined during the Covid-19 and post-pandemic periods. During the Covid-19 period, healthy coral reefs decreased to 50%, while in the post-Covid period the proportion of healthy coral reefs increased only to approximately 55%.

A complete answer must mention the decrease in visitor numbers and the decrease in healthy coral reefs during the Covid period (or only a slight increase in the post-Covid period). Both processes must be supported by specific numbers or percentages from the diagrams.

Award **2 marks** for a complete explanation that includes both processes and specific evidence.
Award **1 mark** for a partial explanation that includes one of the processes and specific evidence.
Award **1 mark** for a partial explanation that includes both processes without specific evidence.

Accept any other relevant and correct answer.

3 m

4. For this question, refer to **Resource Booklet: Figures E4 and E5.**

Explain one possible **cause of coral degradation** in each of the following periods.

Point marking.

Suggested answers:

Pre-Covid period (2016-2019):

- **Tourism pressure**: High and increasing visitor numbers (rising steadily from 575,000 in 2017 to 680,000 in 2019) led to intense recreational diving and snorkelling activity, causing physical disturbance to corals.
- **Thermal bleaching:** Environmental factors, particularly thermal bleaching caused by sea surface temperatures (SST) exceeding 31 °C (as shown in Figure 2).

Covid period (2020-2021):

- **Developmental impact / sedimentation:** Local accommodation operators renovated and constructed new facilities during this period, resulting in coastal construction disturbances. Increased rainfall led to greater runoff and sediment transport into the bay.

Post-Covid period (2022-2024):

- **Tourism pressure:** A sharp and rapid increase in tourist numbers (rising from 280,000 in 2022 to 650,000 in 2024) resulted in a sudden return of heavy physical pressure from snorkellers and divers on already stressed reefs.
- **Environmental pollution:** The operation and waste production from newly built and renovated bayside accommodation facilities increased localised pollution and direct stress on the marine ecosystem.
- **Thermal bleaching:** Environmental factors, specifically thermal bleaching caused by sea surface temperatures (SST) exceeding 31 °C (as shown in Figure 2).

Award one explanation for each period.
Award **1 mark** for each fully explained cause of coral degradation.
Award **0.5 mark** for a partially explained cause of coral degradation.
Do not award identified cause without an explanation.

Accept any other relevant and correct answer.

4 m

5. Outline **two management strategies** for ecotourism that would help maintain the integrity of the coral reef ecosystem and socio-economic development in the bay.

Point marking.

Suggested answers:

- **Strategy A: Visitor limits / Carrying capacity quotas**
  - Identification: Establish daily or annual limits on the number of tourists and tour boats allowed in the bay.
  - Explanation: Directly addresses the post-Covid surge (reaching 650,000–750,000 visitors), preventing overcrowding and physical reef damage while maintaining a stable and predictable tourism economy for local accommodation providers.
- **Strategy B:** Zoning and marine protected areas
  - Identification: Divide the bay into designated zones, creating strictly protected "no-entry/no-dive" regeneration areas alongside dedicated ecotourism zones.
  - Explanation: Protects remaining healthy coral environments (Figure E1-D) and allows compromised areas (Figure E1-E) time to recover from tourist contact and thermal bleaching, while keeping alternative areas open to support local business livelihoods.
- **Strategy C:** Infrastructure and environmental regulations for operators
  - Identification: Enforce strict environmental protocols (e.g., zero-wastewater discharge, green certifications) for bayside accommodations.
  - Explanation: Addresses the threat posed by operators who renovated and built facilities during the pandemic, ensuring land-based sewage or runoff does not accelerate coral degradation as visitor numbers peak.
- **Strategy D:** Compulsory eco-briefings and guide certification
  - Identification: Require mandatory educational briefings for all snorkellers and divers, and certify local tour operators in reef-safe practices.
  - Explanation: Explanation: Minimises direct human contact and accidental physical damage caused by divers (as shown in Figure B1-E), improving conservation outcomes without reducing tourist arrivals.

Award a maximum of two strategies.
Award **2 marks** for each fully elaborated strategy.
Award **1 mark** for each partially elaborated strategy.
Award **0.5 mark** for each identified strategy without elaboration.

Accept any other relevant and correct answer.

Student number: 22

Section F: Data centres and AI infrastructure

Artificial intelligence, cloud computing, social media, streaming platforms, and online services depend on large data centres. Although digital technologies may seem "weightless", they require extensive physical infrastructure, including buildings, power supplies, cooling systems, fibre-optic networks, and land. The rapid growth of AI has increased demand for data centre capacity worldwide.

Resource Booklet: Figure F1 shows AI data centres in the world in June 2025.
Resource Booklet; Figure F2 presents land use in the Grange Castle Business Park, Dublin, Ireland in 2012 and 2025
Resource Booklet: Figure F3 displays infrastructure related to AI: (A) Google data centre in the Netherlands; (B) Solar farm in the USA; (C) Amazon Web Services data centre in the USA; (D) Cooling infrastructure for a data centre in Denmark.
Resource Booklet: Figure F4 shows global electricity consumption by data centres (TWh).

