Climate and society in modern Ireland: past and future vulnerabilities

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[Accepted 2 September 2020. Published 30 October 2020.]

Abstract

Sitting astride the main storm tracks of the North Atlantic, Ireland's location has historically rendered it vulnerable to the vicissitudes of weather and climate. Throughout the nineteenth century and for much of the twentieth century, the imperative of achieving a food, fodder and fuel surplus meant agrarian Irish society was a greater hostage to climate than many other parts of Europe where the Industrial Revolution had enabled the worst effects of the Little Ice Age to be mitigated. Closer examination of society–climate relationships has been facilitated by documentary sources and by direct observations from the nineteenth century onwards, which have provided new insights into Irish climate hazards such as storms, floods and droughts. As Ireland modernised, new concerns such as urban flooding emerged, and new ways of managing climate risks were devised. Ultimately though, as more benign climatic conditions in the mid-nineteenth century gave way to more instability and rapid warming in the twentieth and early twenty first, the need for adaptation and mitigation of climate change became evident. Improvements in global and regional climate modelling and forecasting were instrumental in assisting with this. However, Irish society has been slow to react to climate change concerns and only through a series of catalytic extreme events has public and political attitudes shifted, induced by both 'bottom-up' activism and 'top-down' international agreements. Accordingly, Ireland is now on the threshold of taking the radical steps necessary to shed its 'climate laggard' status and embark on the road to a post-carbon society.

Introduction

Though the conclusion in the nineteenth century of the Little Ice Age (LIA) was accompanied by an improvement in average annual air temperature, Ireland remained highly vulnerable to the vagaries of climate. The omnipresent preoccupation with fodder, fuel and food was magnified during the first half of the century by a rapidly rising population. On top of this, the lingering effects of the Little Ice Age continued to be felt and it would be the middle of the century before consistent mildness was experienced. (Ironically the mildness of 1845/6

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doi: https://doi.org/10.3318/PRIAC.2020.120.12

brought its own negative consequences as it facilitated the spread of potato blight, which was the source of the Great Famine—the single greatest environmental catastrophe since the Great Frost Famine of 1740–41.) Moreover, the recovery from the harsh winters of the LIA was punctuated by extreme events which brought further challenges to Irish society.

Climate and weather from the nineteenth century to the present

In 1801, Ireland had a population of 5.2 million. The corresponding population of England was 8.9 million. A century later Ireland had 4.5 million people while England had 32.5 million. The Industrial Revolution fundamentally changed the respective demographic and economic positions of the two countries. The Industrial Revolution also strongly incentivised organised weather observations. In the crowded industrial cities of Europe, public health and sanitation became a matter of great concern once the link was established between disease, sanitation and living conditions. A reliable water supply and sewerage network needed objectively measured data on rainfall and river resources. In an Ireland largely bypassed by the Industrial Revolution, it was 'Big House' astronomical observatories such as Armagh (1790), Birr (1845), Dunsink (1788) and Markree (1824) that formed the early observational nucleus. These were all inland. However, many of the climate gradients in Ireland are coastal-interior orientated. This reflects the importance of oceanic influences on temperature and temperature-related parameters such as frost days and measures of the growing season. The skeletal observational network did not address marine issues from the outset. It took the loss of 459 lives in 1854 when a storm sunk the passenger ship Royal Charter off Anglesey to prompt the establishment, at the instigation of Admiral Robert Fitzroy (1805–65), of 15 coastal weather stations across Britain and Ireland. A key component of this network was Valentia, which provided a telegraphic link to the UK to service the transatlantic cable that was laid in 1856. Since then, Ireland's west coast weather stations have acted as valuable sentinels for Atlantic storm systems, providing early warning to locations further east in Europe.

The fear of storm, which lies deep in the Irish psyche, was intensified as early instrumental records emerged. Perhaps the most potent nineteenth-century reminder to Irish society was provided on the night of the Epiphany, 6 January 1839—Oíche na Gaoithe Móire, the Night of the Big Wind—when the country was impacted by a depression which may have had a central pressure as low as 918hPa.[1] At any event, 250–300 people perished, 42 ships were wrecked, 20–25 per cent of the houses in Dublin city were destroyed or damaged, and several thousand trees were blown down. Vegetation was drenched in brine

[1] L. Shields and D. Fitzgerald, 'The "Night of the Big Wind" in Ireland, 6–7 January 1839', *Irish Geography* 22:1 (1989), 31–43.

up to 15km from the coast (with anecdotal accounts of herring and other fish being deposited 6km inland). Stacks of hay and corn were devastated by fire, as were many thatched houses, which were disproportionately the residents of the less well off. Such losses may have diminished their capacity to cope with the Great Famine, which was to descend on the island in 1845. So deeply was the event etched in the folk memory that when old age pensions were introduced in Ireland seventy years later, memory of the event was used by the authorities to establish the entitlement of some septuagenarians who could not furnish a birth certificate.

Most storm events in Ireland tend to be felt on a national scale. It is relatively infrequent for an event to be limited to a locality. Such an event occurred on 18 April 1850 in Dublin when the city was subject to its most destructive hailstorm.[2] This storm was accompanied by walnut-sized hailstones which shattered thousands of window panes and roof slates in addition to causing considerable property damage. In College Park, ten trees fell towards the north west at the beginning of the storm while nine trees fell towards the south east later.[3] As the centre of the storm appears to have been distinguishable as it passed directly through the city, it may well have been a tornado. Certainly the damage costs were estimated at 40% of the 1839 event.

