The Beast from the East and drought of summer 2018: an example of compound event impacts upon Ireland's agricultural sector

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Introduction

Human-induced climate change is already causing changes in the frequency and/or intensity of extreme weather events across the globe, and is the most noticeable and damaging manifestation of human-induced climate change (Otto *et al*., 2018). The IPCC AR6 WGI report makes clear that many of the most extreme events will scale with global warming (Seneviratne *et al*., 2021). The most extreme of extremes, those events that impact entire communities and regions, will see the largest increases in frequency and intensity (Seneviratne *et al*., 2021). Of particular concern is any change in compound events, which can have significant consequences either for specific sectors or all of society (Seneviratne *et al*., 2021). IPCC defines compound events as follows: 'the combination of two or more not necessarily extreme weather or climate events that occur: (i) at the same time; (ii) in close succession; or (iii) concurrently in different regions, can lead to extreme impacts that are much larger than the sum of the impacts due to the occurrence of individual extremes alone' (Seneviratne *et al*., 2021).

Of the various types of compound events, those events occurring in close succession have received the least attention in the literature (Zscheischler *et al*., 2018, 2020; Matthews *et al*., 2019). What constitutes 'close' in the term 'close succession' is clearly a complicating factor and is dependent upon how long an event has an impact upon a given system or sector. It is equally unclear what should be counted as constituting compounding impacts from such events.

Here we highlight how agricultural productivity for grass fed ruminant systems, which is inherently a smoothed time integral process over the entire annual cycle, is sensitive to compound events occurring within a single growing season. To many readers, such events may seem 'remote' instead of 'close'. We use a case study based upon the 2018 growing season in Ireland which was impacted by two significant climatic extremes separated by several months.

Sections 'The Beast from the East and its impacts upon Ireland' and 'The summer drought of 2018 and its impacts upon Ireland' discuss the Beast from the East and the summer drought and their immediate effects on broader society, respectively. The following section 'The combined impacts upon the agricultural sector' then analyses how the combination of the two events constituted a compound event specifically for the agriculture sector. The final section 'Summary' concludes the paper.

The Beast from the East and its impacts upon Ireland

The so-called 'Beast from the East' occurred in late February and early March 2018. A large anticyclone centred over Scandinavia advected cold air of Siberian origins across northern Europe over several days leading up to the event. Then storm *Emma* (named by the Portuguese Met Service), encroaching from off the Iberian peninsula towards the British and Irish Isles ran up against this cold air leading, as is typical for such synoptic set-ups at the time of year, to significant localised snowfalls (Figure 1).

Early on Wednesday morning, the 28th February, Met Éireann issued its first ever status red warning for Dublin, Kildare, Louth, Wicklow and Meath as heavy snowfall in "sea-effect" (the same as Lake Effect snowfall, but forming over the Irish Sea) bands led to highly locally variable accumulations of snow. On 1 March 2018, Storm *Emma* resulted in the most significant widespread snowfall in Ireland since December 2010. The south, east and Midlands recorded the greatest depths with some drifts reaching over 2m (Met Éireann, 2019).

Temperatures struggled to rise above freezing for several days thereafter as cold easterly winds continued to sweep over Ireland. Record-low daily maximum temperatures for March were reported in many locations. It was the first time since digitised records began in 1942 that ice days were recorded in March for any station in Ireland (an ice day occurs when the temperature does not rise above freezing for a 24-h period) (Met Éireann, 2019).

Met Éireann's Mullingar synoptic station, located in the Midlands, is used as a representative station for temperatures across Ireland herein. Figure 2 presents the daily mean temperature anomalies against the 1981–2010 climatology for the Mullingar synoptic station. A full 52 of the 73 days over the period 1 February 2018 to 14 April 2018 registered temperatures below normal. The greatest negative anomaly was recorded during 1 March 2018, –9 degC below the climatology.

