CHANGING SHADES OF GREEN

The environmental and cultural impacts of climate change in Ireland

The Irish American Climate Project
www.irishclimate.org

ABOUT THIS REPORT

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THE IRISH CLIMATE ANALYSIS AND RESEARCH UNITS (ICARUS) is the leading centre for climate change research in Ireland. It was established in 2001 to improve our scientific understanding of climate change and its impacts, with particular emphasis on Ireland. Based at the National University of Ireland, Maynooth, ICARUS works on climate analysis, regional climate modeling and climate change impact assessments. Through research-led activities it has developed significant expertise and capacity in this strategically important area, and ICARUS researchers are recognized nationally and internationally for their significant contribution to climate change research. Since 2001, ICARUS personnel have published over 30 scientific research publications and 4 climate reports for Ireland. Key personnel are also involved with the Intergovernmental Panel on Climate Change and report to the United Nations under the Framework Convention on Climate Change (UNFCCC). For more information, please visit http://icarus.nuim.ie.

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INTRODUCTION

Two perspectives on the Irish climate

This report, as the reader will see, follows two distinct but intertwined paths.

One path, rooted in science, outlines the ecological impacts of climate change in Ireland. We describe climate changes witnessed in the later decades of the 20th century and the most likely scenarios for change in this current century. We do not offer a primer on climate science, nor do we provide great detail on the methodology used to downscale global climate models for modeling the Irish climate. We instead attempt to tell a simple story of how the Irish climate is likely to change, relying exclusively on peer-reviewed scientific literature.

The other path, rooted in culture, describes how these ecological changes may affect the look and feel of the Irish landscape, and how they may affect life in Ireland. These sections do not rely on peer-reviewed literature; they instead rely on an intuitive sense of those things that matter greatly to the Irish. We include discussions of music and poetry because they explain the intense connections between the Irish landscape and Irish culture and how changes to one can affect the other.

The science sections may help the reader *know* these issues; the cultural sections may help the reader *feel* them. For the Irish, a culture that reveres its poets, these two forms of understanding seem equally important, equally valid.

Our intended audience is the 80 million Irish living around the world—only 5 million of whom live on the island of Ireland. The size of the Irish diaspora relative to the size of the resident population, and the involuntary nature of countless departures during more than a century of massive emigration, may explain why many Irish cling fiercely to their cultural roots. Their images of the Irish landscape have real meaning, offering a sense of home to those who may in fact have homes (houses, actually) elsewhere. The gravitational pull of those images was, for a time, essential: How else could a culture survive the tumult of what came to be known as "The Scattering"?

Over the course of this project, we've come to value the two perspectives, resident and exile, and have found real learning in connecting the two around this topic. When an Irish person living in Dublin is told that, with climate change, the Southeast of Ireland will likely have a Mediterranean climate, the initial response often is, "Well that's not such a horrible fate now, is it?" But when an Irish person living in San Francisco hears of the projected change, the response is often an expression of heartbreak.

When the conversation begins in earnest, the Dubliner comes around quickly. Rain and fog are described in lyrical terms; the light of clearing clouds is richly detailed. When the pints are served, the conversation lingers on unique qualities of the landscape and people, and on the connections between the two. It often shifts to the sadness implicit in the subtle changes that may accumulate. It leads to questions of whether the projected climate changes are inevitable, and what we can do to slow or stop global warming.

That is a conversation we hope continues, in Ireland and elsewhere. And so it is that we write.

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EXECUTIVE SUMMARY

Ireland's climate has already changed. Average temperatures increased by 0.72°C (1.3°F) during the last century. This shift is particularly noteworthy for its pace. Since 1980, Ireland's average temperatures have climbed at a much faster rate—0.44°C (0.79°F) per decade—than the global average. The Irish who sense that the weather has changed in their lifetimes are not making outrageous claims: Their casual observations are corroborated by scientific assessments.

An ensemble climate model, based on multimodel averages, projects temperature increases for Ireland that will exceed 2°C (3.6°F) in all seasons by the end of this century. These national averages mask the projections for more significant temperature changes at different regions within Ireland.

The nickname Emerald Isle is a legacy of Ireland's steady rainfall. The island's rainfall regime can be expected to change with global warming. By mid-century, winters could see an increase of more than 12 percent, and summers could see a decrease of more than 12 percent. Seasonal storm intensity changes will increase the impact of these changes. Again, these national averages mask far greater changes projected for various regions within Ireland. The Southeast, for example, may have elements of a Mediterranean climate, with much greater seasonality of rainfall—quite different from what the Irish have come to expect.

The changes noted above will in turn bring significant and highly visible changes to the Irish landscape. Among the examples cited in this report:

- The potato, long an essential staple of Irish agriculture, will be stressed by prolonged summer droughts. It is likely that potatoes will no longer be a commercially viable crop over much of Ireland.
- Perennially green landscapes will see the introduction of new colors, including the brown of dried grasses in summer and autumn.
- Grain from row crops will be necessary to supplement Ireland's livestock industry, which historically has relied on open pastures for silage. This changes more than the industry: It changes the look of Ireland.
- Bog bursts will be more frequent. With only slight increases in summer heat, mountain bogs can be torn from bedrock, leaving scenes that evoke a California mudslide.
- Ireland's famed inland fisheries, which provide some of Europe's best salmon and sea trout fishing opportunities, will be hit very hard by reductions in summer rains and increases in summer and autumn temperatures.

Irish culture is defined, to a great extent, by the country's natural landscape and by its people's connection to that landscape. Irish poetry, literature, music and visual arts celebrate and explore this connection. The massive Irish diaspora tends to hold zealously to images of green hillsides, flowing rivers and soft rains. Some of these images will survive climate change; some will not.

Ireland's climate will change significantly in this century, but the extent of those changes is not yet certain. Their extent will depend, largely, on changes the various nations make in their energy policies, and the speed with which those policy changes are adopted. It will depend, as well, on changes individuals make in their energy consumption, and the speed at which those changes are embraced.

Chapter 1

Climate change is already evident in Ireland

Ireland's climate has already changed.

Over the course of the last century, average temperatures in Ireland increased by 0.72°C (1.3°F). This change mirrors the global trend over the same period, which the Intergovernmental Panel on Climate Change determined to be 0.74°C (1.3°F). The IPCC said it is very likely—meaning, with more than 90 percent certainty—that human activities "caused most of the observed increase in global average temperatures" that has occurred since the mid-20th century.

The Irish shift is particularly noteworthy for its pace. While global temperatures rose an average of 0.13°C (0.23°F) per decade since 1950, Ireland's temperatures initially lagged behind the trend. Since 1980, however, Ireland's temperatures have climbed at the much faster rate of 0.44°C (0.79°F) per decade. Those Irish who sense that the weather has changed in their lifetimes are not making outrageous claims: Their casual observations are corroborated by scientific assessments.

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In Ireland, as is true elsewhere, changes in seasonal, monthly and daily temperatures reveal much more about climate change than annual or decadal averages. (The reason: When significant temperature increases in one season are matched by moderate changes in other seasons, the annual change can look slight, thus masking a temperature change that can have lasting impacts on the natural communities.) Since 1961, Ireland's seasonal mean maximum temperatures have risen the most in winter, resulting in milder winters. Seasonal minimum temperature increases have been the greatest in summer, resulting in warmer summers. Within Ireland, there are also regional variations in these trends.

A warming of the atmosphere has other effects beyond simply a steady rise in temperatures.

The number of frost days in Ireland has decreased, and the frost season is shorter. Frost days are defined as the annual and seasonal count of days when the minimum temperature is less than 0°C (32°F). Frost patterns play an important role in the natural community: Earlier frosts can lead to crop failure, and later frosts can shorten the growing season. Again, we see regional variability, largely in coastal zones, which tend to have less frost. Since the 1950s, Shannon Airport has averaged 32 fewer frost days a year; the frost season now is shorter by

an average of 73 days. Phoenix Park's frost days have decreased by only five days.

Ireland's rainfall has increased, though regional differences are evident. **(FIGURE 1.1)** At Malin Head, in the far North, annual precipitation increased by 37 percent from the 1890s to the 1990s. This shift represents, by any standard, a significant change in the weather. Belmullet and Valentia, both in the West, had increases of close to 19 percent since 1960. At Birr and Armagh, in the Midlands, annual precipitation averages barely changed—but even these averages can give a misleading appearance of stability. In 2002, Armagh had its wettest year since 1872. At Birr, 2002 was the wettest since 1960, but the years before and after were among the driest in decades. The summer of 2007 was the wettest summer in 50 years in eastern Ireland.

Rainfall intensity has changed. More frequent and more intense precipitation events are of particular interest because they can cause economic damage and disruption. One indicator of heavy or extreme precipitation events is the number of days in a year with precipitation greater than a given threshold; in Ireland's case, we use 10 mm (0.39 in.). The instances of single-day rainfalls of 10 mm or more have increased significantly along Ireland's West Coast. This trend is not evident at monitoring stations in the Midlands or along the East Coast.

The change in rainfall intensity is seen with another indicator: the greatest three-, five- and 10-day

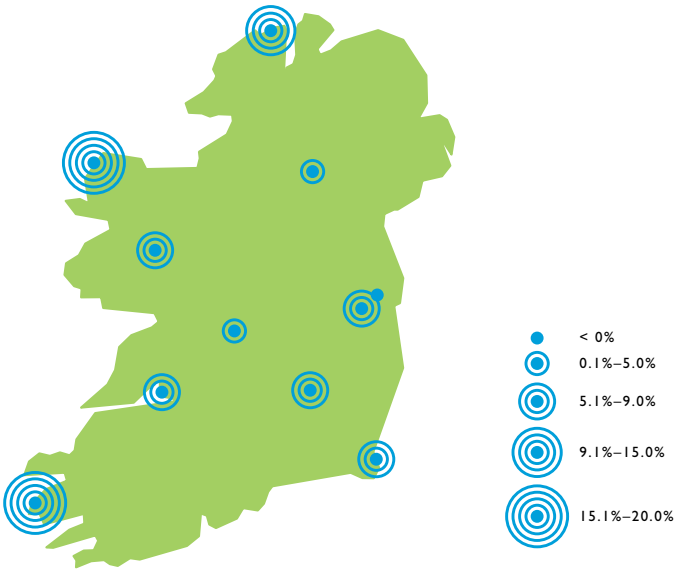


FIGURE 1.1 Percentage change in annual precipitation, 1960–2005 *While national precipitation figures may look as if little has changed, the regional shifts are already significant.*

rainfall totals. These figures are often indicators of potential flooding. Generally, the greatest three-day rainfall totals have decreased during winter at monitoring stations in the Southwest and East Coast, while they have increased that time of year in the Northwest and Midlands. The opposite tends to happen in summer, when decreases have been recorded in the North and Northwest, and increases in the South and East. For the five- and 10-day greatest rainfall totals, the majority occurred in the 1980s and 1990s, indicating a greater intensity of rainfall in recent decades.

The effects noted above are significant and are associated with a global temperature increase of 0.74°C (1.3°F). Looking ahead, unabated climate change could lead to a global temperature rise of 1.8° to 4.0°C (3.2° to 7.2°F) over the course of this century. Such a shift, if allowed to happen, would surely lead to even more dramatic changes to the Irish landscape, as we will see in subsequent sections of this report.

RAIN IN THE MUSIC

A CONVERSATION WITH MARTIN HAYES

MARTIN HAYES, perhaps the best known Irish fiddler in the world, approaches the topic of music and landscape rather slowly. It seems as if the connection is too obvious to explain, or that he shies from discussions that might lead to an artificial or self-conscious session. He says the landscape is so intrinsic to the music that it may not be possible to extract it, or point to its influences.

"Irish music wouldn't produce a feeling dissonant from its home," Hayes said. "It would not rebel against its environment. It would be congruous with the environment. It would be a reflection of being intimately involved on your land for generation after generation. It would be a reflection of a place where every field would be known by name, and every bit of the land would be understood. People wouldn't sit around and talk about the landscape, but it would show up in the music. It would be there."

"We all have some implicit understanding of the feeling that comes from the landscape," Hayes said. "People go to places to feel things, experience things, get a sense of place. Those feelings are difficult to put into words. You can't always say what you really mean. With Irish music, you express some of these feelings. That feeling you get when you look across the landscape of West Clare, or East Clare, or Connemara. That feeling you get when you look at the scene is right there in the music."

As the conversation meanders, Hayes reflects on people and places that have shaped his music. The connections between landscape and music become more direct.

"Sometimes, when I play music, I have memories of summer evenings after all the work was done," Hayes said. "Summer evenings, we had the gentle wetness of the Southwest. If the hay was saved, and a rain had come and gone, there was a warmth and security there. I play music that fits in there. When I play that music, the world comes back to me. The landscape of East Clare comes back. The landscape there has a lot of hidden spots, and gentle rolling hills, and subtle changes. And there is an element of that in the music."

> "People want to know that there are sacred places that we will protect. They want to know that we have a barometer in our being that stops us from doing the irreversible."

The rain, he said, is always a part of the music.

"I make a silly comment when I play on stage—I tend to play seriously but talk silly." Hayes said. "I say, 'I'm here to bring you the music of damp and wet.' And if it's pouring rain, I'll say, 'We're in the climate of the music.' But it really is implicit in the identity. That softness of the rain, it's there."

In a discussion of how climate change, if unchecked, could change the landscape of home in important ways, Hayes doesn't hide his feelings.

"I feel frightened and worried," he said. "I feel despair. It goes into every aspect of my life." And, yet, he also moves directly to an embrace of the landscape and culture. A celebration of what still exists, of what still can be protected.

"When I think of the Irish landscape, and the role it plays for so many people around the world, I think it's a bit like the idea of American wilderness. It's important as an idea. People want to know that there are sacred places that we will protect. They want to know that we have a barometer in our being that stops us from doing the irreversible. That's what Ireland represents for many people. People want this connection to the Celtic, to an identity. They want a connection to this place, as it exists today. They want it to still be Ireland, still be the place that created this culture."

