Climate Change Science: A quick background

32 comments

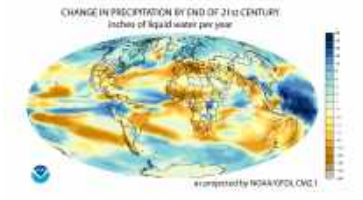
To be able to identify viable solutions to global environmental threats, we first need to understand the nature of those threats. If you are familiar with the basic science of Climate Change, please feel free to skip this step.

Earth is surrounded by a thin layer of gases - the atmosphere - that stops some of Earth's heat energy radiating out to space and sends it back down to the surface. Therefore the atmosphere acts like a blanket by trapping heat energy in. So-called 'greenhouse gases', such as carbon dioxide (CO_2), methane (CH_4) and water vapour play a key role in maintaining this blanket. Without it, Earth would be about -18˚C! The problem is that human activity is producing greenhouse gases. Much of our everyday life involves burning fossil fuels, which released carbon dioxide into the atmosphere, making the blanket thicker. This results in **global warming**.

The blanket effect - Image from NASA

Climate change is more than just global warming. About one-third of our carbon dioxide emissions are absorbed by the oceans, where they react with seawater to form a weak acid. This results in **ocean acidification**, a lowering of the ocean's pH. Furthermore, the oceans are becoming warmer as they absorb much of the extra heat energy being trapped by the atmosphere. This extra heat initially goes into the surface ocean, where for example it can supply more energy to hurricanes, making these storms more ferocious. The acidity and extra heat is also slowly being mixed down into the deep ocean, with worrying implications for ecosystems and habitats that we know very little about, such as deep sea coral reefs.

Back on land, climate change is starting to change precipitation (rain or snowfall) patterns. A warmer atmosphere holds more moisture, and extreme precipitation events are getting more frequent in some regions. Also, the melting of sea-ice surrounding Greenland means more moisture can be picked up and transported to the centre of the Greenland ice sheet and deposited as snowfall there. However, other land regions are getting drier thanks to warming and changes in atmospheric circulation. For example, severe droughts have hit the Amazon rainforest - in 2005, 2010 and again in 2015/6. The Mediterranean is also suffering worsening droughts.



Precipitation changes around the Earth - Image from NOAA

We can look back at the Earth's history to know that what we're seeing today is unprecedented. The rock record allows us to reconstruct the Earth's climate history - nearly all 4.5 billion years of it. For the last 800,000 years, ice cores record changes in the climate and the composition of the atmosphere. Tree rings and pollen records help identify natural variability in recent millennia. By comparing what we know about normal variability in the climate system to what we've observed over the last century we can establish that the climate change we're seeing today is a) occurring at an unprecedented rate and b) caused by human activity.

All parts of the world will be affected in some way by climate change. The Arctic is one of the fastest warming places and sea-ice cover is declining year on year. Glaciers of the Greenland ice sheet and Antarctic peninsula are accelerating and retreating at rates never before seen. Desert expansion is affecting agricultural land in Africa. By the end of this century, sea-level rise will threaten hundreds of millions of people in low-lying cities and countries, including Bangladesh, Bangkok and New York. If you think it won't happen any time soon, remember the events of Hurricane Sandy, when much of Manhattan was flooded by this extreme event.

This course is here to present some of the solutions to the impacts of climate change. One thing is clear though - human greenhouse gas emissions need to be rapidly reduced and stopped by mid-century to avoid some of the most dangerous impacts that climate change could throw at us.

Case Studies

65 comments

Now you've learnt about the key responses to climate change (mitigation, adaptation and geoengineering), take a look at some case studies where each has been applied.

Mitigation

There are many ways to keep greenhouse gas emissions below a level that prevents dangerous climate change. China - the world's largest polluter - pledged in the 2015 Paris accord that by 2030, they would peak their carbon dioxide emissions, and reduce carbon dioxide intensity by 60-65% from the 2005 level. They also agreed to increase forest stocks to strengthen their carbon sink. To achieve this, they have outlined a number of mitigation strategies:

- Introduce a cap-and-trade programme for carbon emissions. This builds upon similar systems in the US and EU.
- Increase the use of renewable energy with investment in many options across the sector, including hydropower, solar and wind.
- Ban the burning of coal in some provinces and, across the nation, reduce the reliance on coal as an energy source. China have also introduced a cap on the amount of coal use after 2020.
- Introducing new building codes and electrical appliance regulations to ensure maximum energy efficiency.

This highlights that no single policy can be employed when introducing a national mitigation strategy. The combination of all of these policies will help China reach its commitments from the 2015 Paris accord.

Global change in forest area 1990 - 2015 shows China's enthusiasm towards afforestation schemes recently. Source: Food and Agriculture Organization of the United Nations, 2015, Global Forest Resources Assessment, FAO, Rome. Reproduced with permission.

Adaptation

The Mekong Delta in Vietnam is low-lying and vulnerable to the effects of sea-level rise. Over 17 million people live in the Mekong Delta and may be impacted by future change. Vietnamese governments and local residents are facing a choice: accept that the Mekong delta will flood or hard engineer to protect low-lying land. Hard engineering can preserve the delta, and is currently being used in the form of dykes and sluice gates to manage salinity changes in the river. But if hard engineering solutions fail, then the knock-on impacts will be even more devastating as locals wouldn't have had the time to prepare. Hard engineering solutions are also expensive, intrusive and difficult to construct across such a large area.

Instead, the Vietnamese government has been focusing on different ways to prepare in the form of social adaptation.

- Buying seeds from local farmers to ensure they can maintain an income and livelihood, even if their crops are destroyed by flooding
- Using water more sustainably and efficiently. Next week, we'll introduce you to how using resources more efficiently in agriculture can help improve food security
- Committing to community outreach work, to increase the awareness of the problems and how individuals can help themselves
- Diversifying incomes and jobs. Move the region away from one that relies solely on agriculture and training locals in new skills so they are not hit economically by sea-level rise

The Mekong Delta, Vietnam.

Geoengineering

Whilst you might think that geoengineering is a long way off, the technology to store carbon dioxide underground is already well established. The Sleipner carbon dioxide storage project has been going since 1996. It has the capacity to store around 1 million tonnes of carbon dioxide each year into deep geological stores around 200km off the coast of Norway. It was built to reduce the CO_2 content of natural gas that was being extracted in the area to meet EU regulations. The carbon dioxide is injected via wells into a sandstone reservoir below the sea floor, at a depth of 800-1,100m below sea-level. Over its lifetime, it has prevented the release of 16.5 million tonnes of carbon dioxide to the atmosphere.

Currently under construction, the Alberta Carbon Trunk Line, USA, will be the largest carbon capture and storage facility in the world, with the capacity to store 14.6 million tonnes of CO_2 each year. But instead of injecting the gas into deep rock, it will be injected into oil reservoirs underground to enhance the recovery of oil, which will then be used. This means the whole process includes some greenhouse gas emissions.

To achieve a true geoengineering solution to climate change these proven carbon capture and storage technologies need to be linked to a process that removes CO_2 from the atmosphere.

The Nuclear Debate

74 comments

Over the next series of articles, we'll present arguments for and against three approaches to meeting energy demands. Firstly, we'll start with nuclear energy. This remains a controversial choice of sustainable energy generation, but which side will you agree with at the end?

Introducing the debate

Power generated from nuclear fission (fusion is still currently not viable), can generate electricity 24/7 without producing harmful greenhouse gas emissions – unlike fossil fuel burning. The chimneys you'll see at a nuclear plant are only releasing water vapour. That's not to say it is completely clean energy, as small amounts of nuclear waste are produced that can take hundreds of thousands of years to decay. Safety is also a concern for residents nearby nuclear plants, given the catastrophic nature of accidents (in the extremely unlikely event they do occur). This website provides a nice (balanced) introduction to nuclear energy. Interestingly, public perception of nuclear energy remains divided. In Britain, a survey found that:

> *"concern about climate change and energy security will only increase acceptance of nuclear power under limited circumstances—specifically once other (preferred) options have been exhausted."*
>
> Corner et al, 2011


No greenhouse gases, only water vapour. But is it the way forward for energy production?

Arguments For

The Sun is a nuclear fusion reactor, which means that we all depend on nuclear energy in a profound way. In order to move away from fossil fuels, there must be a viable alternative for producing 'base load' electricity. This is the minimum continuous supply of an electricity grid. When modelling zero-carbon energy generation

this century, we typically assume that nuclear power is an essential part of the energy mix. In some scenarios, nuclear power is responsible for up to half of energy production. There is enough natural nuclear energy in the world to meet this demand and it could be built fast enough with international co-operation. This requires a global effort, as well as acceptance from individuals and changing societal perceptions. But, in theory, according to enthusiast Barry Brook, *'there are no technical, economic or fuel-related limitations'* for nuclear fission.

Nuclear power plants produce no greenhouse gases (aside from what is required for their construction) and provide a constant, stable supply of electricity. This contrasts with renewables such as wind and solar that depend on variable weather patterns to generate electricity. For the quantity of energy they produce, the financial costs associated with nuclear power plants are decreasing.

