Topic 1 Water and carbon cycles

Water and carbon cycles as natural systems

A system is a type of geographical model that removes incidental detail to highlight fundamental relationships.

A system is an assemblage of interrelated parts that work together by way of some driving process. It consists of a series of stores or components that have connections between them. There are three types of property: **elements**, **attributes** and **relationships**.

A system has a structure that lies within a boundary. It functions by having inputs and outputs of material (energy and/or matter) that is processed within the components, causing it to change in some way.

The two main types of system used in physical geography are as follows:

- Closed systems, which have transfers of energy both into and beyond the system boundary, but where there is no transfer of matter.
- Open systems, where matter and energy can be transferred from the system across the boundary into the surrounding environment. Most ecosystems, for example, are open systems.

When there is a balance between the inputs and outputs, the system is said to be in a state of dynamic equilibrium. If one of the elements of the system changes, then the stores change and the equilibrium is upset. This is called feedback. There are two types of feedback: positive and negative.

Practice questions

1 Draw a labelled sketch of an example of a closed system in physical geography.

2 Complete Figure 1.1, using the following labels:

Component/Store Output Input Flow

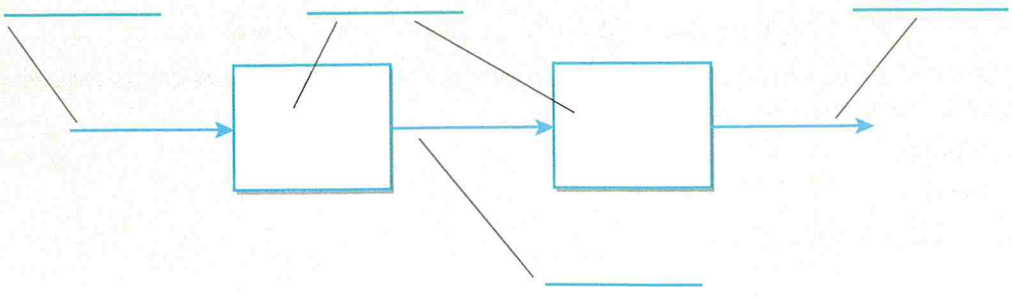


Figure 1.1 An open system

3 Starting with the box labelled 'Global temperature rise', annotate Figure 1.2 with the following labels:

- Carbon dioxide back into the atmosphere
- Warms the oceans
- More carbon dioxide in the atmosphere
- More carbon dioxide to act as a greenhouse gas
- Warm water less able to dissolve gas
- Increased oceanic temperatures
- Dissolved carbon dioxide released by warmer oceans

Give the figure a title.

