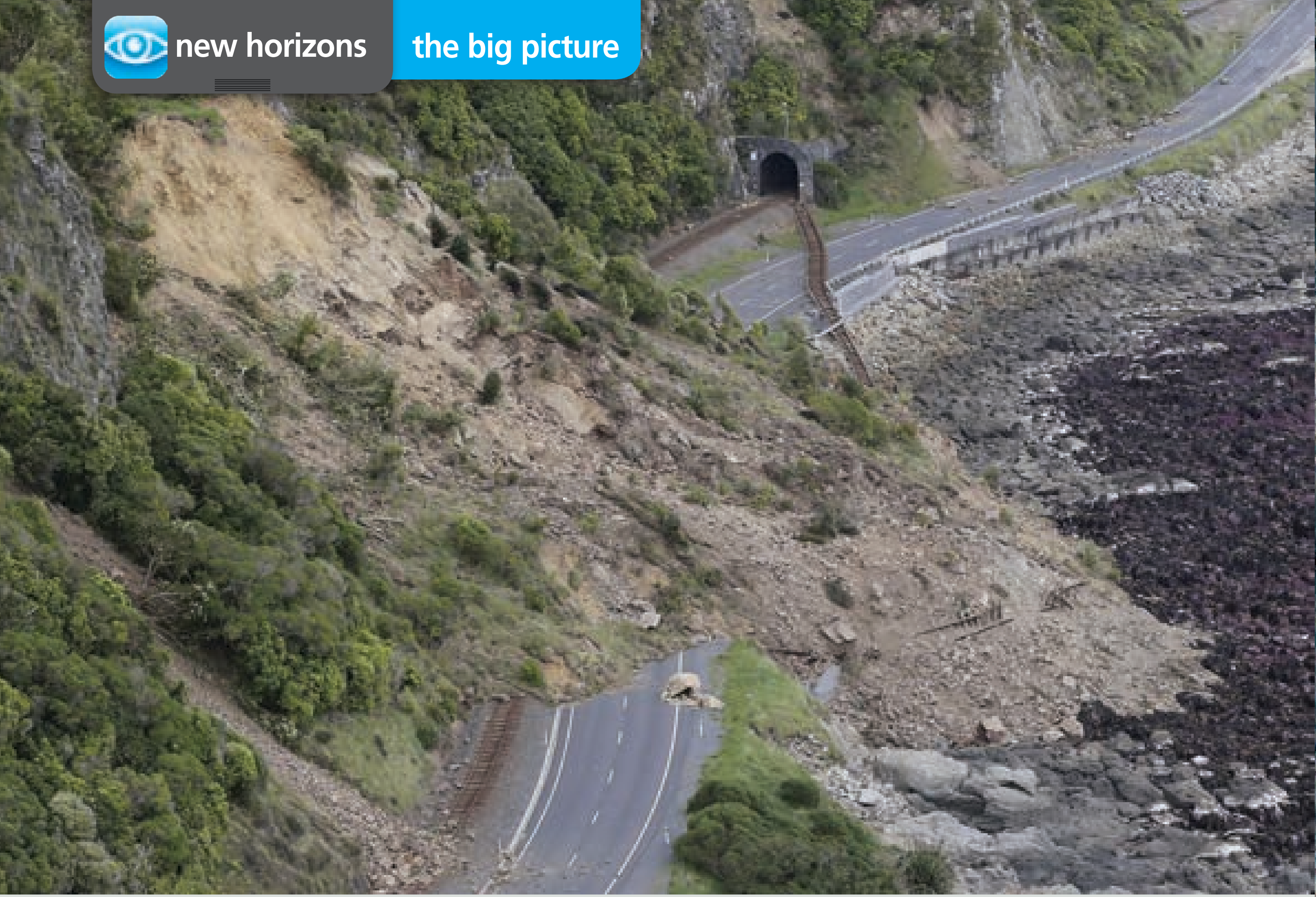

How landscapes respond to tectonic processes

On 14 November 2016 the South Island of New Zealand was hit by a magnitude 7.8 earthquake — one of the most powerful recorded in this region. The geomorphological expression of this event was spectacular. In the days that followed, newspapers around the world showed graphic images of huge ground cracks, uplifted marine platforms, mass movements on hillslopes, and lateral shifts of land. The photograph shows a major landslide that damaged the railway and blocked State Highway 1 on the east coast of South Island, cutting off the town of Kaikoura.

GeoNet is the official source of geological hazard information for New Zealand — its web pages provide a rich source of data on the Kaikoura earthquake (**www.geonet.org.nz**). This earthquake has been documented in great detail and provides a fascinating case study of how landscapes can respond to tectonic processes at a range of scales. Between 80,000 and 100,000 landslides were triggered by the earthquake. Some of the largest landslides blocked valleys and dammed rivers, creating the secondary geohazard of dam burst flooding.

Field surveys reported major ruptures on at least six faults and one of these, the Kekerengu Fault, moved more than 10 m. New Zealand has a network of GPS stations that monitor ground movements and GeoNet reported some remarkable data. Cape Campbell — the northeast tip of the South Island — is now more than 2 m closer to the North Island than it was before the quake. An intensive progamme of data analysis and modelling is underway so that we can better understand both earthquake hazard and landscape evolution in this region.

Jamie Woodward is professor of physical geography at The University of Manchester and an editor of Geography Review.

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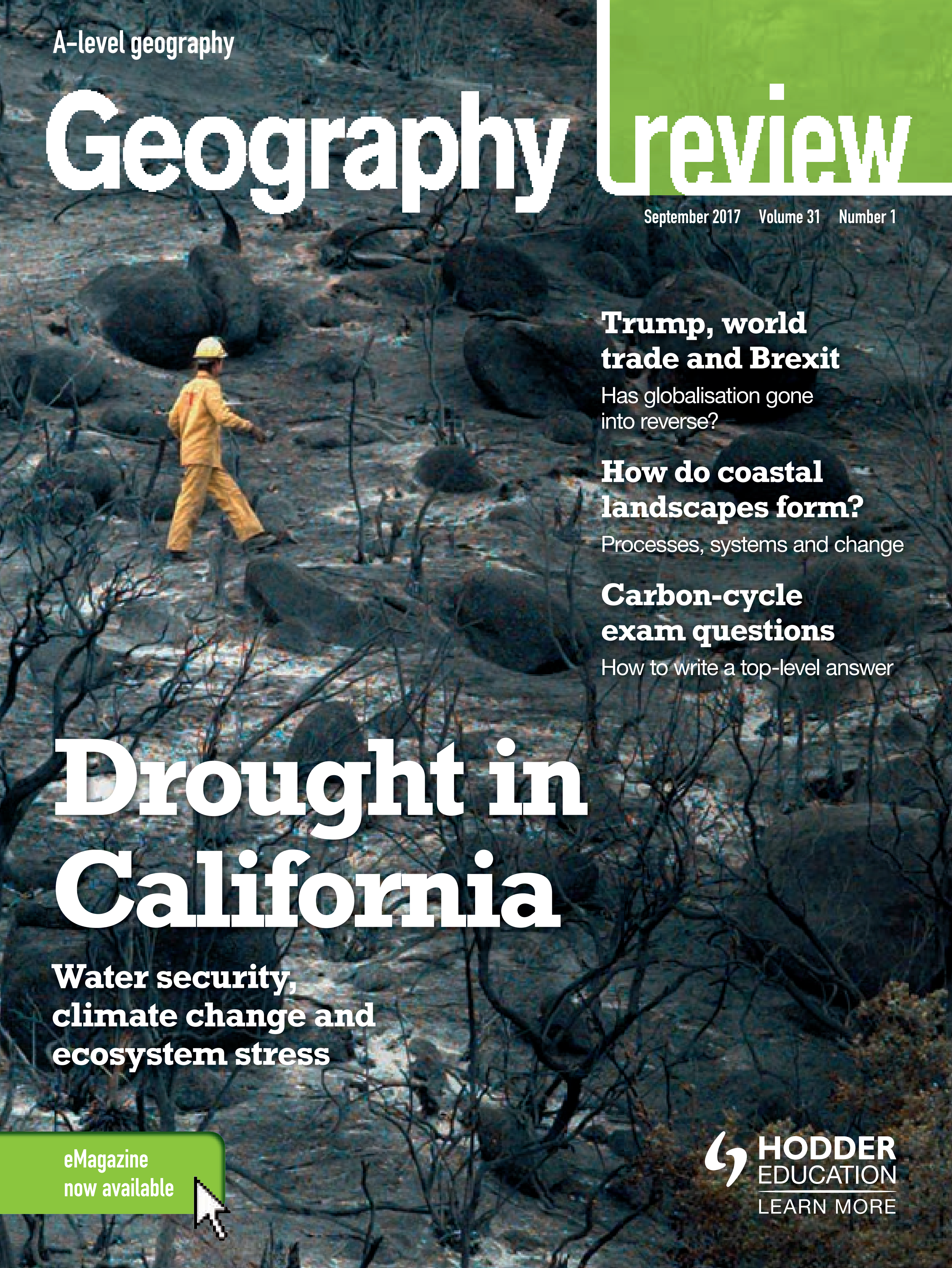

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September 2017 Volume 31 Number 1

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Sarah Woodroffe

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This article provides a clear summary of the processes that create coastal landscapes, and looks at the threats posed by sea-level change. It ends with a case study from the USA of a coastal landscape system under constant erosional change

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For a quiz to test your knowledge of coasts go to: www.hoddereducation.co.uk/geographyreviewextras

Coasts are intensely settled areas. About 40% of the world's population lives within 100 km of the coast, and two thirds of the world's largest cities have coastal locations. Development in coastal areas is often faster than overall national development. It is predicted that, by 2100, around 600 million people will occupy coastal floodplain land below the elevation flooded by a 1,000-year return-interval flood.

Understanding **coastal landscapes**, the hazards that exist at the coast and how these will change through time is therefore important. Natural processes such as wave action, flooding, storm surges, coastal erosion and sedimentation can pose hazards to human occupation and use of the coast. However the single most important factor that will cause future coastal change is sea-level rise (see Box 1 and Figure 1). The way that sea-level rise impacts individual coasts depends on the type of coastal landscape and the different processes taking place in that location.

Limestone cliffs at Vouliagmeni, near Athens, Greece. Two tidal notches can be seen, caused by changes in sea level over the past few thousand years due to tectonic activity

Coastal processes

There are three main processes which affect all coasts and determine the **coastal morphology**. These are sea-level changes, waves and currents, and coastal sediment transport.

Sea-level changes

Sea-level changes can occur at intervals from hours to millennia. The shortest variation in sea level is caused by tides. Tides are produced by the gravitational force of the moon and the sun, which cause highs and lows on a daily cycle. Over days to years fluctuations are caused by storm surges, seasonal variations in pressure and changes in weather patterns caused by cycles such as the El Niño Southern Oscillation.

However the most important time scale of sea-level changes for determining coastal morphology is over thousands to millions of years. Ice-sheet growth and decay over many glacial cycles has caused dramatic changes in sea level and has shaped our present-day coastlines. At the last glacial maximum (the peak of the last ice age, 20,000 years ago), global sea level was about 130 m below present. Most of the world's coasts have experienced drowning due to sea-level rise since this time. For example as sea level rises, river valleys discharging into the sea become flooded by long fingers of sea extending upstream, known as rias.

Waves and currents

Over much shorter time scales wind-generated waves and currents are the most important energy input into the coastal zone and are responsible for coastal erosion and sediment transport. The height, length and period of waves increases with wind speed and with the length of time and distance over water that the wind blows. The stormiest parts of the

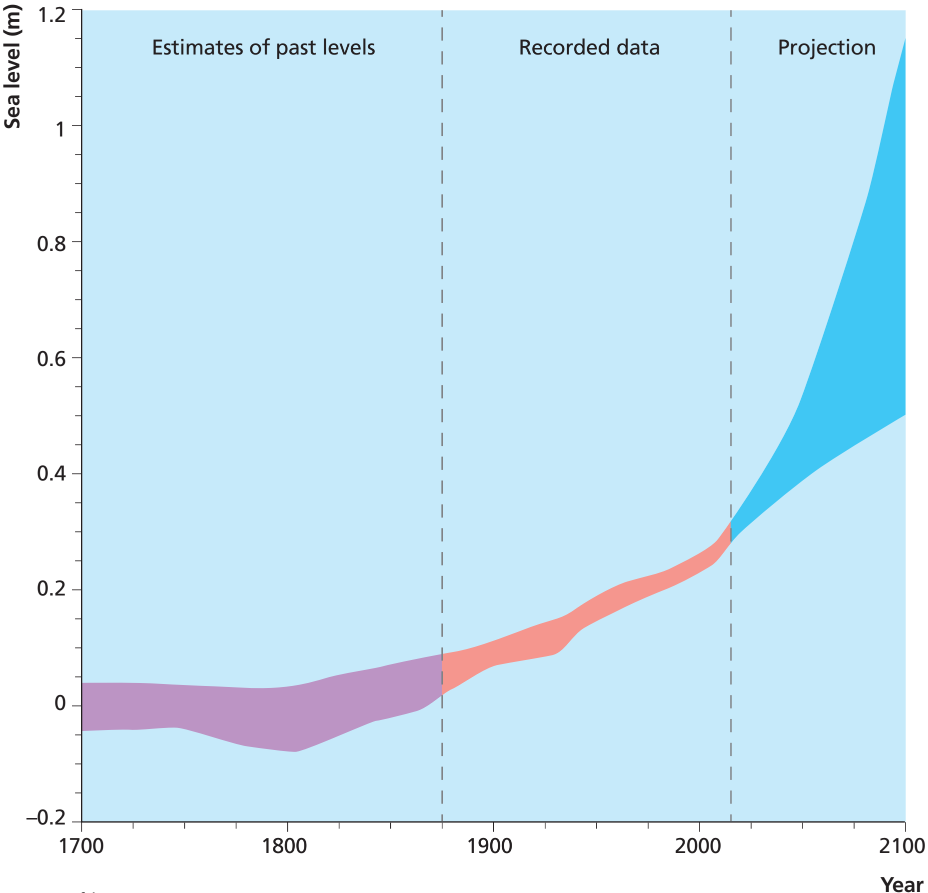
Glossary

Coastal landforms Individual features of the coast such as beaches, dunes, estuaries, cliffs and shore platforms

Coastal landscapes The broad-scale visible features of the coast.

Coastal morphology An intermediate between landforms and landscapes which describes an assemblage of landforms at the coast.

Coastal systems The morphology of the coast plus the processes that cause change.



Source: Fifth IPCC report

Figure 1 Rise in sea level relative to pre-industrial levels, projected for low and high greenhouse-gas emission scenarios

Box 1 Global sea-level rise

Current rates of global sea-level rise are measured by satellite altimeters which accurately record changes in the height of the sea surface over time. Globally, average sea level is rising by 3.4 mm y^{-1}. The Intergovernmental Panel on Climate Change (IPCC) uses models to predict what will happen to sea level in the future. These predict a globally averaged sea-level rise of between 28 and 98 cm between 2014 and 2100 depending on greenhouse-gas emissions between now and then (Figure 1). These figures are global averages, so sea-level rise will vary from one location to another. Note that Figure 1 shows sea-level rise since 1700. It is already around 30 cm above this baseline.

world (e.g. the roaring forties at 40° north and south) have the largest waves and therefore the most energetic coastal environments.

Nearshore currents get their energy from waves breaking. If waves break obliquely to the shore the current will run along the coast, carrying sediment with it. Longshore or littoral drift has a major effect on present-day coastal morphology and causes changes to beaches, bars and spits over hours to decades.

Sediment transport

Erosion, transport and deposition of sediment also determines the present-day morphology of the coast. Sediment is either eroded by waves and currents or brought to the coast by rivers. Coarse sediment is moved alongshore by high-energy waves and currents (longshore drift) and deposited as beaches and bars. Fine sediment moves under lower energy conditions and is deposited in quiet water in estuaries, bays and lagoons, forming mudflats, salt marshes and mangroves.

Coastal landforms

The processes described above produce **coastal landforms** and morphology. There are five main types of landforms found at the coast.

Rocky coasts

Coastal cliffs occur along approximately 80% of the world's coastline. Changes to their morphology occur relatively slowly and sporadically. Most change occurs due to mass movements, such as rockfalls and landslides. Mechanical wave action at the toe of cliffs is the main erosional process in stormy locations where waves are large. Eroded material is removed by waves and littoral drift, leaving a shore platform in the intertidal zone

Spectacular coastal features such as stacks, arches and sea caves are formed by mass movements, particularly where there are differences in the resistance of the rock strata. More resistant rock is left as stacks standing offshore, while the removal of less resistant rock forms sea caves and blow holes.

Beaches and sand dunes

Beaches and sand dunes are part of most coastal landscapes. Sand or gravel from offshore is deposited by waves. There can be a seasonal cycle of beach change, with a steep, well-nourished beach in summer and a flatter eroded beach in winter. Behind the

Beach and coastal dune complex, Poços de Barbaroxa, Portugal

Further reading

Google maps is a great tool for looking at coastal morphology anywhere in the world (don't forget to turn on the 'earth' function for high resolution satellite imagery).

US Geological Survey, *Coasts in Crisis*: **http://pubs.usgs.gov/circ/c1075/** Covers different types of coasts, coastal change and coastal management in detail.

University of Colorado Sea Level Research Group: **http://sealevel.colorado.edu** Up-to-date information on rates of sea-level rise and the different processes responsible.

North Carolina Coastal Hazards Decision Portal (NC COHAZ): **www.coastal.geology.ecu.edu/NCCOHAZ/** Coastal hazards information portal for the Outer Banks with information on the main hazards and links to reports on the state of the coast.


Mangrove creek, Seychelles


Saltmarsh, southwest Greenland

beach may be coastal dunes. They require consistent onshore wind and a large supply of sand to form. Well-developed dune systems act as a buffer to storms and prevent coastal flooding. Dunes eroded by storms are able to rejuvenate during calm conditions when sediment is brought back onshore by waves.

Salt marshes and mangroves

In low-energy environments such as estuaries and behind barriers salt marsh or mangroves can develop in the upper part of the intertidal zone. Salt marsh consists of salt-tolerant grasses and reeds and is confined to temperate latitudes. In the tropics salt-tolerant trees, collectively known as mangroves, are found instead. Sedimentation rates in salt marshes or mangroves can be so fast that sediment surface can grow upwards faster than current rates of sea-level rise.

Salt marshes and mangroves often occupy valuable coastal land that is reclaimed and redeveloped into farm land, locations for coastal industry or hotel complexes. However they provide a natural coastal buffer to sea-level rise and should be more widely protected.

Coral reefs and atolls

Coral reefs form where the sea is warm (continuously above 18°C) and shallow. Reefs grow from the build-up of large amounts of coral, which secretes calcium carbonate, bonding the coral and other organisms together into a wave-resistant body of limestone.

