Article:

Swindles, GT orcid.org/0000-0001-8039-1790, Morris, PJ orcid.org/0000-0002-1145-1478, Mullan, DJ et al. (35 more authors) (2019) Widespread drying of European peatlands in recent centuries. Nature Geoscience, 12. pp. 922-928. ISSN 1752-0894

https://doi.org/10.1038/s41561-019-0462-z

Widespread drying of European peatlands in recent centuries

(1) Graeme T. Swindles*

1. School of Geography, University of Leeds, UK

2. Geography, School of Natural and Built Environment, Queen's University Belfast, UK

3. Ottawa-Carleton Geoscience Centre and Department of Earth Sciences, Carleton University, Ottawa, Ontario, Canada

*Corresponding author

g.t.swindles@leeds.ac.uk

(2) Paul J. Morris

School of Geography, University of Leeds, UK

(3) Donal J. Mullan

School of Natural and Built Environment, Queen's University Belfast, UK

(4) Richard J. Payne

1. Department of Environment and Geography, University of York, UK

2. Institute of Hydrobiology, Lomonosov Moscow State University, Russian Federation

(5) Thomas P. Roland

Geography, College of Life and Environmental Sciences, University of Exeter, UK

(6) Matthew J. Amesbury

1. Environmental Change Research Unit (ECRU), Faculty of Biological and Environmental Sciences, University of Helsinki, Finland

2. Geography, College of Life and Environmental Sciences, University of Exeter, UK

(7) Mariusz Lamentowicz

1. Laboratory of Wetland Ecology and Monitoring, Adam Mickiewicz University, Poznań, Poland

2. Department of Biogeography and Palaeoecology, Adam Mickiewicz University, Poznań, Poland

(8) T. Edward Turner

School of Geography, University of Leeds, UK

(9) Angela Gallego-Sala

Geography, College of Life and Environmental Sciences, University of Exeter, UK

(10) Thomas Sim

School of Geography, University of Leeds, UK

(11) Iestyn D. Barr

School of Science and the Environment, Manchester Metropolitan University, UK

(12) Maarten Blaauw

School of Natural and Built Environment, Queen's University Belfast, UK

(13) Antony Blundell

School of Geography, University of Leeds, UK

(14) Frank M. Chambers

Centre for Environmental Change and Quaternary Research, School of Natural and Social Sciences, University of Gloucestershire, UK

(15) Dan J Charman

Geography, College of Life and Environmental Sciences, University of Exeter, UK

(16) Angelica Feurdean

1. Biodiversity and Climate Research Centre (BiK-F), Senckenberg Gesellschaft für Naturforschung, Frankfurt am Main, Germany

2. Department of Geology, Babeş-Bolyai University, Cluj-Napoca, Romania

(17) Jennifer M. Galloway

1. Aarhus Institute of Advanced Studies, Aarhus University, Aarhus, Denmark

2. Geological Survey of Canada/Commission géologique du Canada, Calgary, Alberta, Canada

(18) Mariusz Gałka

Department of Geobotany and Plant Ecology, Faculty of Biology and Environmental Protection, University of Lodz, Poland

(19) Sophie Green

Geography, College of Life and Environmental Sciences, University of Exeter, UK

(20) Katarzyna Kajukało

1. Laboratory of Wetland Ecology and Monitoring, Adam Mickiewicz University, Poznań, Poland

2. Department of Biogeography and Palaeoecology, Adam Mickiewicz University, Poznań, Poland

(21) Edgar Karofeld

Institute of Ecology and Earth Sciences, University of Tartu, Estonia

(22) Atte Korhola

ECRU, Ecosystems and Environment Research Programme, Faculty of Biological and Environmental Sciences, University of Helsinki, Finland

(23) Łukasz Lamentowicz

1. Laboratory of Wetland Ecology and Monitoring, Adam Mickiewicz University, Poznań, Poland

2. Department of Biogeography and Palaeoecology, Adam Mickiewicz University, Poznań, Poland

(24) Peter Langdon

School of Geography and Environmental Science, University of Southampton, UK

(25) Katarzyna Marcisz

1. Laboratory of Wetland Ecology and Monitoring, Adam Mickiewicz University, Poznań, Poland

2. Department of Biogeography and Palaeoecology, Adam Mickiewicz University, Poznań, Poland

(26) Dmitri Mauquoy

School of Geosciences, The University of Aberdeen, UK

(27) Yuri A. Mazei

Department of General Ecology and Hydrobiology, Lomonosov Moscow State University, Russia