2 m

1. For this question, refer to **Resource Booklet: Figure F1**.

   Analyse and describe the **spatial distribution** of data centres in the world.

   Point marking.

   Suggested answers:
   - Major concentrations are in the USA, European Union and other countries of North-Western Europe and in East Asia.
   - Other emerging data centre concentrations are in the Gulf states, South-East Asia, and in India, Australia, South Africa, Brazil and Chile.
   - Developing countries have almost no data centres.

   Award a maximum of **2 marks** for a complete answer that includes all three categories of countries.
   Award **1 mark** for identifying major concentrations and listing all three regions (USA, Europe, East Asia).
   Award **0.5 mark** for mentioning emerging data centre concentrations. The answer must include at least two specific regions or countries.
   Award **0.5 mark** for noting the absence of data centres in developing countries.
   Award only **0.5 mark** for mentioning concentration in the global North (or developed countries) and absence of data centres in the global South (or developing countries), as this is too generalised.

   Accept any other relevant and correct answer.

3 m

2. For this question, refer to **Resource Booklet: Figure F2**.

Explain three major **land use changes** that have occurred between 2012 and 2025.

Point marking.

Suggested answers:

- **Construction of large-scale data centre buildings:** In 2012, there were few large buildings, indicating sparse industrial development. By 2025, a large area has been developed with large-scale warehouse-type or industrial buildings (blocks).
- **Conversion of agricultural land to industrial use:** The earlier image shows extensive green agricultural land and forest patches. By 2025, forests have been cleared and agricultural land has been converted to built-up areas for industrial use, resulting in the loss of agricultural land and open space.
- **Expansion of transport infrastructure:** Due to limited highway infrastructure, new roads and junctions have been constructed to provide access to the new industrial buildings.
- **Increase in impervious surfaces:** Green areas with natural land cover (soil, vegetation) and crops have been replaced by paved surfaces, parking areas, and buildings.
- **Development of energy infrastructure:** To supply data centres with energy, multiple high-voltage electricity substations have been constructed and the electric grid has been expanded.

Award a maximum of three land use changes.
Award **3 marks** for three fully explained land use changes.
Award **1 mark** for each fully explained land use change.
Award **0.5 mark** for each identified or partially explained land use change.

Accept any other relevant and correct answer.

3 m

3. For this question, refer to **Resource Booklet: Figures F3 and F4**.

Describe **three location factors** that explain why major data centre clusters are concentrated in specific regions.

Point marking.

Suggested answers:

- **Proximity to users and market demand:** Data centres must deliver information quickly. Locating facilities near large populations, businesses, financial institutions, and cloud-service customers reduces data transmission delays. This leads to clustering around major economic centres rather than remote areas.
- **Network connectivity:** Data centres rely on high-capacity fibre-optic networks and submarine cables. Regions that serve as major internet exchange points attract further investment because they offer fast connections to global networks. Once a major connectivity hub is established, additional firms prefer to locate nearby.
- **Reliable and abundant electricity supply:** AI facilities and hyperscale data centres require vast amounts of electricity. Large clusters therefore develop where electrical grids are reliable and can support very high demand. Additionally, large data centres often establish high-voltage solar or wind power plants to supply them.
- **Economies of agglomeration:** Data centres often cluster because firms benefit from shared infrastructure and services. Advantages include existing fibre-optic networks, power substations, skilled technical workers, specialised maintenance companies, and

lower transaction costs. Consequently, established hubs continue to grow faster than new locations.

- **Land availability:** Modern hyperscale facilities require large sites, often exceeding 50–100 hectares. Many large cities have limited available land, high land prices, and strict land regulations. Therefore, data centres tend to locate further from densely populated areas, where sufficient land is available but still well connected to cities.
- **Cooler climates reducing cooling costs:** Cooling servers accounts for a substantial proportion of energy consumption. Cooler regions can reduce cooling costs because outside air can be used for part of the year (e.g. Dublin, Stockholm, Helsinki…).
- **Government policy incentives:** Governments increasingly view AI infrastructure as strategically important. Many regions offer tax incentives, fast planning approvals, subsidised infrastructure and renewable energy projects.

Award a maximum of three explained location factors.
Award **3 marks** for three fully explained location factors.
Award **1 mark** for each fully explained location factor.
Award **0.5 mark** for each suggested or partially explained location factor.

Accept any other relevant and correct answer.

4 m

4. A multinational technology company plans to build a new AI data centre in a rural area near a medium-sized city. Explain **two** potential **benefits** and **two** potential **disadvantages** for the local community.

Level marking.