Coral reef islands (atolls) are formed in the deep ocean around old volcanoes which have subsided through time. The coral builds up on the shoulders of the volcano to form a concentric ring of islands. The volcanic crater in the centre may have long since subsided below the surface of the ocean, forming a lagoon.

Reefs also form in shallow tropical seas and have kept pace with sea-level rise which has progressively flooded the platform. The Great Barrier Reef in northeast Australia is a good

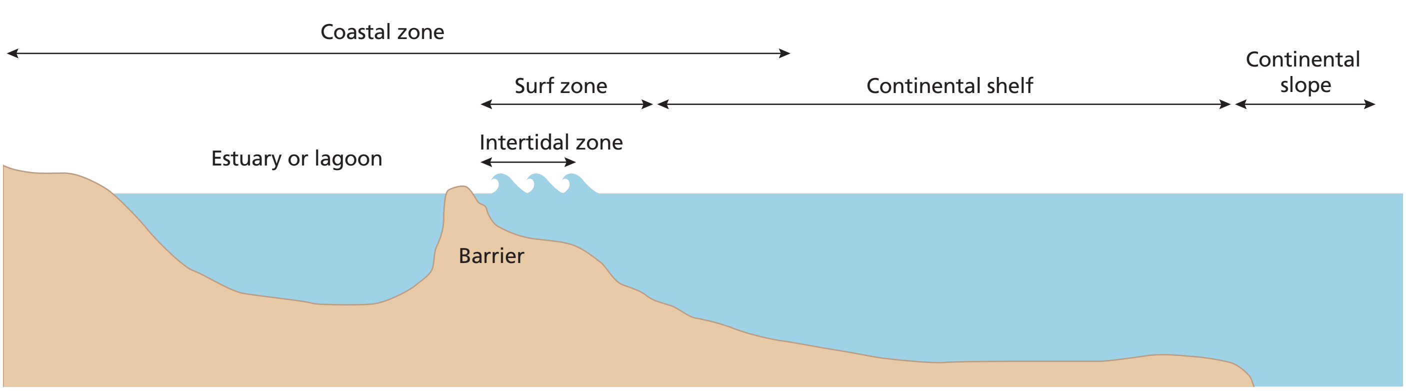


Figure 2 Cross section showing the coastal zone

example of a reef structure on the shallow continental shelf that has kept pace with sea-level rise since the last glacial maximum.

Coastal barriers

Coastal barriers constitute 15% of the world's coastlines. They are really coastal landscape systems rather than landforms, as they contain a series of different landforms including beaches and salt marshes. They consist of long, sandy islands that parallel the coastline, with beaches on their seaward side and salt marshes on their landward side. The protected area between the barrier island(s) and the mainland is called a lagoon (see Figure 2).

They are most common where there is a low gradient continental shelf, abundant sediment supplied from offshore or by littoral drift, and where tidal energy and tidal range are low. The east coast of the USA has a high concentration of barrier systems (totalling 3,100 km) owing to the availability of abundant sand-sized sediment from erosion of the Appalachian mountains.

Coastal barrier case study: the Outer Banks

The Outer Banks is a 300 km string of sandy barrier islands on the coast of North Carolina, USA (Figure 3). It has formed during sea-level rise since the last glaciation. The position of these islands jutting out into the Atlantic means they are often in the path of storms and hurricanes, which move sand onshore from sub-tidal shoals. This coastal system needs sediment to be able to move onshore and to be deposited in deltas just inside the lagoon which build up to become new islands over time (Figure 4).

The islands are a major tourist destination, receiving 2.3 million visitors per year because of opportunities for fishing, water sports and 'ocean-side' holiday rentals. Highway NC12 was built in the 1950s to encourage tourism by linking the islands north of Cape Hatteras together. This has had a detrimental effect on natural coastal processes. Because there are few inlets into the lagoon, sand can't be deposited and island-building has stopped. The islands have narrowed and erosion of the highway and ocean-front residential areas is a constant problem. The government spends millions of dollars each year nourishing beaches, building dune ridges and deploying sand bags to hold the coastline in place. Is

Figure 3 Aerial view of the Outer Banks showing the barrier islands and major inlets

A dune field built to protect highway NC12 on the Outer Banks. The beach on the left is the open coast and the water to the right is Pamlico Sound. At this point the barrier island from the top of the beach to the salt marsh in the lagoon is only about 100 m wide

'Ocean-side' properties at South Nags Head on the Outer Banks. Because of coastal erosion these properties were in the surf zone in 2008 when this photograph was taken but were still being offered as vacation rentals so long as their septic tanks were still connected. By 2016 they had been condemned and demolished

this approach sustainable in the long-term, especially under future sea-level rise?

What is the solution?

If coastal management was stopped and the coastal highway was breached, the barrier islands would rejuvenate naturally as storms brought sand from offshore. The continuous barrier would probably break up into a series of larger barrier islands with inlets between them which could be marketed as destination villages linked by high-speed ferries. However local people argue that ferries couldn't keep pace with the number of visitors wanting access to the islands. They prefer to continue with expensive beach nourishment projects which are paid for by local taxes.

The future of the Outer Banks is uncertain, but the cost of artificially maintaining the area with a continuous highway will continue to increase, as erosion and island narrowing are intensified by sea-level rise.

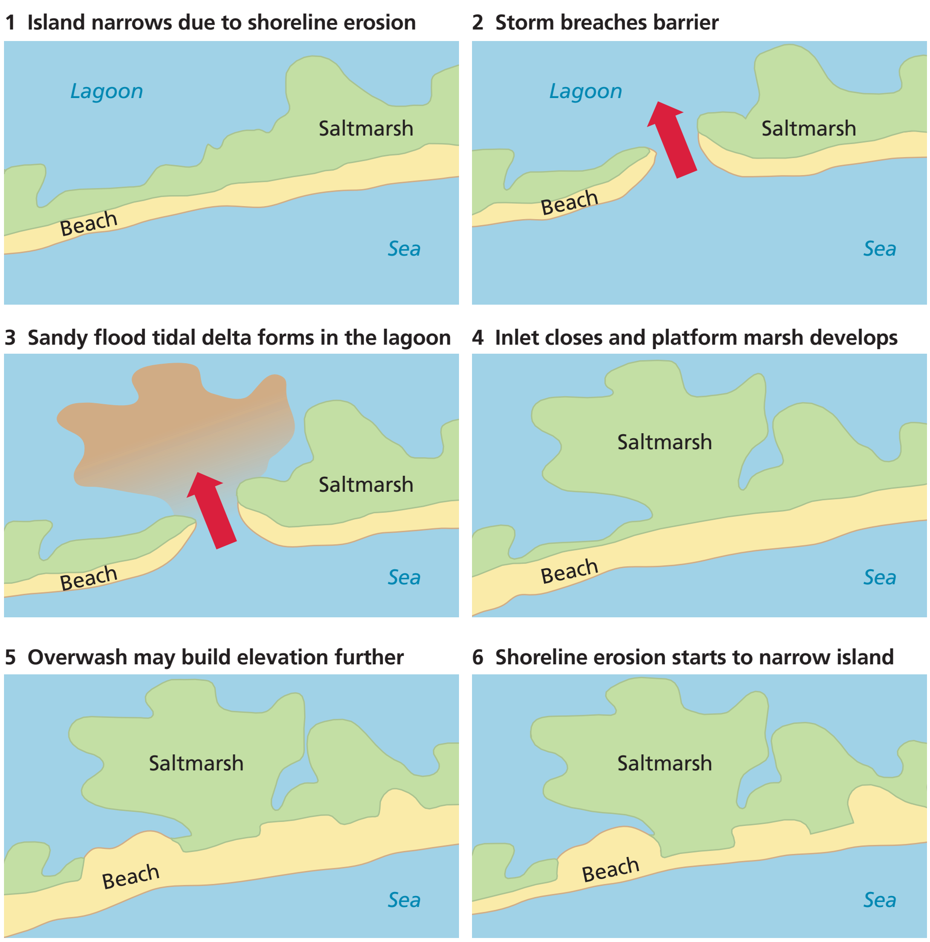
Questions for discussion

1 What are the main factors controlling coastal cliff erosion?

2 Under what conditions do barrier-island coasts form? What are the typical features of this type of coastline?

3 Why will sea-level rise in the twenty-first century not be the same everywhere?

4 What are some of the problems with using hard engineering structures for coastal protection?



Source: North Carolina Coastal Geology Cooperative Research Program

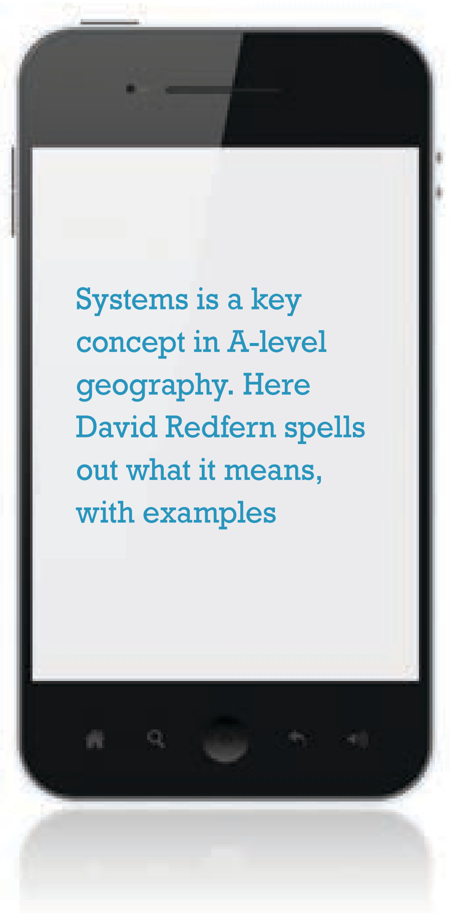
Figure 4 Successional stages during barrier inlet and barrier island evolution

Dr Sarah Woodroffe is a senior lecturer in physical geography at Durham University. Her interests are in sea-level changes over the past few thousand years in tropical mangrove environments and saltmarshes in the Arctic, and what these can tell us about the amount and rate of melt from the polar ice sheets through time.

Key points

- Coastal landscapes are made up of a series of landforms.
- The dominant processes acting on global coastal landscapes are sea-level changes, waves and currents, and sediment transport.
- Sea-level changes since the last glacial maximum have shaped the overall coastal landscape while waves, currents and sediment transport act at smaller and shorter scales.
- Coastal cliffs make up 80% of the world's coastline but change occurs here slowly and sporadically.
- Coastal barriers make up 15% of the world's coastline. Barriers are really coastal systems that contain beaches, sand dunes, salt marshes and lagoons.
- In the tropics coral atolls form in the deep ocean around subsiding volcanoes. They are relatively rare but have a spectacular morphology.

Systems and equilibrium



How many students in your class own a smartphone? When you take delivery of a new phone it comes pre-loaded with various programs that allow it to operate. It may also have a few standard applications (apps): a browser, a calendar, a mail app. One of the key things that might have influenced your purchase of the phone is its storage capability — how many gigabytes (GB) it has available for your use.

Probably the first thing you do is to download more apps, such as WhatsApp, Snapchat and Instagram. These all have a size, given in megabytes (MB), that takes up some of the storage. They also operate as part of a wider system, connecting with similar apps on the phones of your friends and family. Then you may decide to output some text messages, or make phone calls, or post images on to social media.

Had you noticed? Your phone is illustrating some aspects of systems theory.

Systems in geography

A system is a collection of interrelated parts that work together in an environment. Systems are delimited by boundaries and can be defined at a range of spatial scales (for example from a pond to a drainage basin to the Earth). Systems have inputs (energy and matter that enters the system), outputs (energy and matter that leaves the system), and stores of energy and matter within the system. Material and energy are transferred and transformed within the system by a series of environmental processes.

Most systems share the same common characteristics (Figure 1):

- They are generalisations of reality, removing incidental detail that obscures fundamental relationships.
- All systems are delimited by **boundaries**, whether conceptual or physical.
- They have **inputs** and **outputs** of material which are processed within the system. Imbalances of inputs and outputs lead to changes in **storage** within the system.
- They involve the flow of energy and material between components.

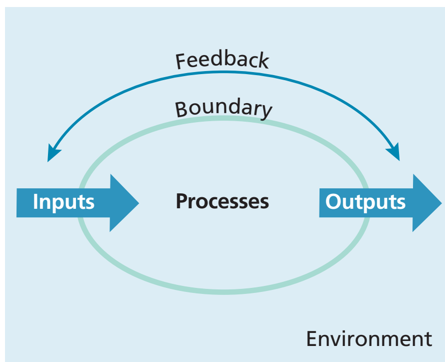


Figure 1 General characteristics of systems

Systems can be classified as:

- **Closed systems** which have transfers of energy both into and beyond the system boundary, but not transfer of matter. The Earth can be considered to be a closed system
- **Open systems** in which both matter and energy can be transferred from the system across the boundary into the surrounding environment. Most ecosystems are examples of open systems.

Equilibrium in systems

Where there is a balance between inputs and outputs the system is said to be in a state of equilibrium. This means that the sizes of the stores stay the same, as material is both added and removed from them. However, if one of the elements of the system changes, for example one of the inputs increases without any corresponding change in the outputs, then the storage goes up. This may disrupt the equilibrium.

Consider the example of a stretch of river. Sediment is input from upstream, stored on the river bed and output downstream. An increase in inputs with no change in outputs is likely to mean increased sediment deposition on the river bed, leading to increased storage and disequilibrium. However, the deposition may eventually steepen channel slope and lead to more erosion of the channel floor. Larger outputs therefore may balance the increased inputs, leading to a new equilibrium.

This is an example of feedback where a change in one part of the system leads to a corresponding change in another part (see 'Geographical ideas: Feedback', in GEOGRAPHY REVIEW Vol. 30, No. 3 for a more detailed look at feedback within systems).

Sometimes there may be smaller systems operating within one larger system. These are called sub-systems. Changes in the sub-system may lead to changes in output which perturb the larger system. For example, the drainage basin sub-system is part of the larger water cycle system.

Some examples of systems

Water cycle

In the case of the water cycle we might consider the sub-system of a drainage basin which has inputs of rainfall from the atmosphere, outputs of river discharge (to the sea) and evaporation (to the atmosphere) and includes storage on the surface (lakes, rivers and even puddles) and sub-surface storage as soil moisture and groundwater. Flows include infiltration and percolation.

Landscapes

Landscapes can be viewed as geomorphological systems. Here sediment is often transferred from one store to another by a series of flows. Consider a single landform such as a sand

A glacier landscape, like this one in Patagonia, can be seen as a system

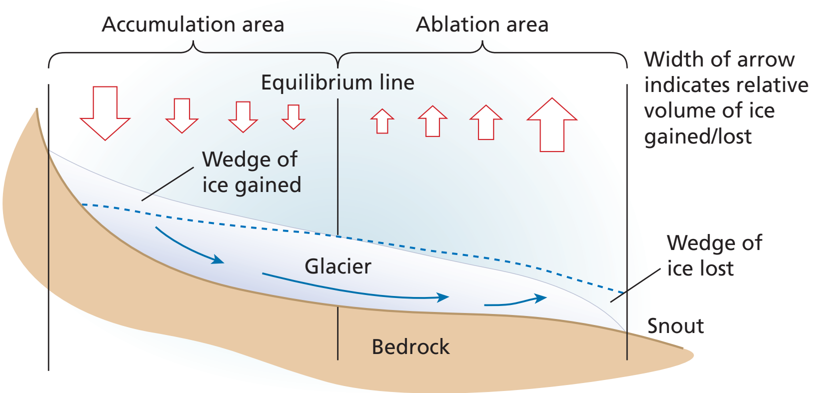


Figure 2 The glacial budget

dune. Inputs would be windblown sediment deposited on the windward side of the dune and outputs would be material eroded from the leeward slope. The change in storage is the difference between input and output. Where it is positive there is net deposition of material and the dune grows. A negative change in storage represents erosion of material from the dune, and it reduces in size.

This sediment budget approach can be expanded from a single landform to look at larger landscape components. For example in a glacial landscape, there are inputs of sediment from weathering on the upper slopes and erosion by the glacier which then transfers the sediment to lower levels. This of course is also influenced by the sub-system of the glacial budget and the balance between accumulation of snow and its ablation (melting) (Figure 2). When accumulation is greater than ablation, there is net growth of the glacier and more material is transported. When ablation is greater than accumulation, there is a net loss of the glacier, the snout retreats, less sediment is eroded, and quantities of debris are deposited across a large area by either the melting ice, or fluvioglacial meltwater flowing from the glacier.

Human systems

In a human context, transnational corporations (TNCs) can also be seen to operate as systems, though they tend to be a little more complex. They have inputs (raw materials, labour and investment) and outputs (products, by-products and waste materials) and between the two are the processes operating within the company. They too are likely to have sub-systems — for example R&D, multiple component suppliers, back-office human resources (HR) and finance

Workers are an input to a TNC system

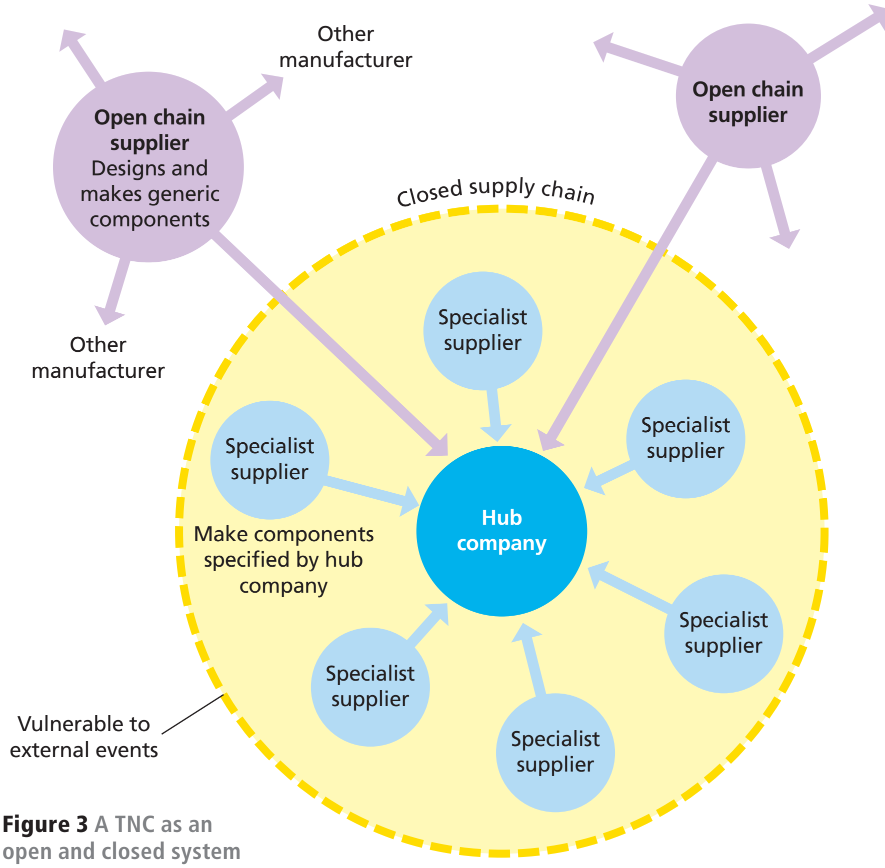


Figure 3 A TNC as an open and closed system

facilities — which all combine to make the company work as efficiently as possible. They can also be seen to have open and closed elements to their activities (Figure 3).

