**Q1.**

Outline the relationship between the water cycle and the carbon cycle in the atmosphere.

**[4 marks]**

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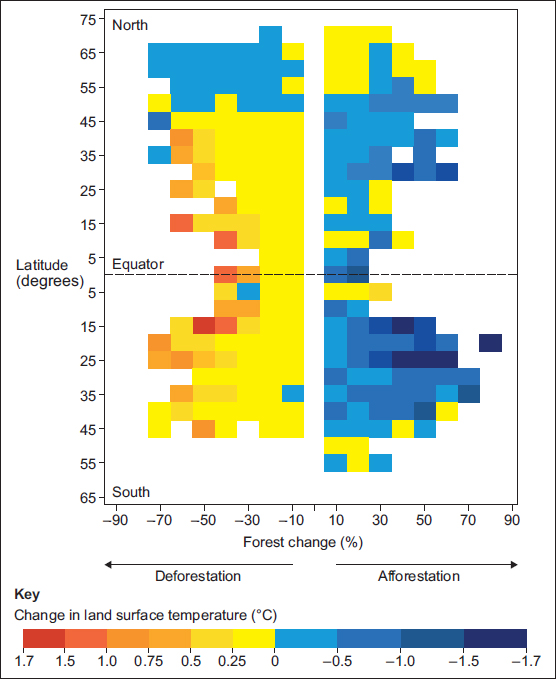
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**Q2.**

The diagram below shows the impact of different rates of deforestation and afforestation upon land surface temperature (LST) at different latitudes. The data was collected between 2000 and 2011.



Analyse the data shown in the diagram above.

**[6 marks]**

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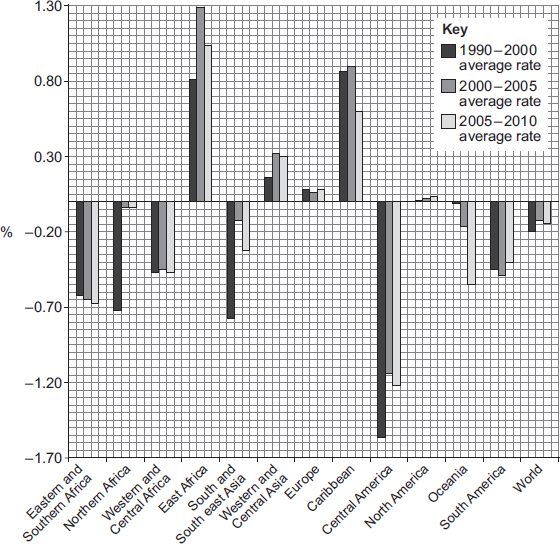
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**Q3.**

**Regional changes in forest cover between 1990 and 2010**

**Figure 1**



Using **Figure 1** and your own knowledge, assess the challenges arising out of the changing forest cover.

**[6 marks]**

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**Q4.**

Assess the extent to which changes in the carbon cycle can lead to water stress.

**[9 marks]**

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**Q5.**

Assess the effects on the carbon cycle of incineration and landfill approaches to waste disposal in urban areas.

**[9 marks]**

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**Q6.**

Explain the concept of negative feedback within the carbon cycle.

**[4 marks]**

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**Q7.**

Outline the process of decomposition in the carbon cycle.

**[4 marks]**

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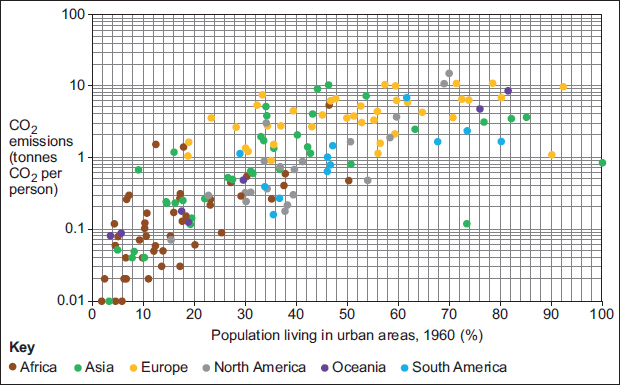
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**Q8.**

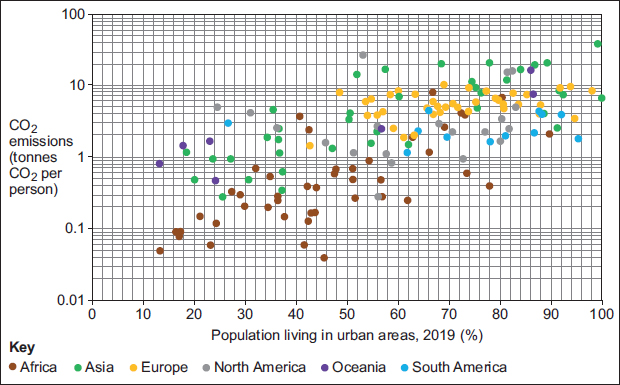
**Figure 1** shows levels of urbanisation and CO2 emissions for selected countries, in different continents, in 1960.

**Figure 2** shows levels of urbanisation and CO2 emissions for the same selected countries in 2019.

**Figure 1**



**Figure 2**



Analyse the data shown in **Figure 1** and **Figure 2**.

**[6 marks]**

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**Q9.**

Assess the scale of changes to stores of carbon in a tropical rainforest you have studied.

**[9 marks]**

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**Q10.**

Assess the extent to which there are inter-relationships between processes in the water cycle and factors driving change in the carbon cycle.

**[20 marks]**

**Q11.**

To what extent do you agree that human activity is responsible for permanent changes to the carbon cycle in tropical rainforests?

**[20 marks]**

**Q12.**

To what does the carbon budget refer?

**[1 mark]**

|  |  |  |
| --- | --- | --- |
| **A** | The amount of carbon in the atmosphere at any one time. |  |
| **B** | The balance of exchanges between the four major stores of carbon. |  |
| **C** | The measurement of the quantity of transferred carbon between the land and ocean. |  |
| **D** | The total quantity of the major stores of carbon. |  |

**Q13.**

“Human activity has caused irreversible damage to the fragile inter-relationship between the water cycle and the carbon cycle.”

To what extent do you agree with this view?

**[20 marks]**

**Q14.**

"The impact of changing carbon budgets is a much greater threat to Antarctica than the impact of tourism or fishing and whaling."

To what extent do you agree with this statement?

**[20 marks]**

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**Q15-18 SECURE MATERIAL**

**Q19.**

Outline the process of photosynthesis in the carbon cycle.

**[3 marks]**

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**Q20.**

How far do you agree that changes to the carbon cycle will lead to increasingly severe storm events?

**[9 marks]**

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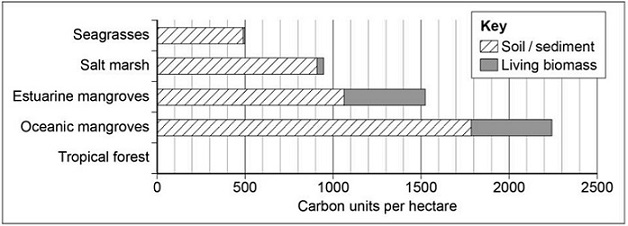
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**Q21.**

The graph below shows the amount of carbon stored in soil / sediment and living biomass in a range of vegetation types.



Complete the graph above by adding the data shown below, and then analyse the information shown in the completed graph.

|  |  |
| --- | --- |
| **Tropical forest carbon storage** | **Carbon units per hectare** |
| Soil / sediment | 200 |
| Living biomass | 600 |

**[6 marks]**

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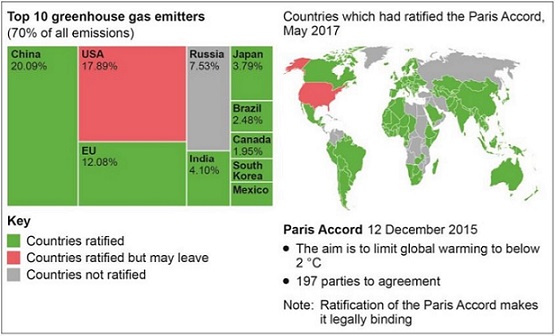
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**Q22.**

The diagram below shows the contribution of the top ten greenhouse gas emitters and information regarding the ratification of the Paris Accord climate change agreement as of May 2017.



Using the diagram above and your own knowledge, assess the challenges associated with reducing greenhouse gas emissions.

**[6 marks]**

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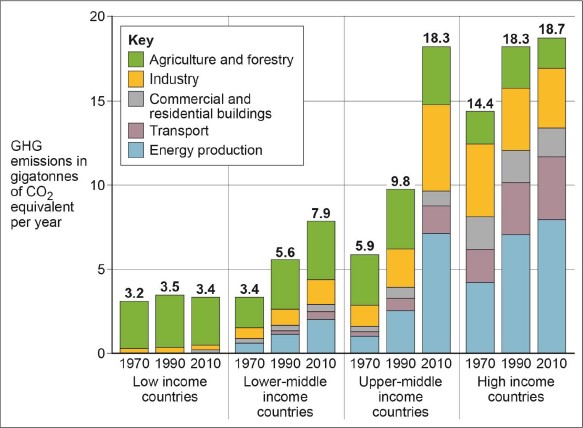
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**Q23.**

The graph below shows change in greenhouse gas (GHG) emissions, grouped by relative wealth of country, between 1970 and 2010.



Analyse the data shown in the graph above.

**[6 marks]**

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**Q24.**

Assess the impact of natural changes to the carbon cycle upon life on Earth.

**[9 marks]**

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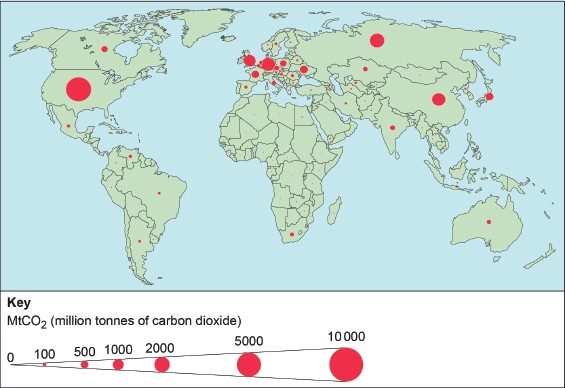
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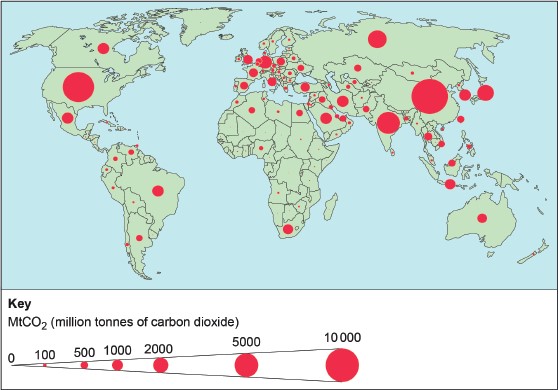
**Q25.**

**Figure 1** and **Figure 2** show information about emissions of carbon dioxide into the atmosphere from fossil fuel use in 1960 and 2016.

**Figure 1 − 1960**



**Figure 2 − 2016**



Analyse the data shown in **Figure 1** and **Figure 2**.

**[6 marks]**

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**Q26.**

Which of the following is a human intervention in the carbon cycle designed to mitigate the impacts of climate change?

**[1 mark]**

|  |  |  |
| --- | --- | --- |
| **A** | Carbon dioxide produced at coal-fired power stations is captured, liquefied and stored deep underground, known as carbon capture and storage. |  |
| **B** | Changes to rural land use leads to increased deforestation, which decreases the amount of carbon dioxide removed from the atmosphere by vegetation. |  |
| **C** | Increased use of concrete as a building material. Cement production involves the heating of calcium carbonate releasing carbon dioxide into the atmosphere. |  |
| **D** | Higher global gas and oil prices makes exploiting untapped fossil fuel reserves via processes like fracking more viable than renewable sources of energy. |  |

**Q27.**

To what extent does an understanding of feedback systems in the carbon cycle help with attempts to mitigate the impacts of climate change?

**[20 marks]**

**Q28.**

Assess the relative importance of carbon sequestration and fossil fuel combustion on major stores of carbon.

**[9 marks]**

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**Q29.**

Assess the impact of farming practices on the carbon budget.

**[20 marks]**

**Q30.**

In the carbon cycle, which of these represents the process of respiration?

**[1 mark]**

|  |  |  |
| --- | --- | --- |
| **A** | Carbohydrate + oxygen → carbon dioxide + water + energy |  |
| **B** | Carbon dioxide + water + sunlight → carbohydrate + oxygen + energy |  |
| **C** | Carbonic acid + calcium carbonate → calcium bicarbonate |  |
| **D** | Organic compounds → carbon dioxide + methane |  |

**Q31.**

Outline the process of combustion in the carbon cycle.

**[3 marks]**

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**Q32.**

‘Human activity has led to irreversible changes to the carbon cycle, causing negative impacts for life on Earth.’

To what extent do you agree with this statement?

**[20 marks]**

Mark schemes

**Q1.**

Point marked

Allow 1 mark per valid point with extra mark(s) for developed points (d). For example:

Notes for answers

•   Increasing concentrations of carbon (and Methane) in the atmosphere has a warming effect on the planet and leads to increased evaporation (1). This can increase rates of precipitation or equally higher rates of evaporation can further exacerbate aridity (1) (d).