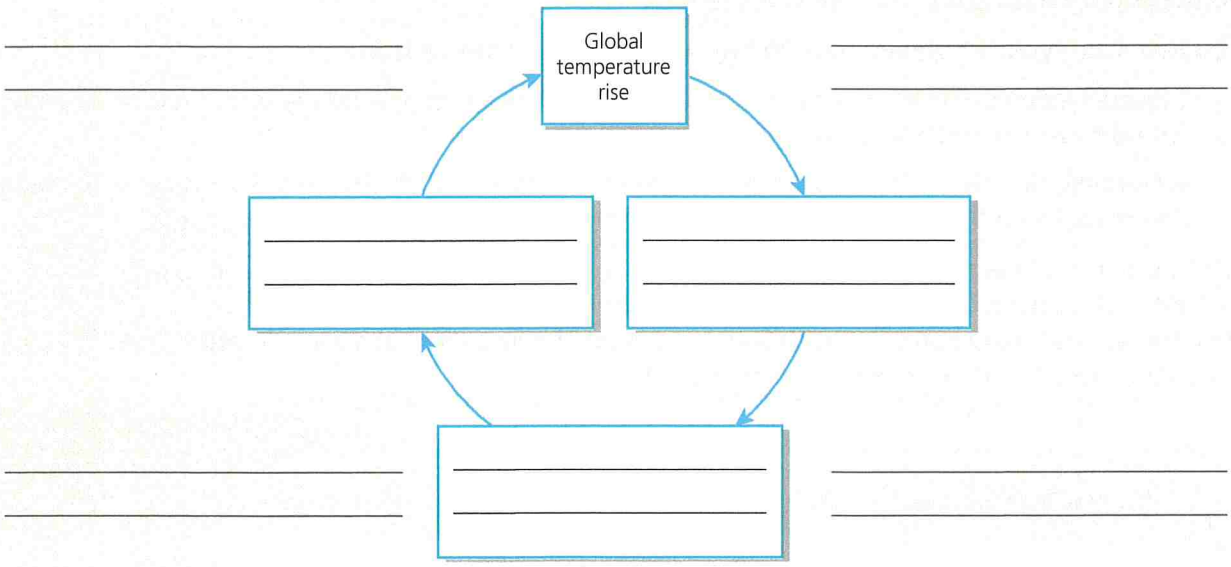


Figure 1.2

4 Complete the following paragraph by filling in the gaps with items from the list below.

Negative feedback

Following a rise in the _____, global carbon dioxide levels _____. This leads to a global temperature increase which, in turn, results in _____, meaning that there is an increase in the _____. This has a _____ and reduces _____.

List:

take-up of carbon dioxide increase dampening effect
use of fossil fuels increased plant growth global temperatures

5 Using an example, explain how a systematic approach can be applied to **one** of the following within a global systems framework:

- Flows of people
- Flows of money
- Flows of ideas and technology

The water cycle

Water exists on Earth in three forms: liquid water, solid ice and gaseous water vapour.

A drainage basin (or catchment area) is the area that supplies a river with its water. This includes water found below the water table as well as soil water and any surface flow. A useful way of looking at drainage basins is to consider them as cascading systems. These are a series of open systems that link together so that the output of one is the input of the next.

Within a drainage basin, the balance between inputs and outputs is known as the water balance or budget:

precipitation (P) = discharge (Q) + evapotranspiration (E) ± changes in storage (S)

River levels rise and fall, often showing an annual pattern (called the river's **regime**). They also vary in the short term following heavy rainfall. These short-term changes in river discharge can be displayed using a flood (or storm) hydrograph. Although all storm hydrographs have the same common elements, they are not all the same shape. Their shape is determined by both physical and human factors.

Practice questions

6 Using the data from Table 1.1, describe the distribution of the Earth's water.

Table 1.1

All water	%
Oceanic salt water	97
Fresh water	3

Fresh water	%
Cryospheric water	79
Groundwater	20
Easily accessible surface water	1

Easily accessible surface water	%
Lakes	52
Soil	38
Atmosphere	8
Biomass	1
Rivers	1

.....

.....

.....

.....

.....

7 Figure 1.3 shows how water moves about a small drainage basin and the nearby ocean. Using Table 1.2, complete Figure 1.3.

Table 1.2

Inputs	Stores	Transfers	Outputs
Precipitation onto land	Lakes and surface water	Overland flow	Evaporation and transpiration from vegetation
Precipitation onto the sea	River channel	Channel flow	Evaporation from water surfaces
	Interception by plants	Infiltration	Runoff from the river
	Soil water	Percolation	Evaporation from the sea
	Groundwater	Throughflow	
		Groundwater flow	
		Throughfall/Stemflow	