Arguments Against

Despite the rigorous safety mechanisms that nuclear power plants must employ, they are not immune to natural disasters, as the 2011 earthquake and tsunami that struck the Fukushima plant in Japan showed. Less obvious, but more insidious, is a historical tie between civil nuclear energy generation and military nuclear capability. For some, a completely nuclear free world is the safest path to reducing future political confrontations.

Nuclear energy can only contribute 'base load' electricity – it cannot respond to peaks in demand. This base load can be provided by alternatives, such as fossil fuel power stations equipped with carbon capture and storage technology. There are a number of other concerns about nuclear energy. This includes the high environmental cost of searching for, extracting and transporting uranium, 'lifecycle greenhouse gas emissions', rising costs, and safety issues. There are also issues around the disposal of environmental waste and the high relative costs of construction and operation of nuclear plants.

What do you think?

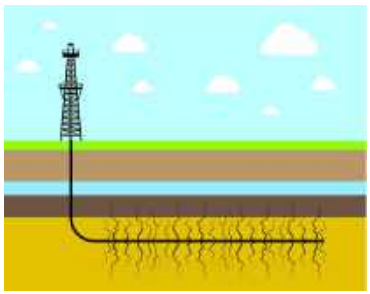
This article presents a brief introduction to some of the key arguments for and against nuclear power. Reflect on each, try and do some of your own research, and decide whether you think nuclear energy is a viable alternative to fossil fuels.

Frack on, or frack off?

60 comments

Hydraulic fracturing (fracking) has been around since the 1950s and is used across North America to extract natural gas.

The process of fracking involves drilling deep into shale rock to reach untapped reserves of natural gas in very small cracks. Drills can move horizontally so natural gas can be extracted many miles away from a fracking site. Water, sand and other materials are pumped into the hole to open the cracks in the rock, allowing the natural gas to flow out and be used.


Simple diagram of the fracking procedure. The pipes beneath the ground can be many miles long.

Arguments For

Proponents of fracking argue that it has helped to secure a reliable source of natural gas in North America, and this technology could be applied to areas such as the UK, South Africa and New Zealand. The US and Canada benefit from around 100 years of gas security because of fracking. For the consumer, a plentiful supply of gas drives down prices, as well as creating jobs.

The horizontal drilling mechanism can allow areas of natural beauty such as National Parks to be protected, by extracting the gas beneath them with no visible effects on the surface. Difficult-to-reach areas such as beneath the sea could also be reached from land with this technology. Furthermore, the burning of the gas itself produces roughly half the carbon dioxide emissions of coal burning.

Arguments Against

Despite the reduced carbon dioxide emissions, there are significant pollutants involved elsewhere in the fracking process. The natural gas itself, which is mostly methane, has been found to leak in the production process, and as a more potent greenhouse gas than carbon dioxide, is more important to keep control of. The enormous volume of water, and the infrastructure used to pump it below ground, requires transporting and maintaining at the expense of further carbon dioxide emissions.

There are also legitimate concerns surrounding the leakage of contaminated water into conventional groundwater supplies that are often used as drinking water. This is usually dealt with by sealing the pipe with concrete in the upper portion, but leaks could still occur. Furthermore, public health concerns have been raised about some of the chemicals pumped to keep the cracks open - the details of which are not always fully disclosed.

Fracking and NIMBYism

Are you for fracking or against it? What if large shale gas deposits were found beneath your home, would you then be for or against fracking them? With all proposed energy solutions it is worth considering whether you would be a NIMBY (Not In My Back Yard!) or a YIMBY (Yes in My Back Yard!).

Summary

Fracking can release untapped natural gas reserves, providing a relatively cheap and easy to transport source of energy, with less carbon dioxide emissions than coal burning. But, when methane leakage is taken into account it may be just as bad for the climate, so calling it a ‘transition fuel’ (on the way to a zero carbon economy) can be questioned.

Rising Renewables

56 comments

On the 7th June 2017, renewables – for the first time ever – briefly generated more than 50% of the UK's electricity. This is nothing new for some countries, with Paraguay, Iceland and Norway producing more than 98% of electricity with renewables. So are they the future?

Introducing the debate

There are a vast array of renewable energy sources – hydropower, wind energy, solar energy and biofuels to name a few. They're decreasing in cost and increasing in popularity, but not every country is able to exploit their full potential. Some, such as Brazil, are able to capitalize on their natural resources very well, while others don't have such luck. For some renewable technologies, their use remains controversial and 'green status' somewhat questionable.

Hydropower

River damming is the reason why some countries are able to generate close to 100% of their electricity capacity with renewables. A single hydropower plant can generate more electricity than 1000 wind turbines. With the exception of the energy used to build the dam and power station, the technology is free of greenhouse gas emissions. But, the land required to produce a reservoir big enough can be hundreds, if not thousands of square kilometers. In Brazil, the Belo Monte dam will flood virgin Amazonian forest. In China, the Three Gorges Dam resulted in the displacement of a million people. Flooded vegetation and soil at the bottom of the reservoir can decompose to release methane gas – each molecule of which traps 25 times more heat energy than carbon dioxide.

Solar

The decreasing cost of solar panels means that it is becoming an increasingly viable alternative to fossil fuels. The panels are becoming more efficient and sophisticated, with tracking mechanisms to follow the sun to improve their output. Solar farms can be built on less productive land, such as Solar Star farm – built in the Californian desert. But when there's no sun, they stop working. At night, when electricity demand can peak, solar power cannot help - unless it has been stored from the day using batteries or some other form of storage technology (e.g. pumping water uphill which is later released to generate hydropower). For private homeowners

looking to put solar panels on their roofs, the upfront cost can be very high – although in the long-run there's a big financial saving.

Wind

Wind farms are also becoming more popular as the price of the turbines decreases. Growth is largely in off-shore wind farms, partly because of a strong NIMBY (Not In My Back Yard!) reaction to onshore wind farms. Wind turbines produce electricity whenever sufficient wind is blowing, unlike solar, but are unable to respond to peaks in demand or at times of low wind. Onshore wind farms typically make good use of land and offshore wind farms can also often be situated close to large cities, thus reducing the cost and inefficiency of transmission. The London Array is the largest offshore wind farm in the world and is under 100km from London. However, expansion was stopped due to the impact on migratory birds that can be killed by the turbines.

Global food security solutions

83 comments

In 2016, the United Nations Food and Agriculture Organisation reported that almost 800 million people were suffering from chronic undernourishment. Of these, 98.2% live in developing countries and areas that are likely to be hit hard by climate change. With growing population and changing diets, we need to double global food production by 2050.

What does a global solution look like?

Global solutions to food security first and foremost need to be sustainable. They need to be properly funded and ensure that the aid reaches the right people. Mitigating against climate change alongside on-the-ground aid will help ensure bigger problems such as desertification (the expansion of deserts) don't take over. In this article, consider how each solution could be applied to different areas of the world to help provide global food security at all scales.

Reduce meat intake

Currently, we grow food that is then used to feed livestock and cattle that we then consume. Each stage in the food chain results in a massive loss of food energy. If we grew food on the same area of land to be consumed by humans, instead of animals, we could feed another 4 billion people. This is an enormous dietary lever, and a very simple way of improving food security. But, there are important cultural and political reasons why reducing meat intake may not be favorable across the world.

Reducing meat intake doesn't need to mean going completely vegetarian. You could start by having meat-free Mondays and swapping red meats for chicken or tofu. Small positive changes all make a difference.

Use water and fertilisers more efficiently

Around 60% of Nitrogen and 48% of Phosphorus that is added to crops to help them grow is in excess. This leads to pollution for nearby ecosystems, and nitrous oxide and methane emissions (which contribute to global warming). Growing rice and wheat consumes around 59% of all global irrigation too. There is significant regional variation in these statistics though, with China, India and the US the most 'wasteful' with fertilisers and water. Better farm management is an important way to improve global food security.

Reduce food waste

Globally, 30-50% of food is wasted. This varies hugely by region. In India approximately 3 calories per person per day is wasted, while the US wastes around 290 calories per person per day. If China, USA and India cut their food waste, over 400 million people could be fed. Some countries and supermarkets are beginning to introduce 'wonky fruit and veg' - consumables that are perfectly fine to eat, but may look less attractive. Look out for these the next time you shop to help cut food waste, and try not to buy more than you can eat.

Improving yield on existing land

Current yields from agricultural land are globally around 50% below their potential. Again this varies between regions, with the greatest potential for gains in Africa. But, climate change will change the potential to improve yields on existing land. This is why climate change and food security are so intrinsically linked - because a sustainable solution to food security has to work in a future climate when we'll have 2 billion more mouths to feed.

Statistics in this article from West et al, 2014, Science.

The history of land-use change

51 comments

Humans evolved over 100,000 years ago and we've been impacting the environment around us ever since. Societies are intrinsically linked to the climate, and we've been changing ourselves, and the land around us, for thousands of years.

