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Fig. 1 The bog garden and pond at Oxford Botanic Garden for plants requiring damper conditions

How will climate change affect our gardens, and what can we do?

Timothy Riggs

According to the campaign group 350.org, the basics of climate science are:

1. It's warming
2. It's us
3. We're sure
4. It's bad
5. We can fix it

Global climate change is a phenomenon of such massive and imminent threat to our way of life, and indeed to millions of lives, that to focus merely on how it affects our gardens seems grotesquely parochial. However, as growers and cultivators of plants, we are perhaps more environmentally aware than most. We will certainly need to adapt our practices, and indeed we could be collectively and uniquely able to play our part in trying to 'fix it'.

In the early 1970s James Lovelock and Lynn Margulis postulated that life on Earth actively keeps the surface conditions always favourable for those organisms currently occupying the planet, rather than life simply adapting to independent planetary conditions. This was initially called the *Gaia Hypothesis*, but it's now generally accepted as *Gaia Theory*, whereby the Earth is seen as a single, self-regulating system comprised of physical, chemical, biological and human components. The interactions and feedbacks between the component parts are complex and variable.

Significant, measurable changes now threaten this balance. After the last ice age, which ended about 11,000 years ago, the Earth's climate remained relatively stable up to the mid-1800s, with an average global temperature of about 14°C. The 'Little Ice Age', which occurred in two phases between around 1300 to the mid-1800s, was an exceptionally cold period, but temperatures have been rising globally since then. This has been associated with increased levels of carbon dioxide (CO_2) in the atmosphere. Before 1850, our atmosphere typically contained about 280 parts per million (ppm) CO_2. As the use of fossil fuels spread throughout the world, the amount of carbon dioxide in the atmosphere shot up exponentially, and is now well over 400ppm (fig.2).

Carbon dioxide is a so-called 'greenhouse gas', along with methane (CH_4), nitrous oxide (N_2O), ozone (O_3) and water vapour. These gases absorb infrared radiation and radiate heat back to the Earth's surface. Hence, the Earth is warmed, as happens in a greenhouse, where the sun's energy easily penetrates the glass windows, but the radiated heat generated inside is largely trapped. At current levels of greenhouse-gas emission, it is estimated that by the end of the 21st century global temperatures could increase by between 2.5 and 5°C relative to the period 1950–2005. Effects of this can become self-perpetuating, as for instance the melting of polar ice: snow-covered ice is highly reflective of solar energy back into space – the albedo effect – and therefore stays cold, but once the snow at the edges begins to melt it exposes dark ground which absorbs sunlight and therefore gets warmer and accelerates further warming. Again, there is a fear that rising temperatures will free carbon trapped in frozen soil (permafrost) in the Arctic and below Arctic lakes. Large quantities of methane, which is a more potent greenhouse gas than CO_2, could be released and thus further exacerbate global warming. These are examples of positive feedback: any addition of heat from any source will be amplified.

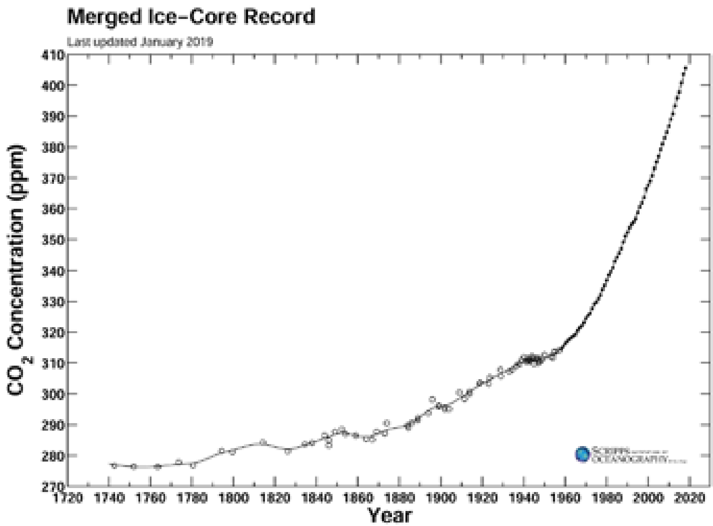

Fig. 2 Merged ice-core record of the time trend of the concentration of CO_2, in ppm, in air extracted from an Antarctic ice core combined with the trend based on direct atmospheric measurements.