•   Volcanic eruptions release both carbon dioxide and water vapour into the atmosphere (1).

•   Photosynthesis requires both precipitation and carbon dioxide (1).

•   Decomposition releases carbon dioxide and requires the presence of water (1). Some may link this to the melting of permafrost, which is a significant contributor to CO2 release (1) (d).

•   Some may consider the acid rain as an outcome of the relationship between water and carbon on the atmosphere (1). This may be further linked to ocean acidification (1) (d).

The notes for answers are not exhaustive. Credit any valid points.

**AO1 = 4**

**[Total 4 marks]**

**Q2.**

**AO3** – There should be clear analysis of the relationships evident in the resource. Analysis should consider the relationship between forest cover, land surface temperature and latitude.

Mark scheme

**Level 2 (4–6 marks)**

**AO3** – Clear analysis of the quantitative evidence provided, which makes appropriate use of data in support. Clear connection(s) between different aspects of the data and evidence.

**Level 1 (1–3 marks)**

**AO3** – Basic analysis of the quantitative evidence provided, which makes limited use of data and evidence in support. Basic connection(s) between different aspects of the data and evidence.

Notes for answers

**AO3**

•   Afforestation is more likely to lead to a reduction in land surface temperature. The most extreme temperature decreases can be seen where temperatures fall by up to 1.7°C at latitudes -25°S and a reduction in 50–70% surface cover.

•   Some obvious anomalies exist eg at 5°S, 10%–30% afforestation appears to lead to a small temperature increase. Similarly at around 40°s, up to 50% afforestation leads to temperature decrease but at 60% afforestation, temperatures appear to increase. The highest latitudes also tend to see temperature increases with afforestation, more so in the northern hemisphere, though here data extends to 75°N, compared to only 55°S.

•   The pattern is arguably less predictable for deforestation. As a generalisation increasing deforestation leads to higher land surface temperatures with figures up to 1.7°C noted between 15°N and 15°S.

•   Between 55 and 75°N, almost any deforestation leads to temperature decrease and at around 45°N, with 70% decrease in forest, there is a significant drop in land surface temperature.

•   Some may note the lack of data particularly between 25°N and 15°S. This does make it more difficult to identify patterns within the data at these latitudes and also makes it more difficult to compare latitudes.

•   Some may consider deforestation in isolation and look for variation in patterns here. This is creditworthy at Level 1.

Credit any other valid analysis.

**AO3 = 6**

**[Total 6 marks]**

**Q3.**

**AO1** – Knowledge and understanding of changes to the global carbon budget as a result of human activity. Awareness of deforestation, its causes and impacts.

**AO2** – Application of knowledge to show how changes to global forest cover present major local, regional and international issues.

Mark scheme

**Level 2 (4–6 marks)**

**AO1** – Demonstrates clear knowledge and understanding of concepts, processes, interactions and change.

**AO2** – Applies knowledge and understanding to the novel situation offering clear evaluation and analysis drawn appropriately from the context provided. Connections and relationships between different aspects of study are evident with clear relevance.

**Level 1 (1–3 marks)**

**AO1** – Demonstrates basic knowledge and understanding of concepts, processes, interactions, change.

**AO2** – Applies limited knowledge and understanding to the novel situation offering only basic evaluation and analysis drawn from the context provided. Connections and relationships between different aspects of study are basic with limited relevance.

Notes for answers

**AO1**

•   Global distribution, and size of major stores of carbon – lithosphere, hydrosphere, cryosphere, biosphere, atmosphere.

•   Factors driving change in the magnitude of these stores over time and space, including flows and transfers at plant, sere and continental scales. Photosynthesis, respiration, decomposition, combustion, carbon sequestration in oceans and sediments, weathering.

•   The carbon budget and the impact of the carbon cycle upon land, ocean and atmosphere, including global climate.

**AO2**

•   There are a variety of potential challenges associated with this information. Most are likely to consider the challenges associated with deforestation. There are extensive areas of forest loss in Central and South America, and Eastern and Southern Africa, South East Asia. Some may support this with data, though is not essential. Others may note anomalies such as Northern Africa which lost a lot of forest between 1990 and 2000 and not much since. Some are likely to consider the impact on CO2 levels and the associated climate implications.

•   Others may consider the challenges associated with afforestation. East Asia, Western and Central Asia, Europe and the Caribbean have all experienced gain. Afforestation schemes are only possible where the land-use has not already been taken up by other human activity such as settlement transport or agriculture. These areas experiencing afforestation are likely to be sparsely populated. The much greater challenge is afforesting areas closer to human activity centres, hence the relatively small increases in Europe

•   Interestingly the Great Green Wall in Africa is not evident as an area of afforestation, but some may refer to this. Some may suggest the challenge here was in establishing a co-operative approach across many African countries, with the shared goal of limiting the process of desertification.

•   Others may consider in more generic terms the issues of competing demands on scarce resources. The encroachment into Amazonia may feature here for example. Political issues may also feature, such as the apparent change in policy by the Brazilian government, and the increasing evidence of rainforest exploitation, clearly evident in the resource.

Credit any other valid assessment.

**AO1 = 2, AO2 = 4**

**[Total 6 marks]**

**Q4.**

**AO1** – Knowledge and understanding of the concept of water stress and components of demand for water. Knowledge and understanding of carbon cycles.

**AO2** – Application of knowledge and understanding to evaluate the extent to which changes in the carbon cycle can lead to water stress.

Mark scheme

**Level 3 (7–9 marks)**

**AO1** – Demonstrates detailed knowledge and understanding of concepts, processes, interactions and change. These underpin the response throughout.

**AO2** – Applies knowledge and understanding appropriately with detail. Connections and relationships between different aspects of study are fully developed with complete relevance. Analysis and evaluation are detailed and well supported with appropriate evidence.

**Level 2 (4–6 marks)**

**AO1** – Demonstrates clear knowledge and understanding of concepts, processes, interactions and change. These are mostly relevant though there may be some minor inaccuracy.

**AO2** – Applies clear knowledge and understanding appropriately. Connections and relationships between different aspects of study are evident with some relevance. Analysis and evaluation are evident and supported with clear and appropriate evidence.

**Level 1 (1–3 marks)**

**AO1** – Demonstrates basic knowledge and understanding of concepts, processes, interactions and change. This offers limited relevance with inaccuracy.

**AO2** – Applies limited knowledge and understanding. Connections and relationships between different aspects of study are basic with limited relevance. Analysis and evaluation are basic and supported with limited appropriate evidence.

Notes for answers

The question requires links to be made between two different units namely resource security and water and carbon cycles. The question requires evaluation of the roles played by changes in the carbon cycle in causing water stress. They may consider the importance of other factors that cause water stress. Note that the question is about water stress, not water scarcity.

**AO1**

•   Knowledge and understanding of carbon cycles.

•   The key role of the carbon and water stores and cycles in supporting life on Earth with particular reference to climate.

•   The relationship between the water cycle and carbon cycle in the atmosphere.

•   The role of feedbacks within and between cycles and their link to climate change and implications for life on Earth.

•   Knowledge and understanding of global patterns of water availability and demand.

•   Sources of water – components of demand, water stress.

•   Relationship of water supply (volume and quality) to key aspects of physical geography – climate, geology and drainage.

**AO2**

•   Analysis of the link between areas suffering water stress and the changes in the carbon cycle. Increased global temperatures as a result of increased atmospheric carbon, can lead to less plant growth in arid areas which causes lower levels of evapotranspiration, leading to lower levels of cloud formation and less rainfall, therefore leading to water stress.

•   Increased atmospheric carbon may lead to climate change which might make rainfall less predictable meaning that water stress increases, particularly in marginal semi-arid areas.

•   Evaluation of the role of the carbon cycle in causing water stress. Deforestation in the Amazon is causing increased carbon to be released through burning, resulting in increased temperatures but reduced evapotranspiration resulting in less cloud cover and therefore less rainfall, leading to water stress in areas adjacent to the Amazon.

•   Evaluation of other factors that lead to water stress. For example, many areas suffer economic water scarcity, not because there is a physical water scarcity due to lack of rainfall but as a result of rising demand for water from agriculture eg rice cropping in SE Asia.

•   They may consider that water stress leads to changes in the carbon cycle. For example lower rainfall levels in California have increased irrigation demands from major rivers and groundwater stores, reducing water levels, leading to less natural vegetation growth and therefore reduced carbon stores.

•   Alternative futures may also be considered, for example impact of climate change in different areas. Some areas rely on spring snowmelt for water surface supply and without accumulation of winter snow this could lead to water stress.

•   Students should come to a conclusion as to the extent to which changes in the carbon cycle can lead to water stress. Any conclusion is valid as long as it supports the content of the response.

Credit any other valid approach.

**AO1 = 4, AO2 = 5**

**[Total 9 marks]**

**Q5.**

**AO1** – Knowledge and understanding of incineration and landfill approaches to waste disposal. Knowledge and understanding of the carbon cycle.

**AO2** – Application of knowledge and understanding to analyse and evaluate the impacts of these two approaches to waste disposal on carbon cycle.

Mark scheme

**Level 3 (7–9 marks)**

**AO1** – Demonstrates detailed knowledge and understanding of concepts, processes, interactions and change. These underpin the response throughout.

**AO2** – Applies knowledge and understanding appropriately with detail. Connections and relationships between different aspects of study are fully developed with complete relevance. Analysis and evaluation is detailed and well supported with appropriate evidence. A well-balanced and coherent argument is presented.

**Level 2 (4–6 marks)**

**AO1** – Demonstrates some appropriate knowledge and understanding of concepts, processes, interactions and change. These are mostly relevant though there may be some minor inaccuracy.

**AO2** – Applies some knowledge and understanding appropriately. Connections and relationships between different aspects of study are emerging/evident with some relevance. Analysis and evaluation evident and supported with some appropriate evidence. A clear but partial argument is presented.

**Level 1 (1–3 marks)**

**AO1** – Demonstrates basic/limited knowledge and understanding of concepts, processes, interactions and change. These offer limited relevance with inaccuracy.

**AO2** – Applies limited knowledge and understanding. Connections and relationships between different aspects of study are basic with limited relevance. Analysis and evaluation basic and supported with limited appropriate evidence. A basic argument is presented.

Notes for answers

This question links two different units of the specification, namely Water and Carbon Cycles and Contemporary Urban Environments. Students need to link their knowledge of incineration and landfill approaches to waste disposal and apply this to their knowledge and understanding of the carbon cycle. The specification requires them to study waste disposal with reference to one urban area, so expect to see specific examples. However, there is no requirement in this question for them to use a specified urban area.

**AO1**

•   Comparison of incineration and landfill approaches to waste disposal

•   Urban physical waste generation: sources of waste - industrial and commercial activity, personal consumption.

•   The environmental impacts of alternative approaches to waste disposal: unregulated, recycling, recovery, incineration, burial, submergence and trade.

•   Knowledge and understanding of the carbon cycle

•   Stores of carbon and factors driving change in the magnitude of carbon stores

•   Changes in the carbon cycle over time

**AO2**

•   Analysis of the link between incineration approaches and the carbon cycle. For example, in 2017 UK incinerators produced approximately 11m tonnes of CO2, adding to atmospheric carbon stores as a fast carbon cycle.

•   Evaluation of incineration approaches in removing atmospheric carbon. MSW is burnt and then used to generate electricity. It therefore reduces the impact on slow lithospheric carbon stores as it reduces need for fossil fuel consumption.

•   Analysis of the link between landfill approaches and the carbon cycle. Methane is produced, a greenhouse gas, creating a fast carbon cycle.

•   Evaluation of landfill approaches in changing the carbon cycle and carbon stores. It is a complex picture as once filled it can be re-landscaped with vegetation, removing atmospheric carbon and acting as a terrestrial store. Methane can also be vented and used as a fuel reducing removal of fossil fuel carbon stores.

•   Evaluation of specific urban schemes on the carbon cycle. The AEB plant in Amsterdam saves about 438 kilotons of CO2 per year. It generates about 1 million MWh electricity a year which reduces the need for fossil fuels, thereby not decreasing the size of lithospheric stores.

•   They may take a comparative approach and assess the relative impacts. For example, whilst landfill produces more greenhouse gas emissions than incineration on the whole, plastics produce more CO2 when burnt than buried, therefore for plastics the impact on fast carbon cycles is less for landfill.

•   A comparison of waste approaches in one urban setting on the carbon cycle. For example, in London four times more waste goes to incineration plants than landfill so there is less impact on fast carbon release cycles. However, incineration approaches mean that recycling rates have fallen, resulting in more new products being made, requiring greater use of fossil fuels.

•   They should come to an overall conclusion that evaluates the effects of both waste management approaches on the carbon cycle and/or size of carbon stores. Any view is acceptable as long as it is supported by the rest of the response.

Credit any other valid approach.

**AO1 = 4, AO2 = 5**

**[Total 9 marks]**

**Q6.**

Point marked

Allow 1 mark per valid point with extra mark(s) for developed points (d).

For example:

Notes for answers

•   Feedback is an important aspect of systems and their tendency towards dynamic equilibrium (1).

•   Negative feedback returns a system towards equilibrium (1) and counteracts the impact of earlier changes in the system (1) (d)

•   For example, increased atmospheric CO2 leads to both warmer temperatures and availability of CO2 for uptake by plants (1). This promotes increased photosynthesis rates and carbon capture/storage by plants (1) (d), reducing the carbon levels back to state of balance (1) (d).