During the last ice age, the use of fire by human hunters began to alter landscapes by reducing tree cover. Then at the start of the Holocene (around 10,000 years ago) - which marked the transition from the ice age to a warm and stable 'interglacial' period - the dawn of agriculture caused a major shift in land use. Agriculture started independently in several parts of the world, with different societies domesticating different plants and animals and developing their own ways to work the land. In the West, maize and potatoes became staple foods. In the East, millets and rice dominated agriculture.

Populations began to rise as agriculture developed, and where food surpluses could be generated this supported the development of more complex societies. This was only possible due to the change in the climate. But, the two are more deeply linked. Early agriculture used a lot of land and that led to widespread deforestation, adding carbon dioxide to the atmosphere. Early rice production also added methane to the atmosphere. Then in the 14th century plague struck most of Europe and led to a major crash in populations. Afterwards, because less land had to be cultivated for food, European forests began to recover and this has been linked to a drop in atmospheric carbon dioxide levels.

The Green Revolution

In the middle of the twentieth century, a 'green revolution' was quietly began. This intensification of agriculture ultimately led to a tripling of the world's food availability with only a 30% increase in land area under cultivation. Without the green revolution, food prices would have been 35-65% higher and calorific availability 11-13% lower. The green revolution came about as a result of solutions to dramatically increase the yield of staple crops – wheat, rice, maize etc.

Selective breeding and genetic improvements produced high-yield crop varieties. Significant investment in research, infrastructure and market development combined with improvements in technology. Fertilisers, irrigation and pesticides were used to increase yields, while sparing thousands of hectares of land from changing to agricultural use.

Asian farms benefited significantly from the green revolution. Millions of people were saved from hunger and it allowed Asian economies to develop. But the innovations were inappropriate at the time for African farmers who had land in abundance, little need to intensify and little capacity to participate in the green revolution. Female farmers also gained less than males, with few measures to address societal inequalities alongside environmental degradation.

Using satellite imagery, we can see the impact we have on the land around us very clearly. Fertile land allowed the expansion of Ventura, California. Image from NASA.

Today

Today, agriculture and forestry account for around a quarter of total greenhouse gas emissions from human activity. We've deforested almost 20% of the Amazon rainforest (from pre-1970 levels) and the amount of global area used for crops has increased 550% from 1700 to 1990, while pasture land has increased 658% over the same time period. As land use change continues and the climate warms, we run the risk of changing the terrestrial biosphere from a net carbon sink to a net carbon source.

'Green Revolution 2.0' is also beginning. To feed the 9 billion people projected in 2050, with their increasing dietary demand for meat, we need to try and sustainably increase food output by 70%. In the next step, we'll explore more about what these sustainable agriculture practices might be.

Sustainable Agriculture Practices

31 comments

Sustainable agriculture practices ensure we can meet the requirements of food production today, without compromising the environment or ability for future generations to meet their own food needs. Let's have a look at some of the solutions to implementing sustainable agriculture.

Introduction

The yield gap is the difference between the amount of food a farm could produce and the amount of food a farm is producing. Given we're already using the best quality land for farming, any new land that is changed to agricultural is likely to be of lower quality. A sustainable solution needs to bridge the yield gap, but also needs to recognize the ecosystem services that land provides - such as water filtration or flood protection (where the alternative is to build a filtration plant or engineer defences). For the solutions presented below, identify the economic benefits that each offers. Sustainability is about more than just the environment, and it's likely that solutions will only be implemented if they offer long-term economic viability.

Selective Breeding

What if we could choose the best, most resilient, tastiest and beautiful crops only? This is exactly what's been happening for thousands of years - the seeds of the best crops are grown again to pass on their traits. This can increase the yield potential of land by selecting crops that best match the land its grown on, and can help make a farm more resilient to the effects of climate change. For example, if an area is likely to experience more droughts over time, selectively breeding crops that are most water-efficient will help farmers to be more resilient to climate change.

Be more efficient with nutrients!

Only around 30-50% of nitrogen, and 45% of phosphorus, that is added to a crop is actually taken up by the plants. The diminishing returns from fertilising the land is perversely leading some farmers to add even more nutrients to the detriment of the surrounding environment. Selective breeding plants that use nutrients most efficiently is one solution. Another is to use new remote sensing technology to only apply fertilizer where and when it is most needed. Farmers should also work to reduce the loss of nutrients from soils. Which brings us on to…

Improving soils

Hedgerows and sediment ponds have been used around the world to ‘catch’ farmland runoff during heavy rain events. This means that it doesn’t leave the farm and can simply be scattered back over the crops once the rain stops. Reducing tillage (the ploughing of fields before a crop is planted) allows natural structures to form within the soil that improve water and nutrient retention. For a similar reason, adding organic matter such as manure to soils improves the soil quality and allows the tight binding of nutrients and water. Given human activity increases the rate of soil erosion by at least a factor of 10, it’s vital that we manage this as part of a sustainable agriculture scheme.

Natural organic matter is important to maintaining high quality soils.

Diversify crops and don’t rely on monocultures

Monoculture fields only grow one crop at one time, and usually repeatedly. This makes them susceptible to attack from pests, as they can destroy entire crops incredibly quickly. With climate change, pest species are moving to new environments, and farmers need to prepare for this. Growing multiple crops together improves resilience. Similarly, growing different crops after each other improves soil quality and local biodiversity that can help make a farm more sustainable. It creates a variety of microorganisms in the soil, ensuring the soil remains healthy.

Sustainable ruminant farming

For food security reasons, reducing our meat intake is an important way to live more sustainably - 1kg of meat requires 3-10kg of grain. Animal farming can be made more sustainable with simple changes. Closing the nutrient cycle is important to keeping soils healthy, so using animal manure in nearby crop fields ensures nutrients are recycled back into the ecosystem. Allowing animals to roam freely reduces the risk of pathogens, as well as making the animals healthier. Diseases spread very quickly when animals are cooped up together. A British outbreak of foot-and-mouth disease in the early 2000s lead to the slaughter of 1.2 million animals.

How do we implement the changes?

Providing incentives has been a common method for encouraging farmers to make changes towards a more sustainable system. “Green payments” are subsidies that champion sustainable practices. The European Union has even introduced funding restrictions to farmers that do not employ basic sustainable farming practices, such as diversifying cropland. We can also place the incentives and choice in the hands of the consumer. Better education about where our food comes from and proper labelling of food will empower people to change their diets and change where their food comes from.

Biochar and BECCS

42 comments

Life on Land can be affected by geoengineering methods of Climate Action that remove carbon dioxide from the atmosphere. Two such methods are using Biochar (making charcoal from plant matter that is subsequently buried in soils) and BECCS (Biomass Energy with Carbon Capture and Storage). Both methods use plants to take carbon out of the atmosphere and then convert that carbon in plant matter into longer-lived forms. In this article, we'll explore them in more depth.

Biochar

Biochar is produced from the slow burning of vegetation at around 700˚C in low oxygen environments in a process known as pyrolysis. The end result of this is a porous charcoal that helps soils retain their water, carbon and nutrients. Although biochar is considered a 'geoengineering' method, it is an entirely natural product often found after forest fires. The geoengineering aspect would be to deliberately create biochar outside of natural environments and subsequently bury it to act as a soil enhancer.

As it acts to hold nutrients and water within the soils due to its porosity, using biochar will also reduce the use of fertilisers and make agriculture more water efficient. From what we've learned already this week, you'll know this could have a side-effect of improving global food security too. Experiments have shown that plots with biochar in have greater plant growth as a result of the enhanced nutrient and water availability.

Biochar stores carbon that has come from the atmosphere (via plants), locking it away in a substance that is slow to degrade. By enhancing plant growth it also accelerates the further uptake of carbon from the atmosphere into plants and soils.

While biochar is, in theory, a great way to make soils healthier and store more carbon at the same time, the effectiveness varies from region to region. Less fertile soils will benefit the most from the added nutrients and water that biochar can bring, while other techniques such as biomass energy production are more effective at offsetting coal consumption in fertile soils. If used globally, biochar has the potential to offset around 12% of annual anthropogenic greenhouse gas emissions.

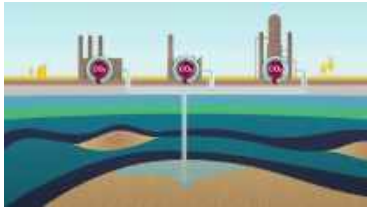
But biochar as a technique requires proper enforcement and management. The author of a landmark scientific review into the feasibility of biochar concluded by saying:

"Biochar production and use must be guided by well-founded and well-enforced sustainability protocols if its potential for mitigating climate change is to be realized"

BECCS (Biomass Energy with Carbon Capture and Storage)

BECCS is a key ingredient in most scenarios to limit global warming to less than 2 degrees. Future emissions projections suggest that reducing atmospheric carbon dioxide concentrations below 400ppm would require BECCS on a large scale, and that it is one of the best value methods for reducing atmospheric CO_2.