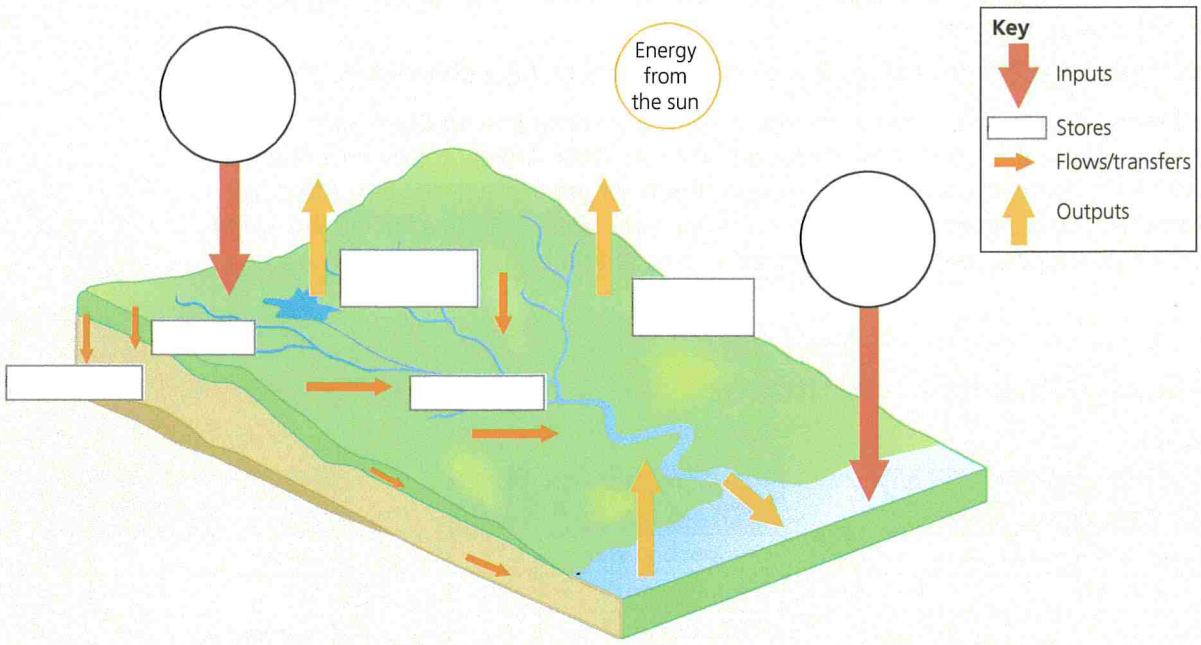


Figure 1.3 The drainage basin hydrological cycle

8 Describe the different ways that water can enter a river channel.

.....

.....

.....

9 Describe each of the following processes as they apply to the water cycle:

a Evaporation

b Condensation

10 Clouds are formed when air is cooled, usually by rising through the atmosphere. Identify the ways in which air can be uplifted and explain the resultant processes that then form clouds and eventually rain.

Worked example

There are three common ways in which air is caused to rise through the atmosphere. First, it can happen when there is a front: where two air masses of different temperatures and densities meet. The warmer, less dense air rises over the colder air. Second, air can be forced to rise over high land. Third, hot land surfaces can heat up local masses of air and cause them to rise by convection.

Knowledge (AO1): Good summary of the way in which air is forced to rise.

Air expands as it rises. As it does so, it cools down. As the air cools, its ability to hold water vapour is reduced and its relative humidity rises until it is saturated. This is called the dew point temperature and is the point at which condensation begins to occur and cloud droplets are formed.

Knowledge (AO1): This describes the processes that occur as air rises.

Coalescence of these droplets causes the growth of raindrops.

Knowledge (AO1): This links the answer to the final part of the question.

11 Complete Figure 1.4 using the following labels:

Bankfull discharge Rising limb Storm flow Peak rainfall Peak discharge
Base flow Lag time Recession limb Flood water Rainfall event