The extreme weather event paralysed Ireland and much of Northern Europe. The impacts from Storm *Emma* were widespread with major travel disruption across Ireland, with some locations cut-off for several days due to deep snow drifts on many roads (Met Éireann, 2019). In addition, many businesses, libraries, public offices, colleges and schools were forced to close. Nationwide public transport systems and ferry services faced widespread cancellations. Over 70 000 passengers were stranded for several days due to 600 flight cancellations at Dublin airport (Met Éireann, 2019). Utility services were severely impacted by Storm *Emma* with over 100 000 homes and businesses without electricity. Irish Water reported that more

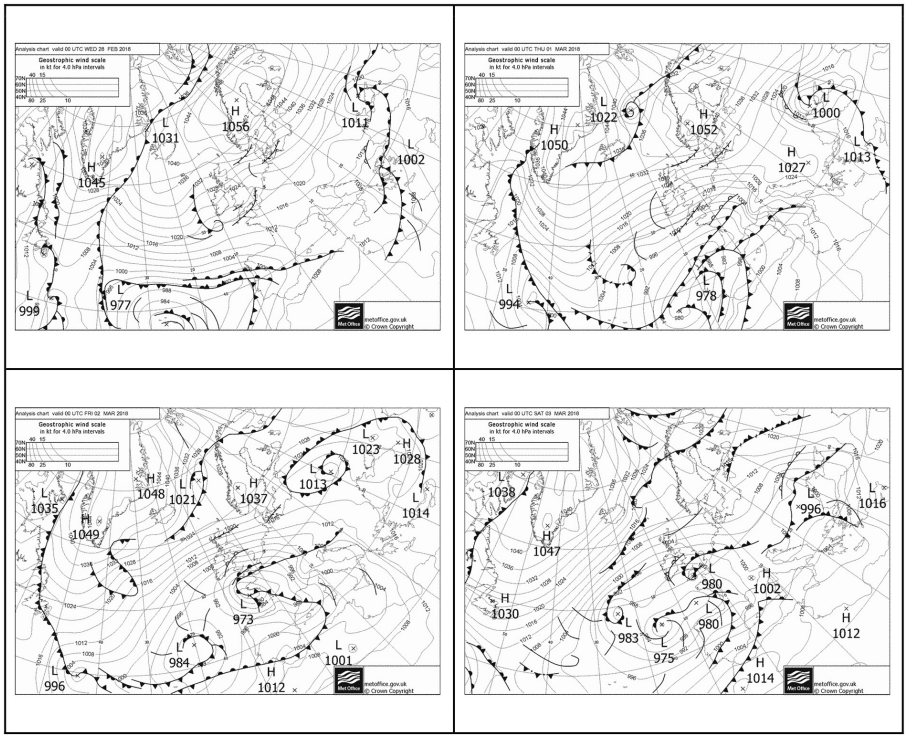

Figure 1. Synoptic evolution for the 'Beast from the East' as shown by Met Office synoptic analyses at 00Z over 28 February 2018 to 3 March 2018.