The key principle of BECCS relies on coupling a few existing technologies together. First, biomass energy crops (fast growing plants) are grown. Then they are used as a bioenergy fuel in power stations to generate electricity. But rather than release the carbon dioxide generated back to the atmosphere it is captured and subsequently stored in rock formations deep underground. The process is carbon negative because the carbon that is being stored beneath the rock came from the plant, which came from the atmosphere originally.



**Carbon Capture and Storage - this page from the CCS Association explains more. **

This isn't a futuristic dream - CCS is being used in combination with coal power plants across the world at the moment and bioenergy power stations exist too. But, if the technique is going to have a globally substantial impact, huge areas of land will be required to grow the bioenergy crops on. Given expanding populations, it's important that this technique doesn't come at the expense of food production, or of natural ecosystems. Very careful management will be needed to ensure that the impacts from land-use change are regulated and the entirety of the technique remains sustainable.

What are your thoughts on Biochar and BECCS? Should they be used in combination with one another, or do you have a favourite? Perhaps neither are appropriate - can you suggest an alternative?

How to strengthen the biosphere

32 comments

Land-use change accounts for around one fifth of total carbon dioxide emissions from human activity. So what can we do about it?

Reducing deforestation and degradation

Perhaps one of the easiest ways to reduce emissions from land-use change is to stop changing the land! Reducing deforestation and forest degradation can make a major contribution to strengthening the land carbon sink. But it requires major societal shifts, including changing consumer choices in far away places, and changing incentives for local people to protect forests. Hence we need to think about all of the sustainable development goals when considering how to reduce deforestation. In Indonesia and Brazil, deforestation continues to be a problem largely because people's livelihoods depend on it. If you want to solve an environmental problem, then you need to tackle the societal and economic problems underlying it.

The United Nations REDD+ program provides incentives for developing countries to reduce deforestation and maintain their forest stocks by creating a financial value for the forest stock. If a country maintains or expands their forests, then they are rewarded with payments proportional to the extent of their action. This helps tackle both environment and development issues in a sustainable approach. REDD+ also increases biodiversity, protects vulnerable and threatened species and allows countries development opportunities.

Can REDD+ help stop deforestation?

Planting and Rehabilitation

Perhaps the best way to combat land-use change is to reverse it! Afforestation and forest regeneration schemes are one of the easiest and cheapest ways to strengthen the land carbon sink. This is increasingly important on abandoned agricultural land and is even being extended to our cities. In China, the 'Great Green Wall' (officially known as the Three-North Shelter Forest Program) is a 4,500km long wall of trees that are being planted and due to be finished by 2050. This is designed to hold back the expansion of the Gobi desert and has contributed to China's astonishing turn around in carbon sequestration.

Planting schemes on this scale are few and far between. But there are numerous local activities. Consider what's happening around you. On the Streatham campus at the University of Exeter, our grounds team maintain over 10,000 trees to reduce the carbon footprint of the University. For every tree that needs to be removed, more are replaced in other parts of the campus. In the picture below, you can see a small woodland area running through the heart of the University. This was likely planted in the 1930s and continues to be maintained and expanded.

The Streatham campus at the University of Exeter.

Sustainable Management of existing forests

Sustainably managing forests involves some form of protection, policy or legislation that is legally binding and maintains or improves forests. Deforestation cannot take place in protected forests and sustainable management can ensure they are more resilient to pressures such as climate change. For example, maintaining forest biodiversity and good quality soils means that they are better protected against extreme events such as droughts.

In the UK, the Forestry Commission have outlined three objectives to protect these ecosystems – in priority order:

- protecting the nation's trees, woodlands and forests from increasing threats such as pests, diseases and climate change
- improving their resilience to these threats and their contribution to economic growth, people's lives and nature
- expanding them to further increase their value

Part of this involves education, and managed woodlands in the UK are often used as educational tools. This is a very easy way to help the public better understand forests and the need to protect them. Increasing public awareness helps people think and act more sustainably. In effect, the Forestry commission are asking the local community to do their bit in preserving their environment. This makes sense in the UK where the recreational value of forests and woodlands to people typically exceeds the value of the timber in the trees.

A truly global problem!

15 comments

Carbon dioxide emissions don't just affect the Earth's atmosphere – climate change has an 'evil twin' – ocean acidification. This has been called 'the other carbon dioxide problem'. It is caused by atmospheric carbon dioxide dissolving into the surface ocean.

Since the Industrial Revolution, the ocean has dropped around 0.1 pH unit (a scale used to measure the acidity or alkalinity of a solution). This compromises the ability for some marine organisms such as corals to calcify and produce carbonate structures. This can impact the whole marine biosphere because of the intricate links between organisms in the oceans. But it's not easy to find solutions to ocean acidification because of the way circulation systems continue to mix water around the world. This means a global solution is imperative.

Mitigation

The best solution is mitigating the causes of ocean acidification by reducing carbon dioxide emissions - which also tackles the most important cause of climate change.

Policy

Despite this inherent link between tackling climate change and ocean acidification, there is a failure to acknowledge the importance of the ocean acidification threat at an international level. In the 32-page document that lays out the UNFCCC (United Nations Framework Convention on Climate Change) 2015 Paris Agreement, 'ocean' only appears once – and not in relation to acidification. Hence some researchers are calling for a multilateral environmental agreement that specifically relates to impacts on the oceans, because of their unique importance. In the meantime practical actions can be taken to build the adaptive capacity of ocean ecosystems.

Marine Protected Areas

Designating and enforcing protected areas of marine environments that cannot be fished from should help ecological communities adapt to ocean acidification by removing another stress factor. Like other adaptation measures, this involves accepting the changes that are likely to occur in the future and building the capacity to

cope with them. Marine protected areas allow a greater biodiversity of organisms to flourish. This includes shallow plants that photosynthesise to lower CO_2 levels locally, which can provide refuge to calcifying organisms. Fish populations that help to cycle carbon can regenerate as overfishing is banned.

Marine Protected Areas create healthy communities and ecosystems that have greater resilience to the impacts that climate change can bring, including acidification. This means that a single event or impact may not lead to the demise of the entire ecosystem, but the area can rebound and recover once again. These are areas away from human pressures, allowing a precious chance for recovery.

Mangrove Restoration

Mangrove forests are one ecosystem that naturally increase the alkalinity (decreasing acidity) of the waters around them. In a similar way to how shallow plants in marine protected areas photosynthesise to take carbon dioxide out of the water, mangroves are highly productive ecosystems that are able to convert this carbon into peat and biomass very quickly. For tropical reef systems, this may allow corals an opportunity to flourish and co-exist with these ecosystems.

In the past, mangroves were often considered as bogs with little value that spread disease as they were often a breeding ground for mosquitoes. As a result, they were often destroyed for timber or to make space for new development. At the peak of decline, 2% of the world's mangroves were being lost each year. Restoration projects are beginning to take shape to restore the ecosystem, now that the full extent of the ecosystem services that are gained from mangroves are known. Indeed, they could be a great adaption mechanism to combat localized ocean acidification.

Can geoengineering buffer ocean acidification?

16 comments

We've looked a lot at mitigation and adaptation responses to climate change – but could geoengineering help reverse ocean acidification?

Which type of geoengineering?

Of the two geoengineering approaches mentioned in the first week, only carbon dioxide removal methods can tackle ocean acidification. Solar radiation management schemes to cool the planet leave CO_2 levels rising, which will continue to result in ocean acidification. Furthermore, cooling the planet actually increases the amount of CO_2 that dissolves in the ocean. Viable geoengineering approaches to tackle ocean acidification involve adding alkalinity to the ocean in different ways.

Adding Limestone Powder

Let's remind ourselves of some key equations in ocean acidification:

1. $CO_2 + H_2O \rightarrow H_2CO_3$

2. $H_2CO_3 \rightarrow H^+ + HCO_3^-$

3. $CO_3^{2-} + H^+ \rightarrow HCO_3^-$

Carbonate ions (CO_3^{2-}) act as a natural buffer to acidification in reaction three - which is great, but their supply cannot keep up with the addition of hydrogen ions from dissolving carbon dioxide (reactions one and two). If we add limestone powder ($CaCO_3$) to the oceans, then it'll dissolve and improve the strength of the ocean's natural buffer to acidification.

Ships would be used to add the limestone powder a few times a year across the oceans. There will be an energy cost in mining the limestone and grinding it down to a very small particle size - but this could be achieved using renewable energy to avoid creating a CO_2 source.

The process won't harm life in the oceans because carbonate weathering happens naturally anyway - it will just be speeded up. The total cost has been estimated at $40-45bn a year, and the process needs to be continued for over 100 years to be truly effective (requiring international co-operation and major investment).

Dissolving Olivine

In a similar principle to adding limestone powder, dissolving olivine (Mg_2SiO_4) could enhance the sequestration of carbon dioxide. For every gram of olivine dissolved, 0.28g of carbon is sequestered. This is equivalent to the natural process of silicate rock weathering. It would help buffer ocean acidification by supplying alkalinity to the ocean (the Mg^{2+} ions ultimately combine with CO_2 to produce $MgCO_3$).