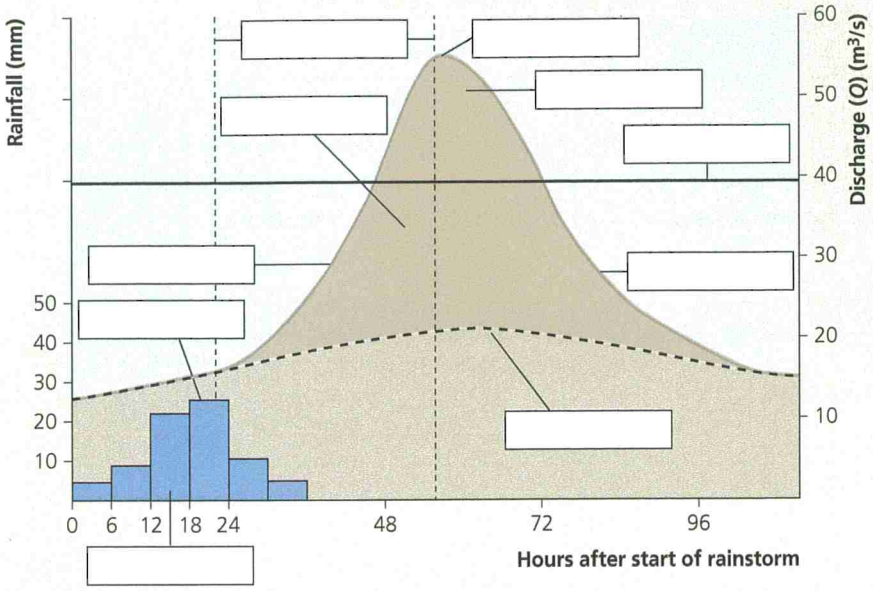


Figure 1.4 A storm hydrograph

12 For **two** named physical factors, outline how they might change the shape of a storm hydrograph.

Physical factor 1 .....

.....

.....

.....

.....

Physical factor 2 .....

.....

.....

.....

.....

13 For **two** named human factors, outline how they might change the shape of a storm hydrograph.

Human factor 1 .....

.....

.....

.....

.....

Human factor 2 .....

.....

.....

.....

.....

14 Analyse the seasonal flow of the River Avon, Bath, as shown in Figure 1.5.

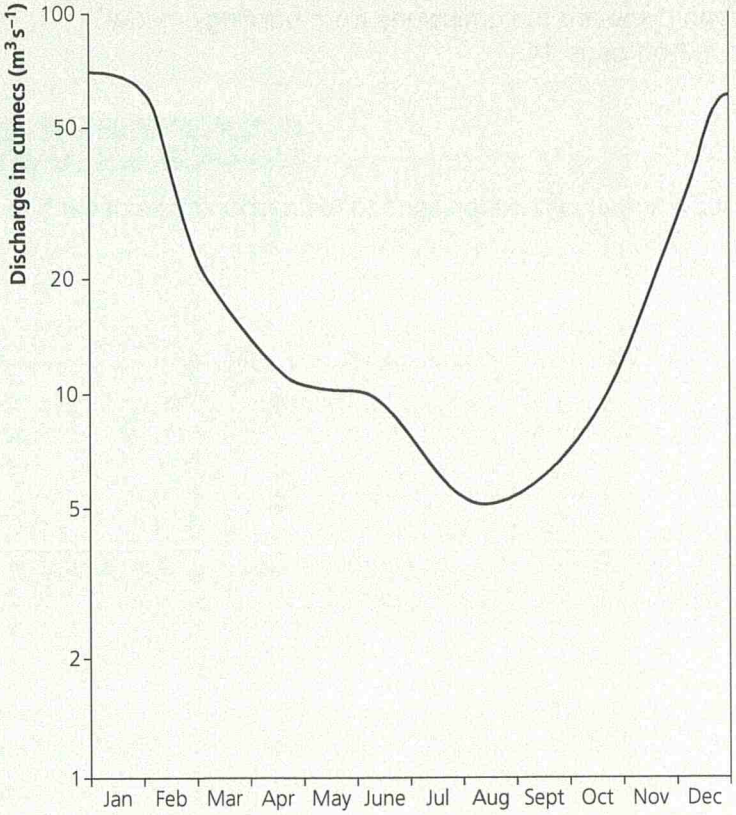


Figure 1.5 Annual flow of the River Avon, Bath

.....

.....

.....

.....

.....

.....

The carbon cycle

Carbon forms more compounds than any other element and scientists believe that there are more than 10 million different carbon compounds in existence today on Earth. It is found in all life forms in addition to sedimentary rocks, diamonds, graphite, coal and petroleum (oil and natural gas).

The global carbon cycle is the pathway by which carbon moves through the Earth system, including the land, oceans, atmosphere and biosphere. Some components of the Earth system, such as the oceans and land, at times act as stores of carbon by storing it for long periods, and at other times act as carbon sources by releasing it back into the atmosphere.