The impacts of weather extremes on Irish society in the pre-instrumental period are well documented in Irish newspapers. Titles, such as the *Belfast Newsletter* (1738-present) and the *Freeman's Journal* (1763–1924), and regional newspapers such as the *Kerry Evening Post* (1813–1917), *Tuam Herald* (1837–1955) and *Nenagh Tribune* (1838-present) are a useful source of information on the effects of the weather from the early nineteenth century, and they are augmented from the mid and later decades by the proliferation in local titles in the second half of the century.[4] Of course it is important to interpret reports carefully—the nature and severity of weather events reported echoes the concerns of the middle and better off classes rather than the poor urban dweller or subsistence farmer. But they assist in the construction of the relationship between weather events and Irish society.[5] They also help contextualise the contemporary events such as Storm Emma in 2018 by illustrating the nature and impact of past bitterly cold winters such as that in 1783/84.[6] Noone *et al*. (2017) have also demonstrated the utility of such sources in reconstructing drought

[2] F.E. Dixon, 'Weather in Old Dublin', Dublin Historical Record, 13:3 (1953), 94–107.
[3] F.E. Dixon, 'Weather in Old Dublin Part II', Dublin Historical Record, 15:3 (1959), 65–73.
[4] M.L. Legg, *Newspapers and nationalism: the Irish provincial press 1850–1892* (Dublin, 1999).
[5] John Sweeney, 'A three-century storm climatology for Dublin, 1715-2000', *Irish Geography* 33:1 (2002), 1–14.
[6] Conor Murphy, 'An icy blast from the past', *Weather* 74:2 (2019), 74; James Kelly, 'Weather, climate and society in Ireland in the long eighteenth century: the experience of later phases of the Little Ice Age', *Proceedings of the Royal Irish Academy*, 120C (2020).

events and their societal impacts.[7] This has alerted us to persistent multi-season drought episodes in the nineteenth and twentieth centuries. Ireland, it transpires, is much more drought-prone than commonly perceived, with recent decades being unrepresentative of the longer-term drought climatology. During the years 1850–2015 for example Irish society had to cope with seven major island-wide drought-rich periods: 1854–60, 1884–96, 1904–12, 1921–23, 1932–35, 1952–54 and 1969–77. Such work provides important yardsticks for calibrating the magnitude and frequency changes that can be expected under future changed climate conditions.

The years 1800 to 1809, for example, was one of the most sustained drought events over the past 250 years, resulting in the importation of emergency supplies of grain and maize from the U.S., the failure of the potato crop, and great distress for those dependent on the water-powered woollen and linen industries. Again, in 1887, a persistent blocking anticyclone settled over Ireland. Commencing in early spring and only breaking down in November, the drought caused crop failure and public water supply crises, which were at their most acute in the east of the country. Murphy *et al*. (2017) report public health concerns in Dublin due to stagnant sewers and also a call to pray for rain from the Church of Ireland Bishop of Meath in the *Irish Times* in early July 1887.[8]

The interactions between extreme climate events and society are well demonstrated by drought situations. The Dublin water crisis of 1893 is a case in point. By late summer, a drought commencing in the spring threatened the city's supply from the reservoir at Vartry. Despite major reductions in supply and lengthy periods when water was cut off, by the autumn the city was down to its last 16 days of supply. The crisis prompted an extensive debate on how new supplies might be obtained. Damming Lough Dan in Wicklow, piping water from the River Avoca, tunnelling through the watershed between Lough Tay and Lough Dan, exploding dynamite above the city to make rain, were just some of the ideas discussed. It is striking how radical suggestions emerge during severe events, only to wither on the vine once the memory fades. Floods and droughts tend to diminish quickly in importance in Irish public consciousness as the more short-term priorities of daily life take over.

Increasing urbanisation and increased overseas trade in the twentieth century changed Irish society's priorities regarding climate hazards. Intense rainfall events and urban flooding assumed greater importance in the public consciousness as property values increased and concerns for food security decreased. Forecasting skills improved steadily and the value of observations became apparent. The early warning capability of Irish observations for Britain

[7] Noone *et al*., 'A 250 year drought catalogue for the island of Ireland (1765–2015)', *International Journal of Climatology*, 37:S1 (2017), 239–54.

[8] Murphy *et al*., 'Irish droughts in newspaper archives: rediscovering forgotten hazards?', *Weather*, 72:6 (2017), 151–55.

and Europe was particularly important, and is well demonstrated by the crucial role observations at Blacksod in Co. Mayo played in the timing of the 1944 D-Day landings. The importance of good quality weather data for the transatlantic flying boats service from Foynes in Co. Limerick was also instrumental in the establishment of the Irish Meteorological Service in 1936.

As better understanding of the internal structure of mid latitude depressions is established, better forecasting of major events was also developed. But still, events could cause surprises. The Mount Merrion storm of 11 June 1963 for example dumped over 184.2mm on the Ballsbridge area of Dublin, with over 75mm of it in a single hour.[9] In many ways this event illustrated the new relationship that was developing between modernising Irish society and climate hazards. Urban flooding was henceforth the number one preoccupation.

Many of Ireland's towns and cities are located close to upland catchments that respond rapidly to high rainfall events. While some large rivers have been partially tamed by dams, vulnerability to smaller rivers, swelled up by high rainfall events in their upper courses, has increased significantly as impermeable urban surfaces spread. Such vulnerability was well demonstrated by 'Hurricane Charley' in August 1986. It is not that unusual for the tail end of a hurricane to reach Ireland in late summer/autumn. Heavily laden with water vapour, any forced ascent can result in large quantities of rain, as was the case with Charley. An estimated 280mm fell on the mountains of Wicklow, sending huge amounts of water along the Dodder, Dargle and other rivers down to lower levels (Fig 1). Even at low levels the rainfall received set a new national record of 200mm at Kilcoole, south of Greystones. The worst flooding for over a century in Dublin ensued with over 400 properties affected, some to depths of 2.5m.