It would take around 100 dedicated ships to distribute olivine over an ocean surface area large enough to make a difference. Alternatively, olivine particles could be added to coastlines where the natural action of the waves would enhance their dissolution.

Could adding olivine partlices to coastlines be the solution to ocean acidification?

Enhanced Weathering strategies

Rather than adding carbonate or silicate rock powder to the ocean with ships, it could be added to the land instead, where it will dissolve and be washed to the ocean. This approach simply accelerates normal, slow processes of weathering that lead to carbon dioxide being locked up in carbonate rocks on the ocean floor. It works because small rock particles dissolve much faster than natural larger ones.

If we can enhance the weathering across one-third of the world's tropical regions, then we could ameliorate ocean acidification by 2100. This approach will enable calcifying organisms (such as corals) to continue calcifying and keep ecosystems such as coral reefs from dying out completely under acidification.

Up to 1 PgC could be sequestered per year via this mechanism - around 10% of anthropogenic emissions. But grinding rocks to tiny particles and distributing them across the land costs energy and carries health risks as the particles are breathable. Proposers of the technique suggest it could cost anywhere between $60-600 trillion, noting:

> *Enhanced weathering is a sobering indication of actions that may be required if fossil fuel emissions are not phased down rapidly.*

Enhanced weathering techniques do have an advantage over traditional carbon capture and storage solutions in that carbon dioxide isn't being stored under pressure as a liquid, but as a rock. This makes it much more stable and unlikely to be leaked again.

What do you think about these solutions to ocean acidification? Are they viable? Are there any alternatives?

How to stop waste reaching the oceans

19 comments

Everyone on the planet bears the responsibility to help clean up the oceans. In this article, we'll share quick and easy ways for you to reduce the amount of plastic waste you generate.

Re-use your cups, cutlery and bags!

We live in a world where plastic is used far too frequently and without consideration. Think about your day-to-day life. Did you use a plastic bag the last time you went shopping? Did you buy a bottle of water or refill one? Using plastic containers more than once will immediately reduce the amount we're consuming. And don't forget to take a 'bag for life' when you go shopping!

Recycle

There are many different types of plastic you can encounter and some might not be recyclable. But many are and it is worth making the effort to find out what you can and can't recycle in your local area. In the UK, did you know that most recycling points can take your plastic bottles, food containers and plastic bags? Search online now for your local waste disposal scheme and find out what they can recycle for you.

Reduce your consumption – think ahead

This can involve simple changes to your shopping habits to reduce the amount of plastic you might unintentionally be buying. For example, instead of buying 10 yoghurts that are individually portioned, why not go for one big pot? Consider the amount of packaging per product. Also, buying second hand rather than new plastic products reduces the amount of waste you generate.


Plastic in the oceans frequently washes up on reef islands around the world that are in the path of ocean currents.

Out of sight, out of mind?

The actions in your home have consequences that can be far reaching. Don't put anything down your drains that shouldn't be there – cooking oils, baby wipes, food waste, anti-freeze, motor oil, cleaning products etc should

not be put in the sink or toilet. Dispose of it properly so that it doesn't pollute rivers that will end up in the ocean.

Clean up your beaches!

If you see plastic or waste at a beach or in a river, pick it up. You may have just saved a marine organism's life! You could even take part in an organized beach clean-up event to remove waste before it enters the ocean system. They are family friendly events and a great way to get out and about making a difference to your community. Find your nearest by searching online.

Educate!

Share what you've learned about using plastics more sustainably with your family, friends, neighbours and community! Action starts with just one person, but needs to filter out to become meaningful. Improving education and knowing what is right / wrong is important to ensuring our oceans are cleaned as best as possible. If top-down action (government led initiatives) isn't happening, then bottom-up action (from everyday citizens) can be just as effective.

How does this relate to climate change?

You might be wondering why we appear to have strayed from the topic of climate change. Reducing pollution impacts on the oceans is important in creating resilience and adaptive capacity for marine species. We need clean habitats for the climate-driven mass-migration that is about to occur in our oceans. There is also new research suggesting that the consumption of microscopic plastic debris by tiny animals in the ocean could weaken the ocean carbon sink.

We've introduced you to only a few of the many ways you can act to help clean up the oceans. Share in the comment section any more that might be of interest to you.

Climate Change: Solutions

How much plastic do you eat? Transcript

00:00
Like it or loathe it, plastic is a huge part of everyday life for people all across the globe. You probably use it to brush your teeth, to drink your coffee from, even to dress yourself. And, as you've probably seen, it's having a particularly harmful effect on our marine wildlife. Seabirds are getting tangled up in fishing line, turtles stuck in the wrap from beer cans and other marine debris, and there are even garbage islands floating around the ocean. But, that's the larger bits of plastic. What about the small bits? The microplastics that you've probably heard of. There's been a recent bit of research that has revealed that microplastics have been found in the guts of fish. So I want to know how big is this problem? Does it move up the food chain? If I eat fish, am I eating plastic?

00:50
To find out more, I've come to the University of Exeter to meet Professor Tamara Galloway who is going to show us how studies are beginning to reveal just how widespread these microplastics could be in the food chain and maybe even in you. So, let's talk plastics. Microplastics. I know that in face creams especially the exfoliating face washes there are microbeads, is that what we're talking about when we talk about microplastics?

1:20
Well, we are and here are some here. We've purified plastic out of this one tube. These are plastics that have been made to be of a tiny size, so 90,000 tiny pieces of plastic for every shower is a rough estimate. But how many? They make up just one tiny portion of the microplastics you find in the ocean. Every time you walk across the beach you'll see items like this, so large pieces of plastic debris that have washed up on the shoreline. What happens over time is that the action of wind and tide and sunlight will break that down, firstly into what we might call macro pieces of plastic and then eventually into microplastic. So these are kind of brittle, we've got fibres in there, broken pieces of bottle and bag all mixed in together.

2:04
Then, I'm guessing all of these bit of macro and these micro get broken down even further. Even smaller, so what we've got here are some things that we've broken down for you to show you what they look like. This is a polyethylene plastic bag, and this is what it looks like when it's been broken down into the microplastic size range. So you've done this here in the lab. We've done this here in the lab, but we would find this in the ocean all of the time, so we haven't analysed a single water sample anywhere in the world that hasn't contained some tiny pieces of plastic. Hang on a minute, you haven't found any sample across the whole world that doesn't have

microplastics? Not one that doesn't have a tiny piece of plastic in it, and that's when we started to realise that we had a problem.

2:47
Do we know how much plastic will actually end up in the ocean? Well that's been estimated from modelling studies and surveys that have been done all around the world and the current estimate is that there is 8 million tonnes of plastic sent to the oceans every year. That's crazy. That's a garbage truck of plastic every minute somewhere in the world is being dumped into the ocean. A garbage truck of plastic every minute dumped into the ocean. That is sickening. So there is a crazy amount of plastic getting into the ocean and then it gets broken down into this phenomenal amount of microplastics and the problem there is that marine organisms consume it.

3:24
Well that's the worry isn't it, because the microplastics overlap with the preferred prey item of so many different animals, particularly animals at the base of the food web, things like cocophods and marine warms, and also bivalve mussels. So the problem is that they don't know what this is, so when they are just bringing in all that water, filter feeding, the microplastics just come in with it. The one experiment that we have set up in the lab for you at the moment, so we've got some bivalve mussels and these are common edible mussels collected from the shorelines around about the south west of the UK and we've given them some algae to feed in the water, so you can see that what they're doing over the time-lapse is filtering that algae out of the water down into their bodies. You'd be surprised at how much water a mussel can filter. It can filter up to 12 litres an hour and if there are tiny particles in the water they will be taken up by the mussels and they could enter into their tissues.

4:14
Now that's an experiment that you've been running here for a very long time? Yes, we've been doing similar experiments and we've used mussels and many other species as well, but we've been studying what happens to that plastic. Is it taken up? If it is taken up, does it get into the animal's tissues, if it does get into the tissues, what might it be doing? Is it going any harm? That's the question, do they filter the microplastic and decide they don't want that and just get rid of it, or do they filter it and it stays? It stays in their gut and they start to try and digest it and they are spending time trying to digest something that's not inherently nutritious and what we've been using is these small plastics. These are 10-micron sized plastic polyvinylchloride, or PVC granules, and they've been dyed with a fluorescent dye so we can study where they go inside the animal.

5:07
And what have you been discovering? What we've been discovering is that the particles are taken in and a lot of them are in with the normal faecal material of the animals. A significant proportion are retained within the animal's bodies.

5:18
Tamara and her team are at the forefront of this science and they've had to develop new ways to study whether plastics are getting into the tissues of filter feeders like mussels. This is how they test them. Oh, and if you're a bit squeamish, best look away. First they dissect out the tissues and add a strong bleach solution. Second, they mix it up into a what's essentially a plastic mussel soup and pop it in the oven at 60 degrees for 48 hours. Here's a sample the team prepared earlier so I can take a look under the microscope.