Of growing importance in the global carbon cycle are the emissions from burning hydrocarbons. These are shown in Table 1.3 on page 14.

Practice questions ?

15 Describe the chemical make-up, occurrence, and importance to the carbon cycle of each of the following:

a Carbon dioxide (CO_2)

.....

.....

.....

b Calcium carbonate ($CaCO_3$)

.....

.....

.....

c Liquid petroleum

.....

.....

.....

16 Describe the following processes. For each one, suggest how it fits into the carbon cycle.

a Photosynthesis

.....

.....

.....

.....

.....

b Respiration

c Decomposition

17 Define the term 'weathering'. Outline the role it plays in the carbon cycle.

18 Complete the graph in Figure 1.6 from the data in Table 1.3. You must label the axes and plot the data.

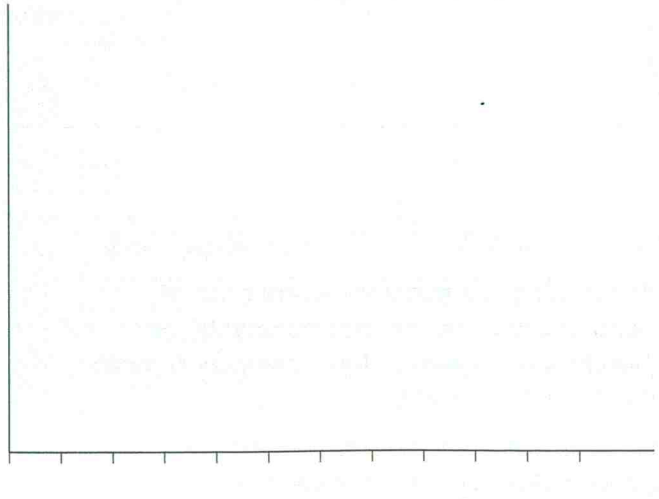


Figure 1.6

Table 1.3 Global carbon emissions from fossil fuels, 1900–2010

Year	Global carbon emissions in millions of metric tonnes of carbon
1900	600
1910	850
1920	1,000
1930	1,100
1940	1,300
1950	1,600
1960	2,600
1970	4,050
1980	5,300
1990	6,100
2000	6,850
2010	9,200

19 Describe the changes in the amount of global carbon emissions as shown in Figure 1.6. What effect could this have on the Earth's climate?

Worked example

In the 110 years between 1900 and 2010, global carbon emissions rose continually so that by the end of the period they were just over 15 times what they were at the beginning. The rise was slow up until 1940 and then they rose rapidly, only slowing down slightly between 1980 and 2000. The most rapid growth of 2,350 mmt was between 2000 and 2010.

Skill (AO3): General trend of changes identified from graph.

Skill (AO3): Accurate use of the graph for more precise description.

The impact of this on global climate could be serious. Carbon emissions are mainly in the form of greenhouse gases. Their build-up in the atmosphere means that they trap outgoing heat radiation from the Earth and cause an atmospheric temperature increase. This is spread around the Earth by winds, tropical storms and ocean currents.

Skill (AO3): Use of the data to draw conclusions. In this case, there is a link between the cause and the effects.

This influences the global pattern of climate. Polar areas will warm up. Trade winds will weaken. Tropical storms will get scarcer, but more intense and longer-lasting. Equatorial areas may become drier while tropical areas will experience longer periods of drought.

Skill (AO3): Some aspects of global climate change identified.

Water, carbon, climate and life on Earth

Without water and carbon, life on Earth would not be possible. Every drop of water cycles continuously through air, land and sea, being used constantly by components within the cycle. Carbon bonds with oxygen to form complex organic compounds that contribute to the existence of living matter.

In the long term, the balance in the amount of carbon in the main global stores (the lithosphere, hydrosphere, biosphere and atmosphere) remains more or less the same. Recent, rapid changes in atmospheric carbon are affecting not only the climate but also the amount of carbon available for plants.