As the twentieth century drew to a close, extreme events were more widely reported. This was due in part to an improved monitoring network, but also to increased public sensitivity and awareness. Greater scrutiny of established methods to protect society from extreme events emerged. For society it is the case that a trade-off will always exist between 100% protection and the high cost of bringing this about. Accordingly, a measure of risk generally deemed to be acceptable has for long been used. A well-established practice of characterising extreme events in terms of their probability of occurrence has been employed, especially for infrastructure such as bridges, dams and flood protection measures. Thus the 1-in-100 year event is calculated from a statistical analysis where a sufficient run of data is available, and structures are designed to withstand what is deemed commensurate with such a risk. Accordingly, for example, a major rainfall event on 27/28 October 1989 at Belmullet was described as having a return period in excess of 100 years, and another event on 11 June 1993 at Casement Aerodrome was described as having a 250-year

[9] W.A. Morgan, 'Rainfall in the Dublin area on 11th June, 1963', Irish Meteorological Service Internal Memorandum IM 72/71 (Dublin, 1963), 1–8.

Fig. 1—The River Dodder reaching the parapet at Ballsbridge, Dublin during 'Hurricane Charley', 25–26 August 1986. (Photograph: Courtesy *The Irish Times*)

return period.[10] Underlying all of this was the assumption that the database that was used reflected a stationary time series. In the event of a trend embedded in the data, such calculations become unreliable. It became increasingly clear in the late twentieth century that this assumption of stationarity was not justified. Irish climate itself was changing and society would need to adjust to a whole new relationship.

Notwithstanding the occasional exceptional extreme storm event, it is clear that the middle to the end of the nineteenth century was marked by more quiescent and benign climate conditions. A greater frequency of anticyclonic conditions would seem to have prevailed, with fewer storms and generally milder conditions. Butler *et al*. (2005) noted these milder conditions at Armagh Observatory during the middle part of the century, [11] lasting roughly until 1870. From the 1890s onwards, however, all this was to change. A new period of instability emerged as Ireland began to warm more quickly. By the mid-twentieth century around 0.5°C of warming had occurred and, after a mid-century lull, the late twentieth century was marked by further rapid warming. Irish climate was no longer fluctuating according to natural drivers alone. Now it was

[10] Met Eireann, Major Weather Events, 2019. Available from: http://www.met.ie/climate/weather-extreme-records (accessed 15 Feb. 2019).

[11] Butler *et al*., 'Air temperatures at Armagh Observatory, Northern Ireland, from 1796 to 2002', *International Journal of Climatology*, 25 (2005), 1055–79.

becoming clear that global forcing in response to anthropogenic influences was involved. The Anthropocene had arrived.

New societal awareness of vulnerability in an age of climate change

In 1985 the International Council for Science, together with the World Meteorological Organisation (WMO) and the United Nations Environment Programme (UNEP), staged a major conference in Austria which concluded that greenhouse gases could warm the earth by several degrees. While this was to some extent a restatement of the validity of the pioneering work of the nineteenth-century Irish scientist John Tyndall and the Swedish scientist Svante Arrhenius, what was different was the acceptance that this was the current trajectory of earth's climate, and that actions were required to address this. As a result, WMO and UNEP established the Intergovernmental Panel on Climate Change (IPCC) in 1988, whose Assessment Reports, published every six or seven years, have laid the foundation for efforts to address global warming. These scientific outputs were used by the United Nations Framework Convention on Climate Change, which was established after the Rio Earth Summit of 1992, in their development of emission mitigation strategies.

Climate change was not deemed a serious issue in Ireland, however, at either the academic or public level for a number of years after the IPCC commenced its activities. Some researchers did suggest that rainfall receipt across Ireland would change should the frequency of particular synoptic circulations alter;[12] but climate modelling was only embarked on its rapid development [13] and it was not possible to downscale even the crude outputs from these with confidence. The first national impact assessment for Ireland merely used hypothetical temperature and rainfall parameters to guide their conclusions.[14] However, rapid advances in computing power modelling after the turn of the century meant it was possible not only to produce scenarios of what future Irish climate might look like, but also to use outputs to drive impacts models in areas of wider interest for society and to pose some major questions.[15] How would water availability

[12] John Sweeney, 'The changing synoptic climatology of Irish rainfall', Transactions of the Institute of British Geographers, 10:4 (1985), 467–80; John Sweeney, *Global change and the Irish environment* (Royal Irish Academy, Dublin, 1997).

[13] P. Lynch, 'Climate modelling', in John Feehan (ed.), *Climate variation and climate change in Ireland?* (Environmental Institute, University College Dublin, 1994).

[14] Brendan McWilliams, Climatic change: studies on the implications for Ireland (Department of the Environment, Dublin, 1992).

[15] John Sweeney and R. Fealy, 'Future climate scenarios for Ireland using high resolution statistical downscaling techniques', in F. Convery and J. Feehan (eds) Achievement and challenge, Rio+10 and Ireland (Environmental Institute, University College Dublin, 2002), 172–79; John Sweeney, *Climate change: Scenarios and impacts for Ireland* (Environmental Protection Agency, Johnstown Castle, Wexford, 2003); McGrath *et al.*, *Climate change: regional climate model predictions for Ireland* (Environmental Protection Agency, Wexford, 2003).

change?[16] How would yields of agricultural crops such as potatoes change?[17] How would forests change?[18] For some crops, the direct effect of having higher carbon dioxide concentrations in the atmosphere could be expected to increase yields; but only if other limitations did not exist. So cereal crops in Ireland could be expected to do as well as at present, if not better, under the future projected conditions, with maize being a particular winner. But other crops such as grass and potatoes would not welcome the drier summers projected. Livestock farming would also be impacted by the projected higher winter rainfall and consequent decrease in accessibility in spring to waterlogged soils, especially in the west of Ireland.