The notes for answers are not exhaustive. Credit any valid points.

**AO1 = 4**

**[Total 4 marks]**

**Q7.**

Point marked

Allow 1 mark per valid point with extra mark(s) for developed points (d). For example:

Notes for answers

•   Decomposition refers to the breakdown / decay of organic matter by bacteria or fungi (1).

•   Animals (such as worms), bacteria and fungi are collectively termed decomposers (1)(d).

•   During decomposition carbon dioxide is released (1).

•   Most of the carbon released into the atmosphere is as a result of decomposition (1)(d).

•   Decomposition is heavily temperature dependent (1). Warmer temperatures are characterised by much higher rates of decomposition as there is more microbial activity (1)(d). However the presence of water is an equally key component in the rate of decomposition and the release of carbon (1)(d).

The Notes for answers are not exhaustive. Credit any valid points.

**AO1 = 4**

**[Total 4 marks]**

**Q8.**

**AO3** – There should be clear analysis of the relationship between levels of urbanisation and CO2 emissions in different continents in both years. Analysis should consider changes in the data over time. There should be data manipulation to support the analysis.

Mark scheme

**Level 2 (4–6 marks)**

**AO3** – Clear analysis of the quantitative evidence provided, which makes appropriate use of data in support. Clear connection(s) between different aspects of the data and evidence.

**Level 1 (1–3 marks)**

**AO3** – Basic analysis of the quantitative evidence provided, which makes limited use of data and evidence in support. Basic connection(s) between different aspects of the data and evidence.

Notes for answers

**AO3**

•   Both graphs show a clear positive relationship between the level of urbanisation and CO2 emissions in both time periods. In 1960 only 5 countries with less than 20% urbanisation have emissions over 1 tCO2 pp, whilst 6 countries with more than 80% urbanisation have over 1 tCO2 p.p. In 2019 however, only 2 countries with less than 20% urbanisation have emissions over 1 tCO2 pp, but ~6 times more countries with more than 80% urbanisation have over 1 tCO2 pp than in 1960.

•   There has been a significant increase in the level of urbanisation between the two time periods. In 1960 ~30% of countries were less than 20% urban, and only 3 countries were over 90% urban, by 2019 only 7 countries were less than 20% urban but almost 4 times as many countries were now over 90% urban.

•   The graphs show that there has been a trend of more countries increasing their emissions. In 1960 about 1/5 of countries had emissions of less than 0.1 tCO2 pp and only 7 countries had emissions of 10 tCO2 pp or above. By 2019 only 7 had less than 0.1 tCO2 pp, but the number with over 10 tCO2 pp had more than doubled, and 5 countries now even had emissions of 20 tCO2 pp or above.

•   There is scope for analysis of data relating to different continents, this is clearly acceptable.

Credit any other valid analysis.

**AO3 = 6**

**[Total 6 marks]**

**Q9.**

**AO1** – Knowledge and understanding of the carbon cycle in a tropical rainforest. Knowledge and understanding of changes to the size of the carbon stores in the case study tropical rainforest.

**AO2** – Application of knowledge and understanding to analyse and evaluate the extent of changes to the size of the stores of carbon in the case study tropical rainforest.

**Level 3 (7–9 marks)**

**AO1** – Demonstrates detailed knowledge and understanding of concepts, processes, interactions and change. These underpin the response throughout.

**AO2** – Applies knowledge and understanding appropriately with detail. Connections and relationships between different aspects of study are fully developed with complete relevance. Assessment is detailed and well-supported with appropriate evidence.

**Level 2 (4–6 marks)**

**AO1** – Demonstrates clear knowledge and understanding of concepts, processes, interactions and change. These are mostly relevant, though there may be some minor inaccuracy.

**AO2** – Applies clear knowledge and understanding appropriately. Connections and relationships between different aspects of study are evident with some relevance. Assessment is evident and supported with clear and appropriate evidence.

**Level 1 (1–3 marks)**

**AO1** – Demonstrates basic knowledge and understanding of concepts, processes, interactions and change. This offers limited relevance with inaccuracy.

**AO2** – Applies limited knowledge and understanding. Connections and relationships between different aspects of study are basic with limited relevance. Assessment is basic and supported with limited appropriate evidence.

Notes for answers

**AO1**

•   Factors driving change in the magnitude of stores of carbon, over time and in space, including flows and transfers at plant and sere scale. Photosynthesis, respiration, decomposition, combustion and carbon sequestration.

•   Changes in the carbon cycle over time, to include natural variation (including wildfires, volcanic activity) and human impact (including hydrocarbon fuel extraction and burning, farming practices, deforestation, land use changes).

•   Case study of a tropical rainforest setting to illustrate and analyse key themes in carbon cycles and their relationship to environmental change and human activity.

**AO2**

•   Responses are likely to be heavily influenced by the exemplification and case study material.

•   Assessment of the impact of deforestation/logging/mining on the size of the biospheric store of carbon and any reduction in the amount of carbon stored in trees is likely to be a prominent feature of responses.

•   Assessment may be given of the spatial scale of change in the named rainforest. A judgement of the geographical area of forest cleared would allow the response to come to a view on the extent of change to that store of carbon.

•   Assessment may be given of the temporal scale of change in the named rainforest. A judgement of the speed with which the forest is being cleared would allow the response to come to a view on the rate of change to that store of carbon.

•   Assessment may be given of the impact of the removal of trees and subsequent impact of the interruption of transfers of carbon to the soil, and soil erosion, on the amount of carbon stored in the soil.

•   Others may provide assessment of the impact of possible afforestation and the replanting of trees on the scale of stores of carbon.

Credit any other valid assessment.

**AO1 = 4, AO2 = 5**

**[Total 9 marks]**

**Q10.**

**AO1** − Knowledge and understanding of processes in the water cycle and factors driving change in the carbon cycle.

**AO2** − Application of knowledge and understanding to assess the inter-relationships between processes in the water cycle and factors driving change in the carbon cycle. Response should come to a view in relation to extent of inter-relationships.

Notes for answers

**AO1**

•   Processes in the water cycle which directly inter-relate to / with the carbon cycle.

•   Processes in the water cycle which do not relate to the carbon cycle. Evaporation and condensation are processes which are determined by the sun’s energy and the variation in temperature related to this.

•   Factors driving change in the magnitude of stores and transfers in the water cycle. These factors may relate to the sun’s energy as well as vegetation coverage in drainage basins.

•   Global distribution and size of major stores of water − lithosphere, hydrosphere, cryosphere and atmosphere. Some may structure their responses around the four major spheres and the inter-relationships which exist in these distinct zones.

•   The role of transpiration in the carbon cycle may be considered as a specific example where there are clear interactions between the two cycles.

•   Global distribution, and size of major stores of carbon − lithosphere, hydrosphere, cryosphere, biosphere, atmosphere and the interactions with the water cycle which exists in these four major zones.

•   Factors driving change in the magnitude of carbon stores over time and space, including flows and transfers at plant, sere and continental scales. Photosynthesis, respiration, decomposition, combustion, carbon sequestration in oceans and sediments, weathering. Knowledge and understanding of the role of the water cycle should be applied here (See AO2).

•   Case study of a tropical rainforest setting to illustrate and analyse key themes in water and carbon cycles and their relationship to environmental change and human activity. This case study may be used to exemplify some of the inter-relationships within the biosphere.

**AO2**

•   Evaluation − Responses may challenge the theme of the question and suggest that the water cycle has many elements which are not inter-related to the carbon cycle. The basic elements of the water cycle involve the transfer of water through the lithosphere, hydrosphere, cryosphere and atmosphere. This is entirely driven by the sun’s energy and gravity and is independent of the carbon cycle.

•   Analysis − Water cycle transfers and stores within drainage basins may also be considered as processes. Infiltration and through flow for example can only occur in the presence of well-formed soils. The formation of soil structures is dependent upon factors driving change in the carbon cycle.

•   Analysis − A number of processes within the carbon cycle directly relate to the water cycle. Photosynthesis for example, converts the sun’s energy into chemical energy. This is completely reliant upon the presence of water for all plant growth. Transpiration may also be considered in this context.

•   Analysis − Decomposition is another important process in the carbon cycle. This activity is undertaken by detritivores which cannot operate without the presence of water in the areas where decomposition occurs. The detritivores themselves respire which is a key carbon process which can only operate in the presence of water, stored in soils and groundwater. It is important to note that some carbon is lost to the system due to detritivore respiration which can only take place in the presence of water, provided via precipitation. Some may use the tropical rainforest case studies to exemplify and support the analysis.

•   Analysis − Some may refer to the fact the carbon can be dissolved directly into large water bodies such as oceans, seas and lakes. Furthermore, carbon can be dissolved in precipitation as rain falls to the earth’s surface. When dissolved in water, carbon dioxide reacts with water molecules and forms carbonic acid, which contributes to ocean acidity.

•   Analysis and evaluation − Responses may also explore the inter-relationships between processes in the water cycle and factors driving change in the carbon cycle in a range of human activities and human life processes. This is a legitimate approach.

•   Analysis − Some may make further links e.g. to decomposition in periglacial areas (cryosphere) which is currently being exacerbated by climate change. The melting ice in the active layer is leading to rapid decomposition and a release of carbon dioxide and methane.

•   Analysis and evaluation − Natural fires may also be considered act as process within the carbon cycle where there are inter-relationships with processes in the water cycle. Pyriscence for example has maturation and release of seeds which is triggered, in whole or in part, by fire or smoke; fire is a critical ingredient in the renewal of some ecosystems (biosphere). This is an example of where a factor driving change in the carbon cycle might impact processes in the water cycle.

•   Analysis and evaluation − Weathering is another process which releases carbon back to the atmosphere (lithosphere and hydrosphere). This requires the presence of water, usually through precipitation or under sea water weathering. This potentially reveals another link between precipitation and the carbon cycle. This potentially reveals another link between processes in the water cycle and the factors driving change in the carbon cycle.

•   Overall evaluation − More sophisticated responses should note that the carbon cycle is entirely dependent upon the water cycle for its existence. Without the cycling of water through the lithosphere, hydrosphere, cryosphere and atmosphere, there could be no carbon cycle.

**Level 4 (16−20 marks)**

•   Detailed evaluative conclusion that is rational and firmly based on knowledge and understanding which is applied to the context of the question (AO2).

•   Detailed, coherent and relevant analysis and evaluation in the application of knowledge and understanding throughout (AO2).

•   Full evidence of links between knowledge and understanding to the application of knowledge and understanding in different contexts (AO2).

•   Detailed, highly relevant and appropriate knowledge and understanding of place(s) and environments used throughout (AO1).

•   Full and accurate knowledge and understanding of key concepts and processes throughout (AO1).

•   Detailed awareness of scale and temporal change which is well integrated where appropriate (AO1).

**Level 3 (11−15 marks)**

•   Clear evaluative conclusion that is based on knowledge and understanding which is applied to the context of the question (AO2).

•   Generally clear, coherent and relevant analysis and evaluation in the application of knowledge and understanding (AO2).

•   Generally clear evidence of links between knowledge and understanding to the application of knowledge and understanding in different contexts (AO2).

•   Generally clear and relevant knowledge and understanding of place(s) and environments (AO1).

•   Generally clear and accurate knowledge and understanding of key concepts and processes (AO1).

•   Generally clear awareness of scale and temporal change which is integrated where appropriate (AO1).

**Level 2 (6−10 marks)**

•   Some sense of an evaluative conclusion partially based upon knowledge and understanding which is applied to the context of the question (AO2).

•   Some partially relevant analysis and evaluation in the application of knowledge and understanding (AO2).

•   Some evidence of links between knowledge and understanding to the application of knowledge and understanding in different contexts (AO2).

•   Some relevant knowledge and understanding of place(s) and environments which is partially relevant (AO1).

•   Some knowledge and understanding of key concepts, processes and interactions and change (AO1).

•   Some awareness of scale and temporal change which is sometimes integrated where appropriate. There may be a few inaccuracies (AO1).

**Level 1 (1−5 marks)**

•   Very limited and / or unsupported evaluative conclusion that is loosely based upon knowledge and understanding which is applied to the context of the question (AO2).

•   Very limited analysis and evaluation in the application of knowledge and understanding. This lacks clarity and coherence (AO2).

•   Very limited and rarely logical evidence of links between knowledge and understanding to the application of knowledge and understanding in different contexts (AO2).

•   Very limited relevant knowledge and understanding of place(s) and environments (AO1).

•   Isolated knowledge and understanding of key concepts and processes (AO1).

•   Very limited awareness of scale and temporal change which is rarely integrated where appropriate. There may be a number of inaccuracies (AO1).

**Level 0 (0 marks)**

•   Nothing worthy of credit.

**AO1 = 10, AO2 = 10**

**[Total 20 marks]**

**Q11.**

**AO1** − Knowledge and understanding of the impact of human activity in rainforests.

**AO2** − Application of knowledge and understanding to analyse and evaluate the impact of this human activity and the extent to which change is permanent and that human activity is responsible.

Notes for answers

**AO1**

•   Factors driving change in the magnitude of carbon stores over time and space, including flows and transfers at plant, sere and continental scales. Photosynthesis, respiration, decomposition, combustion, weathering. This element is a fundamental underpinning to the question. Responses need to show an awareness that the natural cycle of carbon is susceptible to change by human activity.

