Recent insights in developing Standardized-Precipitation- Evapotranspiration index and 152- years drought assessment for Dublin area (1850-2022)

Aristoteles Tegos , John Cody -Ryan Hanley Ltd

Irish National Hydrology Conference 2023, Tullamore

Abstract

The Standardized Precipitation-Evapotranspiration index (SPEI) is a recent approach to operational monitoring and analysis of drought severity. The SPEI combines precipitation and temperature data to quantify drought severity as the difference between precipitation and PET over a specified time-step, similar in principle to established approaches for estimating Soil Moisture index employed by Met Éireann. Quantifying drought severity using the SPEI approach is an area of active research by Met Éireann (Griffin and Lambkin, 2022).

The aim of this poster is to provide recent insights on the sensitivity of S.P.E.I to alternative Potential Evapotranspiration (PET) models. Three different PET models; Penman-Monteith, Thornthwaite and a temperature based Parametric model (Tegos et al. 2022). The benefit of using the parsimonious Parametric model where meteorological datasets required to estimate PET using the Penman Monteith model are unavailable is discussed.

A 152- years drought assessment for Dublin area (1850-2022) is presented using a revised SPEI approach for timescales varying from 1 to 24-months.

Modelling Procedure

- Raw monthly rainfall and temperature timeseries were acquired for Dublin airport gauge station (Noone et al. 2016, Mateus et al 2020)
- In the standardized precipitation-evapotranspiration index, described by Vicente-Serrano et al (2010), the water deficit of rainfall and the potential evapotranspiration are considered at different timescales from 1 month to 48 months. The standardized precipitation-evapotranspiration index uses a three-parameter log-logistic distribution to capture the deficit between rainfall and potential evapotranspiration
- The PET parametric model is a modern temperature-base model based on a simplification of the Penman–Monteith model was used (Tegos et al. 2017)
- The water balance was estimated using the following equation :

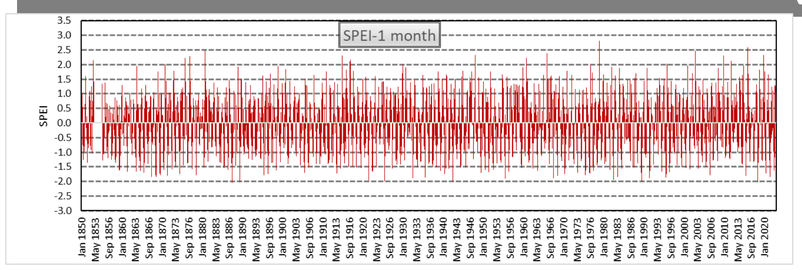
$$D_n^k = \sum_{i=0}^{k-1} P_{n-1} - \mathrm{PET}_{n-1}$$

where P is the rainfall (mm), PET is the potential evapotranspiration (mm), k is the timescale (months) of the aggregation and n is the calculation month.

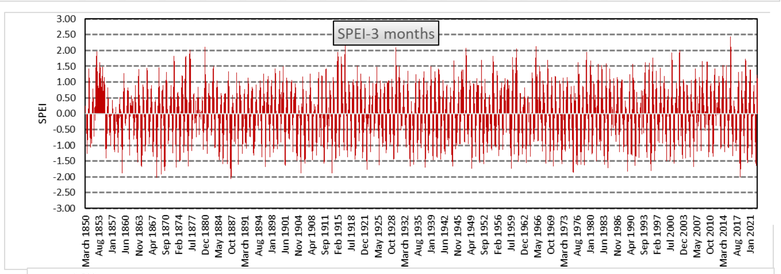
- Drought classification (Table) is estimated by fitting in the empirical distribution D with the employment of three log-logistic distributions

Drought Category	SPEI Value
No drought	>–0.5
Mild drought	–0.5~–1
Moderate drought	–1~–1.5
Severe drought	–1.5~–2
Extreme drought	<–2