As both computing power and model reliability increased, refinement of some of these research questions became possible.[19] Wider concerns for biodiversity also emerged. Species with narrow tolerance ranges, especially montane and boreo-arctic species, and those dependent on peatland or coastal habitats, would face increasing pressures.[20] Society became increasingly aware of the multiplier effect climate change might have in accelerating the extinction of iconic species such as the curlew. At the same time as native species were coming under increasing threat, vacant ecological niches, partly helped by ongoing warming in Ireland, encouraged new invasive species to gain footholds. Mobility of people and goods also facilitated this to a great extent as awareness grew of the threats to native species posed by the zebra mussel, Japanese Knotweed, New Zealand Flatworm, and a host of others. By 2013, 48 non-native species were classified as potentially having a high impact.[21] Pests and diseases of plants have also made the journey north and west. The Horse Chestnut Leaf Miner, first identified in the Republic of North Macedonia in 1984, had by the end of the second decade

[16] Gerard Mills, 'Ireland's water budget – Model validation and a greenhouse experiment', Irish Geography 33:2 (2000), 124–34; Charlton *et al.*, 'Assessing the impact of climate change on water supply and flood hazard in Ireland using statistical downscaling and hydrological modelling techniques', Climatic Change 74:4 (2006), 475–91.

[17] Holden *et al.*, 'Possible change in Irish climate and its impact on barley and potato yields', *Agriculture and Forest Meteorology*, 116:3–4 (2003), 181–96.

[18] Purser *et al.*, 'The potential impact of climate change on Irish Forestry', Irish Forestry 61 (2003), 16–34.

[19] John Sweeney, Climate Change in Ireland: Refining the Impacts (Environmental Protection Agency, Johnstown Castle, Wexford, 2008).

[20] Coll *et al.*, *Climate change impacts on biodiversity in Ireland: Projecting changes and informing adaptation measures* (Environmental Protection Agency, Johnstown Castle, Wexford, 2012).

[21] https://www.biodiversityireland.ie/projects/invasive-species/species-lists/ (accessed 19/08/2020).

of the twenty-first century attacked chestnut trees along the east coast of Ireland and was moving relentlessly westwards.

Societal perceptions regarding climate change were further catalysed by an increasing frequency of extreme events. Ireland today is at least 0.5°C warmer than the average conditions of the 1961–90 standard reference period (Table 1). Every month shows a similar trend, meaning that about four weeks extra growing season is available on average. It also means that the air can hold more water vapour and deliver more intense rainfall. On average 6% more rain was recorded during the 1981–2010 period than the 1961–90 period. Society therefore has to come to terms with the realisation that not only will places with a history of past flooding experience more frequent and more severe events, but also that places hitherto not at risk will become vulnerable. The Office of Public Works has identified 300 communities at serious risk and commenced a programme of protective measures which will require an expenditure of €1 billion over the next decade. For some of these communities, mistakes were made in allowing urbanisation to occur in areas of known risk such as floodplains, and the reluctance of insurers to provide flood insurance cover once a property had flooded has emerged as a growing problem. The extent to which Irish individuals perceive themselves as primarily responsible for flood protection for their properties, as opposed to relying on state intervention, was studied in the context of social contract theory with reference to two communities affected by the same flood event in November 2009, one in Galway and the other in Cumbria (UK).[22] Significant differences were found in the expectations of both communities of state protection with Irish respondents more inclined to deem their local authorities to be falling short of the responsibilities expected, producing a greater sense of helplessness than in their Cumbrian counterparts.

Growing social awareness of the flood threat was accompanied by increased sensitivity as to whether extreme events were harbingers of wider climate change phenomena which would arrive down the track. This was catalysed by a series of extreme events, both individual and seasonal in nature. In an analysis of storm activity over the Ireland-UK domain, Matthews *et al*. (2014) concluded that the winter of 2013/14 was the stormiest for at least 143 years.[23] Two years later, the winter of 2015/16 turned out to be the wettest ever recorded at more than half the observing stations. Indeed the decade 2006–15 was the wettest 10-year period in more than 300 years.[24] Perhaps the single

[22] Adger *et al*., 'Changing social contracts in climate-change adaptation', *Nature Climate Change* 3 (2013), 330–33.

[23] Matthews *et al*., 'Stormiest winter on record for Ireland and UK', *Nature Climate Change* 4 (2014), 738–40.

[24] Murphy *et al*., 'A 305-year continuous monthly rainfall series for the island of Ireland (1711–2016)', *Climate of the Past*, 14 (2018), 413–40.

Table 1—Comparison of 1961–90 and 1981–2010 temperature averages for selected Irish stations

1961–90 and 1981–2010 averages for temperature: Dublin													
Casement Aerodrome	*Jan*	*Feb*	*Mar*	*Apr*	*May*	*Jun*	*Jul*	*Aug*	*Sep*	*Oct*	*Nov*	*Dec*	*year*
Mean temperature 1981–2010	5.1	5.1	6.8	8.2	10.9	13.6	15.7	15.4	13.3	10.3	7.2	5.4	9.7
Mean temperature 1961–1990	4.9	4.6	6.0	7.5	10.1	13.1	15.2	14.8	12.6	10.1	6.7	5.6	9.3
1961–90 and 1981–2010 averages for temperature: Cork													
Cork Airport	*Jan*	*Feb*	*Mar*	*Apr*	*May*	*Jun*	*Jul*	*Aug*	*Sep*	*Oct*	*Nov*	*Dec*	*year*
Mean temperature 1981–2010	5.6	5.7	6.9	8.4	10.9	13.5	15.3	15.2	13.3	10.5	7.8	6.1	9.9
Mean temperature 1961–1990	5.1	5.0	6.2	7.7	10.2	12.9	14.8	14.5	12.7	10.3	7.2	6.1	9.4
1961–90 and 1981–2010 averages for temperature: Donegal													
Malin Head	*Jan*	*Feb*	*Mar*	*Apr*	*May*	*Jun*	*Jul*	*Aug*	*Sep*	*Oct*	*Nov*	*Dec*	*year*
Mean temperature 1981–2010	5.9	5.8	6.9	8.3	10.5	12.7	14.5	14.7	13.3	10.8	8.2	6.4	9.8
Mean temperature 1961–1990	5.4	5.2	6.2	7.6	9.9	12.3	13.8	14.0	12.7	10.7	7.5	6.3	9.3