Hayes suggested that an embrace of green policies may have value beyond the spiritual.

"I think Ireland should be all things green, no pun intended," Hayes said. "Given the image of our country, we should embrace sustainable ideas wholeheartedly. It has all kinds of advantages. Ireland should be a haven of organic food, of renewable energies. It's one of the countries that wasn't ravaged by the industrial revolution. Building on that would be an obvious economic advantage for the country to embrace. The greening of the country. It's our brand!"

As the discussion was finishing, this writer mentioned a 1994 interview Hayes did with Fiddler Magazine (raising the topic only as a way to mention a favorite song). Hayes was reminded that in the interview, he followed a description of a musician playing "The Britches" by saying, "The only thing that was amiss around him was a world that didn't understand what was going on." Hayes held onto the recollection, as if celebrating the music, but then shot right to the heart of the climate crisis. "Well, there you are. That's the predicament we now face with climate change. What's really amiss is a world that doesn't understand what's going on. That's the predicament. That's the challenge."

"When I play that music, the world comes back to me. The landscape of East Clare comes back. The landscape there has a lot of hidden spots, and gentle rolling hills, and subtle changes. And there is an element of that in the music."

MARTIN HAYES

Chapter 2

The range of future possibilities

The IPCC's Fourth Assessment Report (2007) stated that warming of the earth's climate system is unequivocal. The report further asserted that most of the warming observed over the 20th century is very likely (greater than 90 percent likelihood) due to the observed increases in anthropogenic greenhouse gas emissions. A discernible human influence now extends to many parts of the climate system, some of which have been outlined in the previous chapter. Present-day atmospheric concentrations of CO_2 are over 380 ppmv (parts per million volume), 35 percent above their pre-industrial levels of 280 ppmv. If we were to include the GWP—the global warming potential of all greenhouse gases converted to the effective warming of 1 tonne (2,200 lbs.) of CO_2 (termed CO_2-equivalent)—current atmospheric concentrations would equate to approximately 425 ppmv CO_2-equivalent. For example, the global warming potential of 1 tonne of methane (CH_4) is 21 times that of 1 tonne of CO_2, when compared over a 100-year period.

The ensemble model represents what one could characterize as a midrange projection—and is far from the worst-case scenario.

The choices we make now and in the future regarding our energy use will largely determine our future emissions of greenhouse gases. Even if all emissions of greenhouse gases were to cease, global surface temperatures would continue to increase for the next few decades primarily due to two factors: the slow response times of the oceans and the length of time these gases reside in the atmosphere (they continue to have a warming effect for decades after their release). However, in the absence of any binding international agreements to impose strict limits on global emissions, it is likely that emissions will continue to increase over the course of the century.

Figure 2.1 shows the projected annual emissions for four emissions scenarios outlined below. These emissions projections are developed from a range of narrative story lines, each of which describes a different future world and characterizes distinct future demographic, socioeconomic and technological development pathways.

A1 These scenarios assume rapid economic growth, a global population that peaks in mid-century and the rapid introduction of new and more efficient technologies. A1FI assumes we continue with a fossil fuel-intensive energy system, A1B assumes a more balanced energy mix and A1T (the "T" is for technology) assumes a predominantly non-fossil fuel mix.

A2 This scenario assumes a continuously increasing global population and economic growth that varies by region and is slower than in other story lines.

B1 This scenario assumes a global population that peaks in mid-century (as with the A1), but with rapid changes in economic structures toward a service and information economy, reductions in material intensity and the introduction of clean and resource-efficient technologies. It assumes that nations emphasize global solutions to economic, social and environmental sustainability, but without additional climate initiatives.

B2 This scenario assumes a continuously increasing global population (as in A2), with intermediate economic growth. It assumes that nations emphasize local solutions to economic, social and environmental sustainability.

(Nakicenovic et al., 2000)

If we translate these projected annual emissions in atmospheric concentrations, the stakes become very clear **(FIGURE 2.2)**. Even the low-emissions scenario (B1) would result in end-of-century CO_2 concentrations of 550 ppmv, nearly double the pre-industrial levels. The high-emissions scenario (A1FI) would result in concentrations of almost 1000 ppmv, more than triple pre-industrial levels, by 2100.

Global Climate Scenarios

To determine how the climate system is likely to respond to the projected changes in greenhouse gas emissions, climatologists employ numerical models similar to those used for weather forecasting. These global climate or circulation models (GCMs) can simulate changes in global temperature due to both natural and human causes. Natural forcings are represented in these models through the inclusion of changes in solar variation and volcanic activity, while anthropogenic forcings are represented by varying levels of greenhouse gases, outlined above, and sulphate aerosols in addition to land use changes.

The climate scenarios or projections output from these GCMs do not represent forecasts but a range of plausible futures based on prescribed changes in emissions and subsequent atmospheric concentrations of greenhouse gases.

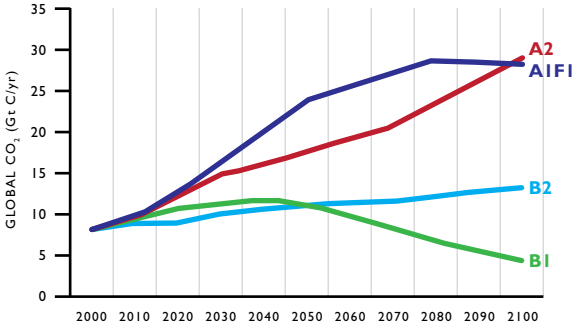


FIGURE 2.1 Projected CO_2 annual emissions for the present century (IPCC, 2001)

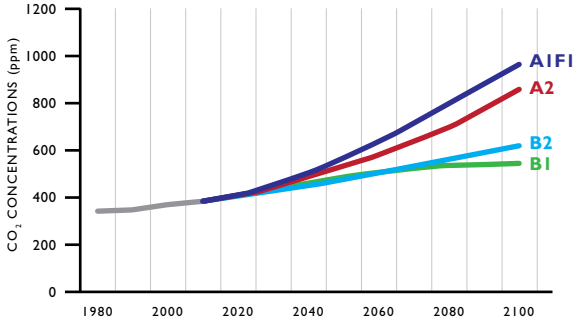


FIGURE 2.2 Projected CO_2 concentrations for the present century (IPCC, 2001)

Based on the emissions scenarios for this century, global surface temperatures are likely to rise by 1.8° to 4.0°C (3.2° to 7.2°F) over the course of the century. If we can limit future emissions, consistent with the low-emissions scenario (B1), the temperature increase is likely to lie closer to 1.8°C (likely range is 1.1° to 2.9°C, or 2.0° to 5.2°F). If, on the other hand, future emissions continue at their present rate, the increase in global temperatures is more likely lie near 4.0°C (likely range is 2.4° to 6.4°C, or 4.3° to 11.5°F). **(FIGURE 2.4)** While these figures reflect increases that are likely to occur in the global average surface temperatures, they mask significant regional variation that is likely to occur. For example, average temperatures at high-latitude land regions around the Arctic have increased at almost

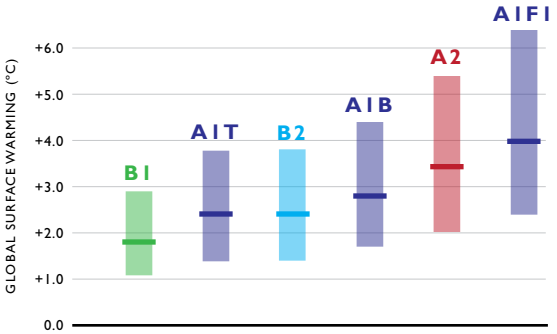


FIGURE 2.3 Projected global mean surface temperature increases for 2100, for six emissions scenarios. *Horizontal lines indicate best estimates for mean surface warming in the year 2100. Vertical bars show the full range projected by the model. The bar heights show the uncertainty, as well as the potential stakes: one range reaches 6.4°C (11.4°F).*

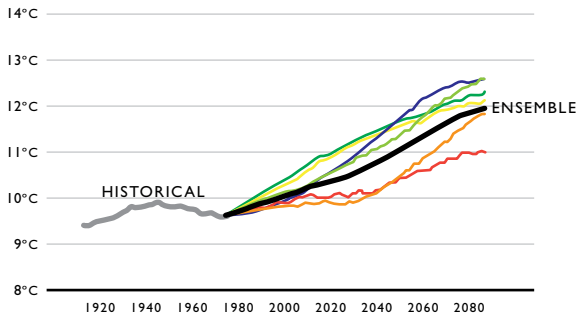


FIGURE 2.4 Past and projected mean surface temperatures in Ireland, for three GCMs, driven with two emissions scenarios. *This shows that the ensemble, used throughout the report, projects warming in the range of 2°C.*

The top graph shows a wide range of possible futures, as the models factor in a variety of choices humans may make with regard to carbon emissions. The bottom graph shows a smaller range because the ensemble model is based on an average of medium-high and medium-low scenarios. If global mean temperatures move toward the higher end of the spectrum shown, mean temperatures for Ireland are likely to be greater as well.

twice the global average, and model projections suggest that this trend is likely to continue over the century. (IPCC, 2007)

Irish Climate Scenarios

To determine likely changes in the Irish climate due to increasing concentrations of greenhouse gases, a number of global climate models were employed to provide the basis for producing "downscaled" (or localized) climate scenarios for Ireland. Of the more than 20 available global climate models used in the Fourth Assessment Report (IPCC, 2007), three were selected for developing the climate scenarios for Ireland. The selected GCMs are state-of-the-art climate models previously employed for similar studies in other regions around the world. To account for different future emissions pathways, two scenarios, the A2 and B2, were selected from each of the global climate models. The A2 emissions scenario represents a "medium-high" concentration level of greenhouse gases by the end of the century, while the B2 scenario represents a "medium-low" concentration level. **(FIGURE 2.2)**

While the individual models and emissions-based scenarios indicate differing rates of warming for Ireland over the course of the century, they are all consistent in projecting the direction of change. Intermodel differences reflect different responses of the model climate to a doubling of CO_2 or "equilibrium climate sensitivity," which is likely to lie in the range 2° to 4.5°C, with a most likely value of about 3°C (4.4°F) (IPCC, 2007). In the absence of knowing what pathway future emissions are likely to follow and to allow for uncertainties associated with the equilibrium climate sensitivity, a multi-model average, the climate ensemble, was constructed from the three GCMs and both the "medium-high" and "medium-low" emissions scenario. **(FIGURE 2.4)**

Based on this ensemble, mean temperatures are projected to increase by 2°C or more in all seasons by 2070–2099, relative to the 1961–1990 period, with

the greatest warming projected to occur during the autumn months. **(TABLE 2.1)** Greater temperature increases are associated with the A2, or "medium-high," emissions scenario reflecting a greater radiative forcing due to the higher atmospheric concentrations of greenhouse gases, while temperature increases associated with the B2, or "medium-low,'" emissions scenario reflect the lower atmospheric concentration levels associated with this scenario.

SEASON	ENSEMBLE	A2 SCENARIO	B2 SCENARIO	RANGE
Winter	2.1	2.4	1.8	0.8–3.9
Spring	2.0	2.2	1.8	1.3–2.5
Summer	2.4	2.9	1.9	1.7–3.3
Autumn	2.7	2.9	2.5	1.7–3.6

TABLE 2.1 Projected changes in seasonal temperatures for Ireland based on three GCMs and two emissions scenarios for the 2070–2099 period, relative to 1961–1990. The range is based on downscaled results from the individual GCMs and emissions scenarios.

Table 2.1 shows the seasonal temperature increases for the end of the present century for the ensemble climate scenario, along with the individual "medium-high" (A2) and "medium-low" (B2) emissions scenario. The ensemble climate represents what one could characterize as a mid-range projection. It assumes that emissions will be higher that those of the "medium-low" B2 scenario and lower than the "medium-high" (A2) scenario. However, there is no scientific basis in making the assumption that future emissions will follow along a particular prescribed pathway. Therefore, the range of projections has also been included in Table 2.1 to identify the spread of possible future temperature changes in Ireland. If emissions continue to increase, the higher values in this column become more probable. If we can act now to reduce emissions globally, the lower values in this column become more likely.

In the following chapters, the ensemble climate scenario is used as the basis to assess regional changes in rainfall amounts that are likely to occur in Ireland over this century. Changes in rainfall may prove to have a greater impact than the projected changes in temperature outlined in this chapter, particularly for commercial activities such as agriculture but also for domestic users who are dependent on a continuous supply of high-quality water.

The scenarios outlined in this chapter and employed in subsequent chapters assume that global temperatures will increase gradually over the course of the century and that therefore we can make some attempt to "predict" the likely changes. However, we need to be conscious of the climate lessons from the past; evidence suggests that climate can change in abrupt, unpredictable ways, with temperature increases of 5° to 10°C (9° to 18°F) occurring over a few decades or less. These abrupt, rapid changes in climate indicate that the climate system may have "tipping points." Once a critical threshold has been reached—much like pressing a switch to turn on a light—a new and very different climate state occurs.

Based on the climate ensemble model, mean temperatures are projected to increase by 2°C or greater in all seasons by 2070–2099.

Such tipping points may be associated with a slowdown in the strength and flow of the thermohaline circulation, of which the Gulf Stream in the North Atlantic Ocean is part, or a collapse of the West Antarctic Ice Sheet. While these are considered catastrophic events with potentially global scale impacts, the consensus within the scientific community is that their probability of occurring is low. However, the likelihood of catastrophic climate change increases as increasing global temperatures rise.

CONNEMARA FISHING

SUBTLE CHANGES WITH PERMANENT IMPACTS

THE CASLA RIVER winds its way southward through a windswept Connemara bog complex. For much of the year, the bright yellow flower tips on gorse clusters offer shocks of color, particularly in momentary cloud breaks. Late summer heather blooms bring a hint of violet. Native grasses change appearance almost hourly—bobbing against the wind, matted down in a heavy rain, or reflecting a colorful sunrise. With trees few and far between, there is little to block the views, or the weather. Oscar Wilde's description of the region holds true today: "Connemara is a savage beauty."