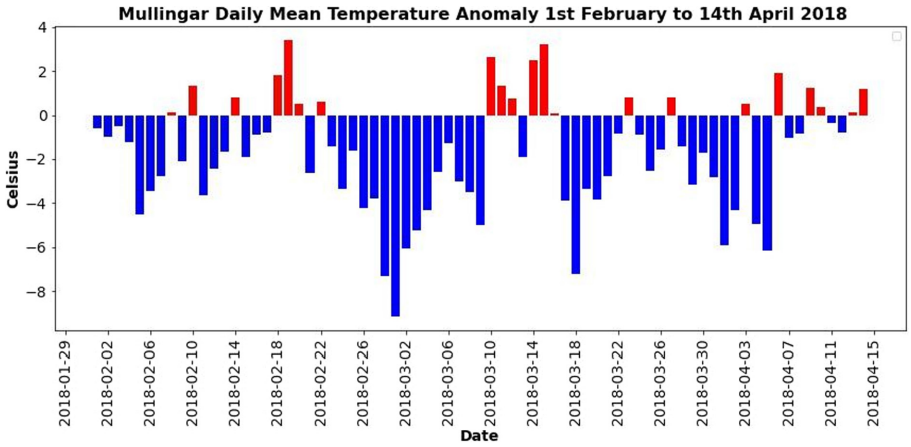

Figure 2. Mean daily temperature anomalies against the 1981–2010 climatology for Mullingar synoptic station located in the midlands of Ireland for the period 1 February 2018 to 14 April 2018. Red bars indicate positive values and blue bars indicate negative values.

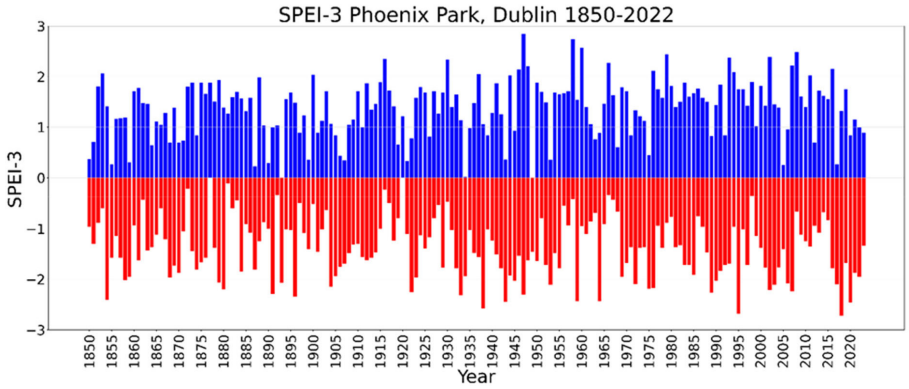

Figure 3. SPEI-3 values calculated on the monthly meteorological data at Phoenix Park from January 1850–2022. Red areas show 3-month cumulative deficits and blue areas show 3-month cumulative surpluses.

than 23 000 homes had no water supply and a further 39 000 experienced restricted water supply (Irish Independent, 2018a). Other vital services such as fire and ambulance services as well as hospitals were put under severe pressure with an increase in patients, overcrowding and backlogs in outpatient clinics (Irish Independent, 2018b).

The summer drought of 2018 and its impacts upon Ireland

The summer of 2018 is remembered for the heatwave and drought conditions that affected Ireland. The definition of a heatwave used by Met Éireann is shaded air temperatures reaching highs of above 25°C on five or more consecutive days at the same location. Drought is generally defined as a period of abnormally dry weather over an extended period that causes a considerable water imbalance that can lead to water shortages, crop damage, low river flows or depletion of groundwater and soil moisture. In Falzoi *et al*. (2019), droughts are classified as 'meteorological (1–3 months), defined on the basis of rainfall deficiency; agricultural (1–6 months), when soil moisture is insufficient and results in a lack of crop growth and production; hydrological (6–24 months), when there is a lack of water in the hydrological system; and socio-economic, when the demand for water exceeds the supply'. There are three different meteorological drought classifications used by Met Éireann: (i) a dry spell is a period of 15 or more consecutive days with daily precipitation of less than 1mm; (ii) an absolute drought is a period of 15 or more consecutive days with daily precipitation less than 0.2mm; and (iii) a partial drought is a period of at least 29 consecutive days with a rainfall total averaging less than 0.2mm of rain per day (Murphy, 2020). Droughts usually occur during the spring/summer, when a persistent high-pressure system results in warm, dry weather for an extended period.