most significant event which shaped Irish society's perceptions of climate change was the arrival of Storm Ophelia in October 2017. Widely regarded as the worst storm to affect Ireland since Hurricane Debbie in 1961, Ophelia intensified into a Category 4 hurricane for a time south of the Azores before moving north-eastwards towards Ireland, losing its tropical characteristics shortly before making landfall on the south coast. Irish society was well prepared for the event, Met Eireann issuing a rare red warning well in advance of its arrival. Despite the country effectively going into lockdown, damage losses of €70 million were estimated and three people lost their lives. A wind gust of 155.6kph was measured at Roches Point, Co. Cork. Offshore at the Fastnet Rock the corresponding figure was 191kph with a nearby weather buoy recording a wave height of 17.81m.

For many people, any lingering doubts they harboured regarding the link between extreme events and climate change were dissipated by the events of 2018. This started after a fairly average winter which culminated in easterly blizzard-like conditions as Storm Emma moved eastwards through the Celtic Sea. A Siberian airflow is not an uncommon event during Irish winters, bringing bitterly cold clear conditions. This often follows a sudden stratospheric warming event which disrupts the normal westerlies and encourages a blocking anticyclone to develop. When this happens the normal passage of depressions from west to east can be disrupted. So it was with Storm Emma which brought tropical air laden with water vapour northwards at the beginning of March to collide with the continental polar easterly airflow dominating Ireland at the time. Snow drifts of over 2m were measured with several stations reporting days with temperatures not rising above 0°C. This was the first time that such conditions were observed in March in Ireland.

The delayed spring of 2018 was followed by a summer of heatwaves and droughts. The all-time record high temperature for Ireland of 33.3°C, which dates from 1887, was approached by a value of 32°C at Shannon Airport on 28 June 2018. A similar temperature was measured in northern Norway, well north of the Arctic Circle, indicating that much of Europe was enveloped by the heatwave. It was estimated that human-induced global warming more than doubled the probability of this event occurring, and in some parts of the continent made it five times more likely. Such estimates are possible because the growth in computing power has enabled customised multiple model runs to be made with, for example, pre-industrial and current levels of greenhouse gas concentrations. The resultant comparisons have provided climate scientists with a powerful tool to demonstrate the role played by anthropogenic influences in individual extreme events. Thus, for example, it can be suggested that the record breaking French heat wave of June 2019 was 10 times more likely than was the case in the last century and that climate change increased the chances of the prolonged Siberian heat wave of 2020, which produced temperatures of 38°C in the high Arctic, 600 times than would be the case in the absence of greenhouse gas loadings of the

atmosphere.[25] Such progress enables new, authoritative, public statements to be made by climate scientists, not least in Ireland, finally dispelling the sceptical view that increased frequency of extreme events does not have anthropogenic climate causes.

The 2018 heat wave in Ireland gave way to a prolonged drought which lasted from early June until late July. Absolute drought conditions prevailed in many parts of eastern Ireland throughout this period, with a June rainfall at the Phoenix Park (on average over 69mm) of only 3.8mm, which was its lowest total since 1941. Grass growth failed forcing farmers to house their cattle indoors during the summer months, putting further strains on dwindling fodder resources. Imports of alfalfa from Mediterranean countries continued throughout the summer until benign conditions resumed in the autumn. If further evidence was needed, a recurrence of drought conditions in spring 2020 produced the driest spring since 1837 in the Dublin region. Lengthy periods of water restrictions to towns and cities further reinforced the perception of many citizens that climate change was something that Ireland had to take more seriously.

Facing up to the future as laggard or leader

Decisions on how to cope with climate change ultimately have to be made at local level, and should be based on knowledge of local climate conditions and a prognosis of how they will change over time. The production of future climate scenarios is crucial for this. Limitations in computing power for long restricted the outputs of Global Climate Models to very coarse grid cells, in the case of Ireland perhaps only two or three covering the entire island. This was unhelpful for communities wondering how their particular location would be affected, how their local river would behave, or how their crop yields might change, for example. Fragmenting coarse grid outputs into smaller units was the only way of addressing this. Downscaling techniques evolved initially based on statistical relationships between large and small scale meteorological variables, frequently based on combinations of multiple linear regression techniques and stochastic weather generators.[26] It was with these early scenarios for Ireland that the case for adaptation became clear.[27] Later, the introduction of Regional Climate Models provided a more dynamically grounded approach and, as computing power increased, enabled multiple models to be combined in a configuration aimed at

[25] World Weather Attribution, 'Attribution of the 2018 heat in northern Europe', World Weather Attribution, 2018: https://www.worldweatherattribution.org/attribution-of-the-2018-heat-in-northern-europe/ (accessed 2 Mar. 2019).

[26] R. Wilby and C. Dawson, 'The statistical downscaling model: insights from one decade of application', *International Journal of Climatology* 33:7 (2013), 1707–19.