Open Black Circles: Antarctic ice core record from Law Dome before 1958 (Macfarling Meure, *C. et al.*, 2006: Geophysical Research Letters, 33.)

Closed Black Circles: Seasonally detrended arithmetic average of air measurements from Mauna Loa and the South Pole from the Scripps CO_2 program after and including 1958 (Scripps Institution of Oceanography at UC San Diego).

In the planetary carbon cycle, CO_2 is released into the atmosphere by animal and plant respiration, and by decay and burning of vegetation, only to be reincorporated into vegetation by photosynthesis or absorbed by the oceans. This naturally occurs as a dynamic equilibrium, but human intervention through industry and agriculture has unbalanced the system and increased the atmospheric component. Whether the system can react sufficiently fast to restore the equilibrium will depend partly on how quickly we can stabilise and eventually reduce our emissions, but there will be a considerable lag as, although transfers of CO_2 to the land – predominantly by photosynthesis – are rapid, vegetation represents a relatively small sink compared with that of the oceans, whose uptake is slow. Even if anthropogenic production stopped now, it could take thousands of years for the atmosphere and oceans to regain equilibrium.

According to a World Resources Institute blog[1], mitigation to reduce emissions as quickly as possible will still not be enough to prevent the worst impacts of climate change. We need to remove carbon from the air faster than we are putting it in and reach net-negative emissions. So far, it seems, we don't have the technology for this, so we do need to protect and encourage the natural

[1] *Taking Greenhouse Gases from the Sky: 7 Things to Know About Carbon Removal.* Levin, Mulligan and Ellison, www.wri.org, March 19, 2018.

Fig. 3 A broad division of the UK into climatic regions

carbon removal processes in soils, forests and wetlands.

The Paris Agreement on Climate Change was negotiated in 2015 by more than 190 nations and entered into force in November 2016, though the US has since withdrawn. The signatories pledged to cut carbon emissions sufficiently to limit further global temperature rise to 2°C relative to pre-industrial levels[2], with a goal of 1.5°C to prevent some of the worst effects of climate change.

Human-induced warming has already reached approximately 1°C above pre-industrial levels, but past emissions are unlikely to raise global mean temperature by more than a further 0.5°C over the next two or three decades. Therefore, if all greenhouse-gas emissions could be reduced to zero immediately, overall warming would not exceed the 1.5°C target set by the Intergovernmental Panel on Climate Change (IPCC). Unfortunately, there is now considerable concern that such reductions are not happening fast enough. Even small amounts of further warming could have large effects. The latest projections suggest that at 1.5°C, 70–90% of coral reefs will suffer, but at 2°C they would be totally destroyed. Also at 2°C melting ice will raise sea levels by 10cm more than at 1.5°C – a small difference, but potentially devastating for millions of people living on vulnerable coasts.

So, what does this mean for us in the UK? We experience a temperate *climate*, within which there is variation in local *weather* conditions. There is considerable variation in growth conditions for plants, from west to east and south to north (see fig. 3). Coastal regions are generally milder in winter and cooler in summer; highland regions are cooler and wetter. There is also variation from year to year around these major differences. Winds are predominantly from the south-west, but the UK is affected by Arctic air from the north and tropical air from the continent (fig.4).