•   Changes in the carbon cycle over time, to include natural variation and human impact (including fuel extraction and burning, farming practices, deforestation, land use changes). This range of human activity is not exhaustive. The material should be used to show how the carbon cycle can be disrupted by a range of human activity.

•   The carbon budget and the impact of the carbon cycle upon land, ocean and atmosphere, including global climate.

•   The key role of the carbon cycle in supporting life on Earth with particular reference to climate. The role of feedbacks within the carbon cycle and its link to climate change and implications for life on Earth. This is where responses can begin to engage with the concept of permanent change.

•   Human interventions in the carbon cycle designed to influence carbon transfers and mitigate the impacts of climate change. This element allows responses to challenge the statement in the question. These attempts at mitigation offer a counterbalance against the notion of permanent change.

•   Case study of a tropical rainforest setting to illustrate and analyse key themes in the carbon cycle and its relationship to environmental change and human activity.

**AO2**

•   Evaluation − The human activity is not really the focus of the question. It is the impact of the human activity and the extent to which this is causing permanent change.

•   Analysis − The human activities are likely to cover issues associated with the exploitation of tropical rainforests. Expect to see deforestation for wood, land clearance, transport and settlement. Mining is also likely to feature as an activity causing potentially permanent change to the carbon cycle.

•   Analysis and evaluation − In terms of expanding upon the ‘permanent’ change, expect to see reference to the impact of deforestation on the nutrient cycle in rainforests. Once trees are removed in large numbers the carbon cycle is interrupted. Leaf litter is no longer returned to the ground for decomposition. The humus layer is left exposed to soil erosion as the canopy no longer exists. This further weakens the soil structure due to rainsplash impact. Eroded soil is less capable of sustaining new plant growth once exposed. This process of rainforest desertification can lead to significant damage to carbon cycle. Some may link this to an ensuing lack of convection rainfall, caused by a lack of transpiration. Provided this is clearly linked to the associated difficulties in maintaining a healthy carbon cycle, this is an appropriate approach.

•   Evaluation − In terms of the notion of permanence, some may argue that the cycle will always return to equilibrium once human activity recedes. It really depends upon the timescales in which the response is pitched. Others may argue that damage is permanent in the sense that, for the foreseeable future, some areas have experienced irreversible loss. Both approaches are valid provided there is clear rationale based upon preceding content.

**Level 4 (16−20 marks)**

•   Detailed evaluative conclusion that is rational and firmly based on knowledge and understanding which is applied to the context of the question (AO2).

•   Detailed, coherent and relevant analysis and evaluation in the application of knowledge and understanding throughout (AO2).

•   Full evidence of links between knowledge and understanding to the application of knowledge and understanding in different contexts (AO2).

•   Detailed, highly relevant and appropriate knowledge and understanding of place(s) and environments used throughout (AO1).

•   Full and accurate knowledge and understanding of key concepts and processes throughout (AO1).

•   Detailed awareness of scale and temporal change which is well integrated where appropriate (AO1).

**Level 3 (11−15 marks)**

•   Clear evaluative conclusion that is based on knowledge and understanding which is applied to the context of the question (AO2).

•   Generally clear, coherent and relevant analysis and evaluation in the application of knowledge and understanding (AO2).

•   Generally clear evidence of links between knowledge and understanding to the application of knowledge and understanding in different contexts (AO2).

•   Generally clear and relevant knowledge and understanding of place(s) and environments (AO1).

•   Generally clear and accurate knowledge and understanding of key concepts and processes (AO1).

•   Generally clear awareness of scale and temporal change which is integrated where appropriate (AO1).

**Level 2 (6−10 marks)**

•   Some sense of an evaluative conclusion partially based upon knowledge and understanding which is applied to the context of the question (AO2).

•   Some partially relevant analysis and evaluation in the application of knowledge and understanding (AO2).

•   Some evidence of links between knowledge and understanding to the application of knowledge and understanding in different contexts (AO2).

•   Some relevant knowledge and understanding of place(s) and environments which is partially relevant (AO1).

•   Some knowledge and understanding of key concepts, processes and interactions and change (AO1).

•   Some awareness of scale and temporal change which is sometimes integrated where appropriate. There may be a few inaccuracies (AO1).

**Level 1 (1−5 marks)**

•   Very limited and / or unsupported evaluative conclusion that is loosely based upon knowledge and understanding which is applied to the context of the question (AO2).

•   Very limited analysis and evaluation in the application of knowledge and understanding. This lacks clarity and coherence (AO2).

•   Very limited and rarely logical evidence of links between knowledge and understanding to the application of knowledge and understanding in different contexts (AO2).

•   Very limited relevant knowledge and understanding of place(s) and environments (AO1).

•   Isolated knowledge and understanding of key concepts and processes (AO1).

•   Very limited awareness of scale and temporal change which is rarely integrated where appropriate. There may be a number of inaccuracies (AO1).

**Level 0 (0 marks)**

•   Nothing worthy of credit.

**AO1 = 10, AO2 = 10**

**[Total 20 marks]**

**Q12.**

B

**AO1 = 1**

**[Total 1 mark]**

**Q13.**

**AO1** − Knowledge and understanding of the inter-relationships which exist between the water cycle and the carbon cycle.

**AO2** − Application of knowledge and understanding to assess the extent to which there is a fragile relationship between the two cycles and whether human activity has caused irreversible damage to this relationship.

Notes for answers

**AO1**

•   Systems in physical geography: systems concepts and their application to the water and carbon cycles inputs – outputs, energy, stores / components, flows / transfers, positive / negative feedback, dynamic equilibrium.

•   Changes in the water cycle over time to include natural variation including storm events, seasonal changes and human impact including farming practices, land use change and water abstraction.

•   Changes in the carbon cycle over time, to include natural variation (including wild fires, volcanic activity) and human impact (including hydrocarbon fuel extraction and burning, farming practices, deforestation, land use changes).

•   The key role of the carbon and water stores and cycles in supporting life on Earth, with particular reference to climate. The relationship between the water cycle and carbon cycle in the atmosphere.

•   The role of feedbacks within and between cycles and their link to climate change and implications for life on Earth.

•   Human interventions in the carbon cycle designed to influence carbon transfers and mitigate the impacts of climate change.

•   Possible use of case study of a tropical rainforest setting to illustrate and analyse key themes in water and carbon cycles and their relationship to environmental change and human activity.

**AO2**

•   Expect to see a variety of scales in response to this question.

•   Some will consider inter-relationships at the level of the small-scale ecosystem whilst others will consider regional scale inter-relationships in biomes. Another alternative relates to the global inter-relationships including atmospheric CO2 and precipitation.

•   At the scale of a local ecosystem, expect to see concepts of fragility explored in relation to the impact of human activity upon inter-relationships within the ecosystem. For example, both the carbon cycle and water cycle can be disrupted by a range of human activity including farming, vegetation clearing, establishment of plagio-climax vegetation communities and work on local rivers and the associated catchments.

•   At the local scale, some may consider positive actions to support the balance between the two cycles. Afforestation and peat bog development could be referenced as long as it is clear how these activities impact upon the inter-relationships between the cycles.

•   At the regional scale, some may consider the impact of atmospheric changes at the regional scale. For instance, in tropical forests, wide scale removal of vegetation is known to disrupt the cycling of water through convection rainfall. The lack of transpiration causes a reduction in precipitation rates. This in turn can cause a devastating impact upon rainforest vegetation, especially tree growth. Where this occurs, the carbon cycle is effectively broken.

•   Wide scale removal of vegetation can also impact upon the soil carbon stores. The carbon stores are removed through rain splash impact and surface runoff. Rivers carry away soil which contained an important store of carbon.

•   Some may consider drylands as another place where there is a potentially damaging impact of human activity upon the carbon and water cycles. This is particularly the case where precipitation is reduced or where irrigation channels water away from certain locations.

•   Some may make the link between large scale vegetation removal and an increase in weathering. This can trigger slow carbon release through the weathering processes of rocks containing carbon.

•   At the global scale, increased carbon emissions are likely to feature. These must clearly be linked to the inter-relationship between water and carbon in order to access credit for AO2.

•   Mitigation strategies to reduce CO2 may feature but these must be clearly linked to the inter-relationships between water and carbon for AO2 credit.

•   Expect to see some overarching evaluation as to the extent to which the inter-relationships are fragile but also how the extent to which any damage is irreversible.

**Level 4 (16−20 marks)**

•   Detailed evaluative conclusion that is rational and firmly based on knowledge and understanding which is applied to the context of the question. Interpretations are comprehensive, sound and coherent (AO2).

•   Detailed, coherent and relevant analysis and evaluation in the application of knowledge and understanding throughout (AO2).

•   Full evidence of links between knowledge and understanding to the application of knowledge and understanding in different contexts (AO2).

•   Detailed, highly relevant and appropriate knowledge and understanding of place(s) and environments used throughout (AO1).

•   Full and accurate knowledge and understanding of key concepts, processes and interactions and change throughout (AO1).

•   Detailed awareness of scale and temporal change which is well integrated where appropriate (AO1).

**Level 3 (11−15 marks)**

•   Clear evaluative conclusion that is based on knowledge and understanding which is applied to the context of the question. Interpretations are generally clear and support the response in most aspects (AO2).

•   Generally clear, coherent and relevant analysis and evaluation in the application of knowledge and understanding (AO2).

•   Generally clear evidence of links between knowledge and understanding to the application of knowledge and understanding in different contexts (AO2).

•   Generally clear and relevant knowledge and understanding of place(s) and environments (AO1).

•   Generally clear and accurate knowledge and understanding of key concepts, processes and interactions and change (AO1).

•   Generally clear awareness of scale and temporal change which is integrated where appropriate (AO1).

**Level 2 (6−10 marks)**

•   Some sense of an evaluative conclusion partially based upon knowledge and understanding which is applied to the context of the question (AO2). Interpretations are partial but do support the response in places.

•   Some partially relevant analysis and evaluation in the application of knowledge and understanding (AO2).

•   Some evidence of links between knowledge and understanding to the application of knowledge and understanding in different contexts (AO2).

•   Some relevant knowledge and understanding of place(s) and environments which is partially relevant (AO1).

•   Some knowledge and understanding of key concepts, processes and interactions and change. There may be a few inaccuracies (AO1).

•   Some awareness of scale and temporal change which is sometimes integrated where appropriate. There may be a few inaccuracies (AO1).

**Level 1 (1−5 marks)**

•   Very limited and / or unsupported evaluative conclusion that is loosely based upon knowledge and understanding which is applied to the context of the question. Interpretation is basic (AO2).

•   Very limited analysis and evaluation in the application of knowledge and understanding. This lacks clarity and coherence (AO2).

•   Very limited and rarely logical evidence of links between knowledge and understanding to the application of knowledge and understanding in different contexts (AO2).

•   Very limited relevant knowledge and understanding of place(s) and environments (AO1).

•   Isolated knowledge and understanding of key concepts, processes and interactions and change. There may be a number of inaccuracies (AO1).

•   Very limited awareness of scale and temporal change which is rarely integrated where appropriate. There may be a number of inaccuracies (AO1).

**Level 0 (0 marks)**

•   Nothing worthy of credit.

**AO1 = 10, AO2 = 10**

**[Total 20 marks]**

**Q14.**

**AO1** − Knowledge and understanding of the various human threats to Antarctica and the impacts of these threats, including the impact of changing carbon budgets.

**AO2** − Application of knowledge and understanding to analyse and evaluate the extent to which the impacts of changing carbon budgets are a greater threat than that of tourism and fishing and whaling.

Notes for answers

The question requires links to be made across the specification specifically between changing carbon budgets in the Water and Carbon Cycles and Antarctica as a Global Commons in Global Governance.

**AO1**

•   The effects of changing carbon budgets on the Southern Ocean, including ocean warming, ocean acidification, ocean salinity and melting sea-ice.

•   Impacts of ocean acidification on Antarctica where carbonate ions are projected to be so low, ocean waters may actually corrode organisms living there impacting on the fragile marine ecosystem.

•   The causes of changes to ocean salinity resulting from increased atmospheric temperatures in the Southern Ocean. Impacts of this on marine ecosystem.

•   The threats from fishing in the Southern Ocean. Some species of fish are at very low levels such as Antarctic rock cod (now so depleted that it cannot be fished), icefish and more recently the Patagonian toothfish.

•   Fishing for krill in the Southern Ocean is a major cause of concern because krill is a major food source for much of the marine ecosystem.

•   Many bird species such as albatross and petrels drown caught in fishing lines due to unsustainable fishing practices.

•   Whaling and sealing − early exploitation was far from sustainable, with species hunted to near extinction such as the Antarctic fur seal. No steps introduced to reduce or stop the exploitation until very late on, almost too late.

•   Tourism in Antarctica has seen significant increase in recent years with approximately 30 000 arrivals per year. Most visitors arrive by boat and are taken ashore in limited numbers. It is an expensive destination, very little litter / waste is left and research suggests that seals and penguins are not affected by tourists. Of the landing sites 95% are not damaged.

•   Marine pollution from tourist and other sources is a threat, for instance the sinking of the M/S Explorer in the Bransfield Straits in 2007.

•   Introduction of invasive species such as Mediterranean Mussels brought in on tourist boats has an impact on marine ecosystem.

•   Pollution by tourists and the fishing industry actually or potentially affects the Antarctic environment. Discarded plastic, fishing nets and hooks, organic waste, and sewage all contribute to environmental degradation.