Conclusion

At their simplest, systems can be understood as 'black boxes' in that we simply quantify inputs and outputs with internal processes to create material and energy budgets for a system. On the other hand they can be very complex — for example the smartphone discussed at the beginning of this column is itself an output of a complex TNC system.

Activities

1 Think of other systems you have studied — in deserts, on coasts, on farms, in factories, in cities and in trade. Try to break them down into their simple components.

2 What other aspects of your life reflect systems thinking? Think money, cars, health.

David Redfern is a geography A-level consultant, speaker, author and a chartered educational assessor. He is an associate editor of Geography Review.

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Top ten don'ts for your independent investigation

1 Don't go broad

Some titles are just too 'big'. For example 'How successful has urban regeneration been in Liverpool?' There are dozens of regeneration examples in Liverpool and this is more like a life's work than a 3,000–4,000 word piece of coursework.

An academy with a Peter Blake inspired playground — one of many regeneration projects in Liverpool

Don't make your coursework title too narrow

2 Don't narrow it too much

Very narrow titles can also have problems. You might have trouble locating secondary sources to support your findings. You might struggle to link the title to the specification or to wider areas in geography. An example of a title likely to encounter these problems is: 'How successfully have lichens colonised gravestones in St Michael's churchyard?'

All A-level geography students now have to complete an independent investigation or coursework (sometimes called the NEA or non-examined assessment). This is based on both fieldwork and secondary sources. It's a high-stakes part of your course, worth 20% of the total marks. Here are ten things to avoid as you start planning and carrying out your coursework

3 Don't atomise it

A good approach is to break down a title question into two or three key questions or hypotheses. This can make the total task more manageable. However, atomising your title into six or seven key questions usually makes it impossibly long, and difficult to pull together to form an overall conclusion.

4 A hypothesis that isn't

A hypothesis is a potential, and testable, explanation for a geographical phenomenon. This is a hypothesis: 'Coastal recession rates are higher at White Cliff because the sedimentary rock is less resistant to abrasion and hydraulic action'. This statement contains both a phenomenon (higher coastal recession rates) and an explanation (less resistant to abrasion and hydraulic action) that can be tested by measuring erosion rates and rock resistance.

Many coursework 'hypotheses' are no such thing. This is a perfectly acceptable coursework title question 'How far do the costs of defending White Cliff from erosion outweigh the benefits?' but it is not a hypothesis and should not be described as one.

5 My sample size is 3

Counting pebbles on a beach, measuring river discharge, using questionnaires are all types of data collection. To be reliable, they require you to collect a large sample of data, representative of the whole population (of pebbles, as well as people). This is unlikely to be 3. In most cases the minimum sample size is 10, and 15 or 20 would be better. Statistical tests (like Spearman's rank) that you might wish to use in your analysis also have a minimum sample size. You need to know this when you are designing your data collection so you don't find out too late that you haven't collected enough data.

6 Qualitative data only

Qualitative or descriptive data (usually in the form of text and images) are useful — by all means use blogs, interviews and art as part of your coursework. But relying wholly on this type of data will make some types of analysis — statistics, graphical analysis and some cartographic analysis — difficult if not impossible. Without this analysis it can become hard to access some parts of the mark scheme. When planning your project build in the collection of both quantitative *and* qualitative data. The former will let you do some stats and maths, the latter will add some deeper texture to your work.

7 The Burgess model

There are a number of models that have been used for decades in coursework. 'Does the CBD of Southampton fit the Burgess model?' is a title to avoid. The Burgess model is a model of a city, not a CBD. Worse, it dates from 1925 and was based on Chicago. Southampton in 2017 is unlikely to have much in common with a US city of 92 years ago. There are a number of these ancient geographical models. Let them rest in peace.

8 Death by pie chart

Microsoft Excel was released in 1985 and it made the task of drawing a pie chart much easier. By all means use Excel (other spreadsheet packages are available) to demonstrate your mastery of pie charts. But once you have done one, think carefully about including more. Do your 20 pie charts demonstrate greater mastery of the skill than one or two? Are there other types of graph better suited to presenting your data? The examiners marking your work will be impressed by a range of accurately presented techniques much more than one technique repeated dozens of times.

9 York's location in the Milky Way

Most of us can locate York, roughly at least, on a UK map. Even those who cannot might have a sense of it being in the north of England. Therefore, there is no need to begin your coursework with a map of our galaxy, followed by Earth, Europe, the UK and finally Yorkshire to show where York is located. In most cases one quality location map is better than six dodgy ones at ever greater scales.

10 Rampant critique

One skill being tested in your coursework is the ability to identify errors. Perhaps, in hindsight, your sample size was too small. Maybe some of the questions you asked were 'leading'. Critical evaluation of your methods of data collection, analysis and conclusions is great and will yield some marks. But this can go too far and begin to undermine the very conclusions you have come to. The reverse is also true. The idea that the coursework in 100% reliable is likely to be hard to justify. Get the balance right.

GeographyReview*Extras*

For a presentation showing how to sequence your write-up: www.hoddereducation.co.uk/geographyreviewextras

David Hulme and Sally Cawood

The Sustainable

A primary school in Papua New Guinea. Access to basic education is a key SDG

The UN Sustainable Development Goals hold out the promise of a better world for all — improving human rights, global development, health and education, governance and sustainability. This article looks at how the goals came about and the challenges involved in achieving them

In September 2015, all 193 member countries of the United Nations (UN) agreed a set of 17 global goals that they promised to pursue from 2016 to 2030. These Sustainable Development Goals (SDGs) replaced the UN's eight Millennium Development Goals (MDGs) that operated from 2001 to 2015. The SDGs are much more ambitious than the MDGs. They promise to (Figure 1):

- eradicate poverty and hunger everywhere
- make economic growth more environmentally sustainable and reduce climate change
- ensure that everyone has access to basic education and health services
- reduce inequality in incomes and wealth
- improve the ways in which national governments and international agencies work

These are the biggest promises in the world, but there are large question marks beside them. Will all countries and all international **foreign**

Figure 1 The SDGs

Development Goals

Can they succeed?

aid agencies genuinely pursue the SDGs? Will only 'mixed' results be achieved at national, regional and global levels — as happened with the MDGs — or can the SDGs fare better?

UN goals and the MDGs

The member countries of the UN were setting global goals long before the MDGs of 2000. Some of these goals have been successful, like the total eradication of smallpox (a terrible, contagious disease) between the late 1960s and 1980. Other promises have not been met, such as the goal to ensure that every child in the world goes to primary school. In 2015, there were still 57 million school-age children not in primary schooling.

The MDGs were very different from these earlier attempts to set global goals. They were not simply about one big international problem but about many problems. The MDGs were a set of 'super-goals' that promised to make the twenty-first century much better than the twentieth century. They focused on reducing poverty and human suffering in the poorest parts of the world. It may seem surprising, but the MDGs were mainly promoted by rich countries from the **Organisation for Economic Co-operation and Development (OECD)** and foreign aid agencies, like the **World Bank (WB)** and **International Monetary Fund (IMF)**. Within and outside the UN, poor and middle-income countries showed much less interest in these goals.

Did the MDGs work?

When the MDGs emerged in the early 2000s, many people thought they would not have much impact on the actions of national governments and international agencies, such as the UN, WB, IMF and **World Trade Organization (WTO)**. Over time, there is evidence to suggest that the MDGs *did* improve certain policies and practices in some parts of the world. However, the most important factors behind these achievements actually related to processes operating *before* 2000, specifically:

- economic growth in China and India
- the spread of technology (for agriculture, health and industry)
- growing realisation that human-made climate change was underway

The MDGs were only partially achieved by 2015 (see the 2015 progress chart in Further reading). However, the rate at which poverty, child mortality and other big problems declined, led the UN to declare the MDGs as 'the most successful poverty movement in history'.

From MDGs to SDGs

In 2012, the UN created an Open Working Group (OWG), to design a new set of 'post-2015 development goals'. These became known as the Sustainable Development Goals (SDGs) and reflected a big change in political process from the MDGs. For the SDGs, the so-called 'developing countries' took control of the global agenda and would not let the 'rich countries' (in the OECD) lead the discussions, as they had for the MDGs. This was underpinned by the economic advance of the BRICs (Brazil, Russia, India and China), emergence of new middle-income powers (South Africa, Turkey and Indonesia, among others), and the growing confidence of African countries, which had access to new sources of finance, especially from China.

As a result of the OWG negotiations, the SDGs are much longer than the MDGs (17 goals and 169 targets, compared to 8 goals and 60 targets in the MDGs). They are also 'universal'. In other words, the SDGs apply to all countries, not just poorer ones as the MDGs did. So, all UN member countries have promised to improve the lives of their own citizens, help other countries with their development and move towards environmental sustainability. This ambitious agenda can be seen as great progress towards a fairer world and achieving social justice for all human beings (now and in the future). But, it also means that achieving the SDGs involves addressing several big challenges.

The SDGs apply to all countries, including the UK, where the gap between rich and poor is growing

Further reading

Hulme, D. (2016) *Should Rich Nations Help The Poor?* Polity Press.

Oxfam (2016) An economy for the 1%: how privilege and power in the economy drive extreme inequality and how this can be stopped: **www.tinyurl.com/hfmylx9**

UN MDGs 2015 progress chart: **www.tinyurl.com/n3dybsg**

UN 2016 Sustainable Development Goals website: **https://sustainabledevelopment.un.org/**

Challenges facing the SDGs

There are many challenges to the progress of the SDGs, but four are particularly significant:

- national commitment to international cooperation
- the quality of national governance
- sustainable economic growth
- tackling inequality

National commitment to international cooperation

Although all UN member countries committed (verbally and via a **non-binding declaration**) to the SDGs at the UN General Assembly in New York, that does not mean that they will cooperate in practice.

A protest in London about the failure to provide anti-retroviral therapy for HIV/AIDS in South Africa

- Many rich countries (and their citizens) are reluctant to increase their foreign aid budgets.
- Countries say they will move to 'fair trade' agreements, but then will not sign up to them (or are blocked by powerful farmers and business people).
- Transnational companies say they want to 'help the poor' but then insist on high prices for their medicines or on being paid for patents and **intellectual property**.

National and international lobbying is needed to get governments to keep the promises they make.

The quality of national governance

In the UK we take it for granted that our government, councils, schools, hospitals and other institutions work pretty well. In many parts of the world things are very different. There is corruption: political leaders steal from public funds, teachers need a bribe if you want to pass the examination, the police only investigate crimes if you pay them privately… or worse, doctors do not turn up for work. In countries that are poorly governed — such as Nigeria, Haiti and Afghanistan — the capacity to implement the SDGs is very low. Hospitals may be built, but they will not have doctors and medicines. Improved seeds will be purchased to help farmers, but they will be given only to the friends of local politicians. If the SDGs are to be achieved then many governments will have to improve the ways in which they rule.

Sustainable economic growth

Economic growth is an important factor in the success of the SDGs — it is required to reduce poverty, create decent jobs and finance social services. But, to date, economic growth has always depended on processes that release carbon dioxide and other greenhouse gases: industrialisation, agricultural intensification, clearing forests, urbanisation, road and air transport. These all accelerate climate change.

Glossary

Foreign aid agencies Organisations that provide aid (in the form of money, resources or technical assistance) to developing countries. Some, like the World Bank and International Monetary Fund, operate as banks, offering loans for investment in infrastructure and development. Countries must pay these back, often with interest or conditions.

Intellectual property Intangible property that is the result of creations of the mind, such as inventions, literary work and art. It is protected in law by patents, copyright and trademarks, which enable people to earn recognition or financial benefit from what they invent or create.

International Monetary Fund (IMF) Established in 1994, the IMF's primary purpose is to ensure the stability of the international monetary system — the system of exchange rates and international payments that enables countries (and their citizens) to transact with each other.

Non-binding declaration An agreement that is not legally binding. In other words, there are no punishments or sanctions for the signatories if they fail to meet the targets.

Organisation for Economic Co-operation and Development (OECD) Established in 1961, the OECD has 35 member countries. Its mission is to promote policies that will improve the economic and social wellbeing of people around the world.

World Bank (WB) Established in 1944, the World Bank is made up of 189 member countries. Its purpose is to provide financial and technical assistance to developing countries around the world, to reduce poverty and support development.

World Trade Organization (WTO) The only global organisation dealing with the rules of trade between nations. WTO agreements are negotiated and signed by most of the world's trading nations, and ratified in their parliaments. The goal is to help producers of goods and services, exporters and importers conduct their business as smoothly, predictably and freely as possible.

A nurse distributes an anti-malarial drug in Kenya. Why is malaria still one of the biggest killers in the world?

A great deal of research is now going into 'green growth' — wind turbines, solar power, low-input agriculture and recycling of waste. At the same time, the emerging economies (such as the BRICs) are creating growth using the same processes that the rich countries used in the twentieth century — coal-fired power stations, 'dirty' chemical production, road building and growing consumerism. To move towards 'green growth' rich countries and their citizens (you and I) will have to reduce our consumption of materials. We will also need to transfer the green technologies we have created to poorer countries free of charge.

Tackling inequality

The SDGs promise to reduce inequality in income and wealth but in reality global inequality is growing fast (Figure 2). At the national level, will governments and big businesses (usually run by the wealthiest people) redistribute incomes and wealth by increasing tax rates and creating business opportunities for all? At the international level, will rich countries such as the USA and UK change the agreements that help to make them wealthy (unfair trade, poor regulation of banks and international finance, and interfering in domestic politics in other countries)? To tackle inequality the world's most politically powerful people — the rich — will have to share their wealth with others. Can they be persuaded to do this?

Conclusions

The SDGs are the world's biggest promise. They hold out the potential for real social progress in trying to get governments, organisations and individual people to make the world a better place. But many changes will have to occur, and many challenges be overcome, if they are to be achieved.

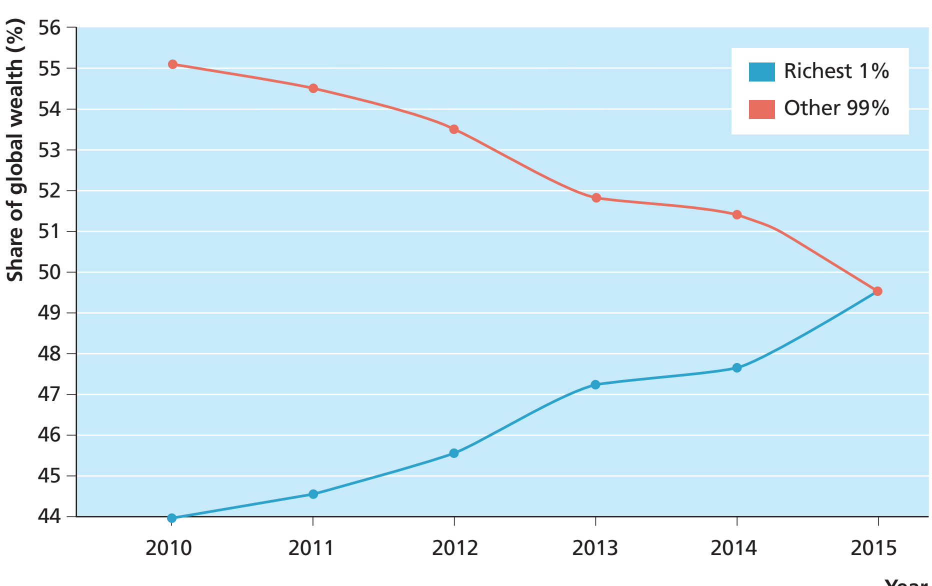


Figure 2 Rising global inequality

- International foreign aid agencies will have to work more effectively.
- National leaders and governments must be pushed to keep their promises.
- Businesses will have to switch to green technologies and change their business models.
- Individual people (including you and me) will have to be less selfish and think much more about others.

Perhaps it is this last point that is most important. Governments, organisations and businesses will only change what they do if they know that their citizens and consumers want a world that is sustainable and socially just. That means you and I have to change, and we have to push our governments to change with and for us, and for future generations.

Questions for discussion

1 Compare the MDGs with the SDGs. In what ways are the SDGs 'much more ambitious' than the MDGs?

2 When people look at the results of the MDGs some are disappointed and take the 'glass half empty' view. Others are impressed with economic and social progress during the MDG era and argue that the world could have done better but these are still good results (the glass is half full). What do you think about the MDGs — is the glass half empty or half full?

3 Why do you think the so-called 'developing countries' of Africa, Latin America, east and south Asia have become much more assertive in recent years in setting global goals at the UN?

David Hulme is professor of development studies at The University of Manchester's Global Development Institute (GDI). His most recent book is *Should Rich Nations Help the Poor* (2016). **Sally Cawood** is a PhD researcher at the institute.

Key points

- For the SDGs to make good progress, many challenges will have to be overcome.
- Four challenges are particularly significant: national commitment to international cooperation, the quality of national governance, sustainable economic growth and tackling inequality.
- Governments, organisations and businesses will only change what they do if they know that their citizens and consumers want a world that is sustainable and socially just. That means you and I have to change, and we have to push our governments to change with and for us.

The carbon cycle and energy security

This Question and Answer considers two parts of an A-level question for the 2016 Edexcel specification. The question tests Topic 6 The carbon cycle and energy security, Paper 1. This topic is covered by the other exam boards using similar style questions (see Box 1) and this piece could be used by students taking other specifications, bearing in mind differences in question and mark-scheme style. The exam comments are the responsibility of GEOGRAPHY REVIEW and have neither been provided nor approved by the examination board

The two sub-questions discussed here are both relatively high demand. They are the last two questions in a sequence of five covering both the water and carbon cycles, arranged as shown in Table 1. In the Paper 1 exam, the sequence could be reversed with the 3–8 mark questions testing the carbon cycle and the 12 and 20 mark questions testing the water cycle.

There are several important points to remember when tackling a full question sequence such as this:

- It is all too easy to spend too long on the 3, 6 and 8 mark questions, leaving too little time to tackle the longer 12 and 20 mark essay-style questions.
- As the mark tariff increases, so does the need to use examples and selected parts of case studies as evidence to support your argument.
- The 3 and 12 mark questions are data-stimulus questions: there is a diagram containing geographical data and this must be referred to as part of your answer.