The Gulf Stream

As an island nation, our weather is affected by the oceans. The North Atlantic Current of the Gulf Stream brings warm surface waters northward towards the pole and helps keep Ireland and the west coast of Britain a couple of degrees warmer than the east coast. As this surface water cools in the polar Atlantic Ocean, it naturally becomes more dense and salty. It sinks, and is then carried south again at a deep level (fig. 5). There is evidence of a weakening of this system of currents by about 15% since the middle of the 20th century, possibly due to melting of the Greenland Ice Sheet releasing a huge volume of fresh water and diluting the salt water so that it fails to sink, even when cooled[3]. This level of change is unprecedented in the past millenium[4] and its long-term effects are difficult to predict,

[2]Defined as an increase in combined surface, air and sea surface temperatures averaged over the globe and a 30-year period, expressed relative to the period 1850 –1900.

[3]https://www.theguardian.com/environment/2018/apr/13/avoid-at-all-costs-gulf-streams-record-weakening-prompts-warnings-global-warming?CMP=share_btn_link

[4]Rahmstorf et al (2015) *Nature Climate Change* **5**, pp 475–480.

but could be catastrophic. According to the Astronomer Royal, Sir Martin Rees, 'flipping' of the Gulf Stream would be a disaster for Western Europe: Britain and neighbouring countries could be plunged into arctic winters like those that currently prevail in similar latitudes in Canada and Siberia[5].

The Jet Stream
The Jet Stream is formed when cold arctic air hits the warmer air from further south. The greater the difference in temperature, the faster the jet stream moves. Here again there are signs that with the melting of the polar ice caps the temperature difference is reduced, with the result that the jet stream has begun to meander and slow down. It also remains in place for longer periods of time, so that weather extremes are prolonged.

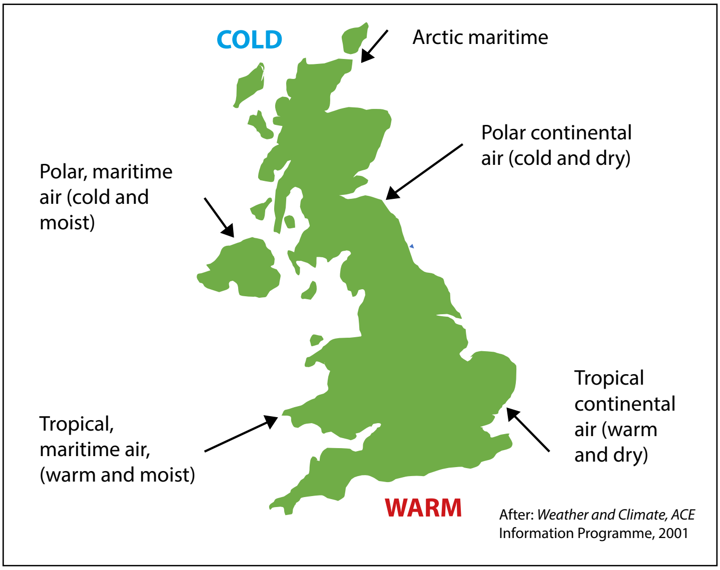

Fig. 4 Air masses affecting the UK climate

The average temperature in the UK over the decade 2008–2017 was 0.8°C warmer than the 1961–90 average, with 8% more rainfall and 6% more sunshine. With the exception of 2018, summers have been wetter compared to the 1961–90 baseline. The summer of 2017 was relatively wet, and there was snow in December, but 2017 was still 1°C warmer than the baseline, and ranked as the fifth warmest year in records dating back to 1910. Nine of the ten warmest years for the UK have occurred since 2002, and the ten warmest have all occurred since 1990. The 21st century has so far been warmer than any of the previous three centuries[6].

The aim of this article is to remind us of this insidious process and its likely impact on our gardening practices and thoughts. How should we think of 'hardy plants'[7] in this new future? How will our gardening practices need to change, and perhaps most importantly, what can we do as gardeners to mitigate further greenhouse gas emissions and preserve biodiversity in our gardens?

Implications for gardens and gardening

The Royal Horticultural Society (RHS) has been concerned for some time about the effects of climate change on gardening in the UK. Its report, *Gardening in the Global Greenhouse*, was published in 2002, when climate models were suggesting rising temperatures and consequently warmer summers. Its most recent report, published in 2017, *Gardening in a Changing Climate*, extends its conclusions in the light

[5]Martin Rees (2003) *Our Final Century*, Arrow Books, p 111.