Heatwave conditions were recorded at 15 synoptic stations for 5 or more days between the 24 June and the 4 July. Oak Park, County Carlow in the southeast of Ireland experienced heatwave conditions for 11 consecutive days. During this period, Shannon Airport, County Clare in the southwest reached 32.0°C. Absolute drought conditions were recorded at 21 stations at various times between the 22 May and the 14 July. In addition, there were partial drought conditions recorded at 10 stations and dry spells recorded at 5 stations at various times between the 28 May and the 25 July (Met Éireann, 2019).

There are numerous drought indices used in the literature, such as the Standardised Precipitation Index (SPI) (McKee *et al*., 1993) which quantifies the anomaly of precipitation accumulations over various periods and

is widely used. The SPI is calculated by summing precipitation over specified accumulation periods (typically, 1, 3, 6, 9, 12 and 24 months) and fitting the accumulation series to a parametric distribution from which probabilities are transformed to the standard normal distribution (McKee *et al*., 1993). Shorter duration accumulation periods (1–6 months) are useful for examining meteorological and agricultural drought, while longer durations (6–24 months) are used to identify hydrological drought and long term water scarcity (WMO, 2019). SPI values between 0.99 and −0.99 are considered to be near normal, −1.00 to −1.49 is moderate drought, −1.50 to −1.99 is severe drought and less than −2.00 is extreme drought (WMO, 2019). Other indices are available which may better characterise flash droughts (a rapid onset or intensification of drought), such as occurred in Ireland in the summer of 2018. For example the Standardised Precipitation and Evapotranspiration Index (SPEI) (Vicente-Serrano *et al*., 2010) which in addition to the SPI includes the removal of water via evaporation and transpiration (precipitation minus evapotranspiration) by incorporating temperature data. In this study we used the R package to calculate the SPEI at Phoenix Park (https://cran.r-project.org/web/packages/SPEI/SPEI.pdf) and details of how SPEI was calculated including all the equations can be found at https://spei.csic.es/home.html.

Phoenix Park, one of the largest enclosed public parks in any capital city in Europe is the longest continuous meteorological station in Dublin, with records dating back to the early 1800s. Updated monthly data for Phoenix Park 1850–2022 from the Island of Ireland Precipitation (IIP) network (Noone *et al*., 2016, 2017) were used to calculate the SPEI-3 values (Figure 3).

The period May to July 2018 is the driest 3-month period under this metric (SPEI-3 = −2.72) since at least 1850 (Table 1). This flash summer drought was notable for particularly high temperatures. When we compare the SPI-3 value for Phoenix Park of −2.19 and the SPEI-3 value of −2.72 for May to July 2018, it is clear how the high temperature for this 3-month period impacted on the severity of the drought due to the increase in evaporation.

The World Meteorological Organization (WMO) statement on the State of the Global Climate in 2018 (WMO, 2019) said: 'Large parts of Europe experienced exceptional heat and drought through the late spring and summer of 2018. Wildfires reached an unprecedented extent in Sweden, with over 25 000 hectares burned, and abnormal wildfire activity also occurred in Latvia, Norway, Germany, the United Kingdom and Ireland'.

Table 1

Table of the 10 most extreme values of SPEI-3 in the Phoenix Park record. Negative values denote deficits. The more negative the index the more severe the drought conditions.

Rank	*Year*	*Month*	*PP_SPEI-3*
1st	2018	7	−2.72
2nd	1995	10	−2.68
3rd	1938	4	−2.57
4th	1995	8	−2.53
5th	2020	5	−2.46
6th	1943	4	−2.45
7th	1959	9	−2.44
8th	1964	2	−2.43
9th	1854	4	−2.40
10th	2018	8	−2.37