[27] Sweeney, *Climate change: Scenarios and impacts for Ireland* (2003); Sweeney, *Climate change in Ireland: refining the impacts* (2008).

reducing uncertainty.[28] Continuing computing advances have also provided opportunities for the high resolution outputs needed by environmental managers.[29]

Simulations of temperature change from the downscaled models are generally in agreement, showing a likely rise, compared with the 1981–2010 average, of approximately 1°C over the next 30 year period 2021–50 and 2–3°C for the period 2051–80 based on a business as usual trajectory. For precipitation, much greater uncertainty exists, though the models tend to agree on a trend towards wetter winters and drier summers (Fig. 2). If realised, these rainfall changes will have profound consequences for Irish society—an increased winter flood problem and a decreased summer water supply, especially in those parts of the country where the bulk of the population resides. Major infrastructural investments will be required to adapt to both circumstances. Given the lengthy lead times for these, a 'wait and see' approach is not an option.[30] Adaptation to both circumstances requires immediate detailed local planning to enable local authorities to prioritise their responses based on an informed risk assessment.[31] The first National Adaptation Framework, which was published in 2018, required each local authority to develop a local adaptation strategy and established four Climate Action Regional Offices to support both mitigation and adaptation measures at local authority level.

Adapting to climate change is not in itself sufficient. Clearly, as a member of the international community, Ireland has an obligation to contribute to the global effort to avoid a business as usual trajectory materialising. This entails a commitment to emissions mitigation proportionate to its historic contribution to the climate change problem. The UN Framework Convention on Climate Change, to which Ireland is a signatory, requires countries to act on the basis of 'common but differentiated responsibilities and respective capabilities'. As part of the EU effort to comply with this, in 2008 Ireland entered into a legally binding commitment with its European partners to reduce its greenhouse gas emissions in transport, agriculture, buildings and waste by 20% on their 2005 levels by 2020. This figure was agreed by the Taoiseach as a member of the Council of Ministers, and by the European Parliament and European

[28] E. Gleeson, R. McGrath and M. Treanor, 'Ireland's climate: the road ahead' (Met Éireann, Dublin, 2013); R. Fealy, C. Bruyére and C. Duffy, Regional Climate Model Simulations for Ireland for the 21st century (Environmental Protection Agency, Wexford, 2018).

[29] O'Sullivan *et al*., 'A high-resolution, multi-model analysis of Irish temperatures for the mid-21st century', *International Journal of Climatology*, 36:3 (2015), 1256–67.

[30] Murphy *et al*., 'Against a 'wait and see' approach in adapting to climate change', *Irish Geography*, 44:1 (2011), 81–95.

[31] Sweeney *et al*., COCOADAPT: Co-ordination, Communication and Adaptation for Climate Change in Ireland: An Integrated Approach (Climate Change Research Programme (CCRP) Report Series No. 30, Environmental Protection Agency, Wexford, 2013).

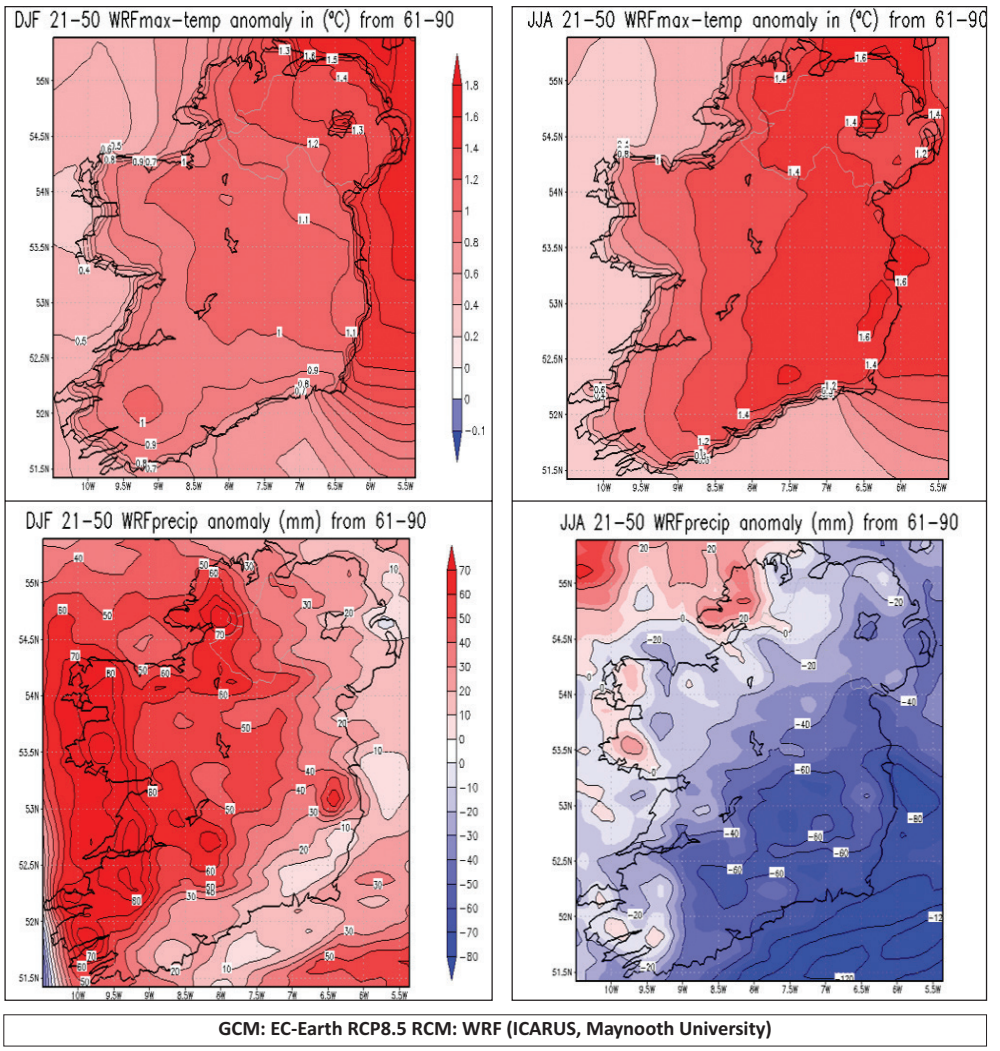

FIG. 2—Downscaled temperature and rainfall projections for Ireland, winter and summer 2021–2050 relative to 1961–1990 (Courtesy R. Teck)