Question 1

Question

Study Figure 1. Assess the likely impacts of climate warming on the components of the carbon cycle shown in Figure 1. (12 marks)

Question 1 makes use of Figure 1. This shows a carbon cycle in the Arctic tundra. You should study the diagram for a minute or two before you 'dive in' and start writing. Notice:

- Three gases appear: carbon dioxide (CO_2), methane (CH_4) and nitrogen oxide (NO).
- Fluxes between the air and ground stores are shown by arrows, and these have time scales attached to them (hours–months, years–decades, centuries–millennia).
- The dashed horizontal white line shows the boundary between soil above and permafrost below, and on the right-hand side thawing of the permafrost is shown.

A full answer needs to refer to warming/thawing, as well as the carbon stores and

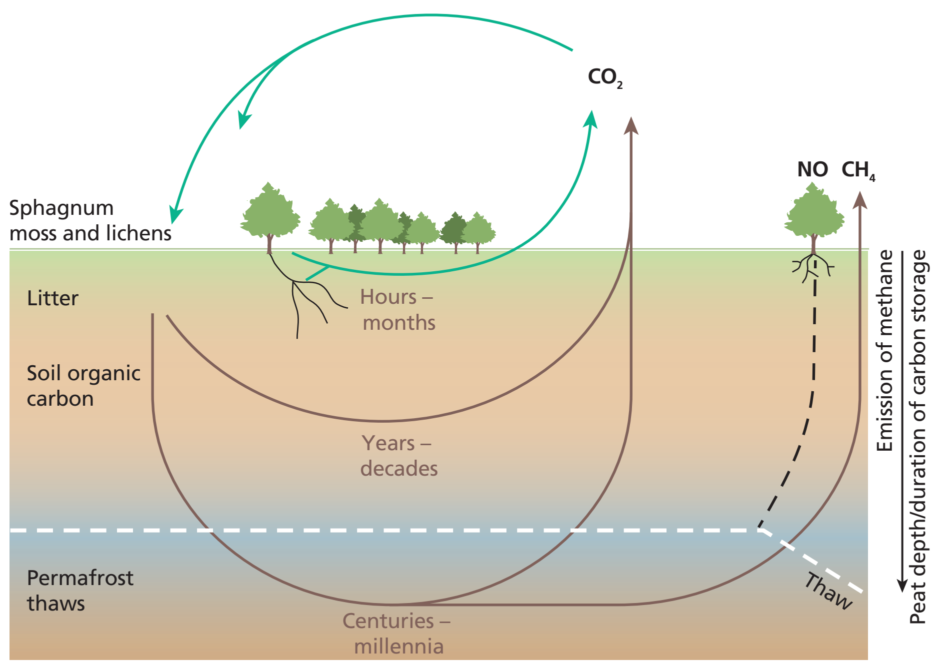


Figure 1 How climate warming impacts on the carbon cycle in a tundra environment

Table 1 Question sequence

Marks	Command word		Topic	Spec
3	Explain		Groundwater	Water cycle
6	Explain		River regimes	
8	Explain		Water insecurity	
12	Assess		Climate warming and the carbon cycle	Carbon cycle
20	Evaluate	Increasing demand	Energy and the carbon cycle	

Box 1 Carbon cycles and exam boards

AQA: Paper 1 Physical geography, Section A Water and carbon cycles.

OCR: Section B Earth's life support systems, A-level H481/01, Physical systems exam paper.

WJEC/Eduqas: Component 2 Global systems and global governance.

fluxes on different time scales. Your task here is not to write an essay about the carbon cycle and global warming, but to explain the information shown in Figure 1. A very good answer would go a bit further. It would assess the impacts of warming. This means explaining that some impacts are more significant than others — for instance by causing larger changes, or change that occurs more rapidly.

A shortened mark scheme is shown in Table 2.

Frank's answer

Figure 1 shows how global warming will affect the carbon cycle. One important aspect is that in a warmer climate the tundra will become more densely covered by plants, possibly even tree cover. Although these plants will absorb and store some atmospheric carbon dioxide — the gas that causes global warming — this sequestration of carbon will be more than offset by the impact of those plants on tundra albedo. Dark surface vegetation will absorb more solar radiation, warming the tundra more, and leading to more melting in a positive feedback loop.

This is significant because in a warmer climate there will be greater decay of soil organic carbon, releasing more carbon dioxide and raising atmospheric

Permafrost in Spitsbergen, Svalbard

Table 2 Mark scheme for question 1

Level 1	1–4 marks	Isolated geographical knowledge and understanding, inaccurate or irrelevant. (AO1) Limited logical connections/relationships. (AO2) Interpretation with limited relevance and/or support. (AO2) Unsupported or generic judgements, few factors, unbalanced. (AO2)
Level 2	5–8 marks	Geographical knowledge and understanding, mostly relevant but some inaccuracies. (AO1) Some relevant connections/relationships. (AO2) Partial but coherent interpretation, mostly relevant, some evidence. (AO2) Judgements about the significance of some factors, partially coherent. (AO2)
Level 3	9–12 marks	Accurate and relevant geographical knowledge and understanding throughout. (AO1) Relevant connections/relationships. (AO2) Full and coherent interpretation that is relevant and supported by evidence. (AO2) Supported judgements about the significance of factors throughout, balanced and coherent argument. (AO2)

concentrations even further. Leaf litter from dead moss and other plants is likely to rapidly decay and release its carbon within months, whereas in the past much of it would have been frozen in permafrost and stored for decades.

In addition, and even more significant, deep permafrost may thaw. Permafrost stores carbon for thousands of years. On melting it releases large quantities of methane which is a powerful greenhouse gas — up to 30 times as powerful as carbon dioxide in terms of warming. This in turn creates a positive feedback loop in which released methane causes further warming, deep permafrost melting and more methane release.

There may be some benefit in the tundra due to increased carbon sequestration from additional vegetation productivity, but overall this is likely to be offset by fluxes in the release of carbon dioxide and methane into the atmosphere from thawing of permafrost and decomposition of soil organic material.

Exam comment

Frank has written a Level 3 answer. His answer is closely linked to Figure 1, and there is repeated reference to different parts of the cycle shown in the diagram. There is an explanation of the different time scales, and how stores of carbon that have built up over centuries–millennia are in danger of being released.

Frank shows accurate understanding of positive feedback mechanisms and understands how different part of the cycle shown connect. There are some judgements, such as the overall importance of methane, which was until recently thought to be locked away in permafrost. One area of the answer that could be improved is that Frank does not consider the release of nitrous oxide (another greenhouse gas) as a result of increased microbial action in a warmer soil.

Question 2

Question

Evaluate the extent to which today's increasing demand for energy is the most important factor modifying the global carbon cycle. (20 marks)

Question 2 is an essay question. The most important word in the question is **evaluate**. There is no point trying to pretend that evaluating is easy. However, there is an approach to this question that might help you. This is the 'washing-line model' shown in Figure 2. Try thinking about question 2 like this:

- It is about modifying, or changing, the carbon cycle.
- It asks you if increasing demand for energy is the most important factor in (cause of) the changes.
- Not all energy is the same. Some fossil fuels have much higher carbon emissions per unit

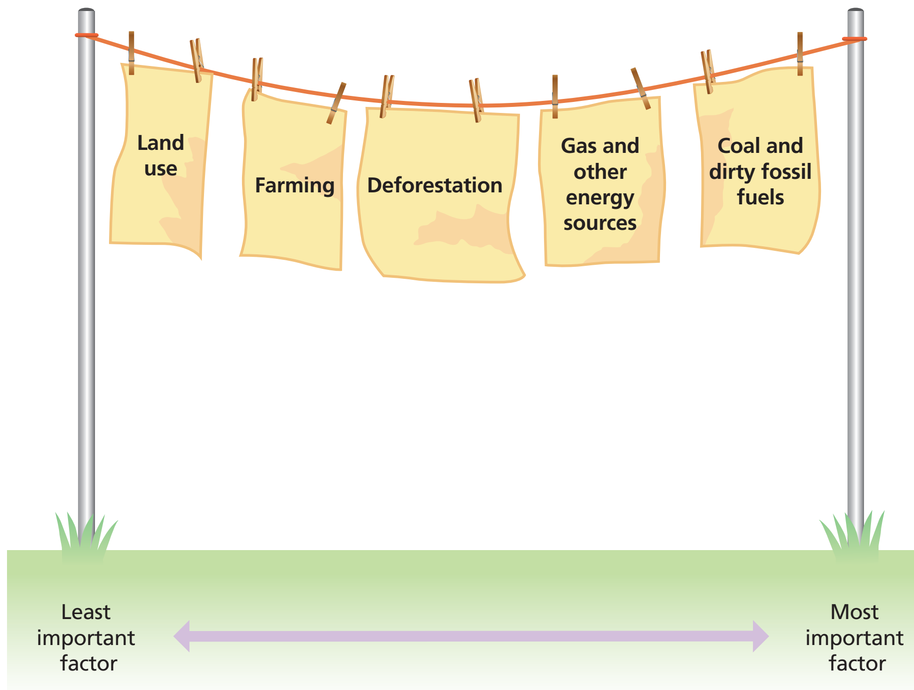


Figure 2 Evaluating using the washing-line model

Table 3 Mark scheme

Level 1	1–5 marks	Isolated elements of geographical knowledge and understanding, some inaccurate or irrelevant. (AO1) Limited and rarely logical connections/relationships. (AO2) Interpretation with limited coherence and support from evidence. (AO2) Unsupported or generic conclusion, unbalanced or lacks coherence. (AO2)
Level 2	6–10 marks	Geographical knowledge and understanding, which is occasionally relevant, may include some inaccuracies. (AO1) Limited but logical connections/relationships. (AO2) Partial interpretation that is supported by some evidence. (AO2) Conclusion, partially supported. (AO2)
Level 3	11–15 marks	Geographical knowledge and understanding, which is mostly relevant and accurate. (AO1) Some logical and relevant connections/relationships. (AO2) Partial but coherent interpretation of some evidence. (AO2) Conclusion, largely supported. (AO2)
L4	16–20 marks	Accurate and relevant geographical knowledge and understanding throughout. (AO1) Fully logical and relevant connections/relationships. (AO2) Full and coherent interpretation supported by evidence. (AO2) Rational, substantiated conclusion, fully supported, drawn together coherently. (AO2)

of energy than others, for example coal and tar sands.

- Energy demand isn't the only factor changing the carbon cycle.
- What are the other factors (causes)? Deforestation, land-use change and farming spring to mind.
- So, which of these factors is the most important cause of the changes?

It is this last bullet point upon which you need to focus in order to answer the command word **evaluate**. Make a judgement about which factors are the most and least important.

Table 3 gives a shortened version of the mark scheme.

Juliana's answer

Global energy demand increased by nearly 50% between 1990 and 2010 and is expected to increase by another 40% to 2030. Fossil fuels supply more than 80% of the world's energy and this is unlikely to change soon, despite increases in renewable energy. According to the US Environmental Protection Agency, about 70% of carbon dioxide production worldwide is a result of emissions from burning fossil fuels. This has increased the concentration of carbon dioxide in the atmospheric store from 315 ppm in 1958 to over 400 ppm today. Burning fossil fuels releases carbon from geological stores into the atmosphere, and also into the oceans which take up some carbon dioxide and in the process become more acidic.

Not all energy sources are the same. Some sources — such as nuclear and wind power — are low-carbon, but these do not meet most of global energy demand. Coal and oil are the main sources of energy. Coal in particular is inefficient and emits large amounts of carbon dioxide in relation to the energy released.

In the near future the development of Canada's tar sands and possibly the USA's oil shales are likely to release even greater amounts of geological carbon. This is because a lot of energy is used in extracting and processing these unconventional fossil fuels even before they are used — so emissions are far greater. Growing global energy demand makes it likely that these sources will need to be tapped in order to increase supply.

Some energy sources are more complex. Biofuels such as maize or sugar cane emit carbon dioxide when combusted, but when they grow in the following season they sequester carbon from the atmosphere. In theory this means their impact is less than that of fossil fuels. However, in Indonesia, palm-oil plantations are created by burning primary tropical forest which releases enormous volumes of carbon dioxide.

Land-use change, especially deforestation, is responsible for up to 25% of global greenhouse gas emissions. Up to 8 million hectares of tropical forest have been destroyed in Indonesia alone just for palm oil. However, deforestation is at least reversible because forests can be replanted. Some countries such as India and Costa Rica have net afforestation so the size of their biological carbon sinks is increasing.

Farming is a major contributor to atmospheric greenhouse emissions. Eighty per cent of all methane emissions are from farming, including farm animals and wet rice cultivation. Fertilisers are a major source of nitrous oxide emissions. As the global population climbs toward the 9 billion expected by the UN by 2050, the challenge of feeding these additional people is likely to increase emissions further, as well as leading to even more deforestation to convert forests to food production. Poor farming practices can lead to more rapid decay of soil organic matter and greater carbon emissions.

Overall, energy demand does have the greatest impact on modifying the carbon cycle, by releasing fossil carbon into the atmosphere and oceans. Not all energy sources have the same impact, with coal and unconventional sources being the most significant. Biofuels are more complex and their impact is not easy to quantify. Deforestation and farming are two other factors, which are often linked. While less significant than energy demand, their importance is only likely to grow as there are more mouths to feed, whereas it may be possible to reduce fossil-fuel use with renewable-energy technologies in the future.


Timber awaiting conversion to wood chips for biofuel, Shropshire

Examiner comment

Juliana's is a Level 4 answer. Her answer shows good understanding of energy demand and how this leads to emissions which alter the carbon cycle. In addition, her answer judges that some energy sources are more significant than others — both today and in the near future. Juliana also considers other factors, particularly deforestation. Her answer judges this as less significant than fossil-fuel burning because deforestation can be stopped and even reversed. Farming is also considered and she argues that this threat is likely to grow in the future. Throughout, examples and data are used to support the answer, i.e. evidence is presented. There is also a coherent overall conclusion.

Smart

The mobile devices we carry and the electronic systems that make up a city provide new and rich sources of data that can be used in the planning and policy-making of urban places

Real-time control

Sensors are now used in cities to control basic functions such as paying for services, intelligent lighting, more efficient energy. At the same time personal and mobile sensors in our smartphones are collecting data that help us make decisions about how we behave in real time.

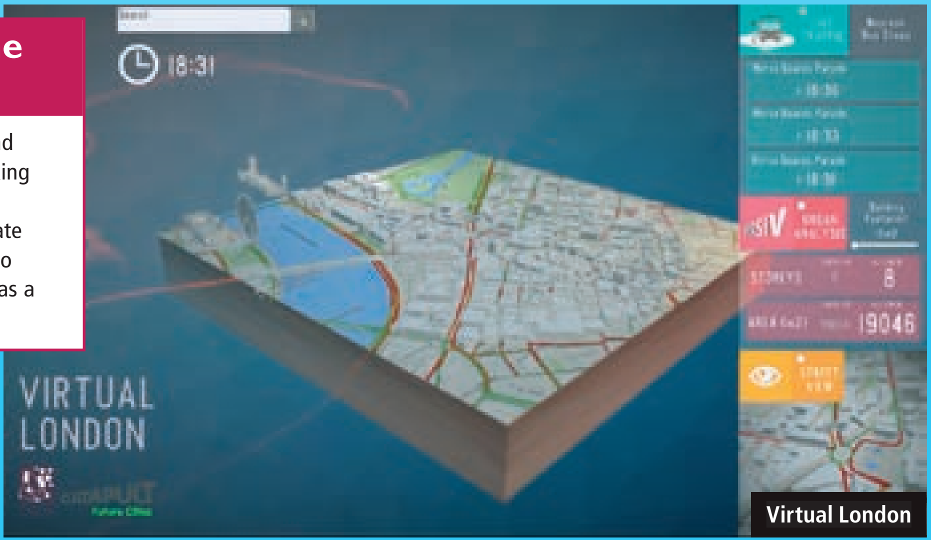
Real-time transport and weather data

What is a smart city?

Today computers are embedded into many of the elements that make up a city — its buildings, streets, cars and so on. In combination these generate ever bigger data about how a city functions and performs in real time. These data allow us to produce more efficient and liveable cities, which we call **smart**.

Mapping and modelling the three-dimensional city

Data from remote sensing, digital cartography and geographic information systems let us build working models of the buildings, streets, physiology and geography of the city. We are now able to generate three-dimensional digital models that enable us to coordinate information, displaying it in real time as a virtual city.



Virtual London

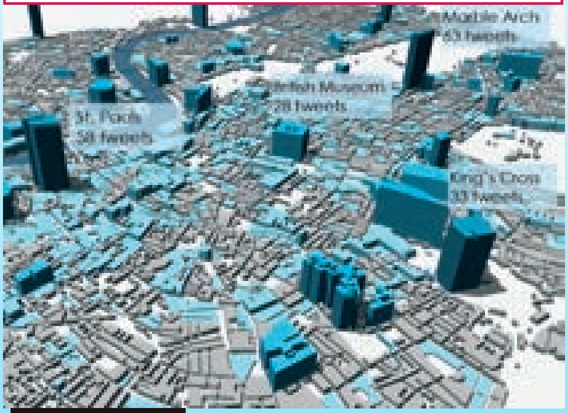
GeographyReview*Extras*

You can download a pdf of this spread to print as a poster at: www.hoddereducation.co.uk/geographyreviewextras

cities

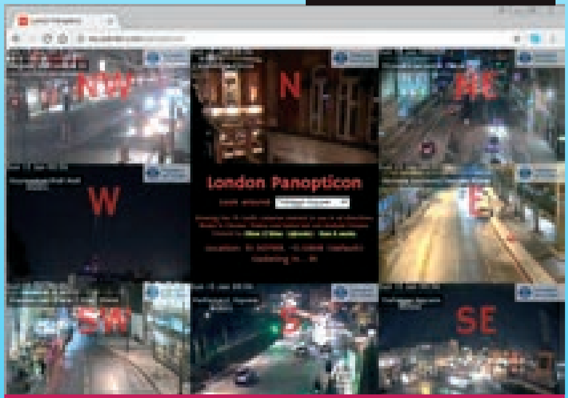
Using social media

Smartphones record our location, and when we post on social media. From these data, we can begin to extract social networks that give us a picture of how, where and with whom we communicate.