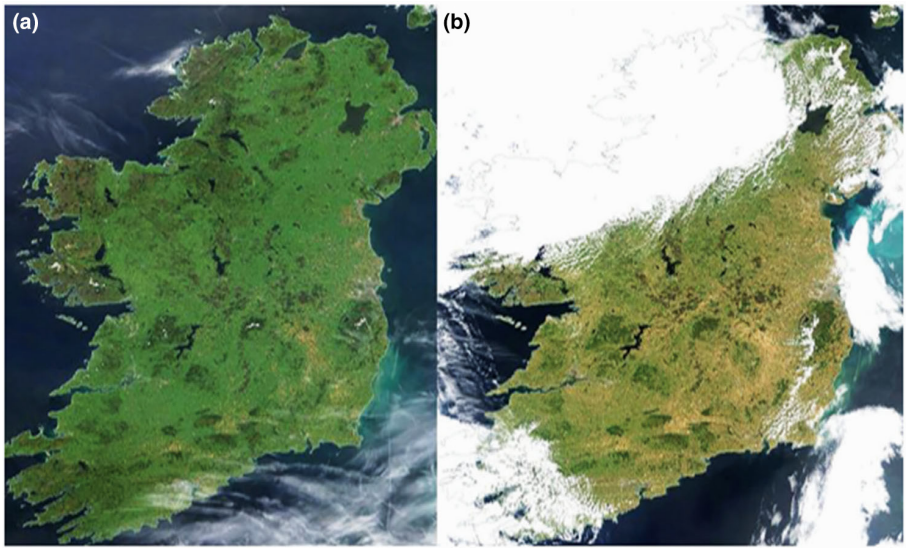

Figure 4. The NASA Terra satellite MODIS true colour imagery for (a) 17 July 2017 and (b) 10 July 2018. The colours reflect the progression of drought affecting much of the island of Ireland through the summer of 2018. (Source: Falzoi et al., 2019.)

River flow levels were extremely low across Ireland; in particular, the rivers Nore and Barrow in the southeast could be measured in small channels of only 4m wide (Catchments News, 2019). The River Liffey in the east and parts of the River Shannon could be waded across safely (Catchments News, 2019). Falzio *et al*. (2019) found that during May to July 2018, the whole of Ireland was experiencing severely dry conditions with southern regions classified as extremely dry. The same study calculated the Soil Moisture Deficit (SMD) (the amount of rain measured in millimetres required to bring the soil moisture content back to field capacity) for a network of Irish stations. A positive SMD indicates a water deficit. The higher the SMD value the higher the water deficit and drier the soil. Between May and June, Dublin Airport experienced the driest soils, with the SMD peaking on the 14th July at 94.3mm, which is close to the maximum possible deficit (Falzio *et al*., 2019). The summer drought in 2018 and heat stress caused a serious reduction in vegetation growth across the country turning the usually green and verdant landscape brown (Falzio *et al*., 2019). Figure 4 shows the change of colour of the vegetation in Ireland in July 2017 compared to July 2018, as measured by NASA's Terra satellite. The fields that were green in July 2017 were desiccated and brown in July 2018.

The drought of 2018 put the Irish Water network under stress with widespread water restrictions and hosepipe bans in place across the country, especially in the East. Restrictions were introduced by Irish Water in early July which were not fully lifted until late September as they warned there were likely to be ongoing 'serious deficiencies' in water availability. Irish Water stated that 'The prolonged hot weather during the summer caused a huge increase in water usage across the country. As demand for water rose to critical levels, our supplies were put under severe stress as we were using more water than we could produce. It was, therefore, necessary to introduce restrictions' (Met Éireann, 2019).

The combined impacts upon the agricultural sector

While each of the Beast from the East and the drought event had immediate impacts upon broader society (Sections 'The Beast from the East and its impacts upon Ireland' and 'The summer drought of 2018 and its impacts upon Ireland'), the impacts of the two events as a compound event upon the agricultural sector was the most significant and long-lasting impact. Ireland's agricultural sector is predominantly grassland-based production with a preponderance of dairy and beef production. This mode of production is critically dependent upon