(28) Michelle McKeown

Manaaki Whenua – Landcare Research, Lincoln, New Zealand

(29) Edward A. D. Mitchell

1. Laboratory of Soil Biodiversity, Institute of Biology, University of Neuchâtel, Switzerland

2. Jardin Botanique de Neuchâtel, Switzerland

(30) Elena Novenko

1. Department of Physical Geography and Landscape Science, Lomonosov Moscow State University, Russia

2. Institute of Geography, Russian Academy of Science, Russia

(31) Gill Plunkett

School of Natural and Built Environment, Queen’s University Belfast, UK

(32) Helen M. Roe

School of Natural and Built Environment, Queen's University Belfast, UK

(33) Kristian Schoning

Geological Survey of Sweden, Uppsala, Sweden

(34) Ülle Sillasoo

Vaida Middle School, Estonia

(35) Andrey N. Tsyganov

1. Department of General Ecology and Hydrobiology, Lomonosov Moscow State University, Russia

2. Department of Zoology and Ecology, Penza State University, Russia

(36) Marjolein van der Linden

BIAX Consult, The Netherlands

(37) Minna Väliranta

ECRU, Ecosystems and Environment Research Programme, Faculty of Biological and Environmental Sciences, University of Helsinki, Finland

(38) Barry Warner

Department of Earth and Environmental Sciences, University of Waterloo, Canada

Keywords: Wetlands; Climate change; Hydrology; Carbon; Europe

An article for Nature Geoscience (revision 2)

Climate warming and human impacts are thought to be causing peatlands to dry, potentially converting them from sinks to sources of carbon. However, it is unclear whether the hydrological status of peatlands has moved beyond their natural envelope. Here we show that European peatlands have undergone substantial, widespread drying during the last ~300 years. We analyse testate amoeba-derived hydrological reconstructions from 31 peatlands across Britain, Ireland, Scandinavia and continental Europe to examine changes in peatland surface wetness during the last 2000 years. 60% of our study sites were drier during the period CE 1800-2000 than they have been for the last 600 years; 40% of sites were drier than they have been for 1000 years; and 24% of sites were drier than they have been for 2000 years. This marked recent transition in the hydrology of European peatlands is concurrent with compound pressures including climatic drying, warming and direct human impacts on peatlands, although these factors vary between regions and individual sites. Our results suggest that the wetness of many European peatlands may now be moving away from natural baselines. Our findings highlight the need for effective management and restoration of European peatlands.

Peatlands have acted as globally-important carbon (C) sinks since the Last Glacial Maximum[1,2] and contain ~20% of the soil C pool, despite only covering ~3% of the global landmass[3,4]. Peatlands accumulate C when the production of plant litter exceeds losses from microbial decomposition[5]. The maintenance of a shallow water table and near-saturated surface conditions are important for inhibiting C losses from microbial respiration in peatlands[6]. Several factors threaten the persistence of peatland ecosystem services: climate change, peat extraction, drainage, burning and land-use modification[7]. Field manipulations[8] and modelling studies[9] have indicated that the deepening of peatland water-tables leads to increasing peat oxidation, in turn causing the peat C stock that has built up over millennia to be decomposed and released to the atmosphere as carbon dioxide, with likely global-scale implications for climate change[8,10]. In Europe, peatlands store approximately five times more carbon than forests[11] and about half of Europe's total soil organic C[12]. These huge C stores deserve an important place in Europe's climate mitigation measures and greenhouse gas emissions policies.

The current stability of peatland ecosystem services is poorly understood. In particular, it is unclear whether the current hydrological condition of peatlands has been substantially influenced by recent climate change and human impacts. Peatland hydrological processes are involved in multiple negative feedbacks at the site scale that may confer a degree of resistance and resilience against climate-induced drying[13]. This is set against clear shifts in palaeohydrological conditions in peat records, which are mostly interpreted as reflecting periods of past climate change[14]. Although monitoring of peatland water tables is now relatively commonplace, the longest instrumental records cover no more than a few decades, and are thus unable to provide any long-term context for the role of climate and human impacts in peatland drying. For example, one of the longest instrumental peatland water-table records in the world is from Männikjärve bog in Estonia. However, this record only began in CE 1951 and is therefore still too short to show long-term changes (Supplementary Section 1).