Concerns over the effects of rising atmospheric carbon have led to attempts to reduce or prevent carbon dioxide emissions. These include:

- the development of industrial and power generation processes with reduced emission of greenhouse gases (e.g. solar power generation)
- attempts to capture and store any emissions that do occur, preventing carbon dioxide from returning to the atmosphere (carbon capture and storage, or CCS)

These are collectively known as climate change mitigation.

Practice questions

20 Using an example (e.g. the UK), describe one national strategy to reduce carbon emissions in the power generation industry. Assess the success of this policy.

21 Assess the extent to which **one** of the following human interventions in the carbon cycle has been successful in the mitigation of the impacts of climate change:

Carbon capture and storage **or** Changing agricultural practices **or** Improved aviation practices

Exam-style set 1

5

1 Outline **two** ways in which water flows through a drainage basin. (AO1) **4 marks**

.....

.....

.....

.....

.....

.....

2 Table 1.4 shows data produced by the US National Oceanic and Atmospheric Administration (NOAA). Complete the table and calculate the Spearman's rank correlation coefficient (R_s) using the formula provided. Interpret your answer using the information provided. (AO3) **6 marks**

7

Null hypothesis: There is no relationship between global temperature change and average atmospheric carbon dioxide.

Table 1.4 A comparison between global temperatures and average atmospheric carbon dioxide

Year	Average atmospheric temperature compared with long-term average temperature [1900–2010]/°C	Rank R_1	Average CO_2 measured at Mauna Loa Observatory, Hawaii/ppm	Rank R_2	Difference in ranks, d	d^2
1970	0.1	10	328	11	–1.0	1.0
1975	0	11	330	10	1.0	1.0
1980	0.3	8	338	9	–1.0	1.0
1985	0.2	9	346	8	1.0	1.0
1990	0.45	6	353	7	–1.0	1.0
1995	0.5		361			
2000	0.4	7	369	5	2.0	4.0
2005	0.7	3.5	379	4	–0.5	0.25
2010	0.7	3.5	390	3	0.5	0.25
2015	0.9	2	401	2	0	0
2019	1.0	1	415	1	0	0

$$R_s = 1 - \left(\frac{6 \sum d^2}{n^3 - n} \right)$$

where R_s is the Spearman's rank correlation coefficient, n is the number of variables and d is the difference in the ranks of the variables.

For 11 pairs of variables, the critical values for R_s are ± 0.536 at the 5% significance level and ± 0.755 at the 1% significance level.

$\sum d^2 =$ _____ $R_s =$ _____

3 Using a completed version of Figure 1.2 (page 6) and your own knowledge, explain how changes in the carbon cycle over time may have an impact on global climate. (AO1, AO2) **6 marks** 7

4 As part of your course you have studied a drainage basin at a local level. Assess the impact of precipitation upon the water stores and transfers in that drainage basin and evaluate the extent to which it affects both a sustainable water supply and flooding. (AO1, AO2) **20 marks** 25

Plan and write your answer on a separate sheet of paper and keep it with your workbook.

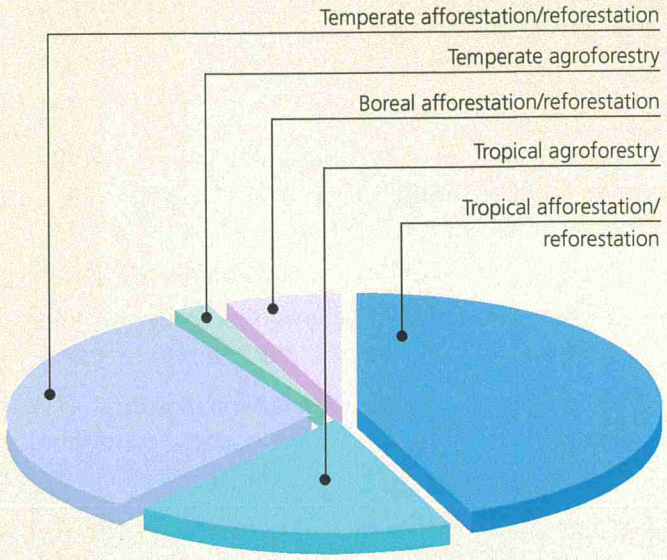
Exam-style set 2

1 Explain the concept of negative feedback in relation to the carbon cycle. (AO1) **4 marks** 5

2 Study Figure 1.7. Analyse the varying potential for global carbon sequestration from different types of forestry management, 1995–2050. (AO3)