Suggested answers:

Possible benefits:

- **Creating new jobs:** During the construction phase, many workers may be employed to build server halls, roads, substations, and supporting infrastructure. In the longer term, the facility may create permanent jobs in engineering, security, maintenance, and administration. Although modern data centres are not as labour-intensive as manufacturing industries, they can still provide highly skilled employment opportunities and diversify the local economy.
- **Economic investments:** Local businesses such as construction firms, hotels, restaurants, and suppliers may benefit from increased demand during the construction phase.
- **Infrastructure improvements:** Data centres require reliable electricity supplies, fibre-optic networks, roads, and utilities. To support the facility, governments and private companies may invest in upgrading local infrastructure, such as electricity networks and fibre optics, constructing new roads and transport links…
- **Local tax revenues:** Property taxes, business rates, and other payments can provide additional funding for schools, healthcare, transport, and public services.

Possible disadvantages:

- **Uneven distribution of economic benefits:** While construction creates many temporary jobs, the number of permanent positions is often relatively small because data centres are highly automated. Local residents often lack the specialised skills required to work in these data centres.
- **Increased property prices:** Increased investment can make housing less affordable for some residents and may contribute to tensions between long-term residents and newcomers.

- **Very high energy consumption:** Local electricity networks may not be sufficient to supply data centres and new power plants may be required. Energy demand may put pressure on local electricity grids.
- **CO2 emissions:** AI data centres consume large quantities of electricity, which can contribute to greenhouse gas emissions if the energy comes from fossil fuels.
- **Need for water supply:** AI data centres often require substantial water resources for cooling. Water use may become particularly controversial in regions that already experience water scarcity or competition between agricultural, industrial, and domestic users.
- **Land use change:** Rural landscapes and agricultural land may be transformed by the construction of large industrial buildings, substations, roads, and transmission lines. Residents may perceive the project as industrialisation of a previously rural area.
- **Environmental degradation:** Agricultural land, forests, or natural habitats could be lost, reducing biodiversity and altering the character of the local environment. The area is transformed from rural to urban, which may not be supported by part of the local community.

A complete answer must include at least **two explained benefits** and **two explained disadvantages**, which may fall into the same category (for example, creating new jobs and a lack of specialised workforce in the local community).

Award **4 marks** for two explained benefits and two explained disadvantages.
Award **2 marks** for two fully explained benefits.
Award **2 marks** for two fully explained disadvantages.
Award **1 mark** for each fully explained benefit/disadvantage.
Award **0.5 mark** for each partially explained benefit/disadvantage.
Do not award marks for an identified benefit/disadvantage that is not explained.

Accept any other relevant and correct answer.

3 m

5. Discuss why the expansion of AI data centres might be a new generator of **global spatial inequality**. Use at least three arguments. You must include both supporting arguments and counterarguments to get full marks.

Level marking.

Supporting arguments:

- **Concentration in wealthy countries:** The largest AI data-centre clusters are located in North America, Western Europe, and East Asia, which already dominate the global economy. Some regions and cities there already possess a disproportionate amount of computing power. This reinforces the dominance of existing economic cores in the digital economy.
- **Benefits concentrated in global tech hubs:** Data centres attract highly skilled workers, research institutions, and technology companies. Economic benefits tend to accumulate in already prosperous regions, increasing the gap between tech hubs and peripheral and less developed regions.
- **Limited infrastructure in developing regions:** Many developing countries lack the reliable electricity grids, fibre-optic networks, and technical expertise needed to support large AI facilities. They are often excluded from hosting major AI infrastructure and may become dependent on services provided from abroad.

- **High energy and capital requirements:** AI data centres require large investments and enormous amounts of electricity. Only governments and companies with substantial financial resources can develop and operate such facilities. This excludes developing regions and countries from entering the AI data centre market.

Counterarguments:

- **Emerging hubs in India and Southeast Asia:** New data centre clusters are developing in cities in India, Malaysia, and other locations, demonstrating that AI infrastructure is not limited to traditional economic centres and may spread further within these countries or regions.
- **Spillover economic benefits:** Data centre projects can stimulate local economies through construction, infrastructure development, and business investment, creating employment and attracting new industries.
- **Improved global digital connectivity:** Data centres are physically concentrated, but their services can be accessed from almost anywhere, reducing some barriers to participation in the digital economy.
- **Technology diffusion over time:** As costs decrease and infrastructure improves, AI capabilities may become increasingly accessible to developing countries. Current inequalities may therefore be temporary rather than permanent.

A complete answer must include a discussion from different points of view and consist of two supporting arguments and one counterargument or vice versa and all arguments have to be elaborated.

Award **3 marks** for a balanced discussion consisting of two explained arguments and one explained counterargument.
Award **2 marks** for an incomplete discussion consisting of one explained argument and one explained counterargument.
Award **2 marks** for a one-sided discussion that includes three explained arguments or three explained counterarguments.
Award **1 mark** for an incomplete discussion that includes at least one explained argument or counterargument and two identified arguments or counterarguments without explanation.
Award **0.5 mark** for a discussion that includes three identified arguments or counterarguments without explanation.

Accept any other relevant and correct answer.

end ■