Hydrological change in European peatlands

In the absence of long-term hydrological monitoring data, testate (or shell-forming) amoebae can be used to reconstruct past water-table depths (WTDs) from peat profiles using statistical transfer function models[15]. Several such studies in Europe have reported deepening water tables in recent centuries[14,16,17]. We carried out a preliminary meta-analysis of 84 published testate-amoeba-based reconstructions (Methods) in order to assess general trends reported in the literature. The meta-analysis shows that shifts to drier conditions in European peatlands over the last 300 years have been reported in 69% of study sites; while shifts to wetter conditions have been reported in just 7% of sites; the remaining 24% of the records have either shown unclear trends or lack the chronological quality or sampling resolution needed to determine any shift (Supplementary Section 2). The most commonly reported ages of dry shifts in the last ~200 years are CE 1850 (8%), 1900 (13%) and 1950 (13%) (Supplementary Section 2). However, these records are difficult to compare because of variations in chronological precision, temporal resolutions, transfer functions, and age modelling approaches. Here we present the first European-wide network of WTD reconstructions using high-quality, high-resolution testate amoeba data (Methods, Supplementary Section 3 and 4), and develop accurate chronological models for each site using Bayesian methods (Supplementary Section 5). We use the reconstructions to examine hydrological changes in European peatlands over the last two millennia and to determine the state of peatland hydrology in recent centuries in the context of longer-term baselines. Reconstructions from a range of peatland types (raised bogs, blanket peatland, poor fens and permafrost plateaus) were included in the analysis.

There is considerable variability in the water-table records between sites owing to regional climatic variability, differences in site response and chronological uncertainties. 78% of sites in Britain, Ireland, Scandinavia and the Baltics have undergone significant drying in the last 400 years (Fig. 1); while the other 22% of sites in these regions exhibited no significant change. 46% of sites in continental Europe have undergone significant drying in the last 400 years, 31% exhibited no significant change, while the remaining 23% have become significantly wetter – the only three sites in the entire dataset to do so. For each site we binned the reconstructed WTDs into 200-year intervals and calculated the average WTD for each bin. The use of 200-year bins strikes an appropriate balance between sufficient data points within each bin to allow statistical confidence, and enough bins to allow the identification of temporal trends. Considering all sites together, we found that 60% were drier in the period CE 1800-2000 (200-year average bins) than they have been for the last 600 years (CE 1400-2000); 40% of sites were drier than they have been for 1000 years (CE 1000-2000); and 24% were drier than they had been during the entire 2000-year record (since CE 1). We recognise that some of the individual peatlands in our dataset have exhibited high-magnitude dry- (and indeed wet-) shifts earlier in the record, but it is only during the last 300 years that a consistent and coherent drying trend has emerged across multiple sites.

Local regression (loess) models highlight general trends in the compiled data (Fig. 2). Compiled records from all three regions show shallow water tables during the Little Ice Age (LIA) followed by rapid drying to present day. Deep water tables are evident during the Medieval Warm Period (MWP) in Britain, Ireland and Scandinavia, although there is no clear response to the MWP in Continental Europe. British and Irish sites show shallow water tables towards the end of the Dark Age Cold Period (DACP), but this is not apparent in other regions. In Scandinavia, this lack of signal may reflect low data density at this time and large chronological errors. Changepoint analysis identifies significant transitions to drier conditions during the past 300 years in the compiled data: CE 1914 in Britain and Ireland; CE 1777 and 1990 in Scandinavia and the Baltics; and CE 1756 in Continental Europe. When all sites are combined a change-point at CE 1751 is identified.

