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TRENDS IN FOOD SCIENCE & TECHNOLOGY

Review

Potential impacts of climate change on agriculture and food safety within the island of Ireland[†]

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Climate and other environmental change presents a number of challenges for effective food safety. Food production, distribution and consumption takes place within functioning ecosystems but this backdrop is often ignored or treated as static and unchanging. The risks presented by environmental change include novel pests and diseases, often caused by problem species expanding their spatial distributions as they track changing conditions, toxin generation in crops, direct effects on crop and animal production, consequences for trade networks driven by shifting economic viability of production methods in changing environments and finally, wholesale transformation of ecosystems as they respond to novel climatic regimes.

Introduction

In an increasingly interconnected and changing world, effective food safety and security is ever more important. Globalisation and the consequent exponential growth in food chain complexity has inflated enormously the potential for the importation of undesirable food components and the establishment of novel agricultural pests and diseases from new sources (Hulme, 2009; Sutherst, 2004; Work, McCullough, Cavey & Komsa, 2005). In addition, global environmental change, particularly climate change, acts in synergy to exacerbate risk: the combination of increased globalisation and environmental change is potentially greater than either component alone (Foley *et al.*, 2005, 2011; Sala *et al.*, 2000; Tilman *et al.*, 2001). The penultimate report of the United Nations Intergovernmental Panel on Climate Change reviews the potential development of climate change in detail (Solomon *et al.*, 2007). The latest available report on global climate change (summary for policymakers: IPCC5, 2013) emphasises the likelihood that the earth's climate will continue to change and that higher temperatures and increased variation in climate for most parts of the world are to be expected. Many aspects of food safety and security are in turn likely to be affected by this, ranging from spoilage organism prevalence, changes in existing plant and animal pathogen epidemiology, and migration, introduction and invasion of novel pests and diseases (Miraglia *et al.*, 2009).

Recommendations on food safety from climate change analyses are typically general and geographically large-scale in scope, yet policymakers and scientists are often constrained to act more locally to gather evidence and deal with the consequences of environmental change within their remit. Weighed against this is the recognition that extra-jurisdictional drivers of change, most obviously climate, are often dominant and do not respect borders. This paper will deal with some of the main climate change related processes likely to affect food safety and security, with an emphasis on the island of Ireland. We err towards a longer-term perspective whilst recognising that some threats are immediate, following from the climate change that has already taken place in the latter half of the 20th century, but others will likely develop in severity and importance over the decades to come.

The challenges presented by climate and environmental change have resulted in thousands of scientific publications over the last few years (17,844 hits for the decade ending 2012: Thomson-Reuters Web of Science search with terms "climate" and "change" in the title; search date 26/11/2013). However, integrative publications on climate change and food safety are much scarcer. Adding the terms "food" and "safety" reduces this to 10 hits in the last decade, suggesting the relevant literature is scattered widely and is multidisciplinary in nature.

Current and future climate change within the island of Ireland

Ireland has an archetypal oceanic climate, caused by its position at the edge of the western Atlantic Ocean, with

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relatively small differences between summer and winter temperatures, high precipitation levels and westerly winds. Hard frosts and snow at low elevations are relatively infrequent compared to similar latitudes in continental Europe (Rohan, 1986). This damp, temperate climate lends itself to production of crops requiring moderate temperature regimes and particularly to livestock production where soil conditions are suitable. Most of Europe experienced increased temperatures in the 20th century, averaging 0.8 °C (Alcamo *et al.*, 2007).