Commission. However, successive National Climate Change policies, and legislation in the form of the Climate Action and Low Carbon Development Act of 2015 have failed to deliver any significant reductions, and breaches of the annual limit values are presently occurring. Indeed, while EU emissions decreased by 25% between 1990 and 2018, Irish greenhouse gas emissions increased by just under 10%. The decoupling of emissions growth from economic growth in Ireland has failed to occur and with the recovery from the recession at the beginning of the first decade of the twenty-first century, emissions began a relentless increase, led by a programme of agricultural intensification and a failure

to tackle car dependency in both rural and urban areas. As with the economic crash of 2008–12 and Kyoto Protocol compliance, the Covid-19 pandemic will provide a temporary fig leaf which will partially disguise the policy failures of the past two decades. But Irish society increasingly requires structural change. This is partially in recognition that the costs of inaction are likely to be increasingly felt beyond the climate impacts themselves. Frequently identified as the worst performing country in the EU in annual assessments carried out by international environmental groups,[32] and its 'laggard' status admitted at the highest level of government, Ireland is likely to incur fines and/or emission quota purchasing costs of several hundred million euros for these policy failures. These costs are likely to be levied on society as a whole and not based on the 'polluter pays' principle.

As Irish society has become increasingly sensitised to the gravity of climate change, impatience with the political response has grown. Much of the initial impetus came from young people increasingly aware that climate change posed an issue of intergenerational inequity. The highly successful An Taisce Green Schools programme is currently operational in over 94% of Irish schools and provides a best practice example that has been extensively studied internationally. Although rooted in sustainability in a wider sense, it has become an instrument for climate change awareness that has now been extended to third level colleges, hospitals, parks and volunteer-run community green spaces. Simultaneously, issues of climate justice have achieved prominence due to the work of distinguished individuals such as former President Mary Robinson and charities such as Trocaire which emphasised the message that former UN Secretary General Ban Ki Moon delivered on a visit to Dublin in 2015: 'Today one cannot be a leader on hunger without also being a leader in climate change.'

The reality of an Ireland that emits more greenhouse gases than the 400 million poorest people on Earth has entered the consciousness of key components of Irish society. Citizen litigation has become more common as evidenced by the successful judicial review in 2020 of the National Mitigation Plan, criticised even by the government-appointed Climate Change Advisory Council. Another manifestation of concern has resulted in increasing pressure on individuals, organisations and the State to divert their investments away from fossil fuel interests towards what are considered ethical funds. A movement that started in US universities spread to Europe rapidly to encompass over 1,200 institutions with managed investments worth over €9 trillion. Maynooth University was followed by Trinity College, Dublin, the Church of Ireland, the Catholic dioceses and many other institutions in committing themselves to such a course. With the

[32] Burck *et al.*, Climate Change performance Index 2019 (Germanwatch/NewClimate Institute/Climate Action Network International, Bonn, 2018).

passage of the Fossil Fuel Divestment Act 2018, Ireland became the first country in the world to commit to fully divest its sovereign wealth fund out of fossil fuel investments.

Irish society's most innovative and potentially effective engagement on climate change came with the consideration of the topic by the Citizens' Assembly in 2017. This exercise in deliberative democracy comprised 99 citizens chaired by a former Supreme Court judge was given the mandate: *How the State can make Ireland a leader in tackling climate change*. Briefed by expert, impartial and factual advice over two weekends, the Assembly overwhelmingly endorsed thirteen recommendations to be laid before government (Table 2). If implemented these would transform Ireland's position on climate change. The Joint Oireachtas Committee established to consider how best to implement these recommendations, however, provided only a selective response, avoiding recommending the major policy actions which alone will permit the transformation from 'laggard' to 'leader'. At the UN Conference of the Parties to the Paris Agreement in Katowice, Poland in December 2018, Irish negotiators declined to join a group of 26 climate leading countries intent on stepping up their climate ambition in response to the latest scientific findings of the IPCC. This was despite growing awareness that even the most progressive countries, such as Sweden and the United Kingdom, have climate policies which are based on unjustifiably large claims on the dwindling global carbon budget.[33] However, while all this might suggest the disjuncture between Irish society and its decision makers was continuing, the bottom-up and top down pressures are combining to force significant changes in the status quo.

The failure of the adherents to the Paris Agreement to agree a rule book for its implementation over the course of six years, and the realisation that many of the pledges made were subject to unrealistic political and/or economic provisos, as well as the more confident identification of a climate change fingerprint in extreme events, has provided the basis for a groundswell of populist grass-roots activism that could not be ignored by decision makers. Within Irish society, groups, such as 'Fridays for Future', 'Extinction Rebellion', 'Stop Climate Chaos' as well as a wide range of environmental NGOs and faith groups have clustered around the principles of climate justice, mobilised on a national scale via recurring demonstrations and marches. A government Climate Action Plan designed to reduce emissions by 3% per annum to 2030 has been superseded in 2020 by a legislative commitment to achieve a 7% per annum reduction over the same period and to achieve the decarbonisation of the Irish economy by 2050. This highly ambitious target still falls short of the figure estimated by researchers to be appropriate for Ireland's fair share of the remaining carbon

[33] K. Anderson, J.F. Broderick and I. Stoddard, 'A factor of two: how the mitigation plans of 'climate progressive' nations fall far short of Paris-compliant pathways', *Climate Policy*, 2020: DOI: 10.1080/14693062.2020.1728209.