Potential climatic drivers

The shifts are closely linked with recent climate change as evidenced through comparison with reanalysis of instrumental climate data (Fig. 3; Supplementary Section 6). In Britain and Ireland, increased dryness in peatlands corresponds with a major decrease in summer (June-July-August: JJA) precipitation (up to 25 mm quarter^{-1}) and an overall increase in summer temperature (up to 1°C), when we compare the second halves of the 19th and 20th centuries. In Scandinavia and the Baltics, most peatlands that have undergone deepening water tables over the same time period have also experienced a major increase in mean annual temperature of up to 2.5ºC (Fig. 3B; Supplementary Section 6). In Continental Europe, the sites that have become drier are in areas that have warmed by up to 1ºC (JJA). The five sites in Continental Europe that have become wetter between the second halves of the 19th and 20th centuries are located in regions that have experienced an increase in rainfall over this interval (Fig. 3A). Fig. 3C shows that most study sites have undergone significant drying from the 17th to the 20th centuries, except three in continental Europe. Gridded climate proxy data suggest that precipitation has decreased across Europe over the last ~400 years (Supplementary Section 6), which is consistent with this trend. The variation in response of our study sites to precipitation and temperature may reflect the finding that summer water deficit is controlled by summer precipitation in mid-latitude oceanic peatlands whereas summer temperature plays a greater role in higher latitude, continental settings[18].

Human impacts on peatland ecosystems

We tested for other possible influences on peatland hydrology in addition to climate (Fig. 4). We classify 42% of our sites as having been significantly damaged by human activities; 29% have minor damage; and 29% are relatively undamaged. The human activities that have contributed to site degradation include peat cutting, drainage, burning, grazing, afforestation and scientific activities (e.g. installation of infrastructure and equipment). All these factors may have contributed to site-scale drying in recent centuries. It is clear that our sites in Britain and Ireland have seen more extensive degradation than elsewhere, particularly through cutting, drainage, burning and grazing. Two sites in Scandinavia have suffered severe damage from afforestation. Only two of our 31 sites (6%) have had no damage to the best of our knowledge (Lappmyran, Sweden and Jelenia Wyspa, Poland).

All global land areas have experienced an increase in atmospheric N deposition over the timeframe of our reconstructions[20]. Atmospheric N deposition has been shown to cause shifts in peatland plant communities, and increases in plant productivity through fertilisation[21] (Berendse et al., 2001). Conversely, ecosystem respiration also increases with N deposition through removal of nutritional constraints on microbial activity and the production of more labile plant litter[22,23]. However, we are aware of no field or modelling evidence for changes in peatland WTD as a direct result of N deposition.

Climate-driven drying of European peatlands is likely to have been exacerbated by direct human impacts during recent centuries. The hydrological shifts occurred at a time of rapidly expanding human populations across Europe[24], expanding cropland, and increasing land-use intensity[25]. It is impossible to separate the effects of climate and direct human impacts in our records, as they are superimposed upon one another. Global and regional climate model projections for Europe generally agree on continued warming and reduced growing season moisture availability into the 21st century[26]. This may lead to continued water-table drawdown, which has been linked to catastrophic loss of peat C stocks through enhanced aerobic decomposition[9]. Our study sites include several of the least damaged peatlands in Europe; however, it is clear that almost all peatlands in Europe have been affected by human activities to some extent. The compound pressures of climate change and human impacts may push European peatlands beyond their capacity for resistance by overriding negative feedbacks amongst ecohydrological processes[13]. Furthermore, a hydrological tipping point may exist in peatlands where irreversible changes in plant communities and a shift from C sink to source is triggered in response to drying[27,28]. Indeed, many European peatlands have already undergone shifts in vegetation composition over the last 300 years, including changes in Sphagnum communities[29], and increases in grass, sedge[30] and shrub (e.g. Calluna vulgaris)[31] cover.

Projects are underway to restore peatlands across Europe, in order to maintain and enhance their vital ecosystem services, primarily through damming or blocking of artificial drains and gullies[32]. These actions may be vital in mitigating against soil C stock loss due to both anthropogenic impacts and future climatic warming. Our data suggest that European peatlands are in a state of transition, which may cause them to become drier than their natural baselines. Management strategies and restoration efforts (e.g. drain blocking) need to take these findings into account.