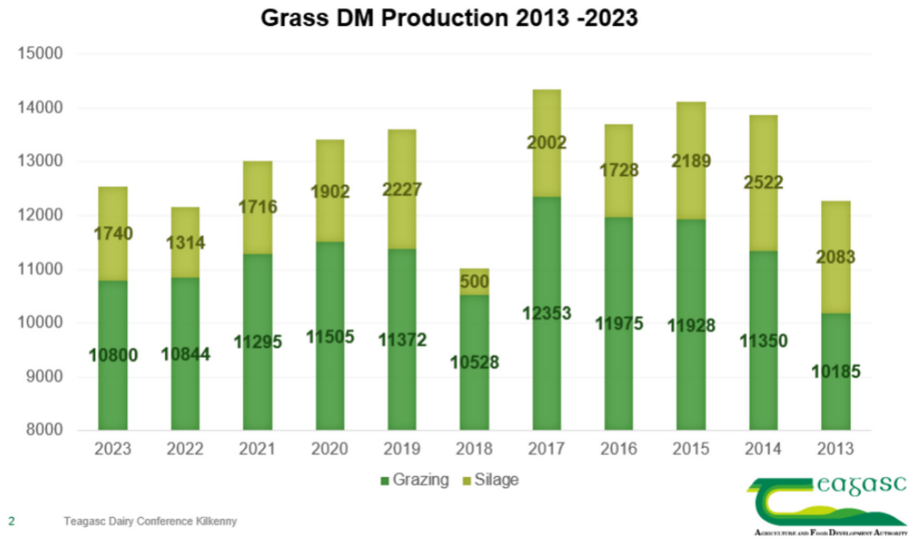

Figure 5. Grass dry matter (DM) production over 2013–2023 from the PastureBase database differentiated into grazing and silage (fodder) productivity. The figure shows the total grass dry matter production (t DM/ha) on dairy and drystock farms recorded in PastureBase Ireland with 30 or greater (dairy) and 20 or greater (drystock) grass cover measurements from 2014 to 2020. (Source: Courtesy of Teagasc.)

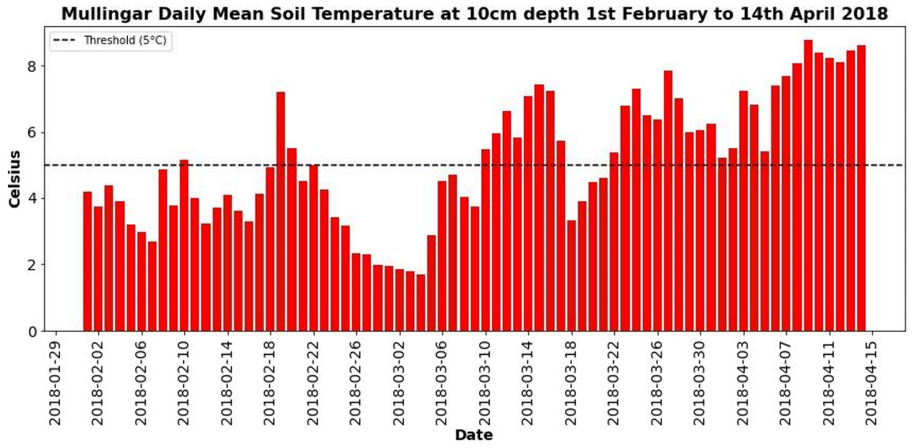

Figure 6. Mean daily soil temperature at 10cm depth for Mullingar synoptic station located in the Midlands of Ireland for the period 1 February 2018 to 14 April 2018. Black dotted line shows 5°C grass growing threshold which was not exceeded for 38 of the 73 days over the period. In Ireland, most grass growth does not begin until soil temperatures at 10cm depth rise above 5°C. However, some grasses may start growing at lower soil temperatures, while white clovers and other legumes will only begin to grow at around 8°C. (Source: Teagasc, 2021.)

growing season characteristics including its onset, cessation and overall productivity integrated across the season. Agricultural systems have been optimised such that during the growing season animals forage on pasture with an excess of production being cut and converted to silage for feeding as fodder in the fallow season, supplemented by feedstocks as necessary. Margins are generally small, and feed additives are expensive.