•   The role of the ‘global commons’ in relation to Antarctica and the role of international government organisations such as the International Whaling Commission, IAATO and United Nations.

**AO2**

•   Evaluation of the effects of changing carbon budgets, with combined pressures of global population increase, increased levels of industrialisation, deforestation etc. The connection with climate change and subsequent impacts on Antarctica.

•   Evaluation of attempts to reduce anthropogenic carbon emissions and the subsequent mitigation of effects on the Southern Ocean.

•   Analysis of the complexities in understanding the effects of changing carbon budgets on Southern Ocean. The difficulties of predicting precise changes in the carbon budget and the subsequent effect on ocean salinity, acidification, nutrient enrichment and storminess.

•   Analysis of the wider threats posed by climate change associated with human activity in Antarctica. Warming of the ice cap is leading to melting ice as well as disturbance to ecosystems. Floating icebergs present a threat to shipping and tourism. If the atmosphere continues to warm, krill populations could be devastated, undermining the entire southern polar food chain, thus undermining environmental sustainability.

•   Analysis of the connections between the changing carbon budget and fishing / whaling in Antarctica. Changes in ocean salinity will impact on marine ecosystems possibly altering biodiversity. This may impact on available quotas. Overfishing will need to be more carefully managed. Sea ice is a unique habitat for algae and the loss of sea ice will impact on the whole food chain from krill to whales.

•   Analysis of the potential impacts of oceanic acidification (from extra dissolved carbon dioxide) on environmental sustainability, already leading to the loss of some marine snails thought to have a significant part to play in the oceanic carbon cycle. Breeding populations and ranges of some penguin species could potentially be altered irrevocably.

•   Evaluation of the extent of the threat from over-fishing. May currently be at more sustainable levels due to the break-up of the Russian fleet. Fishing is monitored in the Southern Ocean by the Convention on the Conservation of Antarctic Marine Living Resources. Fishing clearly has the potential to be sustainable − but the management of the resource is variable.

•   Evaluation of the potential unsustainability of recent revival of whaling. While commercial whaling is prohibited in the Southern Ocean Whale Sanctuary, Japan has continued to hunt whales inside the Sanctuary for the purposes of scientific research.

•   Analysis of the connections between the threat from changing carbon budgets and the threat from tourism. Melting sea-ice may actually increase the danger from tourism due to increased risk of iceberg and boat collisions. Warmer oceans may extend the tourism season, increasing pressures on landing sites.

•   Evaluation of the extent of the threat from tourism: the need for caution due to the fragility of the Antarctic environment. The effectiveness of IAATO and ASOC guidelines are likely to feature here. These ASOC measures are more stringent − but may encourage more sustainable use of the area. Impact studies by Scott Polar Research Institute show that tourism is largely positive, with excellent educational provision on board ships that are visiting. Tourism perhaps offers the best hope for sustainability of the more recent developments. However with increases in wealth in countries such as China, pressure from tourism may increase in the future.

•   Evaluation of the extent to which threats to Antarctica may have a global impact. The importance of Antarctica as a global commons.

•   Analysis of the effectiveness of international scale protection of Antarctica through frameworks such as the United Nations Environment Programme, and resource management such as the IWC Whaling Moratorium, and the extent to which they reduce the threats from tourism and over-fishing. The extent to which changing carbon budgets will make protection of Antarctica an ever-increasing priority.

•   Evaluation of the extent to which the impacts on Antarctica and the Southern Ocean may cause positive feedback loops. They may conclude that the threats from changing carbon budgets are a larger global threat.

•   Analysis of how the threats to Antarctica may operate on different time-scales. Changing carbon budgets may have a much longer-term impact than the more immediate and visible impacts from tourism and fishing.

•   Overall evaluation of the question, giving consideration to the extent of various uses of and threats to the Antarctic region in a changing climate. The extent to which climate change is the greater threat taking into account the effectiveness of climate change mitigation strategies and the work of international agencies, reflecting emerging global governance in mitigating the threats and attempts to achieve environmental and / or economic sustainability.

•   They may conclude that tourism and / or fishing and whaling are a more pressing and immediate threat but that they are easier to manage and so therefore present a lower threat long-term.

**Level 4 (16−20 marks)**

•   Detailed evaluative conclusion that is rational and firmly based on knowledge and understanding which is applied to the context of the question (AO2). Detailed, coherent and relevant analysis and evaluation in the application of knowledge and understanding throughout (AO2).

•   Full evidence of links between knowledge and understanding to the application of knowledge and understanding in different contexts (AO2).

•   Detailed, highly relevant and appropriate knowledge and understanding of place(s) and environments used throughout (AO1).

•   Full and accurate knowledge and understanding of key concepts and processes throughout (AO1).

•   Detailed awareness of scale and temporal change which is well integrated where appropriate (AO1).

**Level 3 (11−15 marks)**

•   Clear evaluative conclusion that is based on knowledge and understanding which is applied to the context of the question (AO2).

•   Generally clear, coherent and relevant analysis and evaluation in the application of knowledge and understanding (AO2).

•   Generally clear evidence of links between knowledge and understanding to the application of knowledge and understanding in different contexts (AO2).

•   Generally clear and relevant knowledge and understanding of place(s) and environments (AO1).

•   Generally clear and accurate knowledge and understanding of key concepts and processes (AO1).

•   Generally clear awareness of scale and temporal change which is integrated where appropriate (AO1).

**Level 2 (6−10 marks)**

•   Some sense of an evaluative conclusion partially based upon knowledge and understanding which is applied to the context of the question (AO2).

•   Some partially relevant analysis and evaluation in the application of knowledge and understanding (AO2).

•   Some evidence of links between knowledge and understanding to the application of knowledge and understanding in different contexts (AO2).

•   Some relevant knowledge and understanding of place(s) and environments which is partially relevant (AO1).

•   Some knowledge and understanding of key concepts, processes and interactions and change (AO1).

•   Some awareness of scale and temporal change which is sometimes integrated where appropriate. There may be a few inaccuracies (AO1).

**Level 1 (1−5 marks)**

•   Very limited and / or unsupported evaluative conclusion that is loosely based upon knowledge and understanding which is applied to the context of the question (AO2).

•   Very limited analysis and evaluation in the application of knowledge and understanding. This lacks clarity and coherence (AO2).

•   Very limited and rarely logical evidence of links between knowledge and understanding to the application of knowledge and understanding in different contexts (AO2).

•   Very limited relevant knowledge and understanding of place(s) and environments (AO1).

•   Isolated knowledge and understanding of key concepts and processes (AO1).

•   Very limited awareness of scale and temporal change which is rarely integrated where appropriate. There may be a number of inaccuracies (AO1).

**Level 0 (0 marks)**

•   Nothing worthy of credit.

**AO1 = 10, AO2 = 10**

**[Total 20 marks]**

**Q15-18 SECURE MATERIAL**

**Q19.**

Mark scheme

Allow 1 mark for each valid point with additional marks for developed points.

Photosynthesis is an integral element of the carbon cycle e.g.:

•   CO2 is taken in from the atmosphere by plants (1).

•   This reacts with chlorophyll to create carbohydrates such as glucose. The glucose is used in processes related to plant growth or stored as starch (1+1 for development).

•   Oxygen is released as a by-product of photosynthesis. This process, in part, maintains the balance between carbon and oxygen in the atmosphere (1).

•   Some may consider the link with plant growth taking carbon out of the atmosphere (possible reference to carbon sinks) (1+1 for development).

Note: Not just oxygen released for credit.

**AO1 = 3**

**[Total 3 marks]**

**Q20.**

**AO1** − Knowledge and understanding of the carbon cycle and how this links to the water cycle.

**AO2** − Application of knowledge and understanding to evaluate the potential impact of changes to the carbon cycle upon atmospheric patterns.

Mark scheme

**Level 3 (7−9 marks)**

**AO1** − Demonstrates detailed knowledge and understanding of concepts, processes, interactions and change. These underpin the response throughout.

**AO2** − Applies knowledge and understanding appropriately with detail. Connections and relationships between different aspects of study are fully developed with complete relevance. Evaluation is detailed and well supported with appropriate evidence.

**Level 2 (4−6 marks)**

**AO1** − Demonstrates clear knowledge and understanding of concepts, processes, interactions and change. These are mostly relevant though there may be some minor inaccuracy.

**AO2** − Applies clear knowledge and understanding appropriately. Connections and relationships between different aspects of study are evident with some relevance. Evaluation is evident and supported with clear and appropriate evidence.

**Level 1 (1−3 marks)**

**AO1** − Demonstrates basic knowledge and understanding of concepts, processes, interactions and change. This offers limited relevance with inaccuracy.

**AO2** − Applies limited knowledge and understanding. Connections and relationships between different aspects of study are basic with limited relevance. Evaluation is basic and supported with limited appropriate evidence.

Notes for answers

**AO1**

•   Global distribution and size of major stores of water − lithosphere, hydrosphere, cryosphere and atmosphere.

•   Factors driving change in the magnitude of carbon stores over time and space, including flows and transfers at plant, sere and continental scales. Photosynthesis, respiration, decomposition, combustion, carbon sequestration in oceans and sediments, weathering.

•   Changes in the carbon cycle over time, to include natural variation (including wild fires, volcanic activity) and human impact (including hydrocarbon fuel extraction and burning, farming practices, deforestation, land use changes).

•   The key role of the carbon and water stores and cycles in supporting life on Earth with particular reference to climate. The relationship between the water cycle and carbon cycle in the atmosphere. The role of feedbacks within and between cycles and their link to climate change and implications for life on Earth.

•   Human interventions in the carbon cycle designed to influence carbon transfers and mitigate the impacts of climate change.

**AO2**

•   There are any number of storms events to which students can refer. They may consider diverse and / or connected issues such as El Niño or tropical storms.

•   Responses should consider the impact of changes to the carbon cycle through deforestation and the burning of fossil fuels. Some may consider natural variation such as forest fire and volcanic eruptions.

•   Those responses which argue in support of the link to increased storm events are likely to consider the impact of increased temperatures upon sea temperatures and evaporation rates. This combined with the changes to atmospheric circulation (particularly jet streams) is likely to place more water vapour into the atmosphere leading to more intense downpours through storm events.

•   There should be reference to increased levels of carbon dioxide in the atmosphere, leading to a more pronounced greenhouse effect, higher temperatures and therefore greater levels of evaporation

•   Some may argue against the idea of increased storm events. In fact the higher temperatures are also leading to increased evaporation on land. The problem of desertification in continental interiors is set to another extreme challenge affecting places which are already arid. In other words changes to the carbon cycle are also linked with the spread of aridity.

**AO1 = 4, AO2 = 5**

**[Total 9 marks]**

**Q21.**

Mark scheme

2 × 1 per accurate plot.

Analysis

Allow 1 mark for each valid point with additional marks for developed points.

•   In all areas with the exception of tropical rainforest, there is more carbon stored in soil than biomass (1). The largest amount is ocean mangroves with around 1800 tCO2eq / ha. This is around 750 tCO2eq / ha more than the next highest (1 mark for manipulation of data).

•   Tropical rainforest is also the only ecosystem where biomass contains more carbon than soil stores (1).

•   Some may note that all water based ecosystems (except seagrasses) contain more carbon than the tropical rainforest (1).

•   Max 3 without manipulation of data.

•   No credit for straight reversals or repetition.

**AO3 = 6**

**[Total 6 marks]**

**Q22.**

**AO1** − The carbon budget and the impact of the carbon cycle upon land, ocean and atmosphere, including global climate. Human interventions in the carbon cycle designed to influence carbon transfers and mitigate the impacts of climate change.

**AO2** − Application of knowledge to show an understanding of the challenges associated with managing climate change including emissions reductions.

Mark scheme

**Level 2 (4−6 marks)**

**AO1** − Demonstrates clear knowledge and understanding of concepts, processes, interactions and change.

**AO2** − Applies knowledge and understanding to the novel situation offering clear evaluation and analysis drawn appropriately from the context provided. Connections and relationships between different aspects of study are evident with clear relevance.

**Level 1 (1−3 marks)**

**AO1** − Demonstrates basic knowledge and understanding of concepts, processes, interactions, change.

**AO2** − Applies limited knowledge and understanding to the novel situation offering only basic evaluation and analysis drawn from the context provided. Connections and relationships between different aspects of study are basic with limited relevance.

Notes for answers.

**AO1**

•   Changes in the carbon cycle over time, human impact (including hydrocarbon fuel extraction and burning, farming practices, deforestation, land use changes).

•   The carbon budget and the impact of the carbon cycle upon land, ocean and atmosphere, including global climate.

•   Human interventions in the carbon cycle designed to influence carbon transfers and mitigate the impacts of climate change.

•   Factors driving change in the carbon cycle − combustion.

**AO2**

•   The challenge has been around obtaining agreement in what is clearly not an equal situation. The richest countries, such as some in Europe and the USA, make a disproportionately high contribution to global warming. This is combined with the fact that USA has sought to pull out of the Paris agreement.

•   If the USA or China pull out of the agreement, the whole agreement is at risk. Many countries make little or no contribution to the global climate change and yet they are signatories. Canada and most African countries contribute very little to global climate change yet most are signatories to the Paris Agreement.

•   For most countries, economic development is synonymous with increased carbon emissions. Restricting emissions to achieve a climate of below 2°C is likely to harm many developing economies. If USA were to pull out this would inevitably raise questions of fairness and place national pressure on sovereign governments to make the same decision.