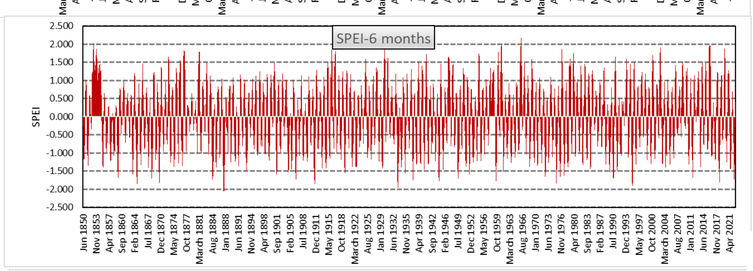
S.P.E.I Classification Dublin (1850-2022)



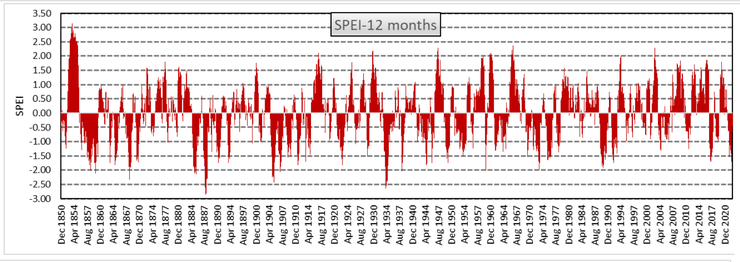
1st ranked 1-month SPE: -2.04, 6/1887
2nd ranked 1-month SPEI: -2.02, 6/1889
3rd ranked 1-month SPEI:-2.02 6/2018
4th Ranked 1-month SPEI: 2.01 6/1942
5th Ranked 1-month SPEI: -2.00 7/1989



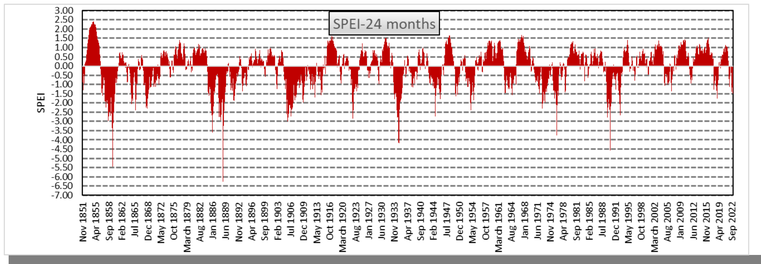
1st ranked 3-months SPE: -2.06, 7/1887
2nd ranked 3-months SPEI: -2.04, 7/1868
3rd ranked 3-months SPEI:-2.02, 7/2018
4th Ranked 3-months SPEI: 2.00, 8/1887
5th Ranked 3-months SPEI: -1.92, 8/1869



1st ranked 6-months SPE: -2.05, 9/1887
2nd ranked 6-months SPEI: -2.05, 8/1887
3rd ranked 6-months SPEI:-1.96, 9/1933
4th Ranked 6-months SPEI: -1.96, 10/1887
5th Ranked 6-months SPEI: -1.90, 9/1995

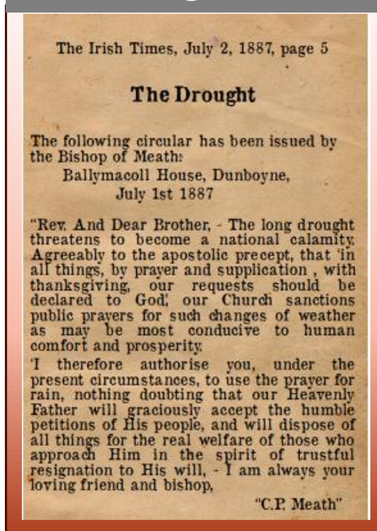


1st ranked 12-months SPE: -2.86, 1/1888
2nd ranked 12-months SPEI: -2.82, 2/1888
3rd ranked 12-months SPEI:-2.76, 12/1887
4th Ranked 12-months SPEI: -2.65, 2/1934
5th Ranked 12-months SPEI: -2.60, 10/1887



1st ranked 24-months SPE: -6.26, 10/1888
2nd ranked 24-months SPEI: -5.46, 10/1859
3rd ranked 24-months SPEI:-4.57, 09/1990
4th Ranked 24-months SPEI: -4.18, 1/1935
5th Ranked 24-months SPEI: -4.14, 11/1934