References

1. Yu, Z., Loisel, J., Brosseau, D. P., Beilman, D. W. & Hunt, S. J. Global peatland dynamics since the Last Glacial Maximum. Geophys. Res. Lett. **37**, L13402 (2010).
2. Gallego-Sala, A. V. et al. Latitudinal limits to the predicted increase of the peatland carbon sink with warming. Nat. Clim. Chang. **8**, 907–913 (2018).
3. Scharlemann, J. P. W., Tanner, E. V. J., Hiederer, R. & Kapos, V. Global soil carbon: Understanding and managing the largest terrestrial carbon pool. Carbon Manag. **5**, 81–91 (2014).
4. Xu, J., Morris, P. J., Liu, J. & Holden, J. PEATMAP: Refining estimates of global peatland distribution based on a meta-analysis. Catena **160,** 134–140 (2018).
5. Clymo, R. S., Turunen, J. & Tolonen, K. Carbon accumulation in peatland. Oikos **81**, 368 (1998).
6. Holden, J. Peatland hydrology and carbon release: Why small-scale process matters. Philos. Trans. R. Soc. A Math. Phys. Eng. Sci. **363**, 28912913 (2005).
7. Page, S. E. & Baird, A. J. Peatlands and global change: response and resilience. Annu. Rev. Environ. Resour. **41**, 35–57 (2016).
8. Dorrepaal, E. et al. Carbon respiration from subsurface peat accelerated by climate warming in the subarctic. Nature **460**, 616–619 (2009).
9. Ise, T., Dunn, A. L., Wofsy, S. C. & Moorcroft, P. R. High sensitivity of peat decomposition to climate change through water-table feedback. Nat. Geosci. **1**, 763–766 (2008).
10. Gill, A. L. et al. Deep peat warming increases surface methane and carbon dioxide emissions in a black spruce-dominated ombrotrophic bog. Global Change Biol. **23**, 5398–5411 (2017).
11. Limpens, J. et al. Peatlands and the carbon cycle: from local processes to global implications – a synthesis. Biogeosciences **5**, 1475–1491 (2008).
12. Panagos, P., Hiederer, R., Van Liedekerke, M. & Bampa, F. Estimating soil organic carbon in Europe based on data collected through an European network. Ecol. Indic. **24**, 439–450 (2013).

13. Waddington, J. M. et al. Hydrological feedbacks in northern peatlands. Ecohydrology **8**, 113–127 (2015).

14. Swindles, G. T. et al. Centennial-scale climate change in Ireland during the Holocene. Earth-Science Rev. **126**, 300–320 (2013).

15. Amesbury, M. J. et al. Development of a new pan-European testate amoeba transfer function for reconstructing peatland palaeohydrology. Quat. Sci. Rev. **152**, 132–151 (2016).

16. Charman, D. J., Blundell, A., Chiverrell, R. C., Hendon, D. & Langdon, P. G. Compilation of non-annually resolved Holocene proxy climate records: stacked Holocene peatland palaeo-water table reconstructions from northern Britain. Quat. Sci. Rev. **25**, 336–350 (2006).

17. Marcisz, K. et al. 2015. Long-term hydrological dynamics and fire history during the last 2000 years in CE Europe reconstructed from a high-resolution peat archive. Quat. Sci. Rev. **112**, 138–152 (2015).

18. Charman, D. J. Summer water deficit variability controls on peatland water-table changes: implications for Holocene palaeoclimate reconstructions. Holocene **17**, 217–227 (2007).

19. Compo, G. P. et al. The twentieth century reanalysis project. Q. J. R. Meteorol. Soc. **137**, 1–28 (2011).

20. Galloway, J. N. et al. Nitrogen cycles: past, present, and future. Biogeochemistry **70**, 153–226 (2004).

21. Berendse, F. et al. Raised atmospheric CO_2 levels and increased N deposition cause shifts in plant species composition and production in Sphagnum bogs. Glob. Chang. Biol. **7**, 591–598 (2001).

22. Bragazza, L. et al. Atmospheric nitrogen deposition promotes carbon loss from peat bogs. Proc. Natl. Acad. Sci. **103**, 19386–19389 (2006).

23. Juutinen, E. et al. Responses of vegetation and ecosystem CO_2 exchange to 9 years of nutrient addition at Mer Bleue Bog. Ecosystems **13**, 874–887 (2010).

24. McEvedy, C. & Jones, R. Atlas of World Population History. (Penguin, 1978).

25. Ramankutty, N. & Foley, J. A. Estimating historical changes in global land cover: Croplands from 1700 to 1992. Global Biogeochem. Cycles **13**, 997–1027 (1999).

26. Jacob, D. et al. Climate impacts in Europe under +1.5℃ global warming. *Earth's Futur.* **6**, 264–285 (2018).

27. Jassey, V. E. J. et al. Tipping point in plant–fungal interactions under severe drought causes abrupt rise in peatland ecosystem respiration. Global Change Biol. **24**, 972–986 (2018).