Anglers know the Casla as one of the world's most beautiful spate fisheries. Regular rains cause occasional spates, or flooding episodes, in which river water rises as much as three feet in a matter of hours. *A decent top-up*, to the locals. Fishing is often at its best as water levels slowly recede; salmon time their upstream surges to these flows.

"It's an incredible life story," is how Terry Gallagher, the local fishery manager, describes these migrations. "It captures the imagination. There has always been a real association for the Irish and salmon. We have a real respect for this species."

Gallagher's work includes the restoration of damaged streambeds, maintenance of healthy riparian zones, and monitoring and management of the native fish populations. The fish populations have stabilized, though they experienced a steep decline a generation ago (before which, they helped prove the adage that "the runs were so thick you could look down from a bridge and expect to walk across the backs of the salmon").

Now, returning salmon and sea trout populations are again in decline. While there are many causes, one of growing concern to Gallagher, and others who managed Ireland's rivers, is climate change. As ocean temperatures change, food sources migrate, and invading species increase competition for what remains. These changes in the saltwater environment have led to smaller fish populations (in both number and size of fish) returning to Ireland's rivers.

Extreme weather events, which are expected to intensify under climate change, take a heavy toll on Ireland's rivers. Large volume floods rip up spawning beds, destroying incubating salmon reds and making spawning difficult in future years. Summertime droughts reduce flow into inlets and bays, forcing salmon to wait much longer to make their inland migration, which leaves them vulnerable to predation or exhaustion.

"In 2006, we had a great flood early in May, but then we didn't get any real flooding until one event in July, and then not again until early September," Gallagher said. "The entire system was very dry. It was problematic. Fish were desperately trying to come in on the tides, and a lot of them were sitting and waiting in deeper pools in the lower river. It puts a great deal of stress on them and means they are prone to poaching and predation. It reduces their viability.

"A spate river system is delicate. If salmon are not happy with the conditions, if the flow isn't to their liking, they may lie out in the bay for too long."

Droughts later in the year can dry out spawning beds at an essential point in the life cycle.

In a recent December, flow was so low that Gallagher and his crew built a temporary dam to ensure that spawning beds, already teeming with reds, remained fully immersed. It was the first time such a step had been taken on the Casla.

"For a long time, I was more concerned about the marine environment," Gallagher said. "But now I'm seeing that we really have to focus on the freshwater side of things. It's a double whammy for salmon. They have a tough time at sea, returning home smaller and weakened. And then they have a difficult time in the river, timing their return and finding decent spawning grounds."

> "Temperature, flow, weather shifts, eating habits—these fish have adapted over millennia to these conditions. If the conditions change over a relatively short period of time, it's quite obvious that these fish will face real challenges."

Anglers at the Casla stock up on wet flies—Watson's fancy, Blue Zulu and various Shrimp patterns are preferred—and stock a few terrestrials, including grasshoppers or spiders. When asked for advice, Gallagher focuses more on the size of the fly, referencing work by the famed angling writer Hugh Falkus, who showed that as water cools, an angler can tie on larger flies. The theory holds even with miniscule temperature shifts.

"It captures the imagination. There has always been a real association for the Irish and salmon. We have a real respect for this species."

"There is a real lesson there, when eating habits change based in large part on water temperature," Gallagher said. "The one thing you can't stress enough is just how sensitive these fish are to their environment. Temperature, flow, weather shifts, eating habits—these fish have adapted over millennia to these conditions. If the conditions change over a relatively short period of time, it's quite obvious that these fish will face real challenges."

For generations, it would have been unimaginable to consider the West of Ireland without wild salmon or sea trout. Gallagher admits that the potential loss no longer requires an imaginative stretch, so he continues working aggressively to protect a resource loved by so many. Increasingly, his work pulls him toward the need for climate solutions.

And, on the river, he urges a bit of precaution. Most of the anglers he guides are engaging in catch-and-release fishing, but there are some who want to bring home a catch.

"I ask people who want to kill a fish to keep only one a day," Gallagher said,"— until we know what we're really dealing with right now."

TERRY GALLAGHER

CRY OF THE CURLEW

A POETIC SENSE OF LOSS

IRISH MOUNTAINEER and filmmaker Dermot Somers is as gracious in conversation as he is graceful ascending a granite wall. His countenance is even, with no wasted movements or words. He uses language carefully. Only minutes into the chitchat of a breakfast meeting in Dublin's Bewley's Cafe, he moved directly to the issue.

He referenced the recently published Climatic Atlas of European Breeding Birds, which predicted that the curlew would be a casualty of climate change and would probably become extinct in Ireland.

"Now I grew up beside the River Shannon in County Roscommon in the Irish midlands, and the curlew was absolutely everywhere," Somers said. "It was the character of the evening. As we read books and sang songs growing up, the curlew was a constant presence.

"The cry of the curlew—it's a real symbol of loneliness, and of big landscape. It suggests this almost historic sense of Irish people living in the country, of long, dark evenings. And so that struck me as a particularly emotional and revealing example of how the landscape—the sound of the landscape and the look of the landscape—is going to change with the loss of that bird."

"It's a real symbol of loneliness, and of big landscape. It suggests this almost historic sense of Irish people living in the country, of long dark evenings."

Somers, also a singer, brought up a famous work of 18th century Irish literature, the poem "An Bonnán Buí." The poet himself is an alcoholic who is warned that he will shortly die because of his inability to stop drinking. He writes of the yellow bittern—the bonnán buí—he sees lying dead alongside a frozen bog hole. He draws a connection between his fate and the bird's: One will die of too much drink, while the other dies of thirst.

"The yellow bittern was a characteristic bird of Ireland in previous centuries," Somers said. "It was a big bird, with a big booming sound. To the people, it represented the bogs and the wilderness. The poet drew this connection, between the people and this bird, and it has resonated ever since in the Irish imagination, and has become an outstanding song."

With the yellow bittern now extinct in Ireland (a victim of habitat loss), the song reveals a sense of loss on multiple layers. It became, says Somers, "a symbol of additional dispossession, of national losses."

"Of course," he added in a wry aside, "the Gaelic poet's sense of irony came to his rescue, and he swore to drink every drop he could find so that at least he wouldn't die of drought like the bonnán buí."

"I think now of the curlew, and the moment we may face," Somers said. "You have all this contemporary Irish literature, and it's saturated with the curlew. It's such a lovely literary device. It represents a kind of a creative loneliness, the kind of thing where your mind opens up late in the evening. It triggers that sense of the romance of the evening.

"But we may face this moment when the poems turn, and are about the loss of the curlew," Somers said. "It will be a symbolic feature, another device to help us ponder our loss."

After a pause, Somers added: "If we understand that now, if we can articulate that poetic sense of loss, perhaps the cry will survive. Perhaps."

Chapter 3

Changes in Ireland's temperature & rainfall

Changes in the global climate are unlikely to be uniformly distributed. This will be the case on a global scale; it will also be the case within regions around the globe. Even within a small country such as Ireland, changes in climate are unlikely to be uniformly distributed, either by season or by location. Evidence for this is apparent in the observed changes that occurred in the Irish climate over the last century.

Projected mean seasonal temperature changes for Ireland indicate that relative to the 1961–1990 period, temperatures in the summer and autumn months are likely to increase at a greater rate in 2070–2099 than those of winter and spring . This is in contrast to current trends in the observational records, which show warming to be greatest during winter. Projections in the ensemble mean suggest that temperatures will increase by a minimum of 2°C (3.6°F) across all seasons by the end of this century, compared with the 1961–1990 period.

Regional climate model projections for Ireland suggest that, over the century, this warming rate will likely be in the range of 0.2° to 0.3°C (0.4° to 0.5°F) per decade. As a consequence, an increase of 0.7° to 1.0°C (1.3° to 1.8°F) is likely to occur in all seasons by the 2020s—a significant increase in the immediate term. **(TABLE 3.1)** This increase will be more or less uniform across Ireland. **(FIGURE 3.1)** By the 2050s, mean seasonal temperatures in Ireland are projected to increase by 1.4° to 1.8°C (2.5° to 3.2°F), with the greatest warming in the autumn months. This increase is likely to be associated with greater warming of the interior of the island, resulting in an enhanced "continental effect." Coastal areas, which benefit from sea breezes, are likely to remain slightly cooler than inland areas in summer months. This continental effect becomes more pronounced by the 2080s, when temperature increases of 2.0° to 2.7°C (3.6° to 4.9°F) are projected.

Even within a small country such as Ireland, changes in climate are unlikely to be uniformly distributed, either by season or by location.

SEASON	2020	2050	2080
Winter	0.7	1.4	2.1
Spring	0.8	1.4	2.0
Summer	0.7	1.5	2.4
Autumn	1.0	1.8	2.7

TABLE 3.1 Projected mean ensemble temperature increases (°C) for each season and time period, relative to the 1961–1990 period

Nationally, only small percentage changes in rainfall are projected to occur by the 2020s, with slight increases of 3 percent likely in winter and reductions

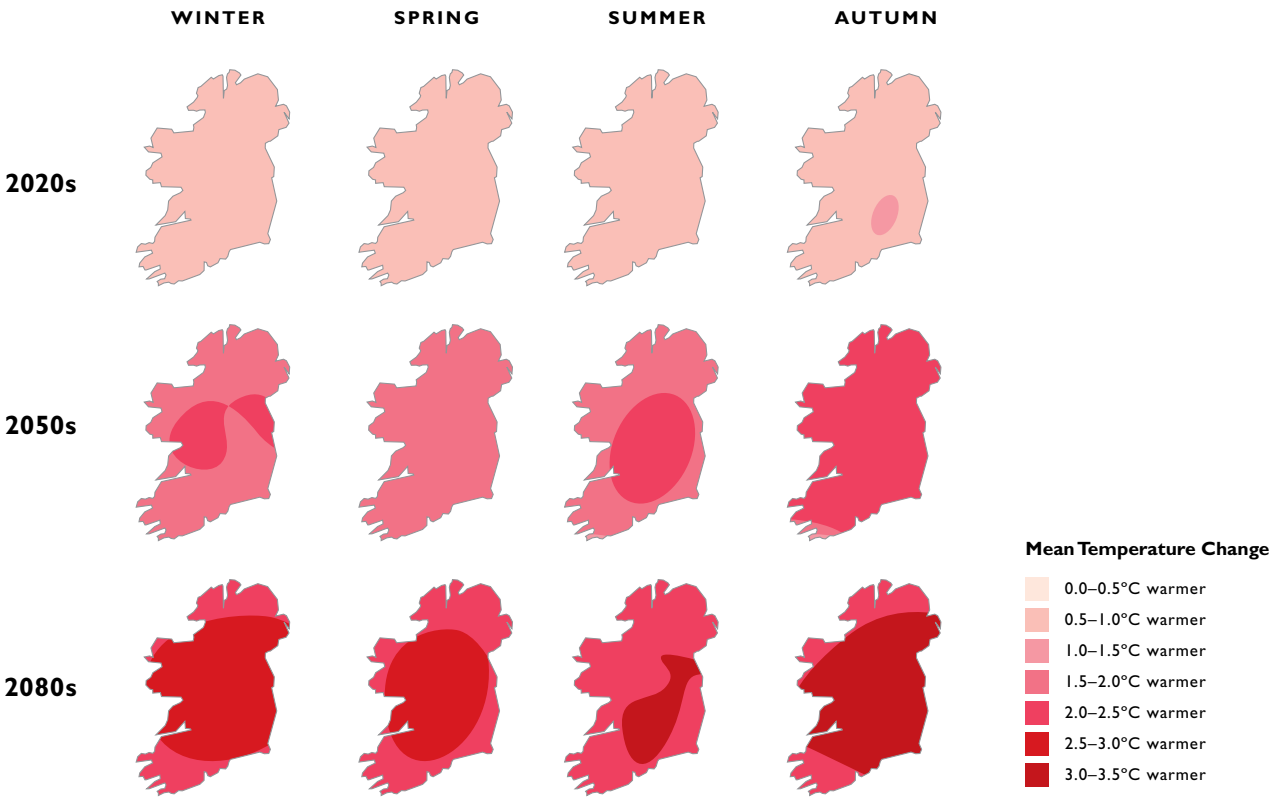


FIGURE 3.1 Ensemble mean seasonal temperature increases projected for 2020s, 2050s and 2080s