•   Some may argue that USA stands to gain comparative advantage. By pulling out of the Paris Agreement, the commitment to green energy production schemes and carbon emissions reduction strategies (as part of the Paris Agreement) are also likely to be dispensed with. This is likely to relieve the burden of substantial economic cost upon the USA. In this sense the biggest polluter will continue to gain economic advantage from burning fossil with none of the costs and arguably responsibility for mitigation.

**AO1 = 2, AO2 = 4**

**[Total 6 marks]**

**Q23.**

**AO3** − There should be detailed analysis of the overarching patterns which shows awareness of the main contributors to greenhouse gas emissions. More sophisticated responses will analyse the detailed differences in countries of varying levels of development.

Mark scheme

**Level 2 (4−6 marks)**

**AO3** − Clear analysis of the quantitative evidence provided, which makes appropriate use of data in support. Clear connection(s) between different aspects of the data and evidence.

**Level 1 (1−3 marks)**

**AO3** − Basic analysis of the quantitative evidence provided, which makes limited use of data and evidence in support. Basic connection(s) between different aspects of the data and evidence.

Notes for answers.

**AO3**

Level 1 responses are likely to simply describe the data without clear attempt to analyse, for instance by manipulating data or spotting trends.

•   The graph shows that high income countries are still the biggest contributors to GHG production but that there has been little growth between 1990 and 2010 in particular (0.4 Gigatonnes of CO2).

•   It is upper-middle income countries which have seen the fastest rates of growth of the time periods. For instance, there has been an almost doubling from 98 to 18.3 gigatonnes of CO2 produced. Industry appears to have more than doubled in its contribution to GHG in this group of countries (from approximately to 2 to around 5 gigatonnes).

•   Low and low-middle income countries contribute relatively little to the overall GHG emissions. For instance, combined in 2010 they produced only 11.3 gigatonnes, 7.4 gigatonnes less than high income countries. These countries greatest contribution comes through agriculture (especially for low income countries) with very little through energy use and transport.

•   Some may conclude that the poorest countries in the world are largely not responsible for the vast majority of the GHG emissions and that this contribution, if anything, is shrinking.

**AO3 = 6**

**[Total 6 marks]**

**Q24.**

**AO1** − Knowledge and understanding of a range of natural changes to the carbon cycle. Knowledge and understanding of factors impacting life on Earth over time.

**AO2** − Application of knowledge and understanding to assess how natural changes to the carbon cycle affect life on Earth.

**Level 3 (7−9 marks)**

**AO1** − Demonstrates detailed knowledge and understanding of concepts, processes, interactions and change. These underpin the response throughout.

**AO2** − Applies knowledge and understanding appropriately with detail. Connections and relationships between different aspects of study are fully developed with complete relevance. Analysis is detailed and well-supported with appropriate evidence.

**Level 2 (4−6 marks)**

**AO1** − Demonstrates clear knowledge and understanding of concepts, processes, interactions and change. These are mostly relevant, though there may be some minor inaccuracy.

**AO2** − Applies clear knowledge and understanding appropriately. Connections and relationships between different aspects of study are evident with some relevance. Analysis is evident and supported with clear and appropriate evidence.

**Level 1 (1−3 marks)**

**AO1** − Demonstrates basic knowledge and understanding of concepts, processes, interactions and change. This offers limited relevance with inaccuracy.

**AO2** − Applies limited knowledge and understanding. Connections and relationships between different aspects of study are basic with limited relevance. Analysis is basic and supported with limited appropriate evidence.

Notes for answers

**AO1**

•   Systems concepts and their application to the carbon cycle: inputs − outputs, energy, stores / components, flows / transfers, positive / negative feedback and dynamic equilibrium.

•   Global distribution and size of major stores of carbon − lithosphere, hydrosphere, cryosphere, biosphere, atmosphere.

•   Factors driving change in the magnitude of these stores, over time and in space, including flows and transfers at plant, sere and continental scales. Photosynthesis, respiration, decomposition, combustion, carbon sequestration in oceans and sediments, weathering.

•   Changes in the carbon cycle over time, to include natural variation (including wild fires, volcanic activity) and their impact upon life on Earth.

•   The carbon budget and the impact of the carbon cycle upon land, ocean and atmosphere and thus life on Earth.

•   The key role of the carbon cycle in supporting life on Earth with particular reference to climate. The relationship between the carbon cycle and the atmosphere. The role of feedbacks within the cycle and their link to climate change and implications for life of Earth.

**AO2**

Assessment:

•   The carbon cycle is a natural cycle of carbon between land, ice, oceans and the atmosphere.

•   Carbon is essential for all known life on Earth. Any natural variation in the cycle can have significant effects of life on Earth.

•   The carbon cycle is affected by natural events such as volcanic eruptions and wild fires leading to transfers of carbon to the atmosphere.

•   The carbon cycle is affected by long term cycles of natural warming and cooling of climate causing cycles of glacials and interglacials altering the various stores and transfers of carbon, and thus affecting climate and life on Earth.

•   Atmospheric concentrations of carbon (as carbon dioxide and methane) are significant factors in controlling the natural greenhouse effect. Natural changes to the concentrations of either / both natural greenhouse gases will affect both climate and life on Earth.

•   Natural variations to climate could affect vegetation cover and the scale of the biosphere carbon store. Natural sequestration stores carbon in trees. Natural factors can disrupt the role of vegetation in cycling and storing carbon, which in turn will affect the amount of atmospheric carbon and thus global climate, thus affecting both climate and life on Earth.

•   Expect some responses to assess how natural changes will disrupt various natural systems within the carbon cycle causing feedback. Responses then may assess the impact of both negative and positive feedback on the climate and life on Earth.

•   Responses could address a broad range of natural changes to the carbon cycle, this is valid, and responses could assess a broad range of effects. All valid changes and effects will be credited.

Overall assessment may come to a view as to which factors may be more or less important in affecting life in Earth.

**AO1 = 4, AO2 = 5**

**[Total 9 marks]**

**Q25.**

**AO3** − Analysis makes clear links between carbon dioxide emissions and evidence provided in **Figure 1** and **Figure 2**. Use and understanding of the map evidence are clear and accurate.

**Level 2 (4−6 marks)**

**AO3** − Clear interpretation and analysis of the quantitative evidence provided, which makes appropriate use of data in support. Clear connection(s) between different aspects of the data and evidence.

**Level 1 (1−3 marks)**

**AO3** − Basic interpretation and evaluation of a geographical issue or question. Basic interpretation and assessment of the quantitative evidence provided, which makes limited use of the data in support. Basic connection(s) between different aspects of the data and evidence.

Notes for answers

**AO3**

•   By 2016 the map evidence suggests that globally there has been a significant increase in emissions over time.

•   By 2016 the map evidence suggests that globally there has been a significant change in the distribution of emissions.

•   Use of the key allows responses to quantify the extent of change and support points with evidence.

•   Responses should note the spatial differences in emissions illustrated in the maps. Points could include, but not exclusively:

•   In 1960 the USA is the only country with over 5,000 MtCO2, by 2016 a number of countries have emissions over 2,000 MtCO2, China, USA, India, Russia and Japan for example.

•   Use of the key suggests that in 1960 the USA has emissions around 3 times higher than the next highest emitting countries including Russia, Germany and China.

•   Use of the key suggests that by 2016, China is the only country with emissions over 10,000 MtCO2, and its emissions are twice as large as India for example.

•   In 1960 the USA, western, central and eastern Europe, Russia and China account for a significant proportion of emissions.

•   Areas with the highest emissions in 1960 continue to have high emissions and still account for significant amounts of emissions.

•   Particularly significant rates of increase seem to be in South America, southern Europe, North Africa, the Middle East, and especially south, east and southeast Asia. (Some responses will support with evidence at country level, for example India’s emissions increasing from 100 MtCO2 to several thousand MtCO2).

•   Some responses may identify significant areas of the world with no significant / negligible emissions in 1960 (i.e. no dot or have a tiny dot / proportional circle indicating significantly less than 100 MtCO2) especially in Africa, the Middle East, Central America and much of southeast Asia, and how despite some of these countries still not showing any significant emissions, parts of South East Asia and the Middle East now show significant emissions. Some may illustrate with named countries as support.

•   Map evidence also shows that some European countries have seen significant growth e.g. Spain and Italy, and that lowest levels are still in Africa, and that there has been significant growth in Australia.

•   Some candidates may identify countries that have seen a reduction in their emissions, e.g. the UK.

•   Although the figures allow for simple visual interpretation and spatial and temporal comparison, some may use the scales in the key as evidence of amounts and rates of change, as examples above show.

•   All valid analytical points will be credited.

**AO3 = 6**

**[Total 6 marks]**

**Q26.**

A

**AO1 = 1**

**[Total 1 mark]**

**Q27.**

**AO1**– An understanding of feedback systems within the carbon cycle. An awareness of strategies involved reducing carbon levels in the atmosphere.

**AO2**– Application of knowledge and understanding to show the extent to which understanding of feedback systems in the carbon cycle contribute to mitigation strategies.

Notes for answers

**AO1**

•   Global distribution, and size of major stores of carbon – lithosphere, hydrosphere, cryosphere biosphere, atmosphere. Factors driving change in the magnitude of these stores over time and space, including flows and transfers at plant, sere and continental scales.

•   Photosynthesis, respiration, decomposition, combustion, carbon sequestration in oceans and sediments, weathering.

•   Changes in the carbon cycle over time, to include natural variation (including wild fires, volcanic activity) and human impact (including hydrocarbon fuel extraction and burning, farming practices, deforestation, land use changes).

•   The carbon budget and the impact of the carbon cycle upon land, ocean and atmosphere, including global climate.

•   The role of feedbacks within and between cycles and their link to climate change and implications for life on Earth.

•   Human interventions in the carbon cycle designed to influence carbon transfers and mitigate the impacts of climate change.

**AO2**

•   Some may first define the concept of feedback. In this context, feedback is concerned with the interconnectedness of change processes in the carbon cycle. With positive feedback impacts can be exacerbated once climate change starts to occur as natural processes tend to compound one another, increasing climatic instability and the likelihood of extreme conditions. In contrast, negative feedback is likely to have a more stabilising impact by depressing rates of the natural processes and moderating rates of atmospheric change.

•   For example, increasing global temperatures will extend growing seasons for plants and lead to increased carbon capture (negative feedback). Equally though increasing global temperatures will release methane from permafrost locations adding more greenhouse gasses to the atmosphere (positive feedback).

•   Many will argue that current rates of greenhouse gas emissions are creating a net positive feedback i.e. creating greater instability in climate change and exacerbating the warming. In this sense, the knock-on effect of increased carbon emissions from human activity is also increasing the natural release of carbon and methane.

•   The obvious way in which an understanding of feedback translates into policy is through afforestation schemes. Clearly by planting natural vegetation or allowing previously deforested areas to regain natural vegetation, the natural creation of carbon sinks begins.

•   Other mitigation strategies clearly take into account the role of feedback. Expect to see reference to carbon sequestration and storage. This strategy again shows a clear understanding of the role of feedback.

•   Some may argue in more general terms a very simple point, if carbon increases are linked to global warming and this is damaging for the environment, then irrespective of an understanding of feedback, human endeavour should be geared towards reducing the amount of carbon produced as a result of energy use and other human activity. This argument may be linked to measures to reduce carbon emissions, which in itself is not driven by an understanding of feedback systems. This is a legitimate approach.

**Credit any other valid approach.**

**Level 4 (16–20 marks)**

•   Detailed evaluative conclusion that is rational and firmly based on knowledge and understanding which is applied to the context of the question. Interpretations are comprehensive, sound and coherent (AO2).

•   Detailed, coherent and relevant analysis and evaluation in the application of knowledge and understanding throughout (AO2).

•   Full evidence of links between knowledge and understanding to the application of knowledge and understanding in different contexts (AO2).

•   Detailed, highly relevant and appropriate knowledge and understanding of place(s) and environments used throughout (AO1).

•   Full and accurate knowledge and understanding of key concepts, processes and interactions and change throughout (AO1).

•   Detailed awareness of scale and temporal change which is well integrated where appropriate (AO1).

**Level 3 (11–15 marks)**

•   Clear evaluative conclusion that is based on knowledge and understanding which is applied to the context of the question. Interpretations are generally clear and support the response in most aspects (AO2).

•   Generally clear, coherent and relevant analysis and evaluation in the application of knowledge and understanding (AO2).

•   Generally clear evidence of links between knowledge and understanding to the application of knowledge and understanding in different contexts (AO2).

•   Generally clear and relevant knowledge and understanding of place(s) and environments (AO1).

•   Generally clear and accurate knowledge and understanding of key concepts, processes and interactions and change (AO1).

•   Generally clear awareness of scale and temporal change which is integrated where appropriate (AO1).

**Level 2 (6–10 marks)**

•   Some sense of an evaluative conclusion partially based upon knowledge and understanding which is applied to the context of the question (AO2). Interpretations are partial but do support the response in places.

•   Some partially relevant analysis and evaluation in the application of knowledge and understanding (AO2).

•   Some evidence of links between knowledge and understanding to the application of knowledge and understanding in different contexts (AO2).

•   Some relevant knowledge and understanding of place(s) and environments which is partially relevant (AO1).