[6]Met Office, *State of the UK Climate 2017, International Journal of Climatology* 38, Issue S2, pp 1-35, July 2018

[7]The HPS leaflet, *What is a Hardy Plant?*, points out that a plant's survival is not simply a matter of temperature – weather changeability is an important factor, and understanding the unique microclimate of our gardens, improving winter drainage and insulating roots against frost will give our plants the best chance.

of further climate and horticultural research. It is an extensive report of 86 pages, but there is a separate Summary of only 12 pages[8].

According to the report, average temperature is projected to increase in all seasons and across all regions of the UK; there will continue to be high year-on-year variability in rainfall, with an increased frequency of very wet days over the winter, particularly in northern areas, while in southern and eastern areas there are likely to be more dry spells over the summer months; gardens close to the coast or near estuaries may experience more flooding due to an increase in the frequency and severity of tidal surges; much of the UK could become totally frost-free in some winters.

In general, the challenges that can be expected to affect gardeners during this century and beyond are longer growing seasons, with warmer springs and autumns; extremes of wet weather with flooding, waterlogging and consequent leaching of nutrients; shortages of water in hot, dry periods; extension of the ranges of some pests and diseases, including some new ones previously poorly adapted to UK conditions; possible escapes from gardens of exotic plant introductions to become invasive in the wild; effects on pollinators of changes in flowering times.

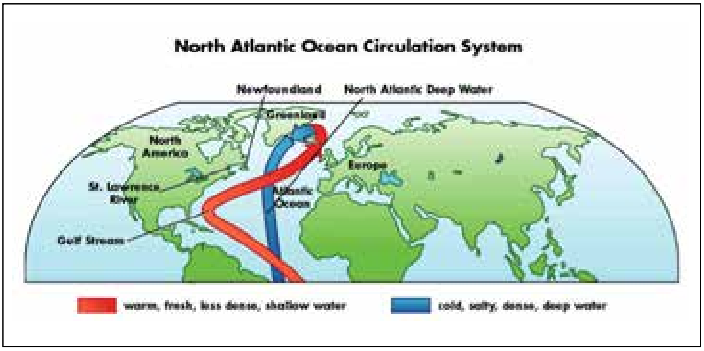

Fig. 5 The path of the Gulf Stream in the North Atlantic. Source: NASA

All these changes will vary in significance in relation to the regional differences that already exist.

Because plants are at the base of the food chain, anything that affects plants has an impact on other parts of the ecosystem. Many interactions between species are becoming mistimed because of differential phenological shifts in response to climate change. According to Jill Attenborough of the Woodland Trust, in the UK spring is coming about two weeks earlier than 30–50 years ago, and autumn about a week later. Many trees, such as oak, horse chestnut and sycamore, are coming into leaf much earlier; butterflies and moths are responding faster than blue tits, which time their broods to correspond with peak availability of caterpillars to feed their chicks. Similarly, differential responses in timing between the flowering of plants and the emergence of the insects which pollinate them could threaten the survival of both.

A technique called *niche modelling* has been used to predict whether a species might die out, do better, or be relatively stable under various climate-change scenarios. By mapping the distribution of a plant species against the range of climatic variables it currently experiences, mathematical models are constructed to assess its likely fate as the climate changes. Most of these studies are based on plants growing in the wild, but an example of a garden plant subjected to this analysis and cited in the RHS Report is *Cyclamen*. Niche models for 20 species in this genus suggest that more than half will lose all the habitat in their natural ranges by 2050, and so be at a high risk of extinction because migration rates through natural seed dispersal will be too slow to keep pace with the changing climate.