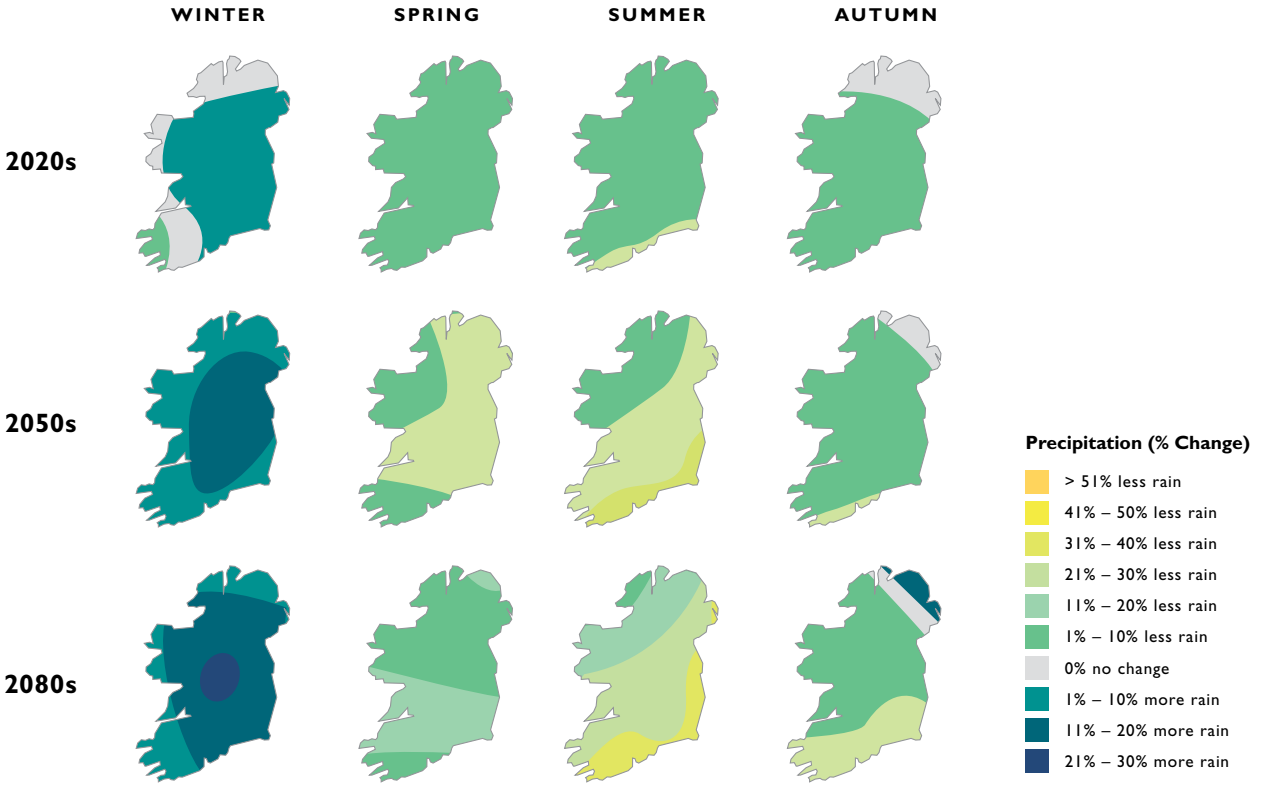


FIGURE 3.2 Ensemble mean seasonal rainfall changes projected for 2020s, 2050s and 2080s

The national figures mask much more significant changes that will be evident on a regional level within Ireland.

of 1 to 3.2 percent in all other seasons. **(TABLE 3.2)** By the 2050s, winter increases are suggested to be in the order of 12 percent, with a similar order of magnitude reduction likely during the summer months. Both the shoulder seasons of spring and autumn are also likely to experience reductions in rainfall.

SEASON	2020	2050	2080
Winter	+3.0	+12.4	+15.6
Spring	-1.0	-7.2	-8.0
Summer	-3.2	-12.1	-19.0
Autumn	-1.7	-2.6	-7.1

TABLE 3.2 Projected ensemble mean percentage change (%) in rainfall for each season and time period, relative to the 1961–1990 period

Those national figures, however, mask much more significant changes that will be evident on a regional level within Ireland. The observed trend toward increased rainfall during the winter in the North and West of the country is likely to continue throughout the century, with greater winter increases likely to be experienced in the Midlands and Northwest. Donegal, for example, already averages one-third more rainfall annually than it did at the beginning of the last century. As a means of comparison, if New York's annual rainfall increased by one-third, it would be equivalent to Miami's. Rainfall changes of this magnitude represent, essentially, different climates.

In Ireland, the greatest decreases in summer, of 20 to 30 percent, are likely for regions along the South and East coasts. **(FIGURE 3.1)** The seasonal contrast in rainfall, between winter and summer, is likely to become further enhanced by the 2080s, with winter increases of 15 percent projected, versus summer reductions of almost 20 percent.

While the climate records display a large degree of variability, largely due to Ireland's location relative to a large body of water, changes occurring in the key climate variables are consistent with those globally. The identified changes in the Irish climate should give cause for concern, particularly if the trends continue over coming decades. While increased temperatures may facilitate new opportunities, particularly in the agricultural sector, the rate of increase may prove too quick for natural systems, such as ecosystems and habitats, to adjust. And the changing character of Irish precipitation—from periods of long duration and low intensity to more intense rainfall—is likely to result in increased incidence of flooding and to give rise to water quality issues.

POETRY AND THE IRISH LANDSCAPE

A CONVERSATION WITH THEO DORGAN

THEO DORGAN has published three volumes of poetry, and his poems have been widely translated; he also has written books, among them a prose account of sailing the Atlantic;. A broadcaster, scriptwriter and editor, he is past director of Poetry Ireland and a member of the Arts Council. His is a leading voice among Ireland's artists, and he has shown no fear when it comes to engaging with challenging political and social topics.

Jumping instantly into a conversation about global warming and the changes it may bring to Ireland, he identified a specific role for Irish poetry. He prefaced it by noting a "context for reading Irish poetry in Ireland, where it's taken as a given that poetry's part of the plenum, and not an objectified element removed from the discourse."

Dorgan started by referencing Seamus Heaney's Anahorish. "When he actually follows in his poems the syllables of place names remembered from his childhood, and replicates them, there is an objective correlative to the name in the sound water makes going over the stones in the streambed; he's also preserving that stream as pristine because it's held in the glass of memory. And because he holds it as pristine, and you can read the poem as pristine, if you walk out and see it clogged with silage effluent, you will be troubled, because the unsullied stream is held in the poem. The poem as an act in memory is therefore a rebuke and a challenge."

"If I write in a poem about Cork, about the view from the top of the hills and the clear air in the morning, and if somebody happens to read the poem," Dorgan continued, "they can see that clear childhood memory of the city—the city of seven hills, clear in the morning sunlight, sun glinting off the gold fish on Shandon, and the light fog rolling through the Lee Valley. But if they're standing there, and they can't hear the person next to them speak because of the roar of morning rush hour traffic, if they can't see Shandon because of the exhaust fumes clouding up St. John's Street going down into Blackpool, they're presented with an antinomy. Here on the one hand is this remembered, imagined world, and here is the brute reality. So there is a dialectic between those two things, and it raises questions.

One of the key functions of poetry, in a culture that values its poetry, is that it does in fact memorialize. And the memorial itself becomes a challenge by virtue of existing as one pole of the possible, often juxtaposed with an actual.

"I'm not saying that poetry has to memorialize. But one of the key functions of poetry, in a culture that values its poetry, is that it does in fact memorialize. And the memorial itself becomes a challenge by virtue of existing as one pole of the possible, often juxtaposed with an actual. In terms of climate change, the scientist examines the actual in the here and now, and this new image is in dialogue with the image as eternal in the poem. You have an index of change.

"If a poet is true and honest, she will write what the poem needs to be," Dorgan said, stepping back from the specific discussion about climate change. "And what the poem always needs to be is clear, lucid, melodic. A good poem has a backward glance and a forward glance. You don't so much read a poem as inhabit a poem, in my view. You become in the poem. A true poet writing about her environment will write things that then become self-evident. So if Moya Cannon writes about the remembered Donegal of her childhood, she doesn't have to put in the electricity pylons that began to emerge over the ridges as she was a young girl—because you go there in the poem. And because scale manages and shapes fact, anybody in Ireland reading a poem set in Donegal, with a vision of landscape in it that doesn't have the electricity pylons, well, the reader will supply them. If they're sensitive, clued-in."

Off on one of countless tangents, Dorgan began describing the "other world" often referenced in Irish literature and felt on the Irish landscape. He talked of sacred places and standing stones.

"I think standing stones are placed in the Irish landscape not as symbols of a religious practice, but as markers of place where you somehow feel the nodal energies that might be present, or where you can have that Maslovian peak experience. And the point of the standing stone is—the standing stone. In this way the ancient Irish culture of the enchanted is very close to the Japanese tradition in poetry, where you're taken in the poem to Cold Mountain so you can be on Cold Mountain, so you can feel and be what you would feel and be on Cold

Mountain. The symbolic register is secondary. The question of self-transportation is key. The point is, when you read Montague on Garvaghy—on the rough field—you're in Garvaghy. It's the Garvaghy of the poem, yes, but there is a connection between the Garvaghy in the poem and Garvaghy in itself."

Dorgan said it is entirely appropriate to use both scientific and poetic voices to attempt to describe the impacts of climate change.

"To me, the inspired scientist and the inspired poet are both doing valuable work," Dorgan said. "The modalities of operation are different, but the operations and consciousness are very analogous. It's to do with *claritas*, like the old Roman virtues of *claritas* and *luciditas*. Look at the things we value: We value clarity, lucidity. Both of these are about illumination."

THEO DORGAN

Chapter 4

Changing landscapes & changing colors

It was during the particularly dry summer of 1995 that the "Emerald Isle" turned brown. The drought was not long by global standards, but it may be a harbinger. As we will see in later sections, unchecked climate change is expected to significantly increase the frequency and duration of drought in Ireland. The 1995 drought has had a profound impact on an island where it rains on average 150 days a year along the East and Southeast coasts and close to 225 days a year in parts of the West. The Irish landscape is intimately fashioned by water in its various states; any interruption to the flow inevitably means a change in appearance. In the case of the occasional seasonal drought, such a change is temporary; within weeks the green mantle is renewed. But if the climate rules are changed, the landscape and its life forms will readjust to a new set of controls, and the visual characteristics we take for granted may be lost for good.

The Irish landscape is intimately fashioned by water in its various states; any interruption to the flow inevitably means a change in appearance.

The Irish landscape is underpinned by a rock skeleton, which is essentially the product of a prolonged period of erosion that relentlessly stripped away younger, softer, sedimentary rocks to reveal more resistant ancient geologies. These are most apparent on the periphery of the island, where they provide the mountainous majesty so beloved by residents and tourists. Rising to just over 1,000 m (3,280 ft.) in the Southwest, these uplands occur as a series of sharply defined units separated from each other by lowland corridors through which the rivers of the Central Plain trench their way across the structural grain to reach the sea. The gently undulating central lowlands, on the other hand, comprise about two-thirds of the island and are generally less than 120 m (400 ft.) above sea level. Superimposed on all of this is a thick covering of glacial deposits and a layer of contemporary soils. On top of all this, the green mantle of flora thrives.

The landscape reflects primarily the suitability of the Irish climate for grass growth. Pasture and grasses account for more than 60 percent of the land cover, a dominance particularly marked in the center. This is partly a reflection of a long growing season, exceeding 330 days, along the South and Southwest coasts. Here, cattle may remain outdoors over winter, though on wetter soils the grasses may get trampled. On the heavy soils of the drumlin belt and the northern Central Plain, there often is no alternative to grassland-based farming, and pasture, silage,

hay, permanent meadow and rough grazing typically account for over 90 percent of agricultural land use.

Climate change will not eliminate the dominance of grass in the Irish landscape in this century. It will, however, begin to threaten productivity of grasses during dry summer months. Summers like 1995 when the grass turns brown are expected to occur more often, especially in the Southeast. Cattle may be missing from the landscape during the height of summer in such areas, requiring shelter and silage supplements. Some irrigation of grass may even be necessary in the drier parts. (Cattle may also not be part of the landscape in late spring as it recovers from increased winter wetness; at these times, the land would be vulnerable to damage by trampling.)

The arable areas are confined mainly to the east, where rainfall is less than 1,000 mm (40 in.). Such areas also correspond with the lighter soils, derived from fluvioglacial parent materials, which warm quickly in spring, are more free-draining and can be worked more easily by machinery. These are particularly prominent along the coast of North Dublin, along the valley of the River Barrow, in the sunnier and drier South and Southeast, and in the rain shadow of some of the western mountains. Some areas of horticulture are scattered through these zones, particularly in the apple-growing areas of eastern Ulster.

The arable landscape will continue to show fields of wheat, barley and increasingly maize as the climate changes. The maize will be grown predominantly for silage, though increasingly for grain production as well. It is likely that the rural landscape will also be characterized by fields devoted to biofuel production—most likely oilseed rape, elephant grass and short rotation forestry.

Peatlands are likely to be highly vulnerable to climate change. This occurs in two distinct patterns. First, on the uplands and wet coastal margins, extensive areas of blanket bog exist. These mantle the slopes to a depth of approximately two meters (6.6 feet), with soil drainage impeded by the iron pan formation below. Second, scattered through the Central Plain are the deeper, and more economically valuable, raised bogs, which occupy infilled lake basins. Both of these waterlogged landscapes will suffer from summer drying. Decomposition will increase and peat formation will decrease, resulting in more scarred hillsides and more acid runoff. These are not ancient deposits, like oil or gas fields; their formation is relatively recent, dating since the last glaciation. These fragile habitats are especially vulnerable to destabilization when a wet autumn follows a dry summer—a typical scenario for future Irish climate. Bog bursts have been a feature of some parts of the uplands of the West in recent decades, and the movement of peat brings economic and social problems as well as landscape changes.

One of Ireland's most unusual landscape features is the turlough. Found only in the limestone areas, these seasonal lakes flood to a depth of a few meters in winter, when the water table rises, only to empty again in the summer months. They provide good summer grazing, partly because of the annual deposit of lime-rich silt. They also provide essential habitat for plants and animals tolerant of moist, alkaline conditions. A fall in the water table during the summer will be harmful for these rare landscapes.

But the landscapes most threatened by immediate climate change in Ireland may be the ones in coastal locations. The dramatic cliffs of the West are not at risk—their ancient crystalline rocks will not succumb to anything the Atlantic can throw at them. Rather, it is the soft coastlines of the East where sea-level rise is already accelerating coastal erosion. The soft boulder clay coasts of south Counties Down, Louth, Dublin, Wicklow and Wexford are where retreat is occurring fastest. In extreme cases, erosion rates are exceeding 3 m (10 ft.) per year. Even in the West and South, however, low-lying bays and estuaries—such as Tralee Bay, Cork Harbour, Clew Bay and especially the Shannon Estuary—are vulnerable increased flooding as sea level rises. The worst-case scenarios of a storm surge occurring in conjunction with a spring tide give a 50–50 chance that 300 km² (116 mi.²) could be flooded at some stage over the coming century.