•   Some knowledge and understanding of key concepts, processes and interactions and change. There may be a few inaccuracies (AO1).

•   Some awareness of scale and temporal change which is sometimes integrated where appropriate. There may be a few inaccuracies (AO1).

**Level 1 (1–5 marks)**

•   Very limited and / or unsupported evaluative conclusion that is loosely based upon knowledge and understanding which is applied to the context of the question. Interpretation is basic (AO2).

•   Very limited analysis and evaluation in the application of knowledge and understanding. This lacks clarity and coherence (AO2).

•   Very limited and rarely logical evidence of links between knowledge and understanding to the application of knowledge and understanding in different contexts (AO2).

•   Very limited relevant knowledge and understanding of place(s) and environments (AO1).

•   Isolated knowledge and understanding of key concepts, processes and interactions and change. There may be a number of inaccuracies. (AO1).

•   Very limited awareness of scale and temporal change which is rarely integrated where appropriate. There may be a number of inaccuracies (AO1).

**Level 0 (0 marks)**

•   Nothing worthy of credit.

**AO1 = 10**

**AO2 = 10**

**[Total 20 marks]**

**Q28.**

**AO1** – Knowledge and understanding of major stores of carbon. Knowledge and understanding of carbon sequestration and fossil fuel combustion.

**AO2** – Application of knowledge and understanding to assess the relative importance of carbon sequestration and fossil fuel combustion on major stores of carbon.

Mark scheme

**Level 3 (7–9 marks)**

**AO1** – Demonstrates detailed knowledge and understanding of concepts, processes, interactions and change. These underpin the response throughout.

**AO2** – Applies knowledge and understanding appropriately with detail. Connections and relationships between different aspects of study are fully developed with complete relevance. Analysis is detailed and well supported with appropriate evidence.

**Level 2 (4–6 marks)**

**AO1** – Demonstrates clear knowledge and understanding of concepts, processes, interactions and change. These are mostly relevant, though there may be some minor inaccuracy.

**AO2** – Applies clear knowledge and understanding appropriately. Connections and relationships between different aspects of study are evident with some relevance. Analysis is evident and supported with clear and appropriate evidence.

**Level 1 (1–3 marks)**

**AO1** – Demonstrates basic knowledge and understanding of concepts, processes, interactions and change. This offers limited relevance with inaccuracy.

**AO2** – Applies limited knowledge and understanding. Connections and relationships between different aspects of study are basic with limited relevance. Analysis is basic and supported with limited appropriate evidence.

Notes for answers

**AO1**

•   Global distribution, and size of major stores of carbon – lithosphere, hydrosphere, cryosphere, biosphere, atmosphere.

•   Factors driving change in the magnitude of these stores, over time and in space, including flows and transfers at plant, sere, continental and global scales. Photosynthesis, respiration, decomposition, combustion, carbon sequestration in oceans and sediments, weathering.

•   Systems in physical geography: systems concepts and their application to the carbon cycle inputs – outputs, energy, stores / components, flows / transfers, positive / negative feedback, dynamic equilibrium.

**AO2**

•   Carbon sequestration and fossil fuel combustion are both processes that drive change in the magnitude of major stores of carbon.

•   Both processes are similar in that they both operate over a range of temporal scales and can involve transfers at the plant, sere and continental scales. Responses may support with illustrative examples.

•   Responses are likely to suggest that carbon sequestration and fossil fuel combustion have very different impacts on major stores of carbon.

•   Responses should come to the view that the importance of carbon sequestration differs to fossil fuel combustion in that sequestration transfers carbon in the form of carbon dioxide from the atmosphere and oceans to be stored in solid or liquid form in the biosphere, lithosphere or hydrosphere stores. Whereas fossil fuel combustion is important in transferring carbon from the biosphere and lithosphere stores into the atmosphere, thus reducing the magnitude of the initial stores and increasing the magnitude of the latter.

•   The importance of carbon sequestration and fossil fuel combustion differ in that they are the result of different natural and human processes, and they differ in the nature of the impacts of those processes. Natural carbon sequestration includes processes such as organic matter falling to the ocean floor where it accumulates as carbon-rich layers of sediments that eventually lithify (increasing the lithosphere store). Human processes involving fossil fuel combustion include the burning of hydrocarbon based fuels especially for energy production (reducing the lithosphere store and increasing the atmosphere store). Whereas human processes of carbon sequestration involve capturing carbon dioxide from sources such as power stations and injecting it in liquid form to stores underground (increasing the lithosphere store), or by planting vegetation to remove CO2 from the atmosphere and store it as organic material in the biosphere store (decreasing the atmosphere store and increasing the biosphere store).

•   Some responses may creditably support points with evidence of the different scales of these transfers and impacts. For example the role of human induced fossil fuel combustion in bringing atmospheric concentrations of CO2 to over 400 parts per million, whilst the global capacity of carbon capture and storage systems is approximately 40 million tonnes of CO2 per year.

•   Some responses may creditably assess the importance of the processes named in the question with respect to other processes that may also affect major stores of carbon, including those listed in AO1 above.

Overall assessment can focus on any features of the importance of both processes, but overall responses should come to a clear point of view concerning the importance of the processes named in the question. Assessment of the importance of the processes on the major stores of carbon could be addressed in a number of ways.

**Credit any other valid assessment**

**AO1 = 4**

**AO2 = 5**

**[Total 9 marks]**

**Q29.**

**AO1** – An understanding of farming practices within the context of water and carbon. An awareness of the impact of human activity upon the carbon budget.

**AO2** – Application of knowledge and understanding to show how farming practices can alter/affect carbon stores and transfers at local, regional and global scales.

Notes for answers

**AO1**

•   Global distribution, and size of major stores of carbon – lithosphere, hydrosphere, cryosphere, biosphere, atmosphere. Factors driving change in the magnitude of these stores over time and space, including flows and transfers at plant, sere and continental scales.

•   Photosynthesis, respiration, decomposition, combustion, carbon sequestration in oceans and sediments, weathering.

•   Changes in the carbon cycle over time, to include natural variation (including wild fires, volcanic activity) and human impact (including burning, farming practices, deforestation, land use changes).

•   The carbon budget and the impact of the carbon cycle upon land, ocean and atmosphere, including global climate.

•   The role of feedbacks within and between cycles and their link to climate change and implications for life on Earth.

•   Human interventions in the carbon cycle designed to influence carbon transfers and mitigate the impacts of climate change.

**AO2**

•   Responses are most likely to focus upon the damage caused by farming practices, particularly in tropical rainforests.

•   Some may refer to traditional slash-and-burn techniques and the small-scale nature of this approach to farming. Whilst small-scale rotation is more sustainable, there is still a localised increase in carbon emission associated with the burning.

•   Ranching may also feature in candidate responses. For example, cattle ranching is now the biggest cause of deforestation in the Amazon, and nearly 80 per cent of deforested areas in Brazil are now used for pasture. The cattle industry has grown rapidly since the 1970s, giving Brazil the largest commercial cattle herd in the world. Since 2003, the country has also topped the world’s beef export charts and the government planned to double its share of the market by 2018. The impact this is having on the forest is huge – between 1996 and 2006, an area the size of Portugal was carved out for cattle ranching. Large-scale forest clearance removes a major carbon store and reduces the intake of carbon by photosynthesis. There is also the issue of methane release as a result of cattle farming. Some may link this to the carbon dioxide issue and concerns about increased greenhouse gases. This is an acceptable line of argument in the context of the question.

•   In the state of Acre in western Brazil, farms and pastures are surrounded by large, undisturbed areas of Amazon rainforest. Since January 2005, many areas in the state have been experiencing severe drought, and the forests have become tinder dry. Experts attribute the drought to at least in part be caused by the disruption to convection rainfall. The tinder-dry conditions have led to forest fires, releasing even more carbon into the atmosphere.

•   Soil erosion is another issue. As the areas are over-cultivated, nutrients and minerals become depleted, rendering the area useful for farming but also, at least in the short term, recolonisation by vegetation. In this sense the store for carbon is reduced and emissions carbon in the atmosphere is not reduced thus maintaining a high budget.

•   Some may refer to recent forest fires in places such as Amazonia. Provided this is linked to farming, ie deliberately set fires to clear woodland, this is a valid approach.

•   Some may consider more positive and sustainable farming practices which are having a more positive impact on the carbon budget. The Great Green Wall in the Sahel is an attempt to reverse the impact of desertification and the extension of arid lands in the region. The benefits of this initiative directly relate to opportunities for soil preservation, agricultural extension as well as forestry. It is the forestry which is increasing the store of carbon both above and below ground, with the newly accumulated biomass.

•   Expect to see some reference to feedback systems. Some may argue that current farming practices are leading to a positive feedback loop with an imbalance moving further and further away from equilibrium. Others may suggest that more sustainable practices can produce a negative feedback which returns the carbon budget to equilibrium. Either approach is valid but should be based upon preceding content.

Credit any other valid approach.

**Level 4 (16–20 marks)**

•   Detailed evaluative conclusion that is rational and firmly based on knowledge and understanding which is applied to the context of the question. Interpretations are comprehensive, sound and coherent (AO2).

•   Detailed, coherent and relevant analysis and evaluation in the application of knowledge and understanding throughout (AO2).

•   Full evidence of links between knowledge and understanding to the application of knowledge and understanding in different contexts (AO2).

•   Detailed, highly relevant and appropriate knowledge and understanding of place(s) and environments used throughout (AO1).

•   Full and accurate knowledge and understanding of key concepts, processes and interactions and change throughout (AO1).

•   Detailed awareness of scale and temporal change which is well integrated where appropriate (AO1).

**Level 3 (11–15 marks)**

•   Clear evaluative conclusion that is based on knowledge and understanding which is applied to the context of the question. Interpretations are generally clear and support the response in most aspects (AO2).

•   Generally clear, coherent and relevant analysis and evaluation in the application of knowledge and understanding (AO2).

•   Generally clear evidence of links between knowledge and understanding to the application of knowledge and understanding in different contexts (AO2).

•   Generally clear and relevant knowledge and understanding of place(s) and environments (AO1).

•   Generally clear and accurate knowledge and understanding of key concepts, processes and interactions and change (AO1).

•   Generally clear awareness of scale and temporal change which is integrated where appropriate (AO1).

**Level 2 (6–10 marks)**

•   Some sense of an evaluative conclusion partially based upon knowledge and understanding which is applied to the context of the question (AO2). Interpretations are partial but do support the response in places.

•   Some partially relevant analysis and evaluation in the application of knowledge and understanding (AO2).

•   Some evidence of links between knowledge and understanding to the application of knowledge and understanding in different contexts (AO2).

•   Some relevant knowledge and understanding of place(s) and environments which is partially relevant (AO1).

•   Some knowledge and understanding of key concepts, processes and interactions and change. There may be a few inaccuracies (AO1).

•   Some awareness of scale and temporal change which is sometimes integrated where appropriate. There may be a few inaccuracies (AO1).

**Level 1 (1–5 marks)**

•   Very limited and/or unsupported evaluative conclusion that is loosely based upon knowledge and understanding which is applied to the context of the question. Interpretation is basic (AO2).

•   Very limited analysis and evaluation in the application of knowledge and understanding. This lacks clarity and coherence (AO2).

•   Very limited and rarely logical evidence of links between knowledge and understanding to the application of knowledge and understanding in different contexts (AO2).

•   Very limited relevant knowledge and understanding of place(s) and environments (AO1).

•   Isolated knowledge and understanding of key concepts, processes and interactions and change. There may be a number of inaccuracies. (AO1).

•   Very limited awareness of scale and temporal change which is rarely integrated where appropriate. There may be a number of inaccuracies (AO1).

**Level 0 (0 marks)**

•   Nothing worthy of credit.

**AO1 = 10, AO2 = 10**

**[Total 20 marks]**

**Q30.**

A

**AO1 = 1**

**[Total 1 mark]**

**Q31.**

Point marked

Award one mark for each relevant point with extra mark(s) for developed points (d). For example:

Notes for answers

•   This is a flow or transfer of carbon (1). Carbon is transferred from the biosphere or lithosphere store to the atmosphere store (1d). The magnitude of these stores is changed (1d).

•   Carbon is transferred from a solid or liquid to gaseous state. (1)

•   Wild fires and volcanic activity are examples of natural drivers of combustion (1).

•   Burning fossil fuels is an example of a human cause of combustion. (1).

The notes for answers are not exhaustive. Credit any valid points.

**AO1 = 3**

**[Total 3 marks]**

**Q32.**

**AO1** – Knowledge and understanding of systems theory and its application to understanding the carbon cycle. Knowledge and understanding of impacts of the carbon cycle on life on Earth.

**AO2** – Application of knowledge and understanding to assess the extent to which human activity has led to irreversible changes to the carbon cycle and caused negative impacts for life on Earth.

Notes for answers

**AO1**

•   Changes in the carbon cycle over time, to include natural variation (including wild fires, volcanic activity) and human impact (including hydrocarbon fuel extraction and burning, farming practices, deforestation, land use changes).

•   Systems in physical geography: systems concepts and their application to the water and carbon cycles, inputs – outputs, energy, stores/components, flows/transfers, positive/negative feedback, dynamic equilibrium.

•   The key role of the carbon and water stores and cycles in supporting life on Earth with particular reference to climate. The relationship between the water cycle and carbon cycle in the atmosphere. The role of feedbacks within and between cycles and their link to climate change and implications for life of Earth.