Tweetcity map

Real-time data display

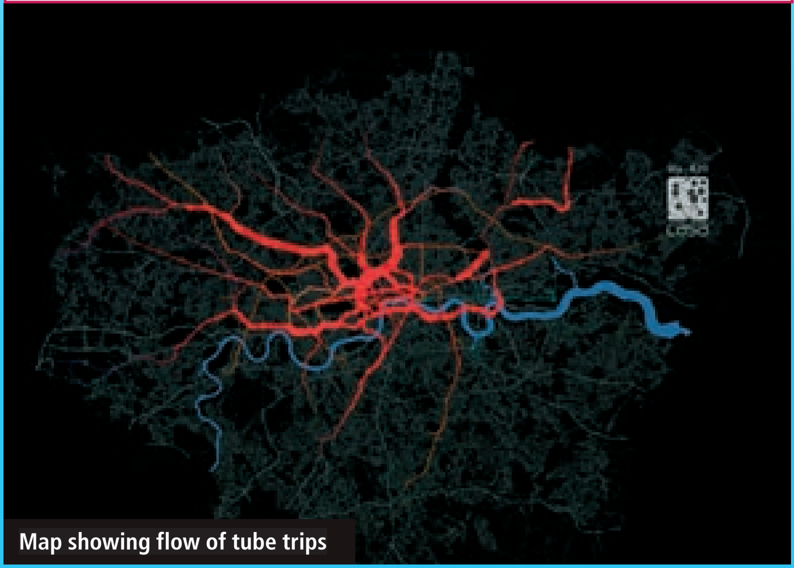


City dashboards and control rooms

Dashboards collect real-time data from different sources, and display the information in a form that gives an instant and continuing picture of how well or badly a city is functioning. Some cities now have control rooms which allow them to spot problems as they emerge, and take immediate action to manage issues like traffic congestion.

Automated travel, autonomous vehicles

Our cities are being automated with technologies that enable us to pay using smart cards such as London's Oyster Card, or to call up services such as Uber from our phones. Autonomous 'driverless' vehicles such as subway trains are already in operation. In the next decade, some of this technology will be used to help us drive better.



Map showing flow of tube trips

Michael Batty is Bartlett professor of planning at University College London. His most recent book is *The New Science of Cities* (MIT Press, 2013). Images Copyright of CASA-UCL, by Ollie O'Brien, Andy Hudson-Smith, Jon Reades, Stephan Hugel and Flora Roumpagni.

Drought and water security

A case study from California

Francesca Quinn

In 2015 and 2016 California faced one of its most severe droughts on record. This article looks at the challenge of climate change in the context of the Californian drought and its impact on local biodiversity. It is relevant to topics on the water cycle and water security, climate change and ecosystems under stress

A dry river bed in front of the San Jose Water Company building

The last ice age ended 11,000 years ago and since then, Earth's climate has been relatively stable at approximately 14°C. Over recent decades evidence of higher average temperatures, changing rainfall patterns, increasing sea levels, retreating glaciers and melting of sea ice and ice sheets has been recorded. Extreme weather events, including **droughts**, have become more frequent.

In 2015 the US state of California experienced one of the worst droughts in its history. This led to real concerns about long-term water security in the region. In October 2016, a quarter of California was lifted out of drought by autumn rains and by spring of 2017 the drought was largely over.

Was this severe drought part of a natural climate cycle or a function of human-induced climate change? It is hard to determine this for an individual event but there is no doubt that the drought provides an insight into the challenges that California may face in a warmer world.

Changing local climate

In January 2015, California was declared to be in a drought state of emergency by state governor Jerry Brown. Water-usage data show that California uses more water than any other state — each Californian uses an average of 181 gallons (823 litres) per day, despite the state receiving on average only 22.2 inches (564 mm) of rain a year.

Glossary

Anthropogenic Human-induced.

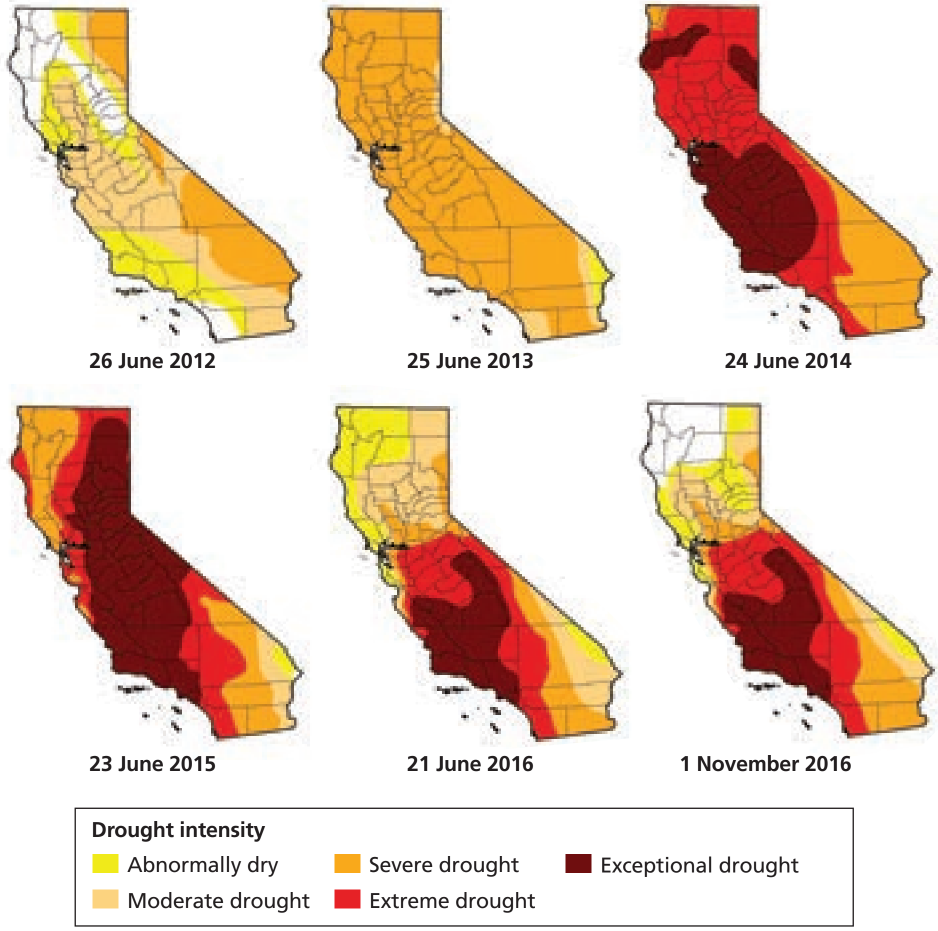
Biodiversity The variety of organisms within an ecosystem.

Drought A prolonged period of insufficient water supply.

Primary productivity The rate at which plants and other photosynthetic organisms produce organic compounds in an ecosystem.

Species diversity The range of different species in an ecological community.

Water security The reliable availability of an acceptable quantity and quality of water for health, livelihoods and production, coupled with an acceptable level of water-related risks.



Source: The US Drought Monitor is jointly produced by the National Drought Mitigation Center at the University of Nebraska-Lincoln, the US Department of Agriculture, and the National Oceanic and Atmospheric Administration. Map courtesy of NDMC-UNL.

Figure 1 US Drought Monitor maps showing drought severity in California, June 2012–November 2016

Over the last 15 years, California has experienced temperature rises, with annual periods of extreme heat. The frequency and intensity of precipitation has not increased to counteract the enhanced evaporation, so there has been a decrease in water security. The lowest calendar year of precipitation was recorded in California between 2013 and 2014, with 2014 also making records as California's hottest year in history. Figure 1 shows the changing drought levels in the state.

Low levels of rain and snow are not uncommon for the state, but warmer conditions than experienced in the recent past have caused precipitation to evaporate quicker than normal and exacerbated the drought. Where there is a high probability of every year being warm, low precipitation leads to a much higher risk of drought.

IPCC climate-modelling data suggest that by 2080 California will experience a decrease in average rainfall and increase in average temperature. Temperatures are expected to rise on average by 4°C, with precipitation dropping by between 2 and 16% below current levels. The Demographic Research Unit of the California Department of Finance has also projected a population increase from 39 million (2014) to 47 million by 2040, causing an extra strain on the state's water supply.

Summer 2015 drought

In summer 2015 the state government had to enforce restrictions on water use, and there was a concerted public effort to preserve supplies. In Beverly Hills, the usually vibrant green but now brown median strips on the highway displayed signs from the local council stating that

Dead fish on the fast-disappearing shoreline of Salton Sea, California's largest lake

'water to the city's grass medians has been turned off due to drought'. At the Getty Centre in Los Angeles all water features were switched off, and highway signs in Pasadena advertised cacti to 'drought-proof your landscape'.

Despite action taken to mitigate the impacts, reports from the US Drought Monitor declared California was suffering 'exceptional drought', with 95% of the state experiencing at least 'severe drought' and 98% experiencing moderate to exceptional drought. It was described by the Californian government as one of the most severe droughts on record.

The snowpack in the State's Sierra Nevada mountains was at an all-time low— after spring thaw this is usually responsible for supplying up to a third of state water.

What happened next?

A heavy dousing of autumnal rain in 2016 — the most in 3 years — lifted the northern quarter of the state out of drought. October 2016 was recorded as the second-wettest on record for the northern Sierra mountains — the source of much of the state's water. But one month of rain in northern California does not resolve a 5-year drought, especially in central and southern California where most of the state's crops are grown and there is a population of 39 million people. Twenty-one per cent of the state, once more in central and southern California, remained in a category of severe drought at the end of 2016. Over the winter of 2016/2017 record rain and snowpack in the Sierra Nevada further lifted the drought threat.

Impacts on biodiversity

Biodiversity varies widely across both land and ocean environments of the world, with physical and **anthropogenic** factors influencing biodiversity levels at local and global scales. Variation in climate (physical factors) plays a vital role, as temperature, humidity, nutrient supply and water availability act as limiting factors on species.

High levels of biodiversity are often present in ecosystems which have few limiting factors, as this allows for high levels of **primary productivity** and energy availability. In contrast, ecosystems experiencing cold temperatures, low light levels or aridity, such as the polar and desert regions, have obvious limiting factors and hence lower levels of biodiversity.

The 2015 drought in California introduced a new limiting factor to biodiversity in the state. Although the Mediterranean ecosystems of California are adapted to dry conditions, the severity and length of the drought was unusual.

Grasslands

A study from the University of California at Davis found a reduction in the **species diversity** of native wildflowers in grasslands. The research found a link between decreases in midwinter precipitation and decline in wildflower diversity. In regions that are becoming increasingly dry, such as the California grasslands, there is a fear diversity losses may foreshadow larger-scale local extinctions. Loss of diversity means the grasslands provide less nutrition to herbivores, and species disturbance is expected to travel up the food chain, affecting insects, birds and even domesticated species such as cattle which all rely on these grasslands for food.

Forests

Hotter and drier conditions could cause conversion of some of southern California's forests to shrub and grassland. These would not be gradual transformations, but would occur as catastrophic change following forest fires. California experienced 2,500 fires in 2015 alone. Drought meant that fire fighters struggled to find water supplies, and

Further reading

UC Davis research on wildflowers: **www.tinyurl.com/m3nj6tp**

News articles about the drought and what happens next:

Live Science: **www.tinyurl.com/mgwu9hy, www.tinyurl.com/n5uyflw**

Southern California local radio: **www.tinyurl.com/njc46rm**

NBC: **www.tinyurl.com/zhgqen9**

BBC: **www.tinyurl.com/mzaw3ag**

Guardian article on the wildfires: **www.tinyurl.com/nuqjaxl**

California's water use: **http://ca.water.usgs.gov/water_use/**

fire-fighting planes and helicopters had to fly further afield to reload. This was the worst recorded fire season in Californian history, with 117,960 acres (47,737 hectares) of land scorched — more than double the 5-year average. Wildfires also occurred in other west coast states such as Oregon, Washington and even in Alaska, where 5 million acres (2 million hectares) burnt in 2015.

As well as wildfires, forests have been devastated by insect infestation, as experienced in the Stanislaus National Forest in spring of 2016. Throughout the Sierras there are approximately 40 million dead and dying trees, and this particular forest is the third most affected. Years of drought and low water supply have damaged the ability of trees to make the sap required to protect them from invasive insects. As a result several species are subject to a bark beetle infestation causing the trees to weaken and die at a rapid rate.

Conclusion

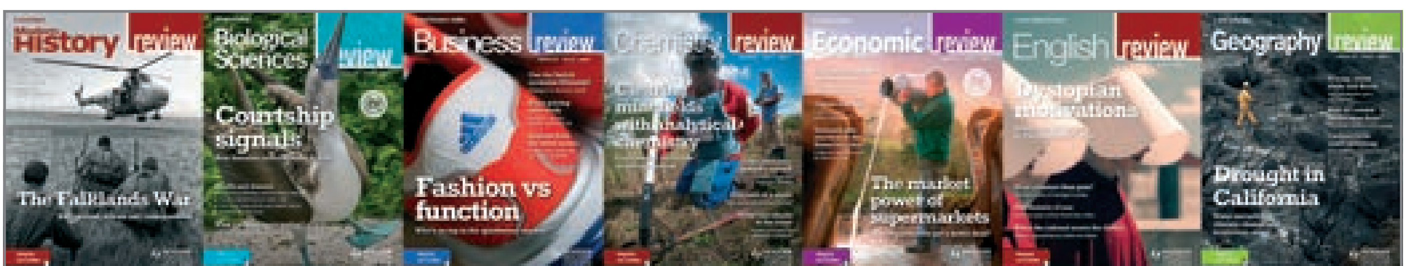
Can California cope with a warmer world? Answering this question requires an understanding of the way in which ecology, hydrology and human systems interact to define the physical and human geography of this region under conditions of climate change. Other regions of the world, such as the Mediterranean, are under similar pressures.

Francesca Quinn is studying for a BSc in physical geography at Durham University.

Fire-fighting helicopter in LA County, August 2015

Key points

- Climate change and global warming are global phenomena with many primary impacts including the increase in frequency of extreme weather events over time.
- The California drought is an example of such a severe weather event. The current drought is one of the most severe on record.
- Secondary impacts include damage to biodiversity over space and time. An imbalance in natural food chains threatens the equilibrium of ecosystems and presents the possibility of extinction for certain species.
- Such impacts are not only occurring in California, but globally, including areas such as the Mediterranean.



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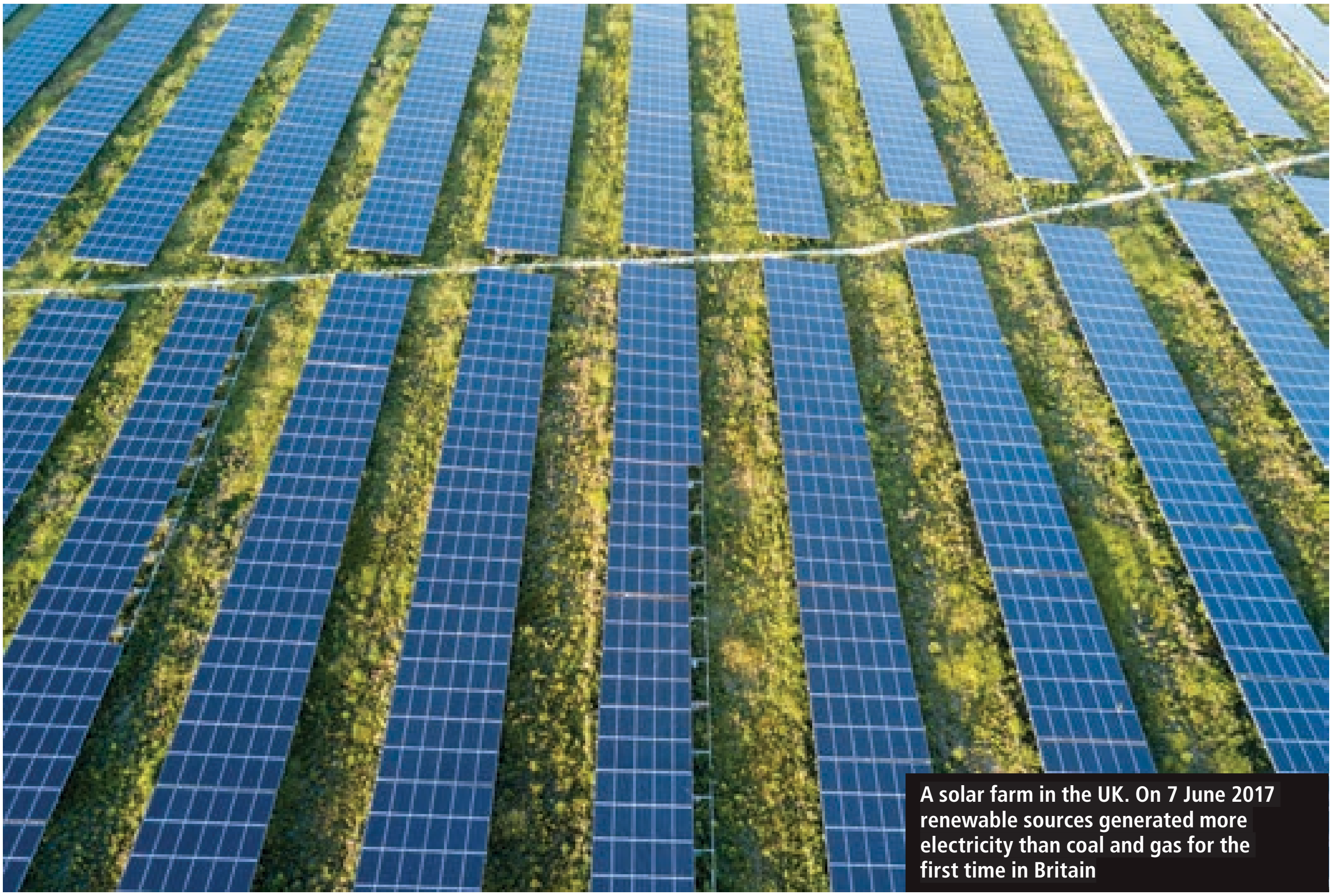
Negative greenhouse-



A solar farm in the UK. On 7 June 2017 renewable sources generated more electricity than coal and gas for the first time in Britain

The Paris Agreement on reducing greenhouse-gas (GHG) emissions, brokered by the United Nations (UN) in late 2015, has now entered into force. Over 100 countries have signed it, including most of the world's largest GHG-emitting countries.

The aim of the Paris agreement

The aim of the agreement is to avoid so-called 'dangerous climate change'. Governments have tasked themselves with keeping GHG emissions low enough that the atmosphere will not warm more than 2°C above pre-1800 levels. Even this much warming will cause significant changes to the planet's physical geography (which is why the UN would much prefer a 1.5° target to be met). But any warming above 2° will take humans into truly uncharted territory. For instance, scientists predict that sea levels could rise by as much as 9 metres over the next three centuries, posing a serious threat to many coastal cities.

In this context, the agreement is a plan to slow down the change rather than applying the emergency brake. Or, to use another metaphor, it intends to adjust the atmospheric thermostat rather than turn off the heating system altogether.

What is happening to emissions levels?

Since the first UN Earth Summit (in 1992) — when governments began to formally acknowledge that humans are changing the Earth's climate — GHG emissions have significantly *increased* rather than decreased. GHG concentrations are today about 30% higher than they were 25 years ago.