Summers when the grass turns brown are expected to occur more often, especially in the Southeast.

Salt marshes and sand dunes, a recognizable feature of coastal Ireland, are highly vulnerable to changes in sea level and storminess. These habitats will likely be unable to migrate inland as sea level rises; the time scale for this process may be too short. And even before their inundation, these habitats will suffer major changes in species composition as a result of warmer temperatures. The Saltmarsh Flatsedge is a case in point: The plant species may disappear entirely from Ireland. Sand dunes will also be affected by summer droughts, with species intolerant of drying out being lost. The ecologically valuable machair landscapes (a type of sand-dune pasture) of Northwest Ireland will be especially at risk of extinction.

Ireland's island setting means that the potential for species loss is greater than for continental areas. Climate change will push many species into new areas; some will be unable to keep ahead of the climate changes and may become extinct. Ireland's climate will change faster than evolution can proceed, perhaps 10 times as fast as the warming at the end of the last glacial period. Long-lived species, such as trees, will find adjustment difficult, if not impossible, in some cases.

Among the most threatened residents of the living landscape in Ireland are likely to be the Arctic and Boreal species and the mountain species in the remoter uplands. Other casualties may include such fish as the Arctic char and pollan, plants such as the cowberry and oyster plant, and species of snails and insects that require colder, moist conditions. The salmon, an important ingredient in the culture and economy of western Ireland, is close to its southern limit in Ireland, and the warming of offshore waters will be troublesome. So, too, will be the warming of the river water in which the salmon breed: Warmer water prompts earlier migration back to sea by juvenile fish, which are then unable to avoid predators. Even in the fish farms, other hazards await. Warmer waters mean more frequent toxic algae outbreaks and more frequent jellyfish invasion. Northern Ireland's only salmon farm was destroyed by an attack of billions of jellyfish in late 2007. All 100,000 fish were wiped out in a few days.

Warmer waters will encourage the invasion and establishment of warm-water species such as trigger fish, red mullet, red bream (red snapper), longfin tuna (albacore), eagle fish, sunfish and amberjack; many of these are already appearing in fishermen's nets. Warming may lure exotic insect species, such as butterflies and moths. Some agricultural insect pests and predatory insect species are also likely to thrive better. Some invasive species, such as the giant rhubarb, rhododendron, New Zealand willow-herb are likely to spread further with climate change.

An integral component of the landscape is its bird population. Birds provide a strong indicator of climate change, and already several species not normally recorded in Ireland have arrived. The little egret, a Mediterranean species, is now well-established beyond its initial South Coast landfall. The Mediterranean gull, traditionally a winter visitor, began nesting in Wexford in 1996. Goosander, blackcap and reed warbler have also begun nesting in Ireland in recent decades. The arrival dates of the swallow and house martin advances a day or two for each 1°C rise in March temperatures. These changes, including the introduction of new species, have a significant negative impact on the native species; they often compete for nesting habitat and food supplies. The curlew, lapwing, snipe and redshank, which nest and feed in wet marshy grasslands, face a more uncertain future as these landscapes disappear.

The landscape we take for granted in Ireland faces many pressures from climate change. Some pressures will result in visual changes to vegetation and land use; others may not be readily apparent to the casual observer but will involve irreversible losses of habitat vital to many species of flora and fauna. And the stability of the landscape itself will change due to greater weather extremes.

Much of what makes Ireland unique will survive for future generations—but some of it will not. The extent of change will be determined largely by decisions made today and in coming decades.

Much of what makes Ireland unique will survive for future generations—but some of it will not.

CHANGING SHADES OF GREEN

A FILMMAKER'S PERSPECTIVE

DISCUSSIONS about the look and feel of the Irish countryside tend to focus on shades of green and the softness of the landscape. When the mountaineer and filmmaker Dermot Somers joins in, the discussion changes slightly. He explains why and how the landscape looks and feels as it does. And he explains how shifts in rainfall patterns, brought on by climate change, will affect the landscape, and our sense of it.

"I work in film, and we try to catch the landscape at its best, at its most evocative," Somers said. "Working in the Irish landscape for years, trying to catch the emotional quality of it, trying to find the light at its best, you develop a sort of instinct for what represents the sense of Ireland. You learn how certain colors and textures express not only the landscape at its best but seem somehow charged with a sense of heritage. The idea of tweed comes to mind. You know the way good tweed is made up of all these subtle shades of wool, all very delicately colored? You get hints of moss, and ash trees, and woodland flowers, and leaves in autumn, and barley. There's a softness, and a richness, and a productive flourishing greenness.

"Those are the colors and textures that represent both an ancient culture and a culture that is vibrant and living in the modern landscape today," Somers said. "It's not something that's in a museum. It's something that's represented in every aspect of the landscape. The colors and the textures go with the music, they go with the literature. You only have to think of John McGahern, or Seamus Heaney, or a poet of the western Irish landscape like Moya Cannon. It's that sense of a timeless landscape and a timeless culture embodied in that landscape."

These colors and textures are produced by Ireland's consistent and soft rains. The projected changes in rainfall patterns associated with climate change—much more intense rainfall events in the winter and prolonged dry spells in the summer—can affect these images greatly.

"Everything in the Irish landscape depends on slow absorption, and slow release," Somers said. "That's how color works, and it's how light works. So, for generations, the Irish weather has settled on the landscape. It takes its time. It seeps in to the earth. It lifts slowly. It's a gradual process but it depends on the absorption of moisture and light, and then the landscape gives the light back and it reveals what it contains.

"Everything in the Irish landscape depends on slow absorption, and slow release. That's how color works, and it's how light works. . . . When you get very abrupt drenches, these sudden downpours of heavy rain and severe wind, that process doesn't work anymore."

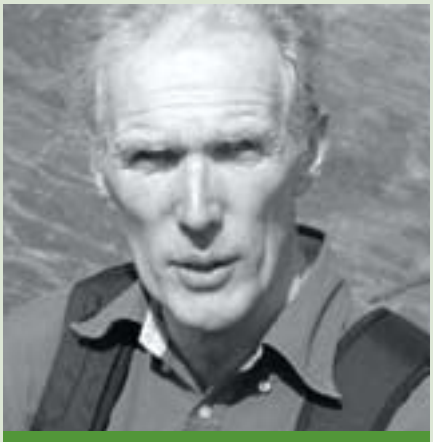
"When you get very abrupt drenches, these sudden downpours of heavy rain and severe wind, that process doesn't work anymore.

"With a deluge, the surface is often damaged, because you get erosion. So many of the things a filmmaker might seek or that a visitor might crave—wildflowers and very subtle colors—are all scraped off by these dramatic weather events. The subtle archaeology that underlies the landscape and that relies on a subtle light to pick it out, that, too, is eroded and very harshly treated.

"But the perception of these things is affected as well. We have been used to a slowness, a kind of seeping absorption, followed by a slow release of light and sensory images. That's what Irish lyric poetry expresses, what *sean-nós* singing evokes. It's the timelessness of events and sensations, and then the slow release of them into emotional perception by people. I would be very worried about the harshness of sudden change affecting that."

The impacts Somers described can already be seen in some places. Overgrazing in the mountains of Donegal and Connemara stripped the uplands of vegetation in places. While those practices were stopped in the 1990s, some hillsides did not have time to recover. When intense rainfalls came, topsoil was washed away.

"I can take you to places where green slopes have become muddy sweeps of gravel," Somers said. "The mountains in Donegal and around the west of Ireland should have a springtime greenness to them, which is characteristic of the Irish uplands—that luminous, saturated green. There are places now, with the increasing rainfall, where erosion is in full spate. A process that was started by poor management practices is made much worse by climate change. That's quite a significant development. It's a sight that should prompt action."



DERMOT SOMERS

TOP *Heavy rains, after a very dry summer, caused a massive bog burst at Pollatomish, County Mayo, in September 2003.*

BOTTOM *Floodwaters, aided by a bog burst, took out the old bridge at Leenane in County Galway. The town center, seen in the background, was a set location for the film "The Field."*

BOG BURST

NEW SCARRING ON THE IRISH LANDSCAPE

THE DIGGING for peat has been a part of the collective Irish memory for as long as the Irish have existed. "The squelch and slap of soggy peat" that Seamus Heaney describes in "Digging" was the subtle background noise of many Irish childhoods. The rhythmic visual image he offers is as iconic as a thatched roof:

Nicking and slicing neatly, heaving sods
Over his, shoulder, going down and down
For the good turf. Digging.

Ireland's relationship to peat has changed, of course. Peat fires no longer provide the bulk of energy for rural Irish homes, though peat still provides roughly 5 percent of Ireland's total energy supply. Most of the peat consumed is harvested mechanically to feed large-scale power stations. The digging continues, but it holds a different place in the culture.

"You'll still see families cutting turf," said Tiernan Henry, of the Earth & Ocean Sciences Department at the National University of Ireland in Galway. "The rights [to the land] have been passed down through generations, and they hand-cut a certain amount every year. You'll see them harvesting in September. It's a family thing as much as anything—a weekend bagging turf."

Another change in the connection to peat is the increased visibility of events referred to as "bog bursts." Masses of peat lose connection to their bedrock anchor and can slide down slope at a runner's pace. The slide gains momentum, forming a slurry strong enough to destroy buildings, roads and wildlife habitats. The resulting images are more likely to evoke a California mudslide than the expected green hills of Ireland.

In 2007, at Leenane in County Galway, a 140-year-old bridge was taken out by floodwaters aided by a bog burst. (The village was the set location for Jim Sheridan's 1990 film "The Field.") At Dún Chaoin in County Kerry, the top layer of a cliff slid to the sea, damaging a key coastal route. A 2003 bog burst at Derrybrien in the Slieve Aughty Mountains filled in large sections of a riverbed, destroying critical aquatic habitat. (That event has been attributed to two factors: weather and poor project management at a local construction site.) One month later, at Pollatomish in County Mayo, a massive bog burst left hillside scars visible for miles.

> What were once rare may become common, and the triggers for these changes are seemingly quite small.

Bog bursts are not new to Ireland; they have occurred historically, linked primarily to weather extremes. What is expected to change, as the weather changes, is their frequency. What were once rare may become common, and the triggers for these changes are seemingly quite small.

"We can see changes in bogs with just slightly drier summers," Henry said, stressing the delicate balance of an upland bog ecosystem. "What would normally happen is that the rainfall lands on the entire surface, it spreads out, and the bog expands." Without Ireland's typical steady rain, "a bog can begin to crack. When any rain does come, it accesses the bedrock almost instantly. The cracks in the bog provide instant conduits to the bedrock."

Because a healthy peat bog is 90 percent water, any changes in rainfall or temperature regimes can also have a significant impact on their development. With some models predicting changes in regional rainfall patterns that may reach 20 percent by 2025, the viability of bogs may be in question. John Feehan, of the School of Biology and Environmental Science at University College Dublin, says peatlands "may disappear within a generation."

In addition to posing threats to lives and property, changes in peat have significant ecological consequences. Ireland's bogs are host to many important species, including hares, peregrine falcons, golden plovers and merlins.

And the decline or loss of peat bogs would add to the list of ironically named "positive feedbacks." Bogs are highly efficient carbon sinks and currently hold the bulk of Ireland's stored carbon. If unabated climate change causes their shrinkage, the Irish landscape would retain less embedded carbon, thus releasing even more carbon into the atmosphere.

DR. TIERNAN HENRY

Chapter 5

Irish farms & straight lines

Farming in Ireland has undergone rapid change in recent decades. Time-honored traditions have been reshaped by a wide range of social and economic pressures. A suite of European Union regulations has changed farm practices and crop selection. Large-scale urbanization has covered once-rural landscapes. Farms are consolidating, with farm numbers declining and farm size increasing. Part-time farming is also becoming more common. These examples set the stage for a new set of changes, this time caused by climate change.

Extreme rainfall events will challenge livestock farmers. With soaked fields, cattle may not be put out to pasture until late Spring.

Changes in temperature, rainfall and extreme weather conditions will necessitate changes on Ireland's farms. New conditions will require new crops and new practices. We refrain from categorizing these changes as "good" or "bad," or to project whether Ireland might be a "winner" or "loser" in relation to other countries where agriculture also is a key component of their society and economy. Rather, we choose a characterization that is clear, but value-neutral: With unchecked climate change, farming in Ireland will change significantly.

Availability of water will be a critical issue. Hotter, drier summers will reduce supplies in summer especially in the South and East, which already experience less summertime rainfall. Enhanced evaporation will exacerbate this during the growing season. Currently, irrigation is not necessary for the majority of Irish farming activities, but as precipitation seasonal patterns are altered, it may well become a priority. Those who are already flood-irrigating potato fields in the East will need to put infrastructure in place to guarantee their supply. Winter rainfall will be to be captured and stored for use in the summer.

Farmers will be competing with industrial and residential water users, especially in the highly populated greater Dublin region. Areas of north Counties Dublin, Meath and Louth—where horticultural markets supplying many of the national supermarkets are located, and where commuter towns are expanding—the demand for water will be at a premium. If market forces are used to determine water availability, farmers may have to pay for water for their crops and livestock.

The recent census of agriculture indicates that the current primary crops in Ireland—potato, barley and sugar beet—have already shown evidence of decline, while wheat has increased since 1991.

Because the potato is highly dependent on an adequate and reliable water supply, it may cease being a commercially viable crop on the island.[12]

It is ironic that a part of the landscape so intertwined with Ireland's cultural and economic history will not figure strongly in its future.

Longer growing seasons, the result of earlier springs and later autumns, will lead farmers to introduce new crop varieties. With warmer temperatures, the range of crops may move northwards; some crops currently grown in southern Europe will be viable in southern and eastern Ireland. Maize is likely to become a dominant crop, while soybeans may also become a marginal specialist crop.[14] The number of commercial vineyards in Ireland is expected to grow in coming years. An increase in carbon dioxide will have direct benefits for some crops due to increased photosynthesis, though reduced rainfall in summer may negate that advantage. The effects of climate change in other parts of Europe may also provide market opportunities.