Drought and its interactions with Water- Food-Society Nexus



The Irish Times, July 2, 1887, page 5

The Drought

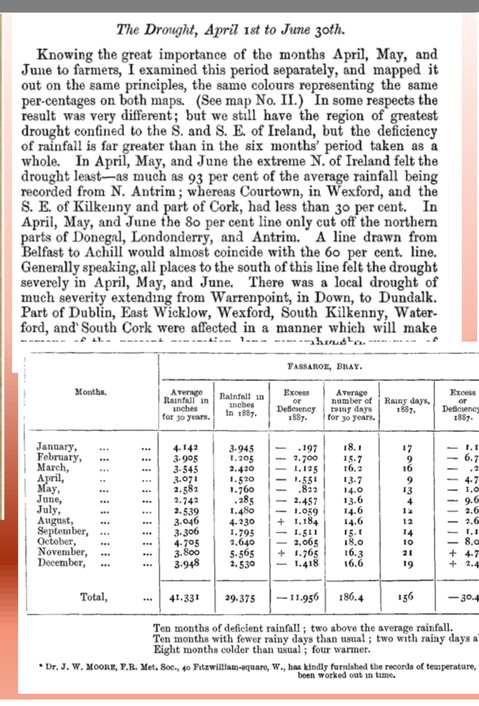
The following circular has been issued by the Bishop of Meath:

Ballymacoll House, Dunboyne,
July 1st 1887

"Rev. And Dear Brother, - The long drought threatens to become a national calamity. Agreeably to the apostolic precept, that 'in all things, by prayer and supplication, with thanksgiving, our requests should be declared to God,' our Church sanctions public prayers for such changes of weather as may be most conducive to human comfort and prosperity.

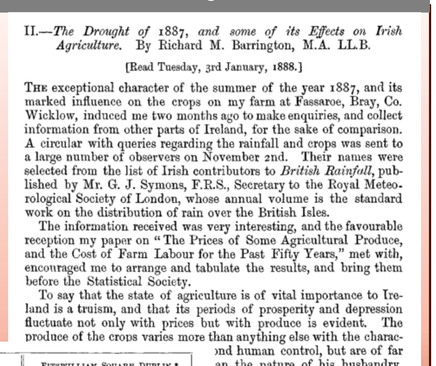
'I therefore authorise you, under the present circumstances, to use the prayer for rain, nothing doubting that our Heavenly Father will graciously accept the humble petitions of His people, and will dispose of all things for the real welfare of those who approach Him in the spirit of trustful resignation to His will, - I am always your loving friend and bishop,

"C.P. Meath"



The Drought, April 1st to June 30th.

Knowing the great importance of the months April, May, and June to farmers, I examined this period separately, and mapped it out on the same principles, the same colours representing the same per-centages on both maps. (See map No. II.) In some respects the result was very different; but we still have the region of greatest drought confined to the S. and S. E. of Ireland, but the deficiency of rainfall is far greater than in the six months' period taken as a whole. In April, May, and June the extreme N. of Ireland felt the drought least—as much as 93 per cent of the average rainfall being recorded from N. Antrim; whereas Courtown, in Wexford, and the S. E. of Kilkenny and part of Cork, had less than 30 per cent. In April, May, and June the 80 per cent line only cut off the northern parts of Donegal, Londonderry, and Antrim. A line drawn from Belfast to Achill would almost coincide with the 60 per cent. line. Generally speaking, all places to the south of this line felt the drought severely in April, May, and June. There was a local drought of much severity extending from Warrenpoint, in Down, to Dundalk. Part of Dublin, East Wicklow, Wexford, South Kilkenny, Waterford, and South Cork were affected in a manner which will make



II.—*The Drought of 1887, and some of its Effects on Irish Agriculture.* By Richard M. Barrington, M.A. LL.B.

[Read Tuesday, 3rd January, 1888.]

The exceptional character of the summer of the year 1887, and its marked influence on the crops on my farm at Fassaroe, Bray, Co. Wicklow, induced me two months ago to make enquiries, and collect information from other parts of Ireland, for the sake of comparison. A circular with queries regarding the rainfall and crops was sent to a large number of observers on November 2nd. Their names were selected from the list of Irish contributors to *British Rainfall*, published by Mr. G. J. Symons, F.R.S., Secretary to the Royal Meteorological Society of London, whose annual volume is the standard work on the distribution of rain over the British Isles.