5:50
So that's what we've got here. That's what we've got here. Just to confirm, this is one mussel. This is one mussel's worth of insides, digested and - alright. So, you're looking at, you can see the squares that are the grids of the filter and what you should be able to see is two lines on that filter paper, so those are fibres. They're plastic fibres? Most probably plastic fibres. What we'll do next in the procedure is go and identify them conclusively using a special microscope. So that shows that in just a randomly selected mussel, you have found fibres? We have found fibres and we've found plastics, fibres or pieces in every mussel that we have studied so far. Hang on a minute, every single mussel? Every single mussel we've found fibres in it. Of course what we would need to know is does that cause any harm? We don't know at this point of time. Does it take any chemicals with it? Does it harm the mussel in any way? How long does it stay in the mussel tissue before it's excreted or disposed of?

6:51
And if that's one mussel, how does that scale up then? Well you can see that in some of these samples that you've got over here. You've got the amount of plastic that you might expect to see in an average mussel in the first container and that's about 4.5 pieces in an average mussel. In the one in the centre, that's how much plastic you might expect to see in your average portion of shellfish. That's about 20-25 mussels. The one furthest away you can see that's the average portion we might expect to see if you're an avid seafood eater over the course of a year. That's a year's consumption, that's 11,000 little pieces of plastic. That's a lot isn't it.

7:31
So is it just filter feeders we should be concerned about? What about other marine species? One of the team working alongside Tamara is PhD student Adam Porter - an expert in this new microplastic science here at Exeter. He's going to talk me through the evidence of microplastics being found in ocean life further up the food chain.

7:50
Here we have a sort of representative example of the fish that we look at here at the University of Exeter. Anything from plankton through to the bull huss and the anchovy and the red mullet in between. We should say that this shark is bycatch. Yeah, we don't want to be taking these out of the ocean but when they are caught by accident then I mean the shark is often dead so we can take it and learn something from it,

which is useful. We can start at the lower end with the zooplankton. These are little organisms, very small, that feed in the surface waters. What they can do is consume little bits of plastic and we've got a video that shows a little dollioid beating its little cilia creating a current sucking plastic into its body and it starts to fill the gut. So if the gut of a little plankton is full, then something like an anchovy might come along and eat that plankton and suddenly he's got 5/6 bits of plastic in his stomach from that one zooplankton.

8:46
This is how contaminants can be passed through a food web. And is known as biomagnification. As we move up a food chain, smaller species are eaten by larger species and the volume of contaminants increases. Zooplankton may ingest just a few tiny pieces of plastic but a small fish like an anchovy will eat hundreds of zooplankton meaning that 1 fish could then contain potentially hundreds of those tiny pieces of microplastic. Further up the food chain, with larger species like humpback whales potentially eating over a ton of fish a day, the volume of plastic they can chew becomes even larger. While some of this plastic will likely be excreted, in theory this means animals at the top of the chain will be the most severely affected. This is a complex food web that scientists are continuing to study to understand the effects of plastics globally.

9:39
But the fact that right in the bottom of the chain it's coming in with the plankton, that's then getting eaten by the anchovy. If we ate an anchovy straight out of one of the tins, we could be eating the plastic? Fish that we eat whole are something of that's interest to us because these are the kind of things that actually we're not cleaning the gut out which is where most of the plastics are. When we eat whole we're eating whatever that fish has eaten. Suddenly there's a potential for us to be eating plastic from these little anchovies that we're consuming whole.

10:09
But definitely for fish that we can chew whole, like a mussel or like an anchovy, you know the evidence is showing there is microplastics in there, we will be consuming them. Absolutely, there is plastic in there that we have shown there is, then yes we are ingesting plastics. When you get to the bigger fish and are eating the flesh, can that plastic get from gut into flesh? The jury is still out on that. But if it does get into the tissue, it's going to be a smaller proportion of the total amount it has eaten. But we could be consuming plastic we just don't know yet because we haven't found conclusive evidence that it's in the tissue of a load of species. If we find it in one then there's a question mark that still hangs over is that going to impact us and we need to look in many species that humans consume a lot of to work that out.

11:00
Wow. What a day. I mean, plastic is just so prolific in our world but the fact that we're dumping you know one garbage truck worth into the ocean every minute and that

they haven't been able to find a sample here of water anywhere in the whole of the world that doesn't contain microplastics in it and they haven't found a mussel that doesn't have microplastics in it. I came here today to find out how much plastic we eat. Clearly if we eat mussels we eat plastic. But this is really new research. We don't yet know if that plastic leaches out into the flesh of fish or how many contaminants it takes along with it and the effect on us when we do consume it. Bottom line is plastic dumped into the ocean by man is causing huge problems for that whole marine ecosystem. But the research that's being done here could lead us to identify which is the worst culprit and then change our practices. If you've got any questions about this, please do put them down into the comments. If you've experiences plastic in the marine environment let me know in the comments and if you're new to the channel - BBC Earth Lab - subscribe and like and I'll see you very soon.

Artecology

4 comments

Coastal environments around the world are eroded by the action of waves on the land. This is a perfectly normal process, but it is bad for coastal settlements as erosion can lead to flooding or subsidence. Sea level rise due to global warming is making matters worse. We put in place a number of measures to protect our coasts – rock armour, groynes, sea walls etc, but because these are unnatural they don't respect the biological needs of coastal species.

Artecology is a project in the UK that aims to bring biodiversity to the built environment by building new habitats on the coastal defences for species to survive in. The technology is transferable to all parts of the built environment, including rooftops and buildings. This is known as urban rewilding and is a form of climate change adaptation. It increases adaptive capacity and resilience for the ecosystems that are being defended.

Protecting our coastal ecosystems

Coastal species are being 'squeezed' between rising sea-levels and increased storm frequency and intensity from one side and a physical barrier (the sea-wall / groyne / rock armour) from the other side. The amount of space for them to live in is diminishing. So, artecology increases the resilience of these species by providing habitats and a space for them to live in.

Vertipool in the splash zone - attached to a sea wall. © Artecology

Set of pool arrays - top half highly disturbed under a freshwater outlet, bottom half with little disturbance and seawater input. © Artecology

Pool attached to groynes on Boscombe beach in South England. © Artecology

Click here to learn more about Artecology with their dedicated page for our course

Adapting the built environment

4 comments

In Tristan's video, he introduced a range of techniques for making buildings more resilient to a changing climate. Let's explore some more ways in which the built environment can be adapted, first with new builds and then by upgrading the existing building stock.

Construction

Good building design starts at the construction phase. To mitigate climate change and reduce the environmental impact of construction, many companies are sourcing their materials more responsibly, reducing transportation costs and planting trees alongside new built environments. But buildings need to be resilient to changes occurring around them - including beneath them.

As precipitation and temperature patterns start to vary, the ground beneath a building can change its water content. Following a heatwave in 2002, insurance claims for building subsidence in the UK rose by 68% over the next year. This can happen if there is too much water in the ground too, leading to the ground swelling. Older buildings are more at risk as building regulations for building foundations have only recently been introduced. As a result, there is a clear need to produce buildings that can withstand these changes.

Adaptation is also about knowing where it is and isn't sensible to build. Sloped areas have been traditionally okay to build on, but we may need to become smarter about building on areas that could destabilize with repeated over-wetting and over-drying on a seasonal, cyclical basis. This is proving tricky though with population increases and expanding cities. In the UK, we're running out of good quality land to build on.

Comfortable, sustainable buildings

But assuming a building has been built and isn't likely to subside any time soon, there is now the challenge of designing them to be as comfortable as possible with hotter summers. Glass is a popular building material – it lets in natural light and makes buildings look nicer. It also has the effect of warming the building naturally as it traps the sun's heat in, like a greenhouse. But what seems like a great thing should be carefully designed.

If heatwaves become more prevalent, the last place you'd want to be is in a greenhouse! Buildings should be designed to be comfortable in all weathers, including the likely possibility of heatwaves. Providing areas of

shading beneath glassed areas allows for a good temperature to be maintained. Similarly, innovation with ventilation and air-tight design can make a building 'breathe' to maintain temperature, rather than use heating and air conditioning.


The Forum building at the University of Exeter was designed with sustainability in mind. Smart technology is deeply embedded in the design to open windows and doors to keep a constant temperature.

Choosing where not to build is important too in an urban environment. It's important to increase the amount of 'green' and 'blue' space (area dedicated to vegetation and open water) to reduce the urban heat island effect. During times of heatwaves, this can reduce the chance of heat stress and even death. Buildings absorb heat and keep it locked in during the night, meaning that urban areas don't cool at night time. Green and blue spaces allow a city to cool at night, meaning people don't dehydrate.

Adapting our existing building stock

So far, we've only talked about new building designs – but our cities are already full of buildings! It's crucial to adapt our existing building stock alongside new developments, although action is slow. A UK government report – 'The business case for adapting buildings to climate change' – wrote that many business and property owners aren't aware of the risks to the built environment and have no plans to upgrade their stock to adapt.