The demand for alternative energy sources could result in a shift of food crops to such biofuels crops as oilseed rape and elephant grass. Elephant grass will be particularly suited to Ireland's warming climate. This grass can grow as tall as 4 to 5 meters (13 to 16 feet) and could be a distinctive feature in a changing farm landscape.

As a result of changing distribution of precipitation, a clear east-west divide of agricultural land may result. Livestock production may dominate in the West, with a consistent supply of grass and water; arable crop and horticultural production will dominate in the East. Extreme rainfalls in the West will cause livestock farmers to have problems, including soil damage, difficulty of field access for animals and machinery, greater land area susceptible to winter flooding and increased risk of pollution from slurry runoff.[13] Soil erosion will be a particular problem from both water and wind, with the resulting depletion of nutrients adversely affecting animals and crops. Hotter summers will increase the possibility of heat stress for cattle and pigs. Temperature changes will affect milk yield and productivity, fertility and general welfare of animals.[13]

Further threats to agriculture will come from pests and diseases. Greater exposure to diseases from nonnative species and crops is likely to increase, especially from southern Europe, as warmer temperatures extend northward. As was seen in late summer 2007 in England, the wind-borne midge that transmits the bluetongue virus to sheep and cattle can spread rapidly and virulently. (Currently, meteorological conditions are reported daily to relevant Irish agencies to ensure that when conditions exist for this disease to be transmitted, farmers can be warned and preventive measures taken.) Some of Ireland's pests and diseases are suited to its mild wet climate; with greater extremes, some of these may not withstand the hotter, drier climate. However, milder winters may allow other pests to survive and attack crops earlier. Liver fluke, a disease that can kill cattle and sheep, is dependent on warm temperatures and slow-moving water; as river flows decrease in summer, it may find more favorable conditions. For cereal crops, diseases such as brown rust could become more prevalent as summer temperatures rise and humid conditions prevail.[12] There is a particular risk when mild winters are followed by warm summers, as is expected with a changing climate.

> The presence of more row crops is likely. The geometric shapes are a real contrast with the rolling hillsides and open fields. The straight lines are foreign when seen next to a weathered hedgerow or a jagged stone fence.

Irish farmers will be challenged by extremes of climate. Harsh frost, strong winds, droughts and intense rainfall can all cause major setbacks to crop

Changes in climate and economics may lead to a reliance on large-scale industrial farming, and the loss of stone fences and hedgerows.

growth and animal welfare. They can result in reduced production and increased costs—sometimes simultaneously. New investments will be necessary for irrigation, new crops or equipment to reduce the severity of climate change impacts. Increased climatic variability will also lead to increased risk on competitive global and European markets.

The ability of farmers to cope with the uncertainty of more extreme weather may further exacerbate the movement away from farming by smaller, traditional farmers. (Many part-time and semiretired farmers already hold disadvantaged land, and thus will find it harder to maintain the land in its traditional function.) This shift, in turn, can affect local economies. Out-migration from rural areas will lead to loss of goods and services, such as traditional post offices and small rural pubs.

Hedgerows, long a visual touchstone of rural Ireland, have historically served as field boundaries. They are also an important home for many species of wildlife. As climate change adds to the stress of farming, one can easily envision the disappearance of nearly innumerable hedgerows. As individual farms become industrial farms, the resulting practices tend not to favor the symbols of traditional agriculture.

The hedgerows serve as a means of introducing another way of describing the changes one can expect in Irish farming. As the presence of row crops expands, the look of the Irish landscape will be affected. The lines and colors of row crops have not occupied large areas of Ireland since the British flax plantations of the 19th century. The geometric shapes are a real contrast with the rolling hillsides and open fields. The straight lines are foreign when seen next to a weathered hedgerow or a jagged stone fence. The bright yellow of the oilseed rape is harsh replacement for the softness of the green Irish countryside.

The impact of climate change on Irish farming may not be catastrophic: Ireland will continue to produce crops. But change will come. Its impact will be both economic and cultural.

MEMORY AWAKENED

AGAIN THE POTATO IS THREATENED

ONE CAN LAUGH about many things in Ireland, but there was a time, not long ago, when two subjects were sacrosanct—marriage and the potato. The nickname "Spud" may have been bestowed on many emigrant Irish, but a strong folk memory of the devastating consequences of crop disease in the mid-19th century ensured that for many at home it was far too serious to joke about.

The fungus *Phytopthora infestans*, which caused a series of potato blights on the island from 1845 to 1847 and was Europe's last great famine, led to the death of 1 million people and the forced emigration of 2 million.

The impact of the great famine still lingers on the psyche, and on a landscape still marked by "lazy beds" in which potatoes were once sown. It is what Patrick Kavanagh described in his poem, "Lough Derg":

The middle of the island looked like the memory
Of some village evicted by the Famine

It is what Eavan Boland, in the poem "The Making of an Irish Goddess," analogized as a woman's body bearing scars of "that agony" of

the failed harvests,
the fields rotting to the horizon,

the children devoured by their mothers
whose souls, they would have said,
went straight to hell,
followed by their own.

The potato is still a staple in the Irish diet, even with a far more mobile and affluent population. Annual consumption is valued at $240 million, with about one-quarter of those potatoes imported as required by a mix of European Union agricultural policies,

Grace Maher, who grew up near Carlow, and San Francisco native Brandon McClane operate Oracle Farm, seven miles outside Carlow. They sell their produce, which includes a variety of potatoes, at Saturday's market in Carlow town.

"Traditionally, Irish people are particular about what type of potato they buy—be it Roosters or Arran Banners," said Maher. "But because we discourage spraying under the organic certification system, we have to focus on blight-resistant varieties, several of which have been bred here—such as Orla [developed in County Carlow], Cara, and Nicola [a Swiss-Irish variety]."

Climate change is expected to make grower's work more difficult because it is likely to increase the risk of blight, which is caused when high temperature and very high relative humidity coincide. It will also have a detrimental effect on the economics of potato farming: As temperatures rise and drought conditions become more common, potato growers in the south and east of the island will likely require irrigation water. If the worst effects of climate change are realized, potato farming may no longer be commercially viable in Ireland at the end of this century.

Grace Maher explained that potatoes sown in the spring—traditionally before St. Patrick's Day—need summer rain. "However," she said, "last summer, a dry spell from March to early May was followed by incessant rain, which flooded fields. Higher temperatures were conducive to blight. The problem is that the milder winters we have been getting in the past few years, with fewer of those hardy days of frost, don't kill those bugs. I've heard of greenflies found in polytunnels in December."

Pat Finnegan, of the environmental advocacy group Grian, has noticed changes over a 25-year period. "There were very small signs in the early 1980s of slightly milder weather extending the growing season, and that's since been proven," he said. "This climate shift has all sorts of implications. Those with their hands in the soil know that climate change is not just a headline anymore."

> "Those with their hands in the soil know that climate change is not just a headline anymore."

BRANDON MCCLANE & GRACE MAHER

Chapter 6

Changes in when & where the rain falls

Water has always been an intrinsic part of the Irish psyche. As the interface between the heavens above and the underworld, water was venerated in Celtic Ireland. Its emanation from below carried the sacred messages and memories from another world, as well as nourishment for life itself. Christianity endowed water sources and courses with healing, wisdom and spiritual qualities. As recently as 60 years ago, there were 3,000 holy wells in Ireland; some still have pilgrimages to them in the present-day.

Ireland and an abundance of water are synonymous images. With more than 3 m (10 ft.) of annual rainfall in some parts of the West and low rates of evaporation in a cloudy, maritime climate, the challenge has always been in moving water to the sea as quickly as possible. A mountainous perimeter and a flat interior have left a legacy of short coastal streams on the peat-covered hills of the West, and a maze of bogs and lakes along the long flood-prone inland rivers such as the Shannon, Barrow, Nore and Suir. This hydrological endowment will be affected in important ways by climate change. The simplest way to describe the effect may be with two mirroring statements: There may be too much water in some places and at some times, and too little of it in other places and at other times.

There may be too much water in some places and at some times, and too little of it in other places and at other times.

Though Irish citizens have access to five times as much fresh water as the average European, the presence of water is skewed towards areas of sparse population. In the Northwest, over 76,000 L (20,000 gal.) per person per day is available; in the more densely populated East, only 10 percent of this quota exists. Clearly, water resources are a much more pressing issue for the cities and towns of the East and South coasts; the expected supply disruptions that result from climate change will be felt there first.

As noted, increases in Ireland's winter rainfall have already been substantial, particularly in the Northwest. In North Donegal, for example, winter rainfall has increased by over two-thirds in the last hundred years.

Increases in winter rainfall are expected throughout the island, and one of the greatest concerns in Ireland relates to the likelihood of increased flooding. Models suggest that large flood events will become more frequent and damaging, particularly in the north and west of the country. Heavier rainfall events will also increase the risk of landslides and soil erosion. For some rivers, floods that once occurred every 50 years could happen every three years by the end of the century.[16] The increased frequency of flooding will be accompanied by an

increased size of floods. In addition to the increased frequency of flooding, new areas will be vulnerable to flooding, and existing flood-prone areas will be affected more often. The integrity of flood defenses, the need for more precautionary planning and development control, the insistence that new developments incorporate sustainable drainage systems—these are all issues that researchers and policymakers are grappling with.

Decreases in summer rainfall, coupled with a rise in rates of evaporation, will mean that periods of low flow become much more persistent in Irish rivers, especially during the summer and autumn months.[15] This will be particularly true in the East. In the Boyne catchment, stream flow in late summer is projected to be reduced by 20 percent as soon as the 2020s and by up to 40 percent by the end of the century. **(FIGURE 6.1)** This is likely to be typical of other rivers in the area, and, if realized, would have substantial implications for the entire water environment. When reduced flow is accompanied by increased demand, less stream flow is available for diluting effluent, which exacerbates problems of pollution, threatening ecosystems and human health. Higher temperatures also increase the risk of water-borne disease. Soil moisture deficits will begin earlier and extend later in the year than currently experienced, affecting key soil processes such as respiration. That, in turn, would affect key ecosystem functions, including carbon storage. Soil moisture deficits are also likely to justify investment in irrigation technology by farmers seeking to sustain crop productivity in the drier parts of the Southeast—not something Irish farmers have historically seriously contemplated.

It is also clear that the impacts of climate change will vary greatly according to the type of catchment concerned. The lower the capacity of soils to hold moisture, the greater the sensitivity to climate change they exhibit. In catchments dominated by heavy clay soils, such as the Boyne, increased summer dryness is reflected much more quickly in the

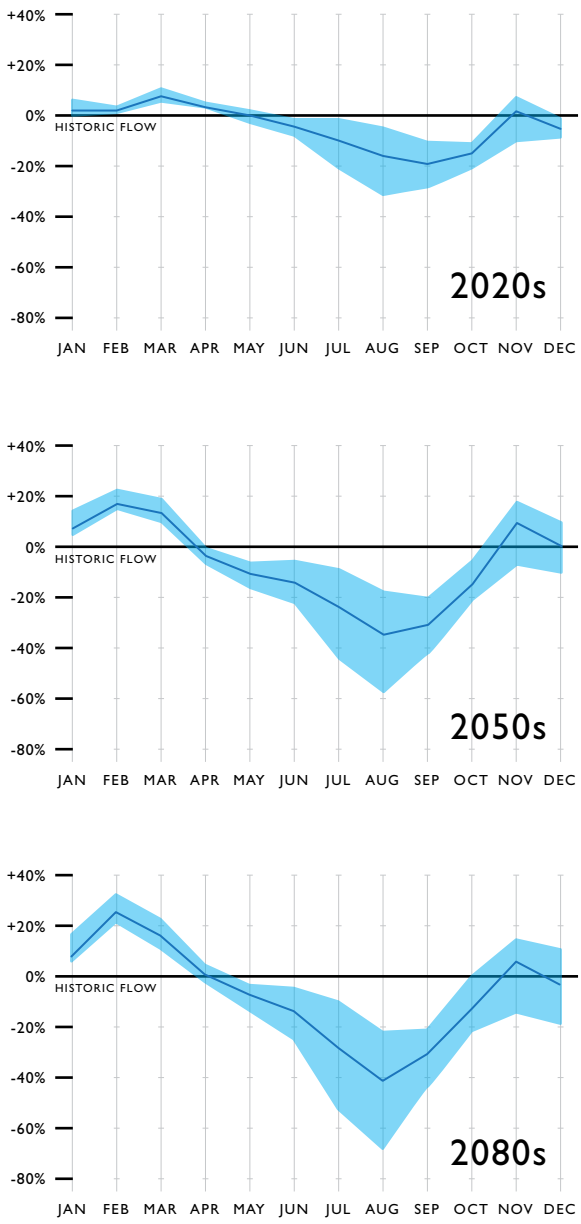


FIGURE 6.1 Projected percent changes in monthly flow of the river Boyne 2020s, 2050s and 2080s[17] *Solid line shows best projection; shaded area shows range of projections*

season by substantial reductions in stream flow. In catchments with highly permeable soils, such as the Suir, Barrow and Blackwater, summer flows hold up better, though once the groundwater is depleted in autumn, a substantial reduction follows. In such rivers, by the middle to latter part of the century, any reduced winter or spring precipitation during the recharge period could lead to significant declines in groundwater storage.

REDUCED FLOW

CLIMATE CHANGE AND WATER SUPPLIES

THE RIVER PERSONIFIED was Anna Livia Plurabelle; her city took the form of Humphrey Chimpden Earwicker. In "Finnegans Wake," James Joyce used their union to tell a universal story of rivers and cities. The River Liffey, with its "waters of babalong," was the beginning and end. It gave the city its life.