The information received was very interesting, and the favourable reception my paper on "The Prices of Some Agricultural Produce, and the Cost of Farm Labour for the Past Fifty Years," met with, encouraged me to arrange and tabulate the results, and bring them before the Statistical Society.

To say that the state of agriculture is of vital importance to Ireland is a truism, and that its periods of prosperity and depression fluctuate not only with prices but with produce is evident. The produce of the crops varies more than anything else with the charac- ond human control, but are of far an the nature of his husbandry, bad by care or negligence. Rain t, and the produce of the crops of fluctuating conditions of moisture

Months.	Fassaroe, Bray. Average Rainfall in inches for 30 years.	Rainfall in inches in 1887.	Excess or Deficiency 1887.	Average number of rainy days for 30 years.	Rainy days, 1887.	Excess or Deficiency, 1887.	Fitzwilliam Square, Dublin.* Average Mean Temperature for 20 years.	Mean Temperature, 1887.	Excess or Deficiency.
January, ...	4.142	3.945	— .197	18.1	17	— 1.1	41.4	41.5	+ 0.1
February, ...	3.905	1.205	— 2.700	15.7	9	— 6.7	43.2	42.9	— 0.3
March, ...	3.545	2.420	— 1.125	16.2	16	— .2	43.5	41.3	— 2.2
April, ...	3.071	1.520	— 1.551	13.7	9	— 4.7	48.1	45.1	— 3.0
May, ...	2.582	1.760	— .822	14.0	13	— 1.0	52.1	51.8	— 0.3
June, ...	2.742	.285	— 2.457	13.6	4	— 9.6	57.7	62.3	+ 4.6
July, ...	2.539	1.480	— 1.059	14.6	12	— 2.6	60.7	63.7	+ 3.0
August, ...	3.046	4.230	+ 1.184	14.6	12	— 2.6	59.9	60.3	+ 0.4
September, ...	3.306	1.795	— 1.511	15.1	14	— 1.1	56.0	54.0	— 2.0
October, ...	4.705	2.640	— 2.065	18.0	10	— 8.0	50.0	47.3	— 2.7
November, ...	3.800	5.565	+ 1.765	16.3	21	+ 4.7	44.4	42.6	— 1.8
December, ...	3.948	2.530	— 1.418	16.6	19	+ 2.4	41.3	39.9	— 1.4
Total, ...	41.331	29.375	—11.956	186.4	156	—30.4	49.85	49.39	— .46

Ten months of deficient rainfall; two above the average rainfall.
Ten months with fewer rainy days than usual; two with rainy days above average.
Eight months colder than usual; four warmer.

* Dr. J. W. Moore, F.R. Met. Soc., 40 Fitzwilliam-square, W., has kindly furnished the records of temperature, the Fassaroe mean temperatures not having been worked out in time.

Extreme Drought 1887-1888

Published: 03 November 1934

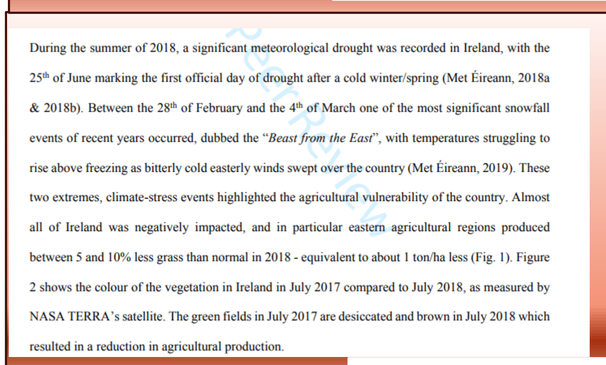
Weather in Great Britain and Ireland in 1933