Table 2—Recommendations of the Citizens' Assembly

i. 97% of the Members recommended that to ensure climate change is at the centre of policy-making in Ireland, as a matter of urgency a new or existing independent body should be resourced appropriately, operate in an open and transparent manner, and be given a broad range of new functions and powers in legislation to urgently address climate change.
ii. 100% of the Members recommended that the State should take a leadership role in addressing climate change through mitigation measures, including, for example, retrofitting public buildings, having low carbon public vehicles, renewable generation on public buildings and through adaptation measures including, for example, increasing the resilience of public land and infrastructure.
iii. 80% of the Members stated that they would be willing to pay higher taxes on carbon intensive activities, subject to the qualifications identified in the question.
iv. 96% of the Members recommended that the State should undertake a comprehensive assessment of the vulnerability of all critical infrastructure (including energy, transport, built environment, water and communications) with a view to building resilience to ongoing climate change and extreme weather events. The outcome of this assessment should be implemented. Recognising the significant costs that the State would bear in the event of failure of critical infrastructure, spending on infrastructure should be prioritised to take account of this.
v. 99% of the Members recommended that the State should enable, through legislation, the selling back into the grid of electricity from micro-generation by private citizens (for example energy from solar panels or wind turbines on people's homes or land) at a price which is at least equivalent to the wholesale price.
vi. 100% of the Members recommended that the State should act to ensure the greatest possible levels of community ownership in all future renewable energy projects by encouraging communities to develop their own projects and by requiring that developer-led projects make share offers to communities to encourage greater local involvement and ownership.
vii. (a) 97% of the Members recommended that the State should end all subsidies for peat extraction and instead spend that money on peat bog restoration and making proper provision for the protection of the rights of the workers impacted; and (b) 61% recommended that the State should end all subsidies on a phased basis over 5 years.c
viii. 93% of the Members recommended that the number of bus lanes, cycling lanes and park and ride facilities should be greatly increased in the next five years, and much greater priority should be given to these modes over private car use.
ix. 96% of the Members recommended that the State should immediately take many steps to support the transition to electric vehicles.
x. 92% of the Members recommended that the State should prioritise the expansion of public transport spending over new road infrastructure spending at a ratio of no less than 2-to-1 to facilitate the broader availability and uptake of public transport options with attention to rural areas.
xi. 89% of the Members recommended that there should be a tax on greenhouse gas emissions from agriculture. There should be rewards for the farmer for land management that sequesters carbon. Any resulting revenue should be reinvested to support climate friendly agricultural practices.

Table 2—(*Continued*)

xii. 93% of the Members recommended the State should introduce a standard form of mandatory measurement and reporting of food waste at every level of the food distribution and supply chain, with the objective of reducing food waste in the future.
xiii. 99% of the Members recommended that the State should review and revise supports for land use diversification with attention to supports for planting forests and encouraging organic farming.

budget.[34] It is, however, closely aligned with the ambition of the EU Green Deal, which is aimed at transforming climate and environmental challenges into opportunities, and, as such, may have an expectation over the period 2021–2027 of availing of supports and finance of up to €150 billion designed to facilitate a just transition for people, companies and regions hitherto dependent on carbon-intensive employment sectors, which in Ireland include those engaged in peat related activities.

Conclusion

Consistent with its position as an island on the north western periphery of Europe, climate has always been a major preoccupation in Ireland. It has influenced Irish well-being, shaped its landscapes and imbued its culture with a range of rituals and practices. The intimate interaction between climate and Irish society has posed different challenges as both climate and society have changed over time. Historically, climate determined what crops could be grown in Ireland, when harvests could be made, when venturing on to the open sea was possible, and the extreme events that needed to be coped with. The imprint on Irish society was always therefore, and continues to be, pervasive. This imprint was not mediated through the classical ethnocentric mechanisms espoused by determinists who believed climate was the main driver of global societal differences,[35] instead climate has constituted an omnipresent factor that social organisation has had to come to terms with.

Throughout most of its history, Irish society was a prisoner of climate as mediated through the necessity of a harvest surplus. The wisdom and experience acquired coping with the vagaries of climate had furthermore to be passed on to the next generation. From prehistoric almost to contemporary times this hostage relationship applied. With the coming of objective measurements, the realisation

[34] McMullin *et al.*, 'Assessing negative carbon dioxide emissions from the perspective of a national 'fair share' of the remaining global Carbon Budget', *Mitigation and Adaptation Strategies for Global Change* 25, 579–602. https://doi.org/10.1007/s11027-019-09881-6.

[35] E. Churchill Semple, *Influences of geographic environment, on the basis of Ratzel's system of anthropo-geography* (New York, 1911); E. Huntington, *Civilization and climate* (New Haven, 1915).

has dawned that the relationship is now reversed. In a global context, climate is now the prisoner of people. Irish society increasingly recognises that to ensure a sustainable future it must play its part in contributing to mitigating the worst effects of ongoing climate change. No longer is the ninth-century Irish monk's sentiment regarding his fate being determined by uncontrollable atmospheric processes valid:

> Bitter is the wind tonight,
> It tosses the sea's white tresses;
> I do not fear the fierce warriors of Norway,
> Who only travel the quiet seas.[36]

Instead, in the words of a contemporary poet, Seamus Heaney:

> The world where we are to make our tarry ark lies before us.[37]

[36] Translation by Kuno Meyer of verse on Cod. Sang. 904: Prisciani grammatica (St. Gallen, Stiftsbibliothek) accessed at http://www.e-codices.unifr.ch/en/list/one/csg/0904.

[37] Seamus Heaney, 'Commencement ceremony at The University of North Carolina at Chapel Hill, 12 May 1996', Internet Poetry Archive: https://www.ibiblio.org/ipa/poems/heaney/unc-commencement.php (accessed 1 August 2020).