It still gives life—the Liffey today provides 80 percent of Dublin's drinking water—but the river's ability to sustain Dublin is in doubt. With global warming leading to changes in Ireland's rainfall patterns, ensemble models show that Liffey flows could be 20 percent lower by 2020 than they are now and 50 percent lower by mid-century. Those reductions could be paired with an increase in demand: The Dublin City Council forecasts a 60 percent growth in Dublin's water needs by 2031. (The spike would come from the 1 million additional people expected to live in the region.)

An already water-stressed Dublin now faces a crisis, and Ireland is witnessing the first signs of California-style water wars.

To meet future demand, the council is considering building desalination plants—an expensive option. Less costly, but proving to be far more controversial, is a proposed alternative: extracting Shannon River water from Lough Ree.

A wide range of groups actively oppose doing that. The Shannon Regional Fisheries Board and Inland Waterways Association have raised both environmental and economic concerns, while a group set up to resist the plan, the Shannon Protection Alliance, notes that "the last great battle of Lough Ree" was fought in A.D. 903 and warns that "those Dublin officials should know that this will be fought just as hard." As its spokesman, PJ Walsh says, "We won't let them put as much as a straw into the river."

Dublin's water woes have many causes, and the solutions will be varied. Repairing or replacing the city's Victorian-era pipes would cut down on the large losses through leakage. And serious conservation efforts—unheard of in water-rich Ireland—would be a sure way to find "new" sources of water.

Still, the current battle is evidence of the societal strains that may come with global warming. The frailties of human practices and systems can be exposed and made worse by climate change. And tensions are sure to rise when a natural resource grows scarce—particularly one assumed to be as constant as Dublin's fresh water supply.

As Dublin looks to the Shannon for new sources of water, protest signs appear at Athlone.

An already water-stressed Dublin now faces a water crisis, and Ireland is witnessing the first signs of California-style water wars.

Chapter 7

Harsh extremes on a soft landscape

Ireland functions as a weather sentry post for much of northwestern Europe, providing an early warning of hazardous weather systems that may subsequently arrive in more populated areas further east. It is also in the vicinity of Ireland that any significant changes in oceanic circulation associated with climate change will be first detected.

This position astride the North Atlantic Drift means Ireland's climate will be characterized by an equability borne of the mass of ocean water, which tempers the sun's warming and cooling effects. Irish temperatures are essentially products of these oceanic controls; both the annual and year-to-year differences in mean temperature follow the offshore temperatures slavishly. Extremes of temperature are rare. Daily maximum temperatures over 30°C (86°F) are a-once-in-a-century event at coastal locations in the Southwest, and the highest extreme temperature in Ireland, recorded at Kilkenny Castle in 1887, was only 33.3°C (91.9°F). Throughout the 20th century, the highest value recorded was a relatively modest 32.5°C (90.5°F). Similarly, the lowest temperature ever recorded, of –19.1°C (–2.4°F) at Markree Castle in 1881, is relatively unremarkable. Extremes of this magnitude are much more frequent in Britain or the near continent. Such unexceptional extremes suggest that climate change in Ireland will not manifest itself in life-threatening extremes of hot or cold.

There is a discernible increase in heavy rainfall events emerging on the west coast, where many of the stations are now recording such events more frequently.

The oceanic location provides the potential for greater extremes in wind and rainfall. In 1960, just under 4 m (13 ft.) of rain fell in the mountains of Kerry while just over 350 cm (140 in.) was recorded at Glasnevin in the entire year of 1887. Similarly, daily extreme values of 243.5 mm (9.6 in.), at Cloore Lake in Kerry in 1993, and a monthly total of 790 mm (31 in.), in Kerry in 1996, are further indications of the volume contained in Atlantic storms. In addition to storm intensity, storm frequency takes its toll: The Atlantic generates an average of 170 weather fronts that pass over Ireland each year. The West is particularly susceptible, and where gaps in the uplands exist, maritime air masses can penetrate more easily, bringing mild (though depressingly wet) winters.

The most feared extreme in Ireland is wind, and notable severe storms are etched into the public consciousness. The most notorious of these was the "Night of the Big Wind" on Jan. 6-7, 1839, which produced gusts in excess of 100 knots, damaged 20 to 25 percent of the housing stock in Dublin and produced events such as salt deposition well inland

A 2002 flood caused significant damage in the East of Ireland. With sea level rise, these floods would be more common.

and a range of other events reported in the early newspapers of the time:

> *The damage which it has done is almost beyond calculation. Several hundred of thousands of trees must have been leveled to the ground. More than half a century must elapse before Ireland, in this regard, presents the appearance she did last summer.*
>
> —Dublin Evening Post, Jan. 12,1839

> *What appeared to be the most astonishing effect of the storm was the blowing of water out of the canal near this town. I visited it this morning and it was nearly dry.*
>
> —Tuam Herald, Jan. 19, 1839

> *Trees, ten or twelve miles from the sea, were covered in salt brine—and in the very centre of the island, forty or fifty miles inland, such vegetable matter as it occurred to individuals to test had universally a saline taste.*
>
> —Dublin Evening Post, Jan. 12, 1839

The so-called "cyclonic bomb," when an explosive deepening of an Atlantic depression occurs west of Ireland, is the chief source of extremes of wind. The exposed coast of western Ireland bears the brunt of such storms. Wave heights are a product of the uninterrupted distances over which a wind blown wave travels, and waves reaching Ireland's western coast may have initially developed several thousand miles further west, growing and growing on their journey to formidable heights. Waves exceeding 10 m (33 ft.) are not exceptional offshore, and on occasion they can reach even greater heights. In December 2007, a particularly vigorous depression moved across the Atlantic, generating huge seas along the West Coast, with wave heights over 14 m (46 ft.). The scalloped landscape of the West Coast becomes easier to understand, as does the respect its inhabitants have for the sea.

Whether climate change will exacerbate or lessen the intensity of these hazards is not yet established. Greater warmth in the Atlantic may mean greater release of energy in the form of storm activity, though evidence of this happening is not yet apparent. Irrespective of any enhancements induced by climate change, the irresistible force of the Atlantic storm will continue to pound the immovable object of the coast and mold the landscape as it has for millennia.

Some signs of changes in climatic extremes are already emerging in Ireland. As might be expected, these are subdued in the area of temperature. In line with the overall warming trend, mean maximum and mean minimum temperatures have increased significantly, by over 1°C (1.8°F) during the past four decades, especially in winter. A striking reduction in frost days has occurred as a result with most places having approximately half the days of frost today that they had in the middle of the 20th century. No significant increase in heat waves has occurred.

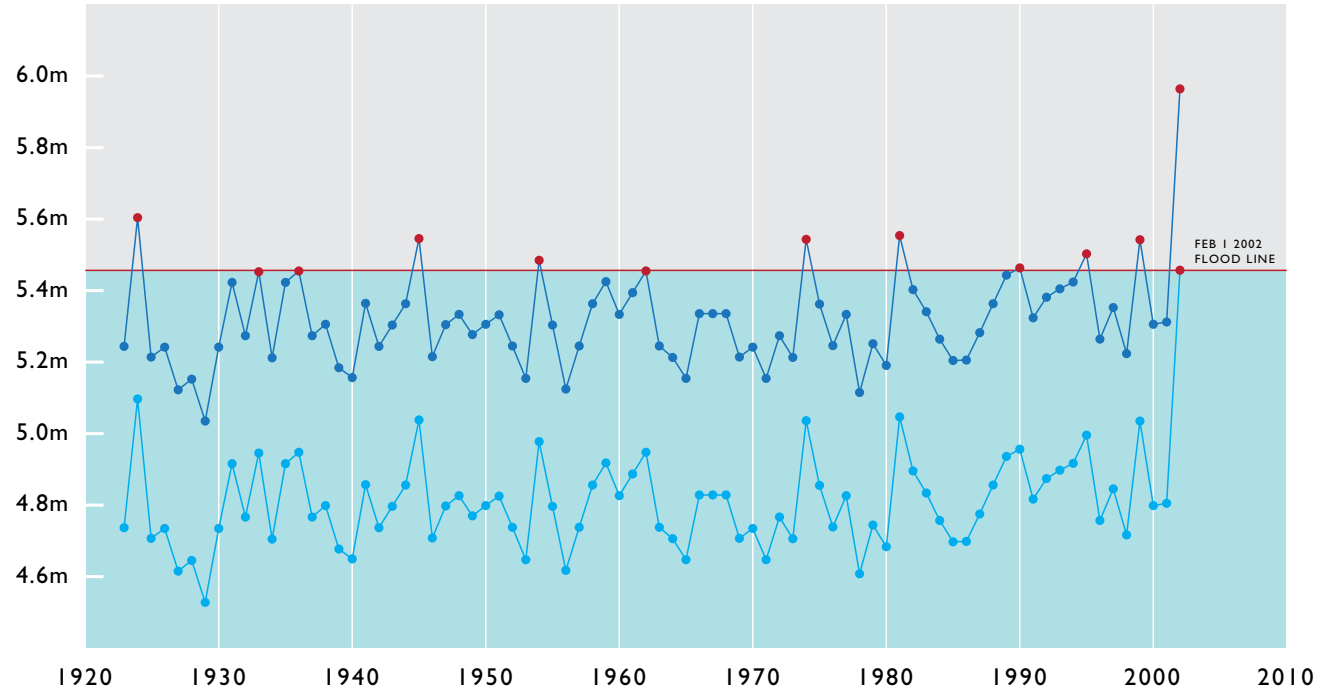


FIGURE 7.1 High water marks in Dublin Bay. *The light blue line shows historic high water levels. The line across the middle shows high water during Dublin's great flood of 2002; it graphically identifies a crisis point. The dark blue line shows what high water levels would have been with a 0.5-meter rise in sea level. The graph shows that a 100-year flood may become a once-a-decade flood.*

With rainfall, there is a discernible increase in heavy rainfall events emerging on the West Coast, where many of the stations are now recording such events more frequently. This appears because of both longer duration and higher intensity and would be in line with what is projected by current global climate models as the nearby Atlantic warms and the warmer land surface triggers greater uplift.

Extreme climatic events, such as the prolonged heat wave in Central Europe during the summer of 2003, or the severe flooding in Eastern Europe during the summer of 2002, tend to have a more visible impact on human society than changes in the mean climate state. While Ireland's maritime location has largely buffered it from such extremes, projected changes in the frequency and magnitude of extreme events are increasingly likely to have an affect on human activities in Ireland over the course of the century.

Modeling Irish climate for the remainder of the present century suggests that an increase in a number of key extremes will occur. For temperature, continued reductions in frost incidence is likely, while heat wave durations are projected to increase by up to three to four days per decade. Most places are also likely to experience an increase in days with exceptionally heavy rainfall. The maximum number of consecutive dry days is projected to increase, an indication of a trend toward summer drought.

Extremes can be crucial for particular sectors of society. For example, changes in rainfall extremes are likely to be highly significant for flood protection measures; Irish scientists are already recalculating return periods for flood events, with a view to providing better defenses. Higher extreme water levels at the coast—as a result of sea level rise and potential increases in storm intensity—are necessitating reviews of sea defenses for cities (including Dublin) and changes in building regulations in vulnerable areas. More summer droughts and milder winters may encourage pest and disease outbreaks—not normally experienced in Ireland's equable climate. Crop varieties and forest tree provenances may also require attention in light of changing extremes. Of particular note is the problem of dry summers followed by heavy autumn and winter rainfall: That is an unfavorable combination for land stability, especially in peatland areas, where the incidence of bog bursts, mudflows and landslides can be expected to increase accordingly.

Anticipating changes in extremes is not an easy task. Conventionally, we handle changes in risk by quantifying the probability of a particular event occurring, often by shifting the distribution of events. That is not always as straightforward as it seems, however, and the distribution shape may also change with climate change producing simultaneous changes at both ends of the distribution. Changes in extremes may be enhanced greatly by climate change. But changes in extremes, more so than changes in mean conditions, may well be the drivers of adaptation policies for Ireland and most countries. Society tends not to respond to gradual shifts in their risk environment. This has been the lesson of environmental hazards of all kinds, ranging from air pollution to drought. Individual extreme events can catalyze perceptions, mobilize political responses and produce legislative changes very quickly.

Modeling Irish climate for the remainder of the present century suggests an increase in a number of key extremes will occur.

TOP *A 100-year storm in the North Atlantic packs venom. Powerful waves tossed boulders onto the tops of these Aran Island cliffs.*
BOTTOM *The human comparison gives a sense of scale. These cliff-top boulders are quite large.*

A WESTERLY APPROACHES

NORTH ATLANTIC CHANGES WILL AFFECT IRELAND

IF THE TOURIST MAP of Ireland is shaded green, the real map of Ireland would tend toward a deep blue. The Republic's sovereign rights extend over a seabed fully 10 times the size of its landmass. The 220 million acres host some of the richest fishing grounds in Europe as well as hints of untapped mineral resources and the potential for renewable energy generated by a highly energetic wave climate.

Ireland cannot be considered *apart* from the North Atlantic; quite often, the island instead seems *a part* of it. Today, 63 percent of the population lives within 10 miles of the 8,960-kilometer (5,570-mile) coastline. For those living on the small islands dotting the west coast, the sea didn't separate; it connected. Liam O'Flaherty, describing life on the Aran Islands, wrote of the sea:

> *Its teeming womb was our store room. When sick, we smelt its breath and chewed the grasses of its stranded bottoms, and were reconditioned in our health. When sad, we sat and listened to its moaning and lost our sorrow. It was our common mother as well as the father of our strength and knowledge.*

Atlantic sounds and rhythms have inspired much music, such as the fairy lament, "Port Na bPúcaí," said to have derived from the song of the humpback whale. But the timelessness implied in tunes and poems can be misleading. The North Atlantic is changing.