Nature **134**, 695 (1934) | Cite this article

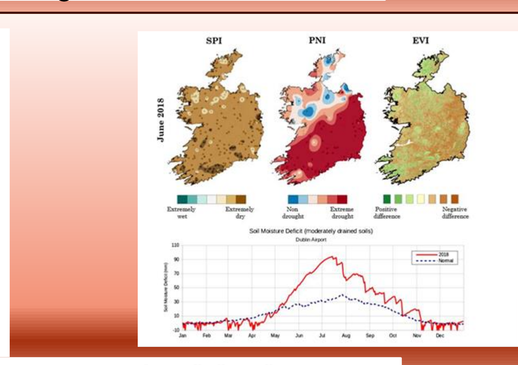
637 Accesses | Metrics

distributed throughout Great Britain and Ireland. The time of commencement was for England within a wet period following a remarkably dry winter, which came at a favourable time for agriculture in so far as it supplied the land with some reserves of water, and enabled many crops to withstand the drought, heat and abnormal sunshine of the summer and autumn of 1933 far better than they would have done had the winter drought not had this pronounced check. The period as a whole was with few exceptions one with excess of sunshine over England, especially in the south-east and the Midlands. There was general dryness and warmth throughout the British Isles, t the warmth being especially pronounced in spring and summer; July and August provided more than one spell of tropical heat, without however quite repeating the very exceptional extremes of the August of the preceding year.