In light of this, people outside government might presume that rapid GHG emissions reductions are now planned, starting in the near future. However, the concept of 'negative emissions' allows signatories of the Paris Agreement to avoid achieving immediate straight line reductions. This Climate Change Update explains the concept of 'negative emissions' and why it has come in for criticism from both climate scientists and those in the world of professional politics and political activism.

Where did the idea come from?

The Intergovernmental Panel on Climate Change (IPCC) is the world's most authoritative organisation when it comes to anthropogenic climate change. Its first reports to governments, back in the 1990s, already indicated the need for drastic global reductions in GHG emissions. Such reductions would be both expensive and technically difficult. This is because the source of the emissions — the burning of fossil fuels in power stations and car engines, the production of cement etc. — was (and still is) vital to daily life in the most developed countries.

Realising that such reductions were unpopular with political leaders and their

gas emissions

What are negative emissions and how are they impacting on attempts to slow down climate change? Noel Castree explains

Further reading

Castree, N. (2016) 'Climate change update: Understanding the 2015 Paris agreement', GEOGRAPHY REVIEW Vol. 30, No. 1, pp. 18–19.

Hulme, M. (2015) 'Engineering the Earth's climate: Can we? Should we?' GEOGRAPHY REVIEW Vol. 29, No. 1, pp. 38–41.

citizens, some experts suggested that delaying them might allow governments to focus on long-term environmental goals while avoiding short-term political and economic pain. This would benefit developed countries, already hugely reliant on fossil-fuel energy. It would also help emerging economies that were seeking to improve living standards by likewise using coal, oil and gas in large quantities.

Negative emissions effectively means removing carbon dioxide from the atmosphere, for example by planting trees as 'carbon sinks', or storing carbon dioxide underground or in the sea (carbon capture). This idea was seen as a respectable way to represent a delay in emissions reductions. In a negative emissions world, far more greenhouse gases would be removed from the atmosphere per annum than are discharged into it. It was therefore acceptable to delay emissions reduction, on the assumption that we will make up for this in the future.

The situation today

In 2017, the negative emissions idea remains central to national GHG emission targets worldwide. For instance, Australia's government pledged a 25% reduction in its emissions compared to 2005 by 2030. However, it does not have the technology and policies to drive such a reduction. The present government is assuming that new technologies and the policies of future politicians will produce a dramatic change after 2020. Those technologies and policies, if they come to fruition, will need to do two things very quickly.

- They will need to sequester enough atmospheric carbon dioxide to compensate not only for 2020–30 emissions but also 'excess' emissions for the 2005–19 period.
- They will need to compensate for the warming effects of other greenhouse gases, such as methane, over the period since 2005.

The carbon budget

To understand the mathematics of this we need to refer to the world's so-called 'carbon budget'. This is the amount of carbon dioxide, in tonnes, estimated to be 'available' to emit before the 2°C target is missed. Much of the budget has been used by our historical predecessors, especially in 'carbon intensive' economies like the USA, Canada, Japan and the western European countries. Based on current emissions levels the budget, of roughly 1 trillion tonnes, is set to be used up by 2038 according to some experts,. To avoid a 'carbon debt' — that is, a blown budget — there are currently three options.

- **Option 1:** a massive increase in the area of land planted with vegetation would sequester a potentially large amount of carbon dioxide (so long as this green 'carbon sink' keeps being replenished).
- **Option 2:** as renewable energy sources receive more government support and scientific focus they could become more economical than fossil-fuel energy sources. This would mean that much of the oil, coal and gas currently targeted for burning would be left in the ground.
- **Option 3:** new carbon capture technologies would store carbon dioxide emitted from any remaining energy sources, such as burning wood chips.

Together, if implemented at a sufficiently grand scale, these measures would keep the carbon budget from going into deficit.

Can we avoid 'blowing' the budget?

Estimating the emissions reduction impact of all but the first of these is hugely uncertain. Even if greater certainty were possible, implementing all three options on a sufficiently large scale is challenging.

- **Option 1:** experts estimate that a land area up to three times the size of India would need to be planted with specific tree, shrub and grass species to make a sizeable dent in the trillion tonne budget. Implementing such a revegetation project will be extraordinarily difficult: which countries will be involved? how will a non-devegetation policy be enforced? and what economic, social and environmental benefits will need to be forgone by devoting land to revegetation rather than other uses? These are not easy questions to answer.
- **Option 2:** though we already have effective renewable energy technologies, like solar panels, large and powerful businesses continue to make enormous amounts of money by selling or utilising fossil fuels. Meanwhile, the economies of entire countries (such as Saudi Arabia and the USA) rely upon the export or import of fossil fuels. This creates huge resistance to switching en masse to renewable sources. It is hard to predict when, and with what mix of low-carbon energy sources, such switching might occur.
- **Option 3:** carbon capture and storage technologies are still at an experimental stage. It is unclear whether breakthroughs will allow enough carbon to be captured (e.g. from future biomass power stations) and safely stored underground forever.

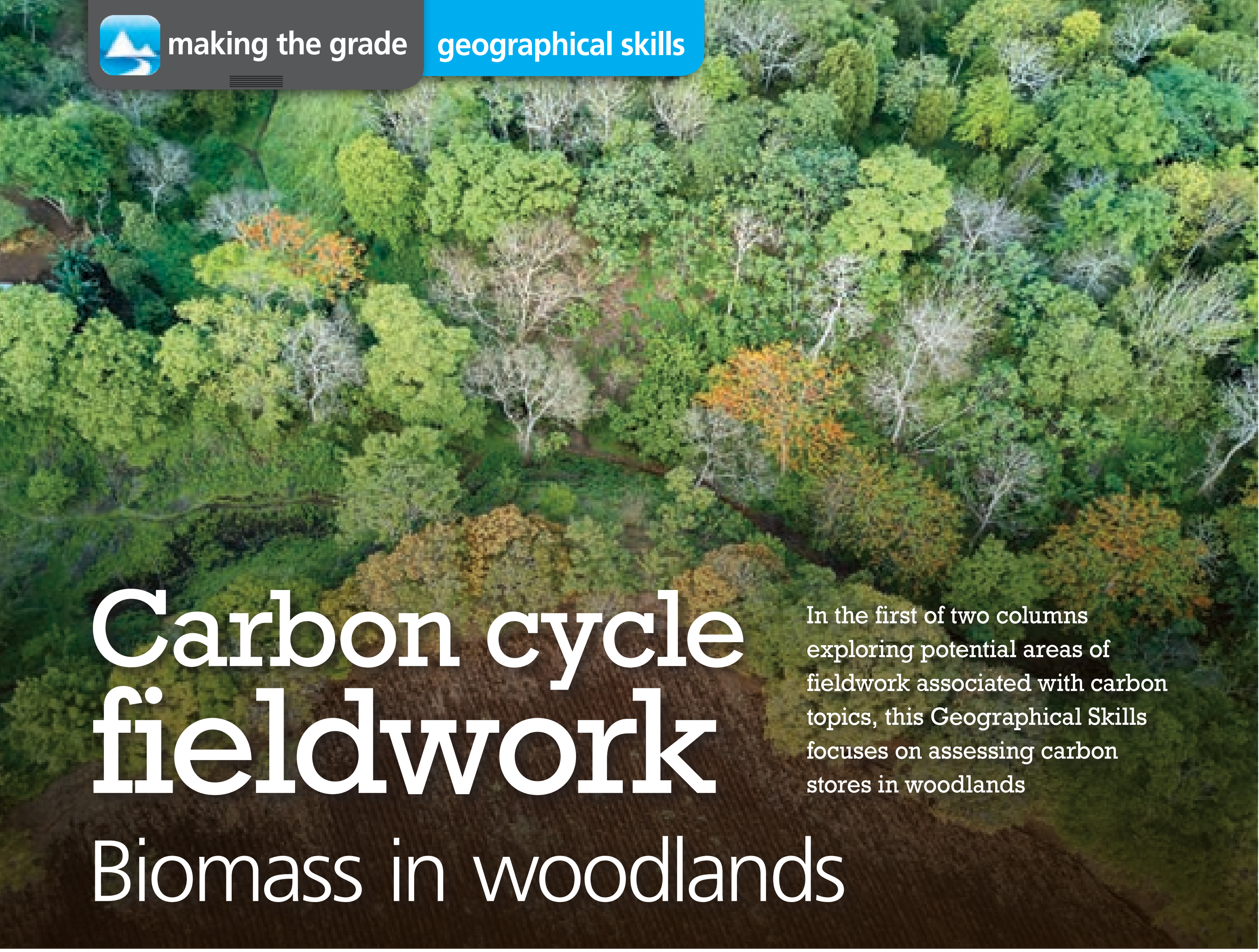
For these reasons, some critics regard the negative emissions concept as a way for national governments to excuse inaction on climate change. Others, by contrast, see it as a useful way for governments to buy time while they lay the ground for more dramatic technical and policy changes down the line.

Either way, if the planet's atmosphere continues to warm up — in 2015 it was already more than 1°C warmer than pre-1800 — this might open the door to so-called 'geoengineering' solutions. These aim to cool down the planet quickly, not by removing GHG gases but by reducing the amount of thermal radiation reaching the Earth's surface (see Mike Hulme's article 'Engineering the Earth's climate: Can we? Should we?' in GEOGRAPHY REVIEW Vol. 29, No.1). Such technologies pose a variety of physical risks and, for critics, can be an excuse for governments not to commit to a 'post-carbon' transition of the world's countries.

Conclusion

The stakes of political inaction are very high indeed. Today's in/decisions will have consequences for hundreds and thousands of years into the future. Even if the carbon budget is not exceeded, scientists give us only a 66% chance of not going beyond the 2°C target (and that target may be 0.5° too much anyway). We must hope the idea of negative emissions is not a fantasy destined to prevent the policy action it is supposed to facilitate.

Noel Castree is a professor of geography at The University of Manchester.



Carbon cycle fieldwork

Biomass in woodlands

In the first of two columns exploring potential areas of fieldwork associated with carbon topics, this Geographical Skills focuses on assessing carbon stores in woodlands

Carbon is a broad topic with links across physical and human geography. Table 1 gives some ideas for fieldwork themes. Fieldwork and research in this area at AS/A-level must inevitably focus on a small and localised part of the carbon cycle or system. This kind of research can provide greater detail and depth of understanding of a part of the system (flow, store, input, output), while linking to a bigger and overarching theme which is topical and relevant.

For example, an investigation into local carbon storage in woodlands could include reference to global carbon budgets or changes in the carbon cycle such as deforestation. The introduction and context for fieldwork would likely include a diagram to show the link between the intended study at a small scale and the carbon cycle at a global scale.

Investigating terrestrial carbon and biomass

One of the most accessible primary fieldwork techniques in relation to terrestrial carbon is

Table 1 Examples of carbon fieldwork themes. Those which are broadly physical are in green, the more people-orientated are in pink

Broad theme	Details and example of focus
Attitudes to energy and lifestyle analysis	Using local interviews and information to find out if there are differences in energy consumption between different groups based on age, gender, location, income etc.
Transport choices and carbon emissions	Using local interviews and information to find out if there are differences in transport choices between different groups based on age, gender, location, income etc. Much of this could be quantified, e.g. mean commuting distance leading to a daily estimate of individual traffic-related carbon dioxide fluxes
Perceptions of climate change and community resilience	Using qualitative observations to find out about potential climate risks in an area, linked to studies of how different groups and stakeholders perceive further risks
Diurnal and seasonal fluxes in carbon	Finding out how and why there are variations in flows of carbon, e.g. dissolved carbon in water from a stream, or diurnal changes in carbon dioxide emissions from transport in a town
The carbon in soils and peat	Investigating the amount of carbon stored in different soils and peat under different land uses, and at different times
Terrestrial carbon in plant and tree biomass	Estimating carbon stored in different types of terrestrial ecosystems, e.g. woodland vs farmland

to estimate the carbon store in a single tree. All you need are a tape measure, a clinometer and a calculator. Taking the four measurements described below allows you to calculate the biomass in the tree and the carbon can be calculated from this. For the calculation to work well, the trunk diameter should be at least 7 cm.

Measure your tree

Take the following measurements (see Figure 1):

- Standing a distance from the tree where you can comfortably see the top and are roughly on the same level as the base, use the clinometer to measure the angle from your eye level to the centre of the top of the tree. Make sure this reading is less than 45°. You may need to move further from the base of the tree. Record this as (q).
- Measure the distance from where you are standing to the base of the tree you are measuring. Record this in metres as (y).
- Next, measure the distance from your eye level to the ground. Record this in metres as (x).
- Last of all, use the tape measure to take a circumference reading around the stem of the tree at 1.5 m above the ground (this is known as breast height). Record this in metres as (c).

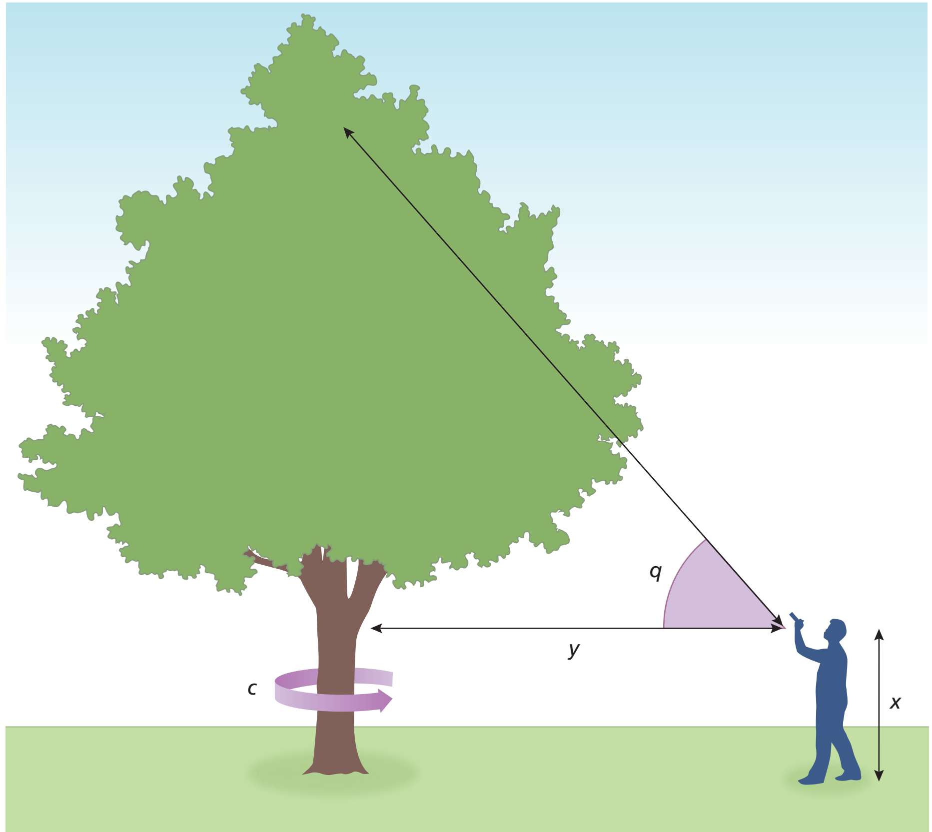


Figure 1 The important tree measurements

Using a clinometer to work out *q*

Calculate its volume

Now you'll need access to a scientific calculator. Assuming the tree is growing at a right angle to the ground, you can imagine the stem as one side of a right-angled triangle. Use the data you have collected so far and the tan button on your calculator to complete the following equation (think trigonometry).

height of stem (m) = y (tan q) + x

Calculating the volume of the stem assumes the tree grows roughly in the shape of a cone. First you need to work out the radius of the tree's stem at breast height (1.5 m off the ground) using the circumference measurement (c):

$r = c/2\pi$

Now put the radius (r) and the height of tree (h) into the following equation to work out the volume. It is important to make sure you are being consistent with your units — all readings are currently in metres.

volume of stem (m^3) = $\pi r^2 \left(\frac{h}{3}\right)$

Estimate stem biomass

So you now have the volume of your tree. But how much of the tree's stem is actually biomass containing carbon? This varies species by species according to its density or nominal specific gravity. Look up the nominal specific gravity of your

Table 2 Conversion figures to specific gravity for different tree species

Species	Nominal specific gravity
Ash	0.53
Beech	0.55
Birch	0.53
Corsican pine	0.40
Douglas fir	0.41
Larch	0.38
Lodgepole pine and other conifer	0.39
Oak and other broadleaf	0.56
Scots pine	0.42
Spruce	0.33
Sycamore	0.49

Source: Jenkins, T.A. et al. (2011) *FC Woodland Carbon Code: Carbon Assessment Protocol*, Forestry Commission.


You can calculate tonnes of carbon per hectare of woodland as part of your enquiry

tree in Table 2. If you need help identifying your tree, you can download the Tree ID app free from the Woodland Trust, or use a standard key.

Enter the stem volume and the nominal specific gravity of your tree into this equation to calculate the biomass in the stem:

stem biomass (oven-dry tonnes)
= volume of stem × nominal specific gravity

Estimate crown and root biomass

A substantial amount of the carbon in a tree is stored in its canopy (crown) and below ground in the roots. The biomass of these can be estimated using the species and radius along with the constants in Tables 3 and 4.

First, take the radius and double it to find the tree's diameter at breast height (*DBH*). Convert this into centimetres.

Use the following equations and the numbers in Table 3 to estimate crown biomass.

If *DBH* is 7–50 cm:
crown biomass (oven-dry tonnes)
$= a \times DBH^b$

If *DBH* is > 50cm:
crown biomass (oven-dry tonnes)
$= c + (d \times DBH)$

Then use the following equations and the numbers in Table 4 to estimate root biomass.

If *DBH* is 7–30 cm:
root biomass (oven-dry tonnes)
$= e \times DBH^{2.5}$

If *DBH* is >30 cm:
root biomass (oven-dry tonnes)
$= f + (g \times DBH)$

Work out total biomass and carbon content

Now you can work out the total biomass of the tree:

total biomass of tree (oven-dry tonnes) = stem biomass + crown biomass + root biomass

You now have everything you need to work out the carbon content of your tree. It is widely accepted that approximately 50% of biomass is carbon.