But there are things that you can do in your own home to take action. You're probably already aware of solutions such as energy efficient lightbulbs, double-glazed windows and loft insulation that can make massive savings to your energy bills. In addition, the falling cost of solar panels and electric vehicles in the developed world means they may become affordable and we'll see more of them around.

Homes in the developing world can also benefit from innovation. Air pollution is one of the biggest environmental risks to health and, according to the UN SDGs, *"household air pollution from cooking with unclean fuels or inefficient technologies [leads] to an estimated 4.3 million deaths each year"*. Better cooking stoves, ventilation systems and education of the risks can reduce this number drastically. In homes with thin, metal roofs, a bottle filled with bleach and water impregnated into the roof can act as a lightbulb and provide surprisingly effective lighting for a home. It works through the refraction of light and provides a sustainable alternative for improving living conditions where access to electricity remains limited.

100 Resilient Cities

2 comments

Not all action against climate change has to be at a national or international level. Cities are beginning to take the future in their own hands to become resilient to the effects of climate change.

In 2017, US President Trump repealed the nation's commitment to the 2015 Paris climate agreement. Despite this, over 300 US city mayors (as part of the Mayors National Climate Action Agenda) agreed to commit to the guidelines of the agreement voluntarily. This is because cities will suffer the effects of climate change if action isn't taken.

100 Resilient Cities is a project designed to create a network of more resilient cities with greater adaptive capacity. This will enable them to cope with, and meet the demands of, 21st century threats - including, but not limited to, climate change. Each of the 100 member cities has produced its own resilience plan which identified the key threats and how best for them to cope with these threats.

For the remainder of this article, we'll look at how two of the 100 Resilient Cities (New York, USA and Bristol, UK) have pledged to combat sea-level rise and increased storm intensity.

New York

In 2012, New York City was struck by Hurricane Sandy - the second costliest hurricane in US history. It caused flooding across the city and a shutdown of key services including the transport network. For New York, climate change will lead to sea-level rise and more frequent and intense storms, which could come with even worse impacts than Hurricane Sandy. It is therefore imperative for the city to come up with a plan to become more resilient to these threats.

New York is planning to both mitigate and adapt to increase its resilience. It will lead the way for US cities to reduce their environmental impact by cutting greenhouse gas emissions by 80% by 2050 and becoming "zero-waste" by 2030. In addition, the city is moving away from the fossil fuels that led to its development in favour of renewable energy. To adapt to the specific threats of flooding, New York is upgrading its coastal defences and improving building design. This hard engineering approach to improve infrastructure should ensure that key systems - such as the subway network - don't get shut down for days following floods.

Bristol

In Bristol, the city faces similar threats. The city has faced a wave of recent flood events - in 2012 from prolonged rainfall, in 2014 from a storm surge and in 2016 from freak thunderstorms. As a result, the city needs to improve its resilience in order to future-proof themselves against these threats.

Like New York, Bristol is also aiming to reduce greenhouse gas emissions and increase the use of renewables to become carbon neutral by 2066. In order to create resilience and adaptive capacity, Bristol will empower individuals and strengthen communities. This creates a sustainable citizen network who have the adaptive capacity to help themselves rather than relying on top-down management and aid in times of crisis. It'll also bring together individuals, business and departments to make Bristol future-proof, collaborate on ideas and share areas of best practice to ensure the impacts of flooding are limited.

Find a Resilient City near you!

The 100 Resilient Cities project reaches every corner of the world. Using this link, find the nearest "resilient city" to you and have a look at some of the solutions to the 'big threats' they are facing. Share your findings in the comment section below.

If you're feeling adventurous, take a look at some other cities to see how resilience practices vary in different regions of the world. Are their differences in the way developing countries are responding to 21st century threats compared to developed countries?

Responses to Climate Change in developing world communities

1 comment

So far, much of what we've discussed has focused on the developed world. In this article, we'll share some of the responses to climate change in developing world communities and learn how sustainable communities can be created in all parts of the world.

The impacts of climate change are predicted to be felt most severely in the developing world. This could amplify existing vulnerabilities and threaten the ability of communities to develop sustainably. The IPCC (Intergovernmental Panel on Climate Change) suggest that developing countries will suffer the most from climate change as a result of the economic importance they place on climate sensitive sectors.

Adaptation

The primary challenge in any developing world community is to improve their resilience and adaptive capacity to be able to cope with the impacts of climate change. The Sustainable Development Goals recognize that, to achieve this, any adaptation measures need to be consistent with achieving other goals. A community cannot improve its resilience while in poverty, without access to education or without addressing gender inequalities to ensure nobody gets left behind.

In rural African communities, access to water is going to become an increasing challenge as drought becomes more prevalent. One of the ways in which communities can adapt is to reduce the demand at the very start of the process by using resources more efficiently. But droughts can dry supplies of drinking water and good infrastructure is needed to be able to provide help. This will enable governments and NGOs to properly access rural communities in need. You can help with this by contributing to The Missing Maps project.

How to develop sustainably

During the negotiations of the 2015 Paris agreement, India was initially resistant to reduce its reliance on coal. From a purely economic perspective, this makes sense – much of the economic growth of India is based on

cheap coal and it is pivotal to ensuring the development of the country. However, India is moving towards renewable energy, recently pledging that renewables will account for 40% of energy generation by 2030. This highlights a number of moral dilemmas. How do developing countries progress economically, while at the same time replacing the fuel for their economic growth? Is it right that developed countries which expanded using 'dirty' fuels, deny developing countries the same privilege? Do developed countries have a moral obligation to help and support developing countries because of this?

It all comes back to the sustainable development goals. By improving the quality of life for individuals in a developing country by alleviating hunger and poverty, this allows them to take action into their own hands. The IPCC hit the nail on the head in their 2007 publication:

> *On the one hand, climate change influences key natural and human living conditions and thereby also the basis for social and economic development, while on the other hand, society's priorities on sustainable development influence both the GHG emissions that are causing climate change and the vulnerability.* IPCC, 2007, Working Group III: Mitigation of Climate Change, 2.1.3.

As a result, climate change may become the biggest barrier to sustainable development. But the 2015 Paris agreement included pledges to help developing countries create an adaptation framework whereby the worlds most vulnerable are helped and supported. The agreement also decides that…

> *financial resources provided to developing countries should enhance the implementation of their policies, strategies, regulations and action plans and their climate change actions with respect to both mitigation and adaptation to contribute to the achievement of the purpose of the Agreement.*

Demographic Transition

A strong correlation exists between areas of the world with large population growth and areas that are susceptible to the effects of climate change. Improving family planning and access to sexual healthcare can help contribute to mitigation against climate change, as well as improve the adaptive capacity of a community. Fewer people reduces the pressure on resources and allows individuals the opportunity to flourish. But this can only happen by bringing down the birth rate of a country, which involves better access to education (Sustainable Development Goal 4) and better access to healthcare (Sustainable Development Goal 3)

Share your stories

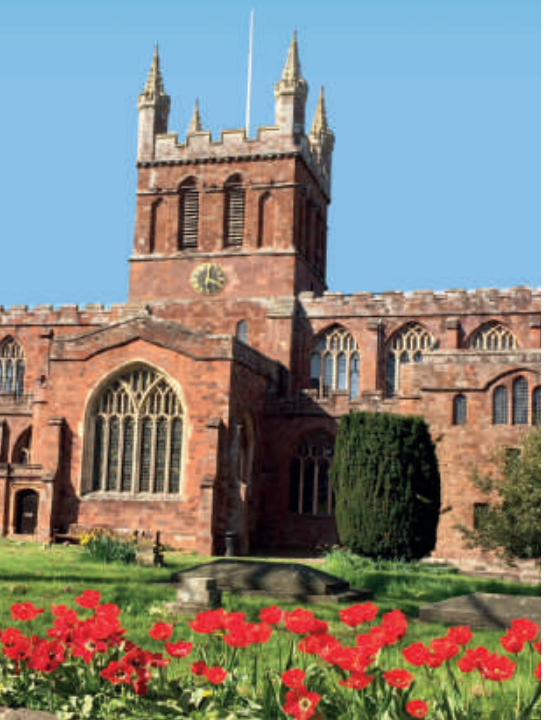
If you're learning with us from a developing country, we'd love to hear from you! Share your story of how you and your community are responding to climate change in the discussion section. For learners from a more developed country, look through the comments and identify the differences between the ways people are responding in the developing world and the developed world.

UNDERSTANDING AND PROMOTING RESILIENCE TO FLOODING IN CREDITON

Crediton Flood Resilience Group 2016

University of Exeter
Devon County Council
Devon & Somerset Fire & Rescue Service
Environment Agency
CCIN
Crediton Town Council

CONTENTS



INTRODUCTION

Flooding is a major and growing problem for rural communities throughout the UK. The winter storms of 2013–14 demonstrated how communities can become cut-off and how people's lives can be disrupted and devastated by the effects of flood water. This project aimed to provide a more effective way for communities to become resilient in the face of hazards like flooding and sought to explore the potential for using 'social learning' between community members, academic researchers and local government and agencies to understand the flood risks. This is particularly important to consider in relation to risks associated with a changing climate and changes to land management in the area. The project has worked towards defining a clear approach for understanding and promoting community resilience to flooding in Crediton that will help people to prepare for and cope with future flood events.