The latest IPCC report, the fifth Assessment Report (IPCC5, 2013), builds on and for the most part reiterates previous conclusions regarding global-scale warming in the past few decades, particularly from the 1970s onwards (Fig. SPM 1 in IPCC5, 2013). The authors conclude that (i) the period 1983–2012 was *likel*y (in their terms) to have been the warmest 30-year period of the last 1400 years in the northern hemisphere, and (ii) that changes in extreme weather events have been observed since the middle of the 20th century, including fewer cold and more warm days and nights, and an increased frequency of heat waves in Europe, Asia and Australia. Precipitation is inherently more variable than temperature, but globally it is likely that heavy precipitation events have increased in frequency (IPPC, 2013). The projections for global rise in temperatures are approximately in the 2–4 °C per century range, depending on emission and economic development scenarios. Local projections, covering Europe for example, are made using regional simulations calibrated using coarser-scale global circulation models. The currently available regional projections are based on the previous generation of global circulation models – updated versions are not currently available. For Ireland, these regional climate models suggest longer growing seasons, a further 2.5 °C increase in July temperatures by 2050, with a reduction in summer rainfall, increase in winter precipitation, milder winters and a geographical bias towards the south east in warming trends (e.g. Dunne *et al.*, 2009).

Small changes in averages produce big changes in extremes

An increase of 1 or 2 °C, such as expected in Ireland and elsewhere in the next few decades, is obviously small compared to the magnitude of seasonal temperature change or indeed within-day variation, but it is the long-term consequences of temperature (and other components of climate) that matter. The soil, vegetation and communities of animals present and their interconnection into functioning ecosystems reflects these long-term ecological processes operating over centennial and millennial time scales. Additionally, small to moderate movements in average conditions typically result in disproportionate changes in the frequency of extreme or marginal conditions (Fig. 1): as the average conditions change, the proportion of extreme values above an arbitrary threshold grows rapidly (and the opposite tail shrinks similarly). This is a general argument applicable to many phenomena. For example, the threshold could apply to a temperature limit above which conditions are suitable for cultivation for particular crops, for example sowing thresholds, (Olesen *et al.*, 2012) or above which toxigenic fungi grow rapidly, or the area of land currently suitable for production of some kind.

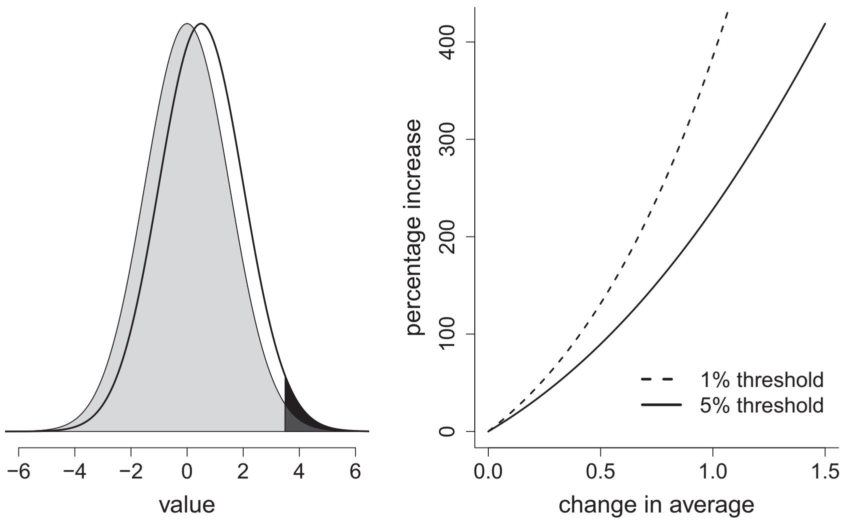

Fig. 1. What appears to be a small change in average conditions has significant implications for the relative frequency of extreme conditions: changes in average environmental conditions are magnified at the extremes. This is simply a consequence of the shape of the Normal or Gaussian distribution. To illustrate this, consider the movement of the mean in time. This results in the rapid increase in the frequency of conditions beyond an arbitrary threshold (left panel: black area shows the growth of marginal conditions over previous frequency, shown in dark grey). The rate at which extreme conditions become commoner is seen in the right panel (expressed as a ratio). If the threshold is set such that 1% of all events are in the tail, these grow more quickly than if it is set such that 5% are in the tail; in other words, the most extreme conditions are also those that grow (or diminish, in the opposite tail) the most rapidly. This margin might be areas suitable for a particular kind of production, for example, or an area subject to an uneconomic parasite burden.