Table 3 Calculating crown biomass

Species	a	b	c	d
Larch	0.000044	2.0291	–0.129047	0.005039
Corsican pine	0.000012	2.4767	–0.299529	0.009949
Lodgepole pine	0.000018	2.4767	–0.430537	0.014300
Scots pine	0.000016	2.4767	–0.394206	0.013094
Douglas fir	0.000017	2.4767	–0.411768	0.013677
Grand fir	0.000015	2.4767	–0.353198	0.011732
Noble fir and other conifers	0.000015	2.4767	–0.353198	0.011732
Hemlock	0.000015	2.4767	–0.353198	0.011732
Norwegian spruce	0.000015	2.4767	–0.353198	0.011732
Cedar	0.000015	2.4767	–0.353198	0.011732
Sitka spruce	0.000015	2.4767	–0.353198	0.011732
Beech, sycamore and maple	0.000019	2.4767	–0.459519	0.015263
Oak and all other broadleaved trees	0.000017	2.4767	–0.411551	0.013670

Source: Randle, T. et al. (2011) *Technical Specification for the Biomass Equations Developed for the 2011 Forecast*, Forest Research. Crown Copyright, courtesy Forestry Commission (date of publication), licensed under the Open Government Licence

Further reading

Jenkins, T.A. et al. (2011) FC Woodland Carbon Code: Carbon Assessment Protocol, Forestry Commission.

Randle, T. et al. (2011) Technical Specification for the Biomass Equations Developed for the 2011 Forecast, Forest Research.

The FSC has more ideas and details on carbon fieldwork that can be accessed here: **www.geography-fieldwork.org**

Therefore:
Carbon content of trees (tonnes)

$$= \frac{\text{total biomass}}{2}$$

Tree surveys

Turning this technique into an enquiry is relatively straightforward. For example, you could:

- Lay out a 10 × 10 metre grid and count the number of trees within it to record tree density. (Consider how many times you may want to repeat these techniques to ensure the data you get are reliable.)
- If you multiply the number of trees in a 10 × 10 m grid by 100 you will get an average number of trees per hectare of woodland. Multiply by 10,000 to get number of trees per km^2.
- Multiply this by your average carbon content of a tree and this reveals the tonnes of carbon stored per hectare of woodland. From this you could compare different types of woodland, work out the quantity of carbon stored in the whole woodland or consider the implication of deforestation.

All these calculations are much easier if you use a spreadsheet.

This type of study does allow for a number of different focuses, for example:

- Comparing carbon stores in different types of woodland.
- Comparing carbon stores in different ages of woodland (if the planting dates are known).
- Calculating the quantity of carbon stored in the whole woodland — the significance of above ground compared to roots.
- Examining the impacts of deforestation in a UK woodland, compared to a tropical system.

The biomass of a tree includes its stem, crown and roots

Conclusions

Most physical geography fieldwork on carbon themes (e.g. those in Table 1) can involve small experiments and investigations, linked to some quantitative and mathematical skills. Remember the need to keep the focus small-scale and manageable, rather like completing a small section of a much bigger jigsaw puzzle. If accurate data are collected these kinds of projects can be both worthwhile and rewarding. They also lend themselves well to using GIS and other geospatial technologies to tell a more interesting geographical story.

The next Geographical Skills column will consider the opportunities for investigating carbon in soils and peat areas.

Table 4 Estimating root biomass

Species	e	f	g
Larch	0.000017	−0.133480	0.007296
Corsican pine	0.000011	−0.082603	0.004515
Lodgepole pine	0.000017	−0.133480	0.007296
Scots pine	0.000015	−0.118673	0.006487
Douglas fir	0.000017	−0.133480	0.007296
Grand fir	0.000015	−0.118673	0.006487
Noble fir	0.000011	−0.082603	0.004515
Hemlock	0.000015	−0.118673	0.006487
Norwegian spruce and other conifers	0.000012	−0.091547	0.005004
Cedar	0.000011	−0.082603	0.004515
Sitka spruce	0.000021	−0.157579	0.008614
Beech	0.000023	−0.174882	0.009559
Oak and all other broadleaved trees	0.000023	−0.174882	0.009559

Source: Randle, T. et al. (2011) *Technical Specification for the Biomass Equations Developed for the 2011 Forecast*, Forest Research. Crown Copyright, courtesy Forestry Commission (date of publication), licensed under the Open Government Licence

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Despite catastrophic predictions of the impact of rising temperatures, and the 2015 Paris Agreement on emissions reduction, governments are proving slow to act on climate change. Noel Castree explores why this is, using Australia, which has one of the highest per capita greenhouse-gas emissions rates, as an example

In 2015 only 14.6% of Australia's energy was supplied by renewable sources such as solar

Why aren't we acting on climate change?

Australia as a case study

Noel Castree

Governments are, among other things, responsible for managing the way humans utilise the natural environment. Their laws, regulations, taxes and other measures can, when effective, both enable and prohibit people's activities in ways consistent with environmental goals. Globally, one of these goals is to keep the average global atmospheric temperature to below 2°C above pre-1800 levels. This goal was agreed by most members of the United Nations (UN) at a climate summit held in Paris in late 2015.

By the start of 2017, over 125 national governments had signed the so-called Paris Agreement (see Climate Change Update in GEOGRAPHY REVIEW Vol. 30, No. 1). The agreement acknowledges that 'global warming' of the atmosphere is caused by the emission of 'greenhouse gases' from power stations and other sources. It allows countries to set their own emission-reduction targets and to meet the targets in whatever ways they see fit, provided they report how close to meeting (or possibly exceeding) targets they are.

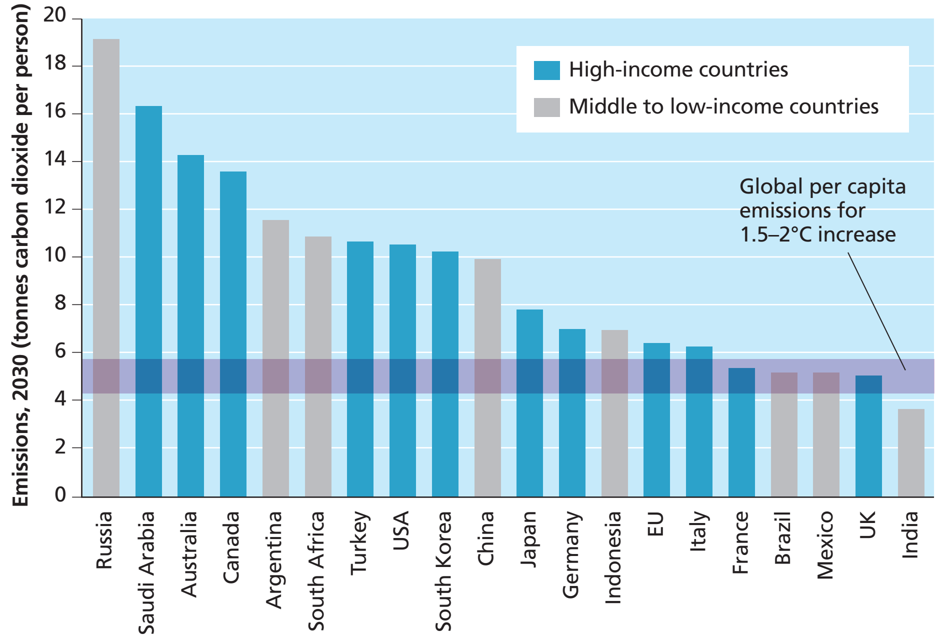
Currently, the world is on track to blow the ever shrinking 'greenhouse-gas budget' (the maximum tonnage of carbon dioxide, methane and other heat-absorbing gases whose discharge into the atmosphere must be reduced if the 2°C goal is to be met). Focusing on Australia, one of several countries with very high greenhouse-gas emissions (GHGEs) per citizen, can help us understand some of the specific and more general reasons why there is such a big gap between the rhetoric and the reality of climate policy.

Australia's contribution to global climate change

Australia is a wealthy country whose citizens, on average, enjoy a high standard of living comparable with that in other so-called 'developed' countries, like Japan and Germany. In Paris in 2015, the current government (a Liberal Party-led coalition) pledged Australia to reduce its GHGEs by 24–26% of 2005 levels by 2030. Though this reduction, even if achieved by all high-emitting countries, is not enough to keep average atmospheric temperature below the 2° target, it is nonetheless a welcome and worthy goal (see Figure 1, produced by an Australian think tank, the Climate Institute).

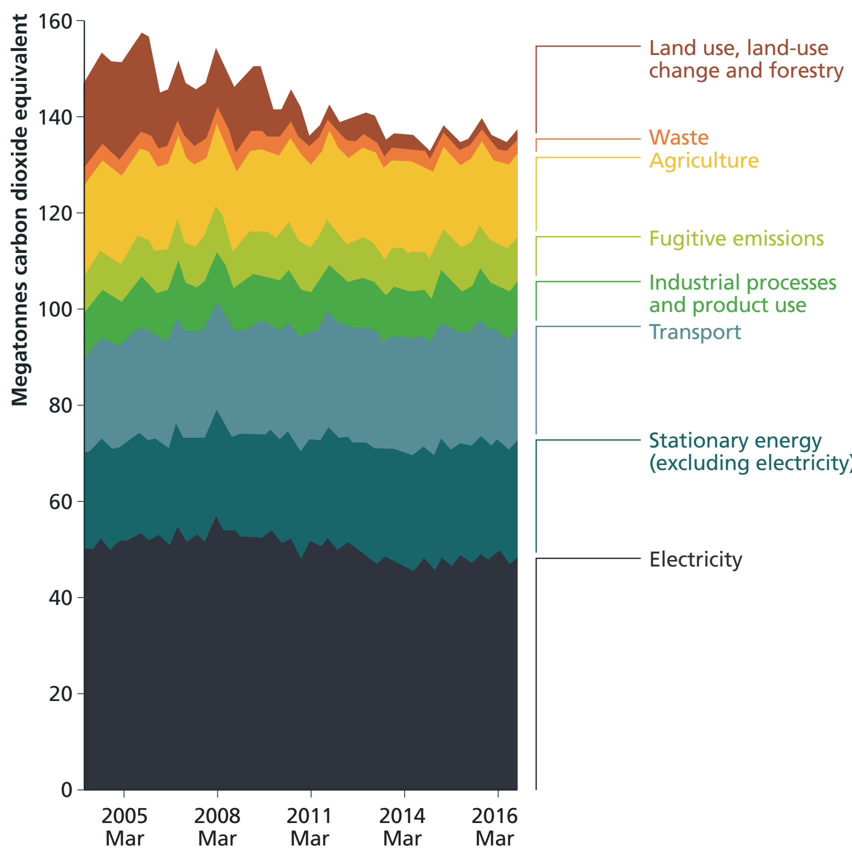
However, a recent independent report by Ndevr Environmental (see Further reading) indicates that Australia's emissions, while now about 8% lower than the 2005–09 average, are not falling fast enough to meet the 2030 target. On a per capita basis, Australia's 23.1 million citizens rank 44 places below the world's lowest GHGEs per person (in Nigeria), 42 places below the world's lowest energy consumption per capita, and 44 places below the lowest consumption of electricity per capita (these figures come from an independent report by the Californian organisation Next 10).

As with many developed and developing countries, Australia's GHGEs come from a few main sources. Figure 2 shows that around one third of annual emissions come



Source: www.climateinstitute.org.uk

Figure 1 Graph showing predictions of the G20 countries' per capita GHG emissions in 2030



Source: Ndevr Environmental

Figure 2 Graph showing emissions by sector in Australia, 2005–16

Box 1
The Great Barrier Reef

During early 2016 large parts of the Great Barrier Reef, a UNESCO World Heritage site, suffered 'bleaching' (when all the fauna and flora die), caused by unusually warm ocean temperatures. Some researchers have presented evidence of gradual ocean warming over recent decades off the Queensland coast and wider southern-hemisphere section of the Pacific Ocean. This is a result of atmospheric warming. So, quite aside from its global responsibility as a contributor to reducing the greenhouse effect, the current Australian government has a national responsibility to address climate change on its own doorstep.

A rally for climate action in Sydney. Protesters hold white coral shapes representing the bleaching of the Great Barrier Reef

from electricity generation, around one seventh from burning fuels for non-electricity purposes (e.g. domestic wood fires), around one seventh from fuels used in transportation (e.g. unleaded petrol), and around one seventh from agriculture (e.g. methane produced by cattle). In short, Australia is a country reliant on burning a lot of fossil fuels.

In this context, we might expect the government, led by prime minister Malcolm Turnbull, to be implementing policies to set Australia on a 'green path' by 2030. The condition of Australia's Great Barrier Reef (see Box 1) brings the urgency of this message home.

GHGE reduction policies

Despite the evident need of Australians to greatly reduce their GHGEs, government emission-reductions policies are not especially effective. Let's take the generation and use of electricity as a focus because it contributes so much (around 33%) to total emissions.

In 2015 only 14.6% of Australia's electricity was provided by renewable-energy sources, such as solar-panel arrays. Most electricity in Australia is generated by burning coal and natural gas, which releases carbon dioxide into the atmosphere. The present government has several policies in place to reduce the amount of carbon dioxide that power stations release (see Box 2):

- The Renewable Energy Target states that power stations — among other large GHG emitters — must offer financial help to ensure that large- and small-scale renewable energy projects (such as wind farms) provide an increased percentage of national energy supply.
- The Emissions Reduction Fund and so-called Safeguard Mechanism use a combination of target setting and financial incentives to ensure that electricity suppliers reduce their GHG emissions over time.
- In addition, Australia's state governments are implementing policies to reduce GHGEs. For instance, New South Wales spends millions of dollars per annum in the form of a Climate Change Fund to help homes, businesses and other organisations use less energy, especially energy derived from burning fossil fuels.

The problem is not a lack of policies to reduce GHGEs. As with many other countries around the world, Australia's problem is that the policies are not yet delivering significant reductions. They are relatively 'toothless'. To many observers, and especially environmentalist organisations such as Greenpeace and Friends of the Earth, this seems irrational. Why do governments not act more decisively when thousands of climate scientists, via the Intergovernmental Panel on Climate Change (IPCC), are adamant that global warming poses a real danger to people and planet (see Box 3)? Some of the many reasons for this are specific to Australia and others are common to most governments.

Explaining the climate 'policy gap' in Australia

Political will

To implement strong emissions-reduction policies governments need:

- to be convinced that global warming is real
- to have enough support among politicians, the business community and the public to avoid becoming highly unpopular

Neither of these two conditions applies in Australia today.

Box 2 Australian government policies on climate change

Like all national governments, Australia's uses a number of laws, regulations, and financial rewards and penalties to change the behaviour of those who supply and use energy to power homes, factories and so on. The aim is to move towards a low-emissions energy system within a larger 'green economy'. The major policies are:

- **The Renewable Energy Target**: government supports energy suppliers that favour low or no use of fossil fuels. It does this by making companies that sell energy to consumers purchase a certain number of 'energy certificates' issued on behalf of 'clean power' projects.
- **The Emissions Reduction Fund**: government pays businesses and communities for the creation of a variety of emissions-reduction projects, including improving energy efficiency, fuel switching, capturing methane from landfills and storing carbon in forests and soils.
- **The Safeguard Mechanism**: government monitors the largest greenhouse-gas emitters and mandates that they reduce emissions to a set level.

In addition, the Australian Renewable Energy Agency and the Clean Energy Finance Corporation are government-created entities which aim to drive innovation in clean-energy technologies. Together the agencies have more than $10 billion to invest in renewable energy, energy efficiency and low emissions technologies for energy production and use.


Proposals to open Australia's largest ever coal mine seem inconsistent with emissions reduction commitments

First, the Liberal Party contains several prominent 'climate-change sceptics' such as former prime minister Tony Abbott and the MP Cori Bernardi.

Second, the party is pro-business and more reluctant than the opposition Australian Labor Party to pressure businesses to move away from fossil-fuel energy sources. Indeed, its leaders abolished the position of minister of state for climate change created by the last two Labor governments.

Third, though many Australian citizens believe scientists' claims that climate change is caused by human activities, by no means all of them do. Meanwhile, many believers do not recognise, or express concern about, the economic and physical risks to people and environment that such change poses. Other issues, such as well-paying jobs and good schools, tend to preoccupy citizens in the run-up to federal and state elections. Because of this third reason, the present government — like its predecessor — has received little public criticism about its weak climate-change policy.

The Carmichael coal mine

In addition, Australia's federal system means that state governments are free to pursue actions that seem inconsistent with the country's Paris commitments. A major example is the Queensland government, led until recently by Liberal Party member Campbell Newman. During his premiership, and with support from the national government's former environment minister (Greg Hunt MP), Newman supported proposals to open Australia's largest ever coal mine.

If the mine goes ahead it will create many jobs and bring billions of dollars of revenue to Queensland over at least a 20-year period. But it will also lead to an estimated 2.3 billion tonnes of coal being burned as fuel in the decades ahead, adding further greenhouse gases to the world's atmosphere.

Negative emissions

'Negative emissions' describes a situation where more greenhouse gases are taken out of the atmosphere (e.g. by planting large areas of forest to sequester carbon dioxide) than discharged into it. Climate Change Update in this issue (pp. 26–27) explains more about this idea. The concept is being used by governments like Australia's to permit 'delayed reductions' in emissions. In other words, if emissions levels plateau or even increase in the years immediately ahead, governments argue that by 2030 their successors will, through stronger policies and technical breakthroughs, still meet the Paris targets. Negative emissions, combined with long-term target setting, allow governments to 'pass the buck' and claim that today's problems can be resolved tomorrow.

UN status

The final reason for the climate-policy gap in Australia relates to the United Nations. The UN created the Paris Agreement and its secretary general worked hard to get the most polluting countries to sign it. But the UN has neither the legal authority nor the resources to penalise any nation that fails to meet its 2030 emission-reductions targets. It mostly relies on goodwill and moral pressure to ensure that signatories to the agreement honour their pledges.

Conclusion: can the policy gap be closed?

A combination of general and specific reasons create a climate policy gap in Australia. Of the several reasons presented above, the first three are relatively specific to Australia, while the others apply to many other countries worldwide.

Can the gap be closed in Australia? There is little evidence to suggest the answer will be yes before 2030. Climate change is an invisible and distant problem in the eyes of many politicians, business people and citizens. Acting decisively to combat it is generally not an important vote winner for political parties seeking to retain, or gain, power.

Meanwhile, the burning of fossil fuels — oil, coal and natural gas — is so central to the economies of all developed and developing countries that eliminating their use in just 20 years or so is almost inconceivable. Australia still relies a lot on mining coal, smelting aluminium and other emissions-intensive activities. They provide invaluable jobs, products, export commodities and energy supply. Only a far-sighted government with a realistic chance of being re-elected two or three times can have the political security to 'decarbonise' the economy deeply and quickly.

Box 3 The IPCC and anthropogenic climate change

The IPCC (Intergovernmental Panel on Climate Change) is the world's most authoritative expert body working on global warming and its likely knock-on effects in the future. The panel is organised into three working groups that examine different aspects of the causes, magnitude and consequences of climate change.

Because climate change is slow in human terms, the panel has to use a range of techniques to predict future climate scenarios, none of which are perfect. Only in the future will we know how accurate the predictions are.