28. Lamentowicz, M. et al. Unveiling tipping points in long-term ecological records from Sphagnum -dominated peatlands. Biol. Lett. **15**, 20190043 (2019).

29. Gałka, M. et al. Palaeoenvironmental changes in Central Europe (NE Poland) during the last 6200 years reconstructed from a high resolution multi-proxy peat archive. Holocene **25**, 421–434 (2015).

30. Gogo, S. et al. Invasion of a Sphagnum-peatland by Betula spp and Molinia caerulea impacts organic matter biochemistry. Implications for carbon and nutrient cycling. Biogeochemistry **106**, 53–69 (2011).

31. Turner, T. E. et al. Late Holocene ecohydrological and carbon dynamics of a UK raised bog: impact of human activity and climate change. Quat. Sci. Rev. **84**, 65–85 (2014).

32. Parry, L. E., Holden, J. & Chapman, P. J. Restoration of blanket peatlands. J. Environ. Manage. **133**, 193–205 (2014).

Acknowledgements

We thank all the organisations that have funded the data used in this analysis: Academy of Finland (296423); Department for Employment and Learning (N. Ireland); European Commission (Fifth Framework); INTERACT (European Community's Seventh Framework Programme); Irish Discovery Programme; Leverhulme Trust; National Science Centre (Poland); Natural Environment Research Council (UK); Natural Sciences and Engineering Research Council of Canada; Netherlands Organisation for Scientific Research; Polish

National Science Centre (NCN - 2015/17/B/ST10/01656); Quaternary Research Association; Russian Science Foundation (19-14-00102); Swiss Contribution to the enlarged European Union; Swiss Federal Office for Education and Science; Swiss National Science Foundation; World University Network; Wüthrich Fund (University of Neuchâtel); Yorkshire Water. TGS is funded by the Leeds-York Natural Environment Research Council (NERC) Doctoral Training Partnership (NE/L002574/1). TET acknowledges NERC Doctoral Training Grant NE/G52398X/1. JMG – this paper represents a contribution from Natural Resources Canada (NRCan contribution number / Numéro de contribution de RNCan: 20190079). GTS acknowledges financial support from the Dutch Foundation for the Conservation of Irish Bogs. We thank Lee Brown and Andy Baird (University of Leeds) for constructive comments on the manuscript. This is a contribution to the PAGES C-PEAT group. PAGES is supported by the US National Science Foundation and the Swiss Academy of Sciences. We dedicate this work to co-author Richard J. Payne who was tragically killed while climbing Nanda Devi in the Garhwal Himalayas whilst the manuscript was in review.

Author contributions

G.T.S. designed the study. G.T.S., P.J.M., D.J.M., R.J.P., T.P.R, M.J.A., M.L., T.E.T, A.G.S. and T.S. compiled site-based data and performed analyses. All other others provided data or carried out a minor component of data compilation or analysis. G.T.S., P.J.M. and D.J.M. carried out the composite data analysis and wrote the manuscript, with input from all authors.

Competing interests

The authors declare no competing interests.

Additional information

Supplementary information is available for this paper at XX.

Reprints and permissions information is available at www.nature.com/reprints. **Correspondence and requests for materials** should be addressed to Graeme T. Swindles (g.t.swindles@leeds.ac.uk).

Publisher's note: Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Figure Captions

Fig. 1. Standardised water-table depth data from each site classified into three broad geographic regions (Britain and Ireland; Scandinavia and Baltics; Continental Europe). Data from the last 2ka and CE 1600-present day are shown. Linear regression trend lines for the period CE 1600 to present day are illustrated: solid trend lines indicate statistically-significant models ($p<0.05$); dashed trend lines indicate non-significant models. The percentage of sites which have become significantly drier or wetter, and the percentage of those with non-significant linear models, are shown. Please see Methods for references to previously published data.

Fig. 2. Compiled standardised water-table data from all sites and the three broad geographic regions (Britain and Ireland; Scandinavia and Baltics; Continental Europe). Greyscale indicates the chronological precision of each data point (determined through Bayesian age modelling). A locally-estimated scatterplot smoothing (loess) model is shown as a yellow line. The red shading indicates 95% confidence limits on the loess function. The timings of the Dark Ages Cold Period (DACP), Medieval Warm Period (MWP) and Little Ice Age (LIA) are illustrated. Significant change point years are illustrated. Please see Methods for references to previously published data.