•   Human interventions in the carbon cycle designed to influence carbon transfers and mitigate the impacts of climate change.

•   The carbon budget and the impact of the carbon cycle upon land, ocean and atmosphere, including global climate.

**AO2**

•   Candidates are free to argue in any direction in relation to the question. Some may remain neutral.

•   Allow any changes to the carbon cycle that are reasonably derived from the chosen human activities.

•   There should be some recognition of unique characteristics of the chosen human activity/ies and the specific impacts the resulting changes to the carbon cycle have on life on Earth.

•   It is acceptable for responses to refer to any forms of life on Earth, including vegetation, animal or human life.

•   Changes to the carbon cycle relating to changing concentrations of atmospheric CO2 resulting from human activity are likely to feature strongly. Responses could assess changes to the carbon cycle over time resulting from human activities including:

-   Hydrocarbon fuel extraction and burning, farming practices, deforestation and land use changes.

Whichever human activities are included in the response there should be assessment that comes to a clear view as to whether the changes they caused in the carbon cycle are in fact irreversible.

•   Responses could assess changes to the carbon cycle that cause impacts to life on Earth on land, in the sea or in the atmosphere.

•   Effects of changes to the carbon cycle are likely to relate to changes in the carbon budget and could include:

-   Assessment of the melting of permafrost, acidification of the oceans, warming of the oceans, melting of sea ice, changes to ocean salinity, sea level rise (due to melting of ice on land or thermal expansion), or increased concentrations of atmospheric greenhouse gases and an enhanced greenhouse effect.

Whichever changes to the carbon cycle are included in the response there should be assessment that comes to a clear view as to whether these changes are in fact irreversible.

•   Responses could assess impacts for life on Earth that include assessment of impacts on:

-   marine life due to ocean acidification and ocean warming.

-   vegetation on land resulting from climatic changes due to atmospheric warming due to an enhanced greenhouse effect.

-   animal life on land resulting from direct and indirect climatic changes due to atmospheric warming due to an enhanced greenhouse effect.

-   humans may stem from the impacts noted on other areas of life on Earth, but they could also be reference to impacts relating to sea level rise.

Whichever impacts on life on Earth resulting from changes to the carbon cycle are included in the response there should be assessment that comes to a clear view on the extent to which these impacts are negative.

Responses should have clear assessment of whether the changes to the carbon cycle relating to human activity are irreversible AND that the impacts these have on life on Earth are negative.

•   Any view is acceptable, as long as it is supported with reasoned argument and illustrative examples and evidence.

Credit any other valid approach.

**Level 4 (16–20 marks)**

•   Detailed evaluative conclusion that is rational and firmly based on knowledge and understanding which is applied to the context of the question (AO2).

•   Detailed, coherent and relevant analysis and evaluation in the application of knowledge and understanding throughout (AO2).

•   Full evidence of links between knowledge and understanding to the application of knowledge and understanding in different contexts (AO2).

•   Detailed, highly relevant and appropriate knowledge and understanding of place(s) and environments used throughout (AO1).

•   Full and accurate knowledge and understanding of key concepts and processes throughout (AO1).

•   Detailed awareness of scale and temporal change which is well-integrated where appropriate (AO1).

**Level 3 (11–15 marks)**

•   Clear evaluative conclusion that is based on knowledge and understanding which is applied to the context of the question (AO2).

•   Generally clear, coherent and relevant analysis and evaluation in the application of knowledge and understanding (AO2).

•   Generally clear evidence of links between knowledge and understanding to the application of knowledge and understanding in different contexts (AO2).

•   Generally clear and relevant knowledge and understanding of place(s) and environments (AO1).

•   Generally clear and accurate knowledge and understanding of key concepts and processes (AO1).

•   Generally clear awareness of scale and temporal change which is integrated where appropriate (AO1).

**Level 2 (6–10 marks)**

•   Some sense of an evaluative conclusion partially based upon knowledge and understanding which is applied to the context of the question (AO2).

•   Some partially relevant analysis and evaluation in the application of knowledge and understanding (AO2).

•   Some evidence of links between knowledge and understanding to the application of knowledge and understanding in different contexts (AO2).

•   Some relevant knowledge and understanding of place(s) and environments which is partially relevant (AO1).

•   Some knowledge and understanding of key concepts, processes and interactions and change (AO1).

•   Some awareness of scale and temporal change which is sometimes integrated where appropriate. There may be a few inaccuracies (AO1).

**Level 1 (1–5 marks)**

•   Very limited and/or unsupported evaluative conclusion that is loosely based upon knowledge and understanding which is applied to the context of the question (AO2).

•   Very limited analysis and evaluation in the application of knowledge and understanding. This lacks clarity and coherence (AO2).

•   Very limited and rarely logical evidence of links between knowledge and understanding to the application of knowledge and understanding in different contexts (AO2).

•   Very limited relevant knowledge and understanding of place(s) and environments (AO1).

•   Isolated knowledge and understanding of key concepts and processes.

•   Very limited awareness of scale and temporal change which is rarely integrated where appropriate. There may be a number of inaccuracies (AO1).

**Level 0 (0 marks)**

Nothing worthy of credit.

**AO1 = 10, AO2 = 10**

**[Total 20 marks]**

Examiner reports

**Q3.**

The average mark was 3 for this question. The main issue holding back weaker responses was that many thought it was a AO3 skills question, rather than an application of knowledge AO1/AO2 question. For those responses, the challenges simply did not feature. Those responses that related the reduction of forest cover to a whole plethora of challenges around habitat loss, species diversity issues, soil related issues and climate challenges, readily scored marks and accessed Level 2.

**Q4.**

Many students seemed unprepared for this cross-specification question. They were asked to apply knowledge of the carbon cycle to causes of water stress. Many students found this very challenging. Many responses were very generic and did not use evidence in support. The best responses used examples of locations suffering water stress and were able to use their knowledge of the location to suggest how changes in the carbon cycle might affect the level of water stress. Teaching concepts through use of examples, certainly provides students more to develop in all exam questions. Weaker responses tended to focus on changes in the carbon cycle with simple links to increased evaporation or more droughts.

**Q5.**

This was the cross-specification question making links between CUE and the Water & Carbon cycles unit from 7037/1. Some students seemed unprepared for this type of questions and were unable to apply knowledge of carbon cycles to incineration and landfill means of waste management. Most students were able to make basic links to how both waste disposal systems create more carbon dioxide or other greenhouse gases, but only the best responses were able to link this to impact on the carbon cycle. Fast and slow cycles, carbon budgets, carbon sinks were rarely talked about – most students just made broad links to global warming at a global scale; The best answers often considered timescales with the idea of incineration causing quicker release of carbon and landfill release taking place over a much longer time. Many students knew some good examples of waste management such as AEB in Amsterdam and were able to evaluate the benefits of incineration over landfill disposal.

**Q6.**

This question was very accessible, scoring an average mark of 2.19. Most understand the concept of negative feedback with a clear definition. The typical approach was then to offer an example. Most went with the idea of increased carbon promoting vegetation growth and returning carbon to the biosphere. Other considered the role of phytoplankton in restoring the dynamic equilibrium of the carbon cycle. This was also valid.

**Q7.**

This question differentiated well overall. There was no significant issues with this question.

**Q8.**

This AO3 skills question proved challenging for many students. Where students were familiar with scatter graphs and logarithmic scales they generally scored well. A surprisingly low number of responses recognised the positive relationship between the two variables, or made links between the two figures to analyse change between the two years. The best answers supported their points with clear use and manipulation of data, whilst weaker responses simply lifted values from the graphs. Few went beyond basic description of the data, with very few using or manipulating the data in a more sophisticated manner. Other responses did not score well when they drifted into explanation or possible reasons for the changes in urban populations and CO2 emissions, this is AO2 and not valid in this AO3 question.

**Q9.**

This question combined both AO1 and AO2 elements. This expected students to make links beyond the Water and Carbon Cycles specification content. Students had to make an evidence-based assessment of the scale of changes to stores of carbon in their named tropical rainforest case study. This question proved accessible to many, and over 40% of students scored in Level 3. These high-level responses gave clear detailed support to the points made, with good use of specific illustrative material. Some weaker responses were limited by a lack of differentiation between the different states of carbon in different stores, and often simply referred to “CO2”, when it would have been more accurate to simply refer to carbon.

**Q19.**

Over 90% of the students accessed credit here but only around 17% scored full marks. The key to credit was in linking photosynthesis to the carbon cycle. Most achieved credit by outlining the fact that CO2 is taken in by plants, but few went further than this. Opportunities were missed to refer to carbon sinks and / or how the release of oxygen as a by-product of photosynthesis maintains the balance between carbon and oxygen in the atmosphere − this was a potential development mark.

**Q20.**

This was the first combined AO1 / AO2 based question. This meant that the thrust of the question did not lie explicitly stated in the specification. Students had to make an evidence based assessment as to whether storm events are likely to become more severe because of changes to the carbon cycle. Many argued that this was the case. This was due to increased temperatures caused by global warming, itself caused by increased CO2 emissions. The increased temperatures were argued to lead to increased sea temperatures and increasing likelihood of tropical storms. Others suggest increased evaporation would lead to increased storms due to the increased water vapour in the atmosphere. Although this approach did not deal particularly well with the notion of severity.

The average mark for this question was 4.3 suggesting students need more preparation in the application of knowledge to questions which do not arise explicitly out of one area of specification content.

**Q21.**

This was an accessible question with around 68% of students accessing 4 or more marks. Most students accessed the two marks for completing the graph. There were some who stopped their vertical line at 600 for living biomass rather than extending this to 800 carbon units as required i.e. they missed the cumulative nature of the exercise. Weaker analyses were repetitive or offered straight reversals of the same trend. These responses failed to manipulate data or consider more complex aspect of the trends e.g. tropical rainforest is the only ecosystem where biomass contains more carbon than soil stores.

**Q22.**

This question was not particularly well answered. There was ample scope to explore a range of issues related to the graphic presented. Some considered the potential unfairness of large wealthy countries pulling out of the *Paris Accord*. Others considered the challenges of ‘going green’ whilst also trying to develop economically. Others compared Russia, China and the USA in relation to their relative positions on the *Paris Accord*. Others did little more than lift data and present information which was already given. This was accepted as application of knowledge. In simple terms, for knowledge to be applied something new has to brought which is not presented in the data. Anything else is either description of analysis and not credited here under AO1 and AO2.

**Q23.**

This was a relatively straightforward question in terms of analysis of data. There were plenty of routes for students to explore − for example the rapid increase in emissions by upper middle income countries or the virtual no change data for low income countries and indeed, a slight decline. This was often accompanied by manipulation of data through minor calculations. Also, many responses looked to make an overarching statement i.e. that as wealth increased so did the production of GHG emissions. Some fell into the trap of explaining the changes. This constituted AO2 and was not credited on this question.

**Q24.**

This question combined both AO1 and AO2 elements. The question expected students to make links between two areas within the water and carbon cycles specification. Students had to make an evidenced assessment of any impacts to life on Earth resulting from natural changes to the carbon cycle. Many limited the credit available to them by making human impacts on the greenhouse effect and enhanced global warming the focus of their argument, rather than natural changes. A number of the better responses explored long-term change in the carbon cycle and the role of natural processes in controlling concentrations of carbon the atmosphere, which impacts on life on Earth by controlling temperatures. Others explored shorter-term impacts, for instance the impact on vegetation as carbon is transferred from biosphere stores to the atmosphere via wildfires.

The average mark for the question was 3.9 suggesting that students need more preparation in the application of knowledge to questions which require them to make links between different elements of the specification.

**Q25.**

This question proved accessible to most students with over two thirds accessing Level 2 and scoring 4 or more marks. Those achieving the highest marks made clear attempts to use and manipulate the data, for example giving estimations of the extent of change in emissions through use of the scale. Others showed careful use of the figures and gave specific map detail to support statements, for example that the UK was an anomaly with emissions decreasing by about a half over the period. A number of responses did not score well as they quickly drifted into explanation or possible reasons for the changes in emissions which is AO2 and not valid in this AO3 question.

**Q26.**

This proved straight forward with nearly all students correctly identifying option A as the correct answer.

**Q27.**

It was pleasing to see that so many students grasped the concept of positive and negative feedback. This is an integral part of the systems approach to physical geography. Many responses used the concepts well and understood the links to mitigation with good application. Even those who did not explicitly show understanding of feedback could still score credit if they were able to apply ideas around mitigation. These responses scored credit by implying knowledge and understanding without explicit reference to the terms. Less effective responses tended to recite just one case study (usually Amazonia), with a protracted narrative around human impact upon the forest. In such instances, it was hard to tease out material relevant to the thrust of the question.

**Q28.**

This question combined both AO1 and AO2 elements, expecting students to make links between two areas within the Water and Carbon Cycles specification. Students had to make an evidence based assessment of the relative importance of carbon sequestration and fossil fuel combustion on major stores of carbon. Many limited the credit available to them by not making stores of carbon the focus of their response. A number of the more effective responses made straightforward and clear links between the process and the store, providing evidence of how the processes both increased and decreased the amount of carbon in different stores. The most effective answers supported their points with some detailed evidence.

**Q29.**

The essay posed no major problems with most considering positive and negative feedback caused by modern agricultural practice, deforestation and use of agricultural machinery. It was good to see some consider the positive impacts of more sustainable farming practices on the carbon budget.