The panel has considered 'extreme' but still possible scenarios, such as a more than 4°C average increase in atmospheric temperature when compared to pre-1800 levels. Such a temperature increase would melt huge amounts of ice around the world, increasing sea levels significantly. It would likely increase the intensity of heatwave events. It would also shift the location of current climatic zones, with large impacts for flora, fauna, agriculture and urbanisation. There is a good chance that hurricanes would become more destructive on average because of warmer oceanic and air temperatures. The possible scenarios are laid out in the *Climate Change 2014: Synthesis Report* (Further reading).

Yallourn coal-fired power station in Victoria

Activities

1 Undertake some internet-based research into climate policy in the country where you live. High-quality newspapers and government departments (e.g. of energy or climate change) usually offer the most reliable information. Try to develop a fairly detailed understanding of the effectiveness of climate policy and compare it with Australia. If your country is ahead of, or behind, Australia in closing the 'policy gap' then try to identify the main reasons why.

2 Anthropogenic climate change is a 'wicked problem' (see Everybody's Talking About… in Geography Review Vol. 30, No. 4). In light of this, consider the sorts of things governments need to do to 'decarbonise' the societies they lead. How can the policy gap be closed in the next 10–15 years, or is the problem just too 'wicked'?

Further reading

IPCC Climate Change 2014: Synthesis Report: www.ipcc.ch/report/ar5/syr/

Ndevr Environmental report: www.tinyurl.com/kz9nou3

Next 10 Green Innovation Index: www.tinyurl.com/mob2znr

NSW Climate Change Fund Report: www.tinyurl.com/mmvwfs9

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Key points

- Climate change is a key global challenge.
- Emissions reductions were agreed at the 2015 Paris summit but many countries are in danger of not meeting targets.
- Australia is a country with high greenhouse-gas emissions, largely owing to its reliance on fossil fuels.
- There are a number of reasons, some universal and some specific to Australia, why it is unlikely to meet its 2030 targets.

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Simon Oakes

Deglobalisation

Has globalisation gone into reverse?

The UK vote to leave the EU, an isolationist US president, slowing of global economic growth — these all indicate a stepping back from global connectedness. Simon Oakes asks whether globalisation has gone into reverse gear

The UK electorate's vote to leave the European Union (EU) was a major shock for global systems and **global governance**. In the 1990s, many academics, business leaders and politicians viewed **globalisation** as an unstoppable and desirable process. Some **hyperglobalisers** prophesied an 'end to geography', believing that nation states would become irrelevant in a 'world of flows'. As societies became more connected and interdependent the differences between places disappeared and a new 'shrinking' and 'borderless' world was created.

The disruptions in Table 1 tell a different story. The *Financial Times* newspaper described the 2016 UK referendum result as a 'roar of rage' by people who felt 'alienated by globalisation'. Attracted by the Leave campaign's promise of stricter immigration controls and the restoration of national sovereignty, British people voted to abandon their economic, political and demographic union with 27 neighbour states.

What is deglobalisation?

The process of deglobalisation involves decreasing, rather than increasing, economic integration of countries, and reduced movement of goods, services and capital across borders. It is the opposite of globalisation. Non-economic dimensions of deglobalisation include weakened global governance and increased opposition to the cultural exchanges brought about by global migration, media and social networking. We can assess each

Table 1 Economic and geopolitical shocks

Year	Event	Impact
2001	9/11 attack on US World Trade Center	Al Qaeda's violent act signalled the start of the so-called 'war on terror'. Daesh (so-called ISIS) has since emerged as the major player in an ongoing conflict, which has brought misery to millions in the Middle East. Daesh attacks on Western cities and tourists appear calculated to disrupt 'business as usual' globalisation
2008	Global financial crisis	The crisis was rooted in US and EU money markets. High-risk lending by banks eventually undermined the entire world economy. Global GDP fell for the first time since 1945, also triggering the Eurozone crisis
2011	Arab Spring	At first, popular uprisings against north African and Middle Eastern dictators appeared to signal political progress. However, the global community failed to avert a crisis in Syria
2014	Russian annexation of Crimea	Thomas Friedman's 'Golden Arches' theory of globalisation states that no two countries with McDonald's restaurants will ever go to war. However, the presence of McDonald's in both Russia and Ukraine did not stop Vladimir Putin from annexing Crimea
2016	UK votes to leave the EU	Could Brexit spark the eventual disintegration of the EU if other populations demand a referendum too?

Glossary

Global citizenship The idea that a person's sense of identity is rooted in global-scale issues, values and culture, rather than a narrower national identity.

Global governance The steering rules, norms and regulations used by global organisations such as the United Nations to regulate human activity at an international level.

Globalisation The way in which the nations of the world become increasingly interconnected through exchange of trade and culture.

Hyperglobalisation A theory which suggests that the relevance and power of countries will reduce over time. People will come to identify as 'global citizens' rather than state citizens.

Nationalism The belief held by people belonging to a particular nation that their own interests are more important than those of people from other nations.

Positive feedback When a change in a system triggers a chain of events that amplifies the effect of the initial change.

Protectionism A nation blocking foreign imports that it views as a threat to its economy.

Re-shoring When companies return to using domestic suppliers because it has become more costly to use offshore suppliers.

Sovereignty The power of a place and its people to self-govern without any outside interference.

International flows of trade and money have slowed since 2007

different aspect of globalisation for evidence that it has retreated or paused (Table 2).

This article investigates two sets of pressures which may be responsible for deglobalisation:

- A global-scale slowdown in some cross-border trade is occurring due to problems with the system itself (Figure 1). The world economy has experienced 'boom and bust' phases before. Some economists view the period since 2008 as a new cyclical or permanent downturn. It follows a boom that began in the late 1980s.
- New barriers are being raised in some places to halt global flows that would otherwise operate. Some economists fear a return to the 1930s when **protectionism** damaged world trade and contributed to the Great Depression. Populist movements against migration or free trade have strengthened recently in many countries.

Is the global system slowing down?

Indications of a cyclical or longer-term downturn in world trade include the following:

- There has been a significant slowdown of emerging economies. Brazil, Russia, South Africa and Nigeria recorded minimal growth or entered recession in 2016. Global GDP growth fell to 2%, less than half its 2007 value.
- International flows of trade, services and finance grew steadily between 1990 and 2007 before collapsing and stagnating. By 2016 global trade had not grown for 5 years in a row. Annual cross-border capital flows of US$3 trillion are well below the 2007 peak of US$8.5 trillion.
- Oil and natural-resource prices have fallen due to a global industrial slowdown. As a result, economic growth in sub-Saharan Africa, which relies on exports of these commodities, has halved, leading several countries to ask the International Monetary Fund (IMF) for help.
- Container-shipping movements have declined. The Baltic dry index (BDIY) — a measure of the price for shipping dry goods such as iron ore and coal — reached a record low in 2016.

What explains this? First, recovery from the global financial crisis in 2008 was short-lived. Figure 2 suggests that the global

Table 2 Signs of advance or retreat in different aspects of globalisation

Aspect of globalisation	Advance, pause or retreat?
Economic connectivity	Financial flows, e.g. foreign direct investment, migrant remittances and internet sales
Social connectivity	International migration and social mixing, global developments in education and health
Cultural connectivity	Changing cultural attitudes and norms, global diffusion of media, music and fashion
Political connectivity	Participation in global agreements, growth of international institutions and organisations

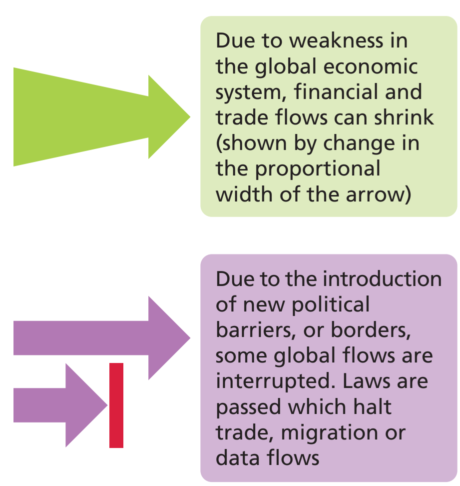
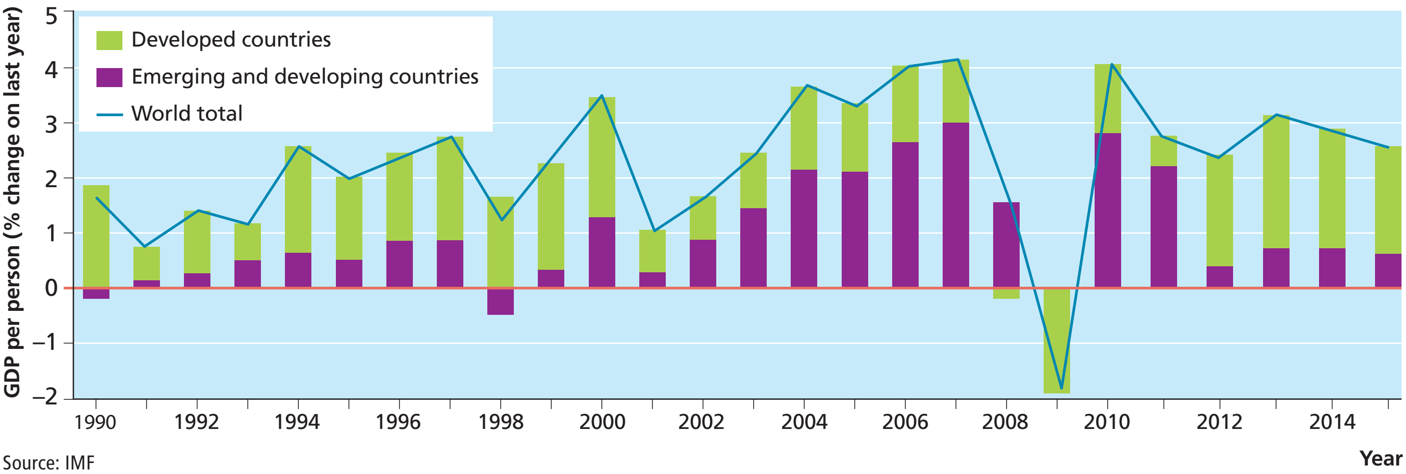


Figure 1 Reasons for the changing size of selected global flows



Source: IMF

Figure 2 World GDP growth, 1990–2015

economy lacked resilience and has yet to regain its previous strength, if it ever will. Second, although the Chinese economy is maturing, its growth rate has halved recently (from 14 to 7%). China was globalisation's growth locomotive: slowdown of the world's largest economy has serious implications for everyone. Moreover, this is a permanent rather than a cyclical change.

Are more states building barriers?

Increased acts of globalisation 'sabotage' by governments and citizens may also play a role in so-called deglobalisation. Some people and political parties dislike the interdependence which comes with globalisation. They prefer independence. 'Even as the world enjoys the benefits of unprecedented free movement of goods, people and ideas,' argues historian Simon Schama, 'so it also recoils against those same things on the realisation they don't guarantee prosperity or happiness.'

Political resistance to globalisation differs from place to place (Table 3). Many citizens in European countries believe the European Parliament and the European Convention on Human Rights undermine their country's **sovereignty**. They object to the free movement of EU citizens (and the passport-free Schengen Agreement) despite the evidence showing that economies benefit from the arrival of young and ambitious migrants. Across Europe, political parties promoting **nationalism** have gained mass support by calling for migration controls.

In the USA, Donald Trump's presidential campaign sought to pin the blame for US job losses on the country's free-trade agreement with Mexico. Trump's call for a border wall with Mexico was well-received by many citizens who want stronger barriers against immigration and foreign imports. Some US globalisation sceptics favour **re-shoring** of

Marine Le Pen, far-right leader of the Front National, campaigning in France in 2017

Table 3 State barriers against selected global interactions

Nations	Barriers created
France	French law is used to promote French-language music (and to limit the influence of English)
Venezuela, Bolivia and Argentina	Several South American governments have taken back control of their own energy supplies from foreign TNCs such as BP, Exxon and Repsol. This is called 'resource nationalism'
North Korea and China	China maintains a strong internet firewall, denying its citizens use of Facebook or the BBC website. Citizens of authoritarian North Korea have little or no access to the internet

Further reading

The Economist (2013) 'The Gated Globe' special report: **www.tinyurl.com/l5njdlp**

Statoil, *Energy Perspectives 2016*. Analysis of future global governance scenarios: **www.tinyurl.com/k49tdqq**

Oakes, S. (2012) 'Globalisation: a risky business', Geography Review Vol. 25, No. 4, pp. 36–41.

Oakes, S. (2015) 'Everybody's talking about… 3D printing', Geography Review Vol. 28, No. 4, pp. 34–36.

industry. Others want hefty tariffs on Chinese imports (including a proposed 500% import tax on Chinese steel) and assert that China's economic rise came at the USA's expense.

As well as economic measures, the USA also shows signs of political deglobalisation, or 'isolationism'. It has increased its energy security by producing its own shale gas through fracking. This means the USA benefits less clearly from military and geopolitical involvement in the oil-rich Middle East, and many political commentators believe it is stepping back from global affairs.

Lagos, Nigeria, is a hub of the global economy

A complex picture of change

The two broad causes of deglobalisation identified by this article are interconnected, of course. They strengthen one another through **positive feedback** as follows:

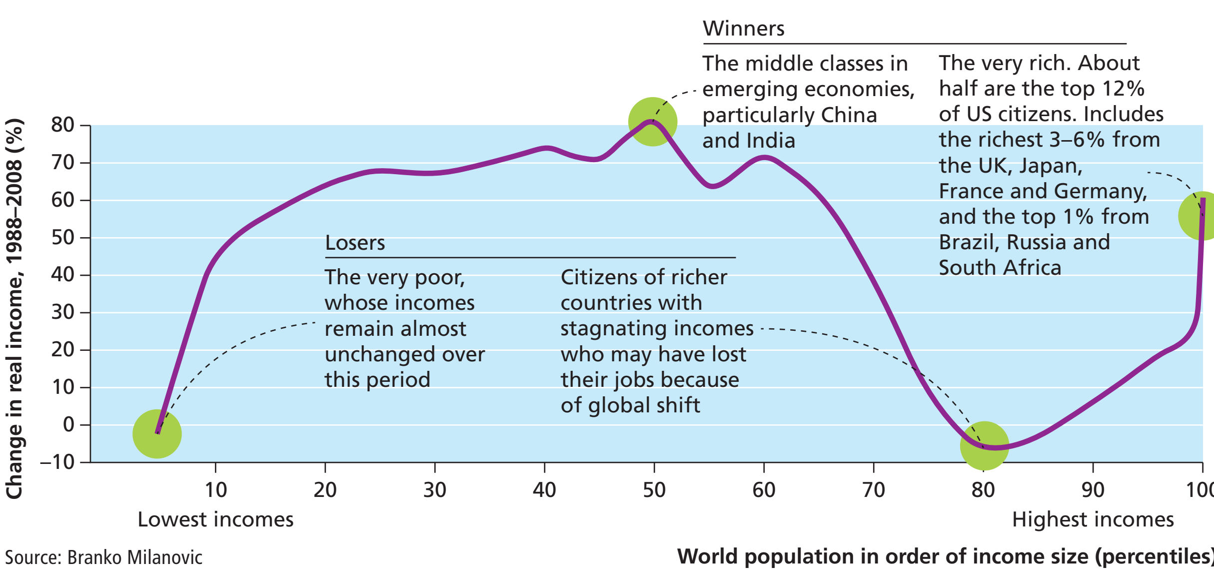
- Slow global economic growth since the global financial crisis has created economic hardship and austerity for many people in Europe and North America.
- This has left many citizens feeling they are 'losers' in a global game which only benefits rival states, migrants and global 'elites and experts' (see Figure 3).
- New political movements have arisen which promise to address these popular concerns by bringing in 'anti-global' measures such as migration controls and import taxes.
- These protectionist measures make slow global growth even more likely (according to economic theory).

Resistance at varying scales

The referendum on EU membership revealed deep rifts in British society. Support for Brexit was high among pensioners, in rural communities and in urban areas of northern England. Younger voters, Londoners and Scots favoured remaining. In other countries too, the reaction against global governance and globalisation is geographically and sociologically complex. Nigeria, for example, is deeply divided. In the rural northeast, a violent campaign against the westernisation of Nigerian society is led by the Boko Haram militia group. In contrast, Nigeria's coastal megacity Lagos is a major hub of the global economy.

Selective deglobalisation

Some groups oppose certain aspects of globalisation but not others. Anti-globalisation



Source: Branko Milanovic

Figure 3 Globalisation's 'winners and losers'

Occupy is an anti-globalisation movement which makes use of global networks to spread its message

movements such as Occupy want to curtail the influence of global corporations and the World Bank but retain a strong belief in **global citizenship**. They use global media networks to spread their anti-capitalist message worldwide. Daesh has embraced 'Western' technology such as YouTube.

The world is still shrinking

Although the slowdown in global trade suggests globalisation has taken a step backwards, data on other indicators suggest the opposite. Table 4 shows other recent steps forward for global integration and interdependency.

Conclusion

The concept of deglobalisation is useful because it prompts us to analyse change in how global systems and global governance are evolving. However, the view that globalisation has 'reversed' is too simplistic. Instead, it has entered a new phase characterised by change in the relative importance of different global flows.

- Commodity flows and some financial flows have fallen and stagnated. Growing signs of protectionism, and the rise of 3D printing, mean physical trade may decelerate further.
- In contrast, migration flows continue to rise and will only fall if more countries reinstate border controls.
- Data flows are accelerating, along with worldwide social media use.

The world is therefore still shrinking in many respects, even if physical cross-border trade flows might be declining. Finally, cultural and economic integration is less obviously driven by the USA now than in the past. Indeed, it might be argued that we are fast approaching a 'de-Americanised' — rather than deglobalised — era of history.

Table 4 Signs of strengthening global interdependency

Year	Event
2012	Facebook registered 1 billion users, representing unprecedented human connectivity
2013	The EU expanded further to include Croatia. Other Balkan states hope to join soon
2015	The COP21 Paris climate change conference was a 'success story' for global governance in many people's view
2015	Chinese investment in Europe and the USA reached a record total of almost US$40 billion
2016	The African Union announced plans for all 54 member states to seek visa-free travel
2016	The number of international migrants reached a record 250 million

Questions for discussion

1 Will emerging economies catch up with developed countries eventually?
2 Could globalisation accelerate again, but with China as the leading global power?
3 Some people view the UK's decision to leave the EU as illogical, given the urgent need for greater international cooperation to tackle threats ranging from climate change and pandemics to terrorism. What is your view?

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Key points

- World trade and financial flows have slowed since the global financial crisis of 2008.
- Opposition to international migration, offshoring and trade bloc membership has increased in some countries.
- More governments show signs of listening to voters who are sceptical of globalisation, and introducing policies including migration controls, trade protection and retreat from global political affairs.
- While more people and politicians in developed countries may be sceptical of globalisation, these attitudes are not necessarily shared in emerging economies.
- The concept of globalisation is complicated and consists of numerous processes, not all of which have slowed.