While the effects of climate change will undoubtedly be disruptive to established ecosystems and current adaptive distributions of plants, it

[8]Both are available to download from the RHS website, www.rhs.org.uk/climate-change.

is worth bearing in mind that longer growing seasons, warmer temperatures, higher rainfall and higher CO_2 concentrations can open up new opportunities as well as challenges for gardeners.

Adaptations in gardening practice

Using projections from the Fifth Assessment Report of the IPCC, the RHS report of 2017 focuses on gardens in three different UK regions to show the likely conditions in each by 2100, and the sorts of design features that could be adopted in response. Few if any reading this will see 2100, but the changes may come faster than we expect.

West Country

The expectation is a frost-free climate with mild, humid winters; rainfall will be heavy in the winter and moderate in the summer; and the growing season will be longer. Gardeners might make raised beds to lift the roots of traditional favourite plants, such as alliums, asters, dianthus, geraniums and tulips, above the water table; plant shrubs and small trees rather than large trees which on wet soil could be toppled by high winds; and make a rain garden to deal with heavy rainfall events. [A rain garden is a shallow depressed area, strategically placed to catch stormwater run-off from roofs and impermeable surfaces, with plants that can stand waterlogging for up to 48 hours as the water slowly drains through the soil.]

East Anglia

This region will have a largely Mediterranean climate, with temperatures perhaps 5°C warmer than now, moderate rainfall in the winter, but relatively dry summers. However, it should be possible to grow a greater range of plants, subject to the limitations of dry soils in summer. Evergreen sclerophyllous plants, their leaves adapted to prevent moisture loss, such as *Arbutus* spp., *Quercus ilex*, eucalyptus and bay, could thrive, as well as drought-tolerant pines and palms; lawns could be replaced by dry meadows (fig. 6) with naturalised bulbs; shady patios could become extra rooms for sitting outside in the higher temperatures; downpipes from roofs would lead rain water to underground tanks for storage for summer watering.

Northern England

The RHS report makes no distinction between the east and west regions of northern England; the west currently has milder winters and higher rainfall, but the possible weakening of the gulf stream owing to climate change might have reduced this difference by 2100. The northern regions generally are expected to have more extreme weather events, including heat waves and heavy rain. Although generally warmer by about 2°C than present, there will still be a significant risk of frost. Plants will be chosen for resistance to wind, waterlogging and drought, but gardening under protection such as greenhouses, polythene tunnels and conservatories is likely to be more important. Plants grown in containers can be moved to and from unprotected and protected areas. Drains and rain-garden areas might be common to divert water away from buildings during heavy rain.

As gardeners, we love and care about plants, both aesthetically and for home-grown production, but outside our gardens humans have exploited

Fig. 6 A prairie garden, adapted to hot, dry summers

their chosen crop plants on a massive scale. The Industrial Revolution wasn't only about factories, smoking chimneys and coal-consuming machines; it also led to the industrialisation of agriculture. Farm machinery has largely replaced human labour, and plant and animal husbandry has also been industrialised. Billions of farm animals live today as part of a mechanised assembly line, and cereal varieties with all genetic variation bred out of them are grown over huge areas of monoculture with attendant chemical-spray regimes and consequent near-elimination of natural meadow plants and many bird, mammal and insect species. Vast areas of rainforest have been destroyed to grow oil-palm plantations and to rear beef cattle. The consequences of this intensive production in terms of declining biodiversity and the pollution of the land, seas and atmosphere, are now horribly apparent.

Horticulture too is culpable, for its considerable use of peat-based composts[9], with consequent destruction of an important carbon sink and water-absorbing resource, together with the biodiversity unique to peat-bog habitats.

What can we do?

Against these large events our humble gardens may seem insignificant, but gardens do matter! They are habitats that we can influence and manage, unlike the fields around us, and in the UK they occupy a significant area. Urban gardens alone cover about 25% of the total urban area in many cities and, because more than 80% of the UK population lives in towns and cities, we can make a difference with our front and back gardens. New initiatives such as Energy Garden Projects at over-ground railway stations around London can increase garden and wildlife areas. An example is Brondesbury Park[10] where, in just under a year, and thanks to the hard work of local residents, station staff, volunteers and the Green Team, it has become a community garden with vegetables and flowers, a solar-powered pump, compost bin and hedgehog house.