The project had the following objectives:

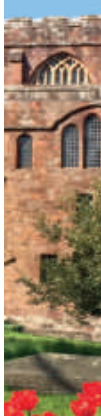
1. To adopt a community-centred approach for understanding risks associated with flooding;
2. To encourage the participation of as many people as possible in the project to understand local flood risks, and use as many sources of information as we can from the local area and the climate science community;
3. To stimulate interest in creating a local approach for managing flood risks and reduce the vulnerability we have to flooding as far as possible.

PREVIOUS RESEARCH AND PROJECT RELEVANCE

There has been increasing controversy in recent years about the causes of flooding events in the UK and what can be done to reduce the risks posed by flooding to lives, property and businesses. In part, this controversy has stemmed from the different ways people understand the environment around them. For example, much of the debate in the aftermath of the flooding on the Somerset Levels in 2014 has focused on the merits and problems of dredging rivers, with many in the scientific community holding different views from some in local communities. Scientists no longer dispute whether humans are changing the climate, but are now working on understanding the degree to which extreme weather events can be attributed to human-induced climate change resulting primarily from greenhouse gas emissions. This project uses these insights to study how serious the risks will be and how to address them. Climate change is expected to lead to an intensification of weather events in the UK and in the southwest, this may bring about increases in the amount and intensity of rainfall. But the media doesn't always reflect this, sometimes giving the impression that scientists are unsure about climate change. This project has been about recognising that there are different types of knowledge we can use, and it aims to find ways of reaching some consensus about how they can be used together. This has drawn on previous work from the University of Exeter, where researchers have worked with Exmoor National Park Authority and people in Dulverton, Somerset, to explore the causes of flooding in the town.

WHY FOCUS ON CREDITON AS A CASE STUDY?

Crediton does not have a severe flooding problem at present, yet it is an area that is surrounded by low-lying land and rivers that can cause severe loss of transport infrastructure in times of flood. Indeed, the town's location means that intense rainfall events can cause serious surface water flooding. The expected increases in extreme weather events caused by climate change therefore mean that the town itself might be at greater risk of sudden and severe flash floods.



THE CREDITON FLOOD RESILIENCE GROUP

The project has been run by the Crediton Flood Resilience Group, which has representatives from the community of Crediton, Devon County Council, Climate Outreach and climate change researchers from the University of Exeter. It has also been supported by the Environment Agency and the Devon and Somerset Fire and Rescue Service. The group is an affiliate of Susitanable Crediton and has explored current understandings of flood risk and the ways Crediton's vulnerability will change in the future by undertaking local research, exploring archives and identifying key vulnerabilities. The group has finished its first phase of research and the findings of its work are now being taken forward to be acted upon in association with Sustainable Crediton.

The group comprises people from Crediton and local agencies and the University of Exeter:

Liz Allnutt	Anne Hughes	John Boyle	Tony Gale
Stewart Barr	Dom Maxwell-Batten	John Heal	Ewan Woodley
Roger Cashmore	Adam Corner	Andi Wyer	Tim Wilkinson

KEY FINDINGS

The following provides a summary of the key findings from the group's research so far, which will form the basis of working with Sustainable Crediton to take the work forward:

The 1960 floods | Image © EXPRESS AND ECHO

- Crediton's recent and historic record of flooding is not dramatic or unusual – but in common with many communities, it has had a number of small-scale problems over the years.

The 2012 floods | Image © CREDITON COURIER

This means that the findings from this project could be of value to many communities experiencing similar issues:

- Crediton's local incidents are sometimes associated with river flooding, but more commonly from intense rainfall causing high levels of water to run-off farmland and streets to cause flash floods;
- There is widespread agreement that farming practices, highway / storm drain maintenance, riparian maintenance of waterways and new development in the built environment all play a major part in the number and severity of flooding incidents;
- We acknowledge the body of evidence on climate change and how this might affect the intensity and frequency of severe weather in the future. We conclude that it would be wise to plan for the possibility of increasing problems associated with severe weather;
- We recognise that for the foreseeable future, public sector spending will continue to be restricted. As a result, local communities might need to become more proactive and self-reliant in managing these issues;
- At a local level, our priority must be to identify what we might do to lessen the number of future events and to lessen their impact. This might be rephrased as:
  - How to reduce or stop flooding from happening;
  - How to respond to specific incidents (crisis management);
  - How to follow through in the aftermath of specific incidents;
  - How to reduce vulnerability from possible events.

Flooding at Dulverton Bridge, Somerset
Image provided with kind permission of Dulverton Town Council

To expand on these four points:-

- **How to reduce flood risks or stop flooding from happening:**
  - Identify the (probable) causes of specific incidents;
  - Identify the parties concerned (e.g. residents affected by flooding, owners / occupiers of land contributing to flooding, local authorities, South West Water, Environment Agency);
  - Endeavour to bring all parties together to discuss problems and potential solutions;
  - Keep working at it! The causes of flooding are often complex and take time to understand.
- **How to respond to specific incidents (crisis management):**
  - Call out neighbours and others willing to help (e.g. friends and family);
  - Check safety of affected parties who may be unable to respond to emergencies (e.g. non-ambulant);
  - Pool available resources (e.g. brooms, sandbags, pumps) and agree who's doing what;

- If lives, homes or businesses are at immediate or imminent risk, call the emergency services;
- If a lower level of risk, call the local authority (e.g. Devon County Council Emergency Centre) to report the incident and request appropriate assistance;
- Take photographs for evidence;
- Make a written record of important events and actions (including timings and measurements, where possible and safe to do so) while these are still fresh in your mind;
- Check regularly to ensure that volunteers are not in danger, not too wet or too tired to continue;
- Keep up morale with tea, snacks, supportive comments;
- Consider other actions that might be required (e.g. moving vehicles which might be needed, moving possessions from ground floor rooms).

How to follow through in the aftermath of specific incidents:

- Encourage all affected parties to meet together to discuss the experience and agree further actions;
- Assemble and compile evidence available. Identify gaps in your pooled knowledge / evidence and seek to rectify;
- Contact local authorities, owners / occupiers of land contributing to flooding, South West Water, Environment Agency to ensure that they are aware of the incident and agree how and when they will work with you in responding to it - endeavouring to bring all parties together to discuss problems and potential solutions;
- Keep working at it. Recognise that some large organisations can take a while to respond to non-urgent issues, but don't give up until you have achieved a workable and acceptable solution;

How to reduce vulnerability from flood events:

- Ensure infrastructure is maintained so that drains, gullies and culverts work effectively during flood events;
- Clarify who is responsible for maintenance and enabling people to know who to contact to report a maintenance problem;
- Consider how hazard-resistant design can reduce flood damage and enable faster recovery times from flood events;
- Ensure that vulnerable groups (such as those who have disabilities, are house-bound and who don't have access to the Internet) are made aware of flood risks and can take action in an emergency;
- Provide community support through emergency services and emotional support in a flood emergency and its immediate aftermath.

NEXT STEPS

The Crediton Flood Resilience Group is working to transform these findings into ways that can help make Crediton and its people more resilient to future flooding, especially in the light of evidence that suggest rainfall events may become more frequent and intense in future.

This is being done in these ways:

- By working with Crediton Town Council as they develop their emergency plan for Crediton, ensuring that flooding is fully integrated into this new plan and by providing a basis for helping the community to consider long-term resilience to flooding, both before and after a flood emergency;
- By engaging with and having a partnership approach to working with local agencies. Devon Country Council, the Devon and Somerset Fire and Rescue Service and the Environment Agency have all been involved with this project and the work of the group and respect and will work with its findings;
- The group has become an affiliate of Sustainable Crediton. By becoming part of a major community group in the area, this will help the flood resilience group to ensure that people in Crediton are involved in understanding, preparing for and reacting to flooding in the future;
- The University of Exeter and the Crediton Flood Resilience Group is working with organisations at the regional level in the South West to promote the research undertaken in Crediton and to learn from the experiences of others about how to promote flood resilience.

RESOURCES

Existing resources to help you understand flood risk can be accessed from the following sites:

- Environemnt Agency Flood Warnings Direct service: fwd.environment-agency.gov.uk/app/olr/home
- Devon County Council's Report a Blocked Drain service: new.devon.gov.uk/roadsandtransport/report-a-problem/
- Devon, Cornwall and Isle of Scilly Local Resilience Forum: www.dcisprepared.org.uk/about-us
- Devon Resilience Forum: www.devoncommunities.org.uk/Pages/Category/devon-community-resilience-forum?Take=17
- Devon County Council Emergency Planning service: new.devon.gov.uk/emergencies/

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