It is our contention that the 'Beast from the East' and drought of 2018 combined resulted in reduced grazing productivity and acute shortages of fodder production across the country in 2018 in a manner that would not have been the case had both events not occurred within the single growing season. Figure 5 clearly shows how anomalous dry matter production was in 2018. Grass production in 2018 was significantly lower on both dairy and drystock farms. The silage yield was the lowest in the period 2013–2023 and the grazing the second lowest. Combined, it was easily the lowest yield in the 11-year record by a considerable margin. The fodder deficit was worse in the southeast, where the soil moisture deficit during the drought was highest (Teagasc, 2018a).

To consider whether the events constitute a compound extreme on the sector requires an understanding of the interplay of agricultural production and the two events. Herein we take a storyline based approach to make the case that these undoubtedly constitute a sectoral specific compound event in the sense that the 'Beast from the East' and late onset growing season exacerbated the challenges associated with the subsequent drought.

First, it is necessary to acknowledge some pre-conditioning. The long winter of 2017/2018 began late November 2017 with Met Éireann issuing a status yellow alert for snow and ice across the country (Irish Examiner, 2017). After an unsettled mild start in the first week of December 2017, Ireland experienced a period of much colder conditions with northwesterly winds bringing wintry showers and freezing temperatures occurring up to 18 December when a return to mixed weather conditions was established (Met Éireann, 2017). January 2018 saw continued unsettled weather and a mainly westerly airflow with Storm *Eleanor* bringing strong winds (Met Éireann, 2018). The net effect of this was that fodder usage was elevated throughout the meteorological winter of 2017/2018 leading to near-exhaustion of fodder supplies harvested in 2017 by the end of winter and the arrival of the 'Beast from the East'.

The 'Beast from the East' and resulting run of depressed temperatures (Figure 6) resulted in elevated levels of winter feeding of cattle and late planting of spring-sown tillage crops. This was then followed by high levels of spring rainfall, which resulted in cattle being removed from pasture and re-housed for a period (Teagasc, 2018b). The Irish farming sector was severely impacted by Storm *Emma* with the loss of livestock due to deep snow and freezing temperatures (Irish Farmers Journal, 2018a). Many farmers experienced fodder (dried hay or straw) shortages as they would have expected most livestock to be grazing on grass at the time of the year and had already exhausted fodder supplies from the 2017 growing season. In addition, frozen water pipes were a major issue for dairy farmers preventing the supply of drinking water for livestock (Irish Farmers Journal, 2018b).

The 'Beast from the East' and the low temperatures that followed led to a substantial delay in the onset to the grass growing season, with grass production in mid-April having only reached 50% of normal values (Figure 7). There was then a brief period of some six weeks in late April/May/early June, during which grass growth reached and then briefly exceeded the normal seasonal production. Following this, the summer of 2018 saw dramatically reduced grass growth yields brought about by the drought conditions with growth only returning to normal in the autumn, well after meteorological drought had ceased.

By the middle of summer there was limited grazing, and an interruption in silage production. The extent of the problem on dairy and beef farms led to a run-down of stocks of first-cut 2018 silage intended