A 2011 RHS Science Review[11] pointed out that gardens can help control urban temperatures, protect us from extreme heat and cold, save on energy bills, help prevent flooding, provide important habitats for wildlife and improve human health, both psychologically and physically. Vegetated areas can reduce temperature by shading (trees and climbers) and evapotranspiration (plants with silvery leaves having high albedo, such as *Stachys byzantina*, can also help to cool their immediate environment by reflecting solar energy back into space). Models suggest that a 10% increase in vegetated surfaces in urban areas can help control summer rises in temperature, while in winter, hedges and trees strategically placed around buildings can provide wind breaks. Trees can intercept intense rain, slowing run-off by holding water temporarily in their canopies, while garden soils will naturally absorb rainfall, relieve pressures on urban drains and help reduce flooding. The benefits of cultivated front gardens, aesthetically, functionally and ecologically in terms of the biodiversity they attract, and the converse risks of unregulated paving of these areas, need to be more widely recognised. British gardens might have the ideal conditions to grow genera and species at risk from the effects of climate change, and by using horticultural techniques to look after them, gardeners can play a useful role in their conservation.

We can expect to modify our gardening strategies in response to the changing environment over the next few decades, and not all the changes will be difficult or unwelcome: gardeners

[9] *A wild anger* (about the exploitation of peat resources by gardeners), Rosemary FitzGerald *The Hardy Plant* Spring 2018, Vol.39 No. 1

[10] http://energygarden.org.uk/brondesbury-park-station-update/

[11] *Urban Gardens* Science Review, https://www.rhs.org.uk/get-involved/greening-grey-britain/why

currently struggling to grow favoured plants close to the edge of their hardiness tolerances might begin to have more success. More significantly, we could also have a large collective impact on the more adverse expectations if environmentally conscious actions are taken. As the advertising phrase goes, 'every little helps'!

It's not always easy to know what action to take. I enjoy a garden bonfire every so often, and I also have a wood-burning stove in my house; the bonfire material and some of the logs are from my own garden, so isn't this just natural recycling – particularly if I'm planting new trees? How else should I dispose of garden material that cannot easily be composted? Should we donate garden material to local council green-waste collections? Do the council lorries contribute significantly more emissions than our own compost heaps? Can we move towards renewable energy sources for our power tools, not to mention our private vehicles? The answers to such questions are for individuals to decide, and may not be straightforward.

In the meantime, it makes sense to:

- Plant more trees, shrubs and hedges for their long-term carbon-fixing capabilities, drought tolerance and shelter-belt functions (fig.7).
- Create wildlife gardens with ponds and water features to provide sanctuaries for animals during hot, dry summers. (fig.1).
- Compost garden and kitchen waste.
- Grow a wider range of pollinator-friendly plants to cover any gaps in the availability of pollen and nectar (see the RHS Perfect for Pollinators lists).
- Use peat-free compost.
- Set up water butts and tanks to provide a natural supply of water during warm, dry periods when hosepipe bans might be in force.
- Help conserve endangered plant species, wild and cultivated.
- Encourage others, especially children and young people, to take an interest in gardens and be environmentally aware.
- Avoid the use of chemicals in the garden and practice Integrated Pest Management (IPM).

We'll enjoy our gardens even more knowing that they truly make a difference to our planet.

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Fig. 7 Blackbird Cottage, Scampston, demonstrating a range of shrubs and trees

Timothy Riggs graduated in botany, and has post-graduate degrees in ecosystems analysis & management, and in plant breeding and genetics. He worked as a plant breeder for agricultural and horticultural crops in the UK and Uganda, and is concerned about the environmental damage caused by the modern horticulture and agriculture industries. In retirement, he lives in the Midlands, keeps bees and gardens on heavy clay.