Ireland's exposure to a relentless Atlantic fetch would make it vulnerable to an increase in the intensity of extreme weather events. North Atlantic storms can be awesome; the horse-sized boulders on 50-meter (160-foot) Aran cliffs (tossed up by massive waves) are evidence. During and after these storms, rural and island communities can experience intense periods of isolation. In come cases, the economic burden of being shut off can be significant.

Slight increases in sea level would intensify storm surges, increasing the risk of temporary inundation. Even without storm surges, key economic and cultural resources would be hit hard by a slow rise in the sea level. The Giant's Causeway is 40,000 interlocking hexagonal basalt columns that legend holds was built by Fionn mac Cumhaill (Finn MacCool). The U.K.'s National Trust reports that coastal erosion and flooding caused by climate change would make access to the site more difficult for the half-million tourists who visit annually.

Ken Whelan, of Ireland's Marine Institute, has been tracking the presence of exotic species in Irish waters. Many—including the triggerfish (a Caribbean native), the golden grey mullet and the gilthead bream—are now permanent residents. These new species have replaced historic stocks of cod and haddock.

Whelan is particularly concerned about the falling survival rate of wild Atlantic salmon. "The southern stocks of salmon returning to our shores are the ones that appear to showing problems," he said. "These are the aquatic canaries in the mine. There's something happening out there that is affecting the survival of first winter fish, long before interception."

Shifting temperatures are one cause of the changing seascape. Whelan notes that marine data buoys off the Irish coast recorded sea temperatures of up to 12°C (54°F) in January; typical temperatures for the month have been 5°–8°C (41°–46°F).

Given the tendency towards algal blooms or red tides in warmer conditions, Whelan believes the island's thriving aquaculture industry may be most immediately affected by warmer sea temperatures. Last summer, an extraordinary jellyfish attack wiped out 100,000 salmon, the entire stock of Northern Ireland's only salmon farm. The species responsible, the mauve stinger, normally occurs in the Mediterranean. Until the past decade, it was rarely spotted in Irish waters.

An extraordinary jellyfish attack wiped out 100,000 salmon, the entire stock of Northern Ireland's only salmon farm.

DR. KEN WHELAN

TOUCHING THE HAWTHORN

DINNER WITH TWO POETS AND A GEOGRAPHER

NUALA NÍ DHOMHNAILL, FIDELMA MULLANE, & MICHAEL D. HIGGINS

ON A MIDWINTER'S Saturday night in Galway's medieval quarter, hard rain was falling, chilled by a northwesterly gale. But down near the Claddagh on Quay Street, warmth could be found in Tigh Neachtain's hostelry. Warmth and a great deal of noise—there was a constant chatter, with feet tapping in time to the notes of a song.

Upstairs over Neachtain's pub, in Ard Bia restaurant, there was more warmth and chatter. In a tiny booth, or "snug," three leading voices on the links between Ireland's landscape and culture gathered to talk with writers for the Irish American Climate Project.

Nuala Ní Dhomhnaill, an Irish-language poet with a worldwide reputation, was in town for a short stay. (She was Ireland Professor of Poetry from 2002 to 2004.) Earlier in the day, at Galway City Museum, she read from her latest collection, "The Fifty Minute Mermaid." Michael D. Higgins, president of Ireland's Labour Party, had just arrived back in Galway from his party's annual conference. He served as arts and culture minister in government from 1992 to 1997 and has published three collections of poems. Fidelma Mullane, a cultural geographer and specialist in vernacular architecture, was at home in Galway. She helps Ireland's Heritage Council preserve unique buildings and landscapes.

Their conversation rambled, over several rounds and courses, but kept returning to spiritual elements of the Irish connection to the landscape. It explained, they said, the depth of this connection, and why it so infused Irish poetry and music. It also explained why the Irish landscape has been largely preserved.

"When I read in the Irish language, or walk in the landscape as part of my research, what I sense is a very particular worldview," Mullane said. "The first precepts were that the other world was only inches away at any time, that the other world was always there right beside you." The connection was spiritual. It was a belief system experienced not on a weekly basis in church, but right there on the land, in every field and on every hilltop.

"Everything informed your actions about your own mortality," Mullane continued. "When a man in Connemara said to me that 'If you throw a stone at a swan, your arm would wither,' it reflected a responsibility towards the environment. He had never tested it, but the meaning was that you could be immediately affected, and you were implicated in your action by the consequences."

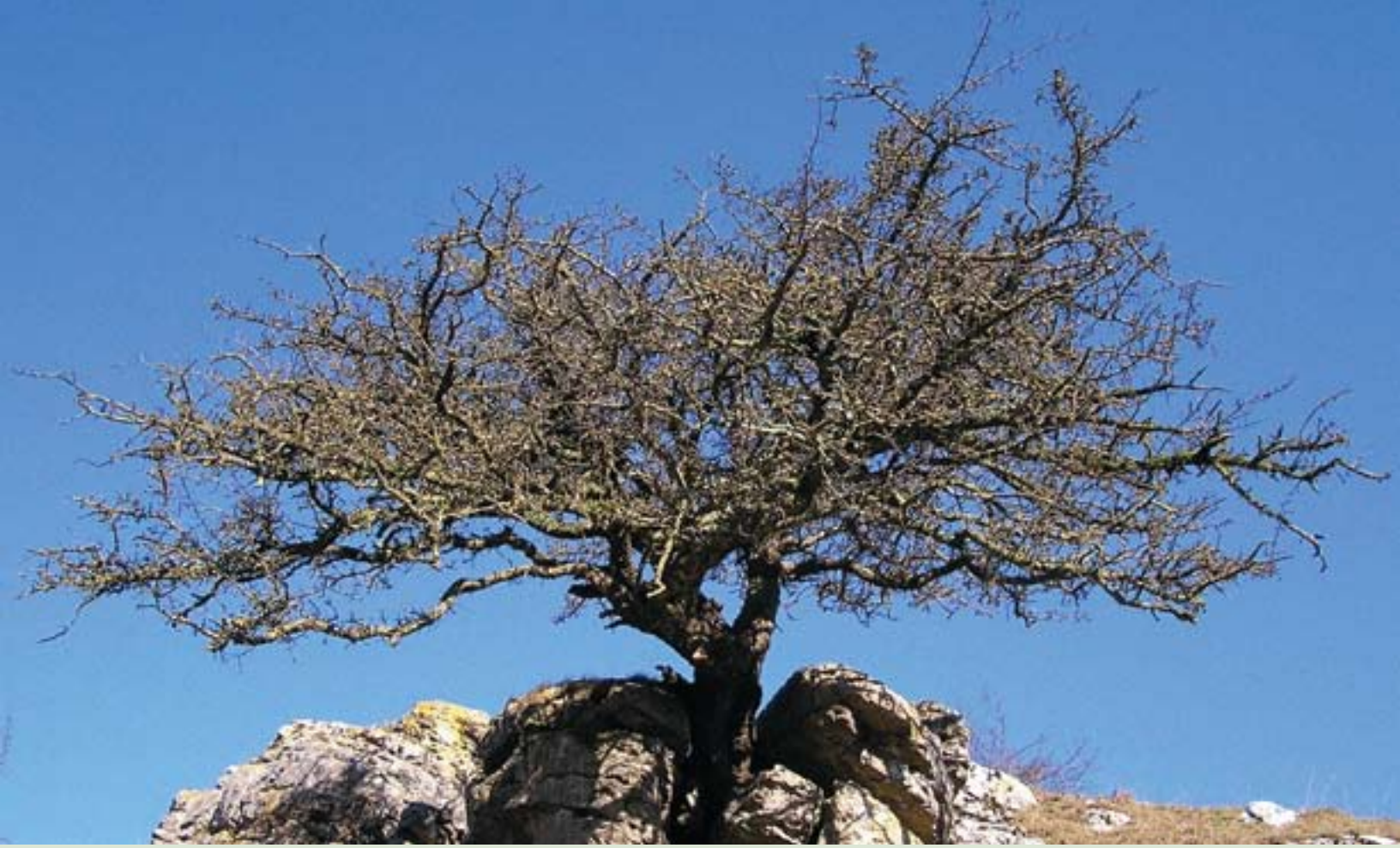
The others weighed in, listing some of the sanctions and rules of Irish folklore. Houses were to be built in the right way and could extend only in certain directions. Homes were never built directly on the coast, for fear that one might turn one's back to the sea. Hawthorn trees were never to be cut: Fairies lived among them, and they would punish anyone who dared ruin their home. So it is that hawthorns continue to thrive in the West of Ireland.

When pressed on how these traditions could still be taken seriously, Ní Dhomhnaill responded: "We can have these two realities, one of which is scientific and one which is a projection of our psychic reality. They can both co-exist, and why not?"

She described a woman who was asked if she believed in fairies. The woman replied by saying she did not believe in fairies—but that they were present.

"It's this ability to have more than one viewpoint, to believe and disbelieve, and to hold these things in your mind without needing to come down 100 percent on one side or the other. That idea is a western limitation, and we [the Irish] are the maladaptive mutations."

Higgins added to her comments, and pulled the discussion into current issues. "The collective memory is connected to the people and the landscape," he said. "And if the landscape disappears, the historical—the storytelling—also disappears. Therefore, you're not losing something that is separate from yourself, or that is specifically physical. You're not losing something that, in a deep ecological sense, never had people in it. It instead is something that has been in a dialogue with people with certain consequences, in terms of names and



Hawthorn trees remain common in Ireland, in part because they were considered to be fairy trees. The spiritual connection to the landscape has shaped Irish culture – and protected the landscape.

story and language, and feeling and music and so forth."

He described a "constant of connection," that has been central to the Irish and their landscape. "A kind of integrity of memory is required—that's how it works. We're never talking about something that is neutral. It isn't narrow in any sense."

"In many of these homes, the same fire was rewoke every morning, for hundreds of years."

"This relates directly to global warming," Mullane said. "This type of responsibility is similar to saying that everyone has their own personal carbon footprint now. Everybody had a more genuine connection in those days. It was all right there. Today, one can be given

> The connection was spiritual. It was a belief system experienced not on a weekly basis in church, but right there on the land, in every field and on every hilltop.

Toward the end of their conversation, they again referred to the traditions that reflect how the Irish have been tethered to place.

Cutting a hawthorn could bring about the worst of fates, Mullane said. "The final, or the worst thing, that might come from it was that you'd be the last of the name."

"There was that fear of the hearth dying, of the fire going out," Ní Dhomhnaill added.

warnings about climate change, but one can still drive another 300 miles in a fancy car. If I was told my hand would wither if I harm a swan, it was a metaphor for action, or for prevention. It had consequences, and was its own sanctions. What is the powerful metaphor today? What are the direct consequences?"

When regulatory measures were suggested (along with dessert suggestions), the group collectively reminded the host that, while regulations were important, the essential element was a rekindling of the Irish spiritual connection to their landscape.

"Before legislation," Mullane said, "we bore this responsibility. It was prescribed, and there was self-regulation. You treated the wells as sacred. Many of the groves were sacred. And those elements that were most important to nature were protected."

As the table was cleared and the three talked of coming events, Ní Dhomhnaill described a process she is using to write a new poem. "I'm looking, for the first time, into Google Earth—I think it is the sublime of our time..."

Mullane jumped in to finish the sentence: "And it's less than a century since we were able to see images of ourselves from a distance."

Those first satellite images of the planet conveyed "the most beautiful images of all," Higgins said. "The lovely colors. The blue-greens."

Again, Mullane interjected. "And there were two of the greenest little patches. One was New Zealand. The other was Ireland."

CONCLUSION

Easter, 2016

Historical trends are often revealed slowly. We tend not to notice the growing movement until an event forces the acknowledgment. Some trends require an individual or a band of leaders to serve as catalysts. Yeats' epic poem, "Easter, 1916," described a particular moment when Irish history was altered.

All changed, changed utterly.
A terribly beauty is born.

In a similar way, weather extremes can catch our attention. (As scientists and writers focused on climate change, we don't consider it a stretch to label this a similarity!) Americans have Katrina as a climate touchstone. The French recall the heat wave of 2003, which killed nearly 15,000 in France and 35,000 across Europe. The British talk of massive floods in the summer of 2007. These events are interpreted by many to be symptoms of a changing climate. They offer glimpses of what the best climate models predict will occur with greater frequency over the course of this century. Still, climates change slowly.

In Ireland, there may not be a moment, or a day, when the full force of a changing climate is recognizable to all at once. There may not be an event that catalyzes a nation. There may not be a speech or a poem that stirs the collective heart. But as we have noted, the changes will come. They may appear to be subtle, at least at first glance: shifts in rainfall, changing patterns of flora, a narrowing of the color range one might experience on a favorite hike.

For each of us, there may be moments of personal recognition, moments of looking back, when we see this clearly. What was not visible on a daily basis will be unavoidably visible over the years. These alterations will accumulate. They will have their impact. All will have changed, changed utterly.

Our intent with this report has been to help the reader understand how global warming will change the look and feel of Ireland. The extent of these changes, however, is not yet certain. Their extent will depend, largely, on changes the various nations make in their energy policies, and the speed with which those policy changes are adopted. Their extent will depend, as well, on changes individuals make in their energy consumption, and the speed at which those changes are embraced.

There is a role for each of us. There is a role for everyone who cares about Ireland. What Yeats wrote of a leader in the Easter uprising (who happened to be a personal enemy) must also be said of us.

He, too, has been changed in his turn,
Transformed utterly:
A terrible beauty is born.

The unique characteristics of the Irish landscape are at risk. Only massive changes in policy and practice, quickly embraced, will stave off the worst effects. Here, finally, we may see a silver lining in the clouds that caused the scattering of Ireland's daughters and sons. The 80 million Irish now live all across the globe. They could, if inspired, be a powerful force for change in many nations. They could, if engaged, help protect the Emerald Isle.

Even more important, their engagement could help protect many landscapes, cultures and people—all across the globe. Their motivation may be rooted in a love of their homeland; their work could benefit people everywhere. They could make a contribution that would help all. And that, as the Irish surely know, would be the stuff of poetry and song.

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