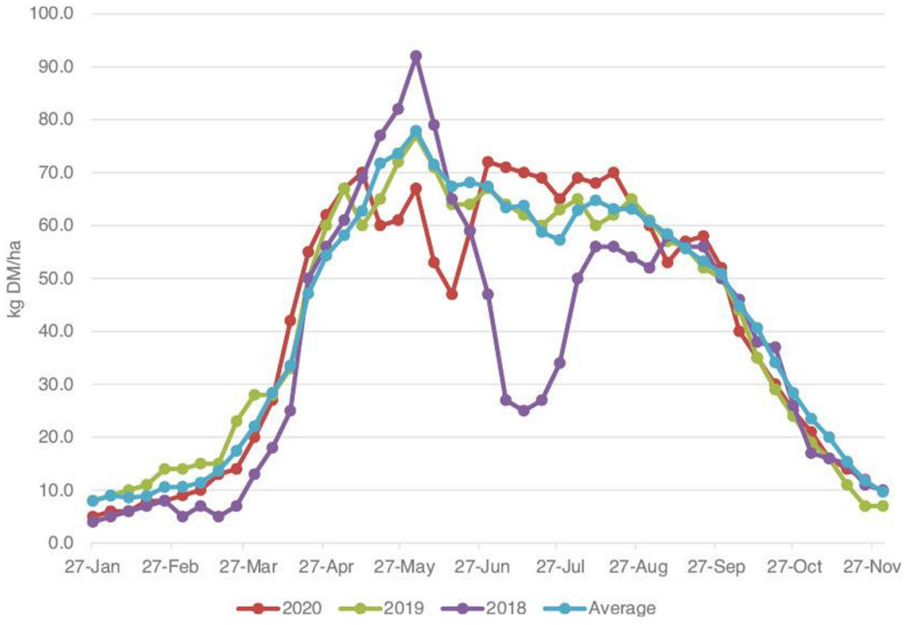

Figure 7. Daily grass growth rates (kg DM/ha) in 2018, 2019 and 2020 and the average growth rate from 2013 to 2020 (inclusive) recorded on PastureBase Ireland. (Source: O'Donovan et al., 2022.)

for the coming winter and the diversion of silage land into grazing (Agriland, 2018a,b; Southern Star, 2018). Tillage farmers found that spring-sown crops (which had been sown late) failed to mature properly. Dairy farmers were badly affected, with many finding that their feed bills doubled due to the limited availability of both grass and fodder. Irish Central Statistics Office data stated that farmer feed and forage costs rose by €500m in 2018, as adverse weather pushed up fodder prices (CSO, 2018).

Teagasc, the Agriculture and Food Development Authority, stated that the average farm income was down by 15% in 2018 and dairy farming income was down by 31% from 2017 due to feed costs (Dillon *et al*., 2018a,b). Teagasc revealed in their 'Outlook 2019'(Teagasc, 2018c) report that the long winter and summer drought 'has had a significant negative impact on Irish farm income in 2018' (Dillon *et al*., 2018a,b). Teagasc also reported that tillage farmers had 'serious difficulty with spring sown crops in 2018, with yields well down on normal'(Dillon *et al*., 2018a,b). The Irish Farmers Association found that 'The country's prolonged drought spell had devastating consequences for Irish field vegetable producers'(Irish Farmers Journal, 2018a,b).

Summary

While both the 'Beast from the East' and the drought of summer 2018 were in their own rights, substantial Irish climate extremes with broad-ranging impacts across many sectors, they may be under-recognised as constituting 'close succession' compound extreme events that significantly affected the agricultural sector in Ireland. We believe that, more generally, agricultural productivity can be significantly impacted by extreme events that would not, for other sectors, be considered as constituting 'close succession' events. In particular, events that in combination lead to delayed onset to the growing season combined with significant reductions in peak growing season productivity can yield substantial cascading impacts in systems which have little capacity slack. It is important for the agricultural sector in Ireland and elsewhere to consider the implications of close succession events where close succession is defined as two or more events with potentially deleterious impacts occurring within the space of a single growing season.

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Author contributions

Clare Noone: Investigation; writing – original draft; methodology; writing – review and editing; data curation. **Simon Noone:** Methodology; writing – review and editing; software; validation; visualization. **Deirdre McClean:** Writing – review and editing. **Peter Thorne:** Conceptualization; writing – original draft; methodology; validation; writing – review and editing; supervision.

Data availability statement

The data that supports the findings of this study are available in the supplementary material of this article.

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