Extreme Drought 1933-1935

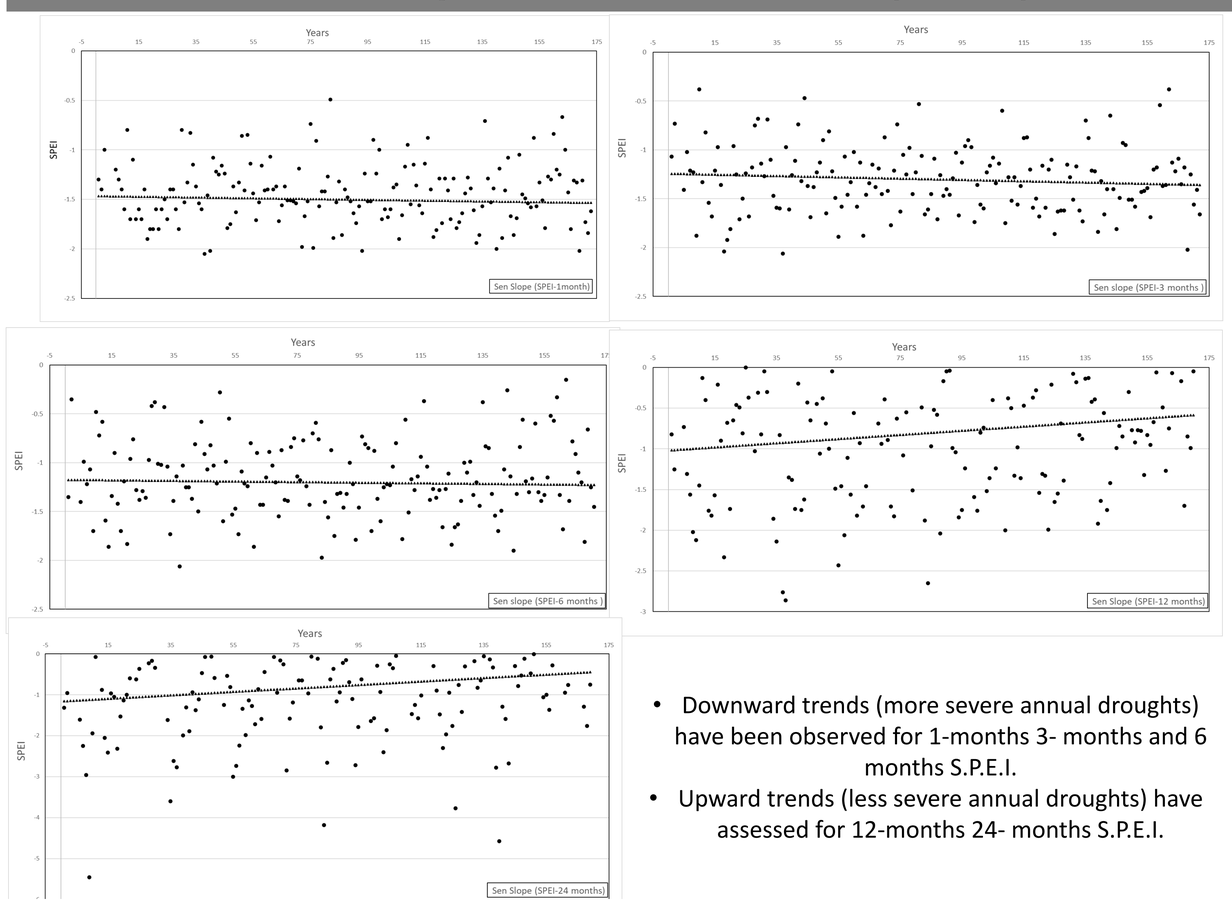


During the summer of 2018, a significant meteorological drought was recorded in Ireland, with the 25th of June marking the first official day of drought after a cold winter/spring (Met Éireann, 2018a & 2018b). Between the 28th of February and the 4th of March one of the most significant snowfall events of recent years occurred, dubbed the "*Beast from the East*", with temperatures struggling to rise above freezing as bitterly cold easterly winds swept over the country (Met Éireann, 2019). These two extremes, climate-stress events highlighted the agricultural vulnerability of the country. Almost all of Ireland was negatively impacted, and in particular eastern agricultural regions produced between 5 and 10% less grass than normal in 2018 - equivalent to about 1 ton/ha less (Fig. 1). Figure 2 shows the colour of the vegetation in Ireland in July 2017 compared to July 2018, as measured by NASA TERRA's satellite. The green fields in July 2017 are desiccated and brown in July 2018 which resulted in a reduction in agricultural production.



Extreme Drought 2018

Trend Analysis of Annual min S.P.E.I (Dublin)



- Downward trends (more severe annual droughts) have been observed for 1-months 3- months and 6 months S.P.E.I.
- Upward trends (less severe annual droughts) have assessed for 12-months 24- months S.P.E.I.

Conclusions

- The S.P.E.I combines precipitation and temperature data, quantifying the severity of a drought as the difference between precipitation and PET in a selected period.
- S.P.E.I represents the hydrological processes that drive drought events more realistically than the Standardized Precipitation Index.
- PET Parametric model has been proven to be a valuable computational tool especially for paleoclimatological studies when only temperature monthly gauges are being available.
- As droughts strongly interact with the environmental, social aspects of water infrastructure elements, new forecasting models and datasets (European Centre for Medium-Range Weather Forecasts) can support robust drought assessment.

References

Falzoi, S., Gleeson, E., Lambkin, K., Zimmermann, J., Marwaha, R., O'Hara, R., ... & Fratianni, S. (2019). Analysis of the severe drought in Ireland in 2018. Weather, 74(11), 368-373.

Noone, Simon, Conor Murphy, John Coll, Tom Matthews, Donal Mullan, Robert L. Wilby, and Seamus Walsh. "Homogenization and analysis of an expanded long-term monthly rainfall network for the Island of Ireland (1850–2010)." International Journal of Climatology 36, no. 8 (2016): 2837-2853.

Noone, Simon, Ciaran Broderick, Catriona Duffy, Tom Matthews, Robert L. Wilby, and Conor Murphy. "A 250-year drought catalogue for the island of Ireland (1765–2015)." International Journal of Climatology 37 (2017): 239-254.

Mateus, C.; Potito, A.; Curley, M. 2020. Reconstruction of a long-term historical daily maximum and minimum air temperature network dataset for Ireland (1831-1968). Geoscience Data Journal

Seánie Griffin and Keith Lambkin "Production of Operational Climate Extreme indices products at Met Éireann", Irish National Hydrology Conference 2022.

Tegos, Aristoteles, Stefanos Stefanidis, John Cody, and Demetris Koutsoyiannis. 2023. "On the Sensitivity of Standardized-Precipitation-Evapotranspiration and Aridity Indexes Using Alternative Potential Evapotranspiration Models" Hydrology

Tegos, Aristoteles, Nikolaos Malamos, Andreas Efstratiadis, Ioannis Tsoukalas, Alexandros Karanasios, and Demetris Koutsoyiannis. "Parametric modelling of potential evapotranspiration: A global survey." Water

Vicente-Serrano, S.M.; Beguería, S.; López-Moreno, J.I. A multiscalar drought index sensitive to global warming: the standardized precipitation evapotranspiration index. J. Clim. 2010, 23, 1696–1718.

Acknowledgment

The authors would like to acknowledge Editorial Board of Hydrology Journal for providing financial sponsorship for this research.