7

6 marks



Total carbon sequestration potential 38 Gt

Figure 1.7 Potential contribution of afforestation/reforestation and agroforestry activities to global carbon sequestration, 1995–2050

3 Figure 1.8 shows the predicted change in global rainfall intensity by the end of the twenty-first century. Using Figure 1.8 and your own knowledge, assess the extent to which this change is evenly spread globally. (AO1, AO2)

7

6 marks

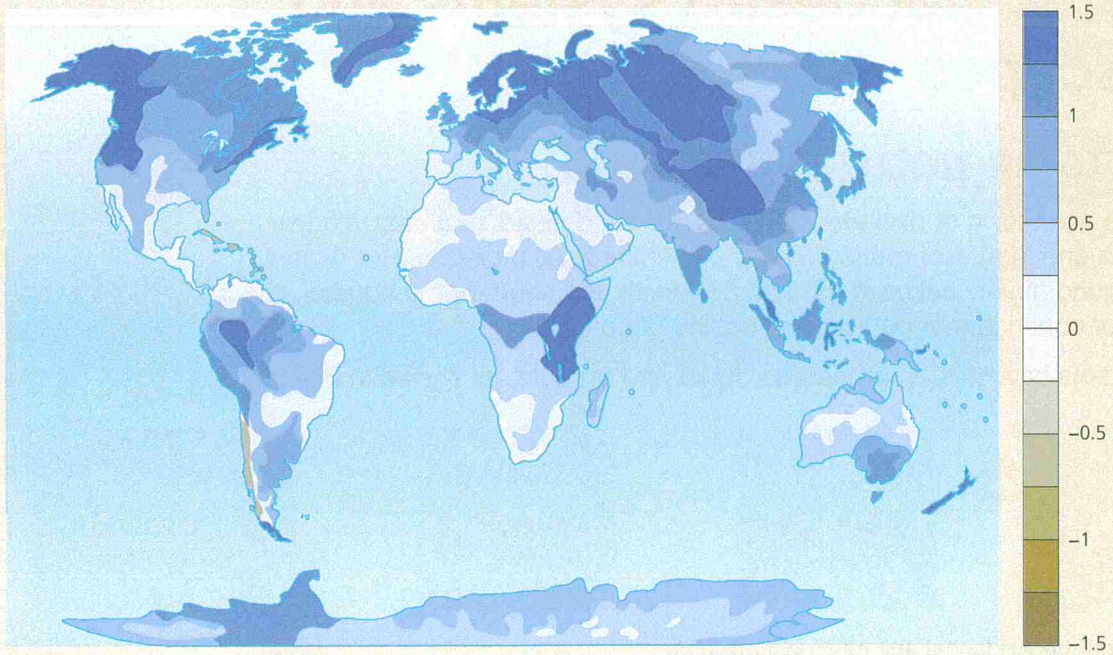


Figure 1.8 The predicted change in rainfall intensity by the end of the twenty-first century

4 'Human intervention is now the only way to mitigate the impacts of climate change.'

Using examples, assess the extent to which you agree with this statement. (AO1, AO2) **20 marks** 25

Plan and write your answer on a separate sheet of paper and keep it with your workbook.

Additional extended prose questions

Plan and write your answers on separate sheets of paper and keep them with your workbook.

1 Assess the extent to which the emergence of laws and institutions designed to regulate global systems has influenced carbon transfers and helped to mitigate the impacts of climate change. (AO1, AO2) **20 marks** 25

2 'Natural variations over time have a greater impact than human activity on changes in the water cycle.'

To what extent do you agree with this statement? (AO1, AO2) **20 marks** 25