Fig. 3. Comparison of peatland and climatic datasets. Changes in summer (June-July-August) precipitation totals (A) and temperatures (B) interpolated from 2° latitude x 2° longitude grid s across Europe between the second half of the 19th and 20th centuries: (CE 1950-1999

average) minus (CE 1850-1899 average). Data taken from NOAA-CIRES Twentieth Century Reanalysis (V2c)[19]. The points in (A) and (B) represent (CE 1950-1999 average) minus (CE 1850-1899 average) standardised water-table depths. Panel C shows (CE 1950-1999 average) minus (CE 1600-1699 average) standardised water-table depths. Literature-based sites reporting a drying or wetting trend in the last ~200 years are also shown (Supplementary Section 2). Please see Methods for references to previously published data.

Fig. 4. Matrix indicating the type and level (major, moderate, minor, none known) of human impacts on each study site. A damage index was calculated as the total sum of all impacts. The type of peatland is indicated in superscript font. Please see Methods for references to previously published data.

Methods

1. Justification of approach

Peat profiles that span the most recent centuries are commonly within the aerobic zone (previously referred to as the "acrotelm" in the diplotelmic peat model); therefore, semi-quantitative reconstructions based on the degree of peat humification were excluded from the meta-analysis as peat within the aerobic zone is subject to further decomposition. Reconstructions using plant macrofossil approaches were also discounted as no European transfer function currently exists for peatland plants. Therefore, only testate amoeba data are considered here as 1) hydrology has consistently been shown to be the primary environmental control of community composition over other factors in ombrotrophic peatlands[33, 34]; 2) levels of pollution associated with atmospheric deposition do not bias reconstructions[35]; and 3) direct comparison of records is possible between transfer-function based water table reconstructions.

2. Literature-based analysis

To support our primary analysis of high-quality data we conducted a comprehensive literature-based review of peat-based palaeohydrological reconstructions covering the last 300 years from northwest Europe (Supplementary Section 2).

2.1 Chronological quality

Records were rated on chronological certainty and proxy resolution. Radiocarbon age-depth models substantiated with known age stratigraphic markers (Hekla 1947 tephra, bomb-pulse), or inferred age stratigraphic markers (Spheroidal Carbonaceous Particles (SCPs), Pinus rise) bolstered with further radiometric dating (^{210}Pb, ^{241}Am), were rated the most chronologically secure (rating = 1); records with radiocarbon-based age-depth models with a single inferred age marker (SCPs or Pinus rise), or short records (200 years or less) with SCP-based chronology where rated as chronologically good (rating = 2); those based on linear interpolation of radiocarbon dates were assigned low chronological confidence (rating = 3).

2.2 Human impacts

The main human impacts recorded in the literature for each site (e.g. peat cutting, drainage, burning, afforestation) were noted.

2.3 Analysis

The timing of any reported change to drier or wetter conditions in the last 300 years from each paper was reported.

3. Quantitative analysis

3.1 Water-table reconstruction

Testate amoeba data from European peatlands were compiled and quality checked before having their taxonomies harmonised to the taxonomic system of Amesbury et al. (2016)[36] for transfer function application. Only datasets with high quality absolute chronologies for the last ~200 years were selected for further analysis. Water-table reconstructions were carried out using the pan-European transfer function of Amesbury et al. (2016)[36] with a weighted averaging tolerance-downweighted model with inverse deshrinking. Water-table depth reconstructions were converted to standard units (z-scores) following Swindles et al. (2015)[37]. Reconstructions were carried out on the full dataset and also a dataset after the weak silicic idiosomic tests (Corythion-Trinema type, Euglypha ciliata type and Euglypha rotunda type[38]) were removed. In reality, there is virtually no difference between the two reconstructions showing that the features observed in the uppermost peat profiles are not related to poor preservation of weak siliceous tests (Supplementary Section 3 and 4). The reconstructions ran on the data without the weak silicic idiosomic tests were used for subsequent analysis.

3.2 Age modelling

Age models were constructed for each site using chronological data including ^{14}C, ^{210}Pb, and other age-equivalent stratigraphic markers such as SCPs. Bayesian age models were generated for each site to achieve good accuracy and quantification of age errors (Supplementary Section 5) using R version 3.4.1[39], and the rbacon package (version 2.3.4)[40]. Bacon uses a priori information of peat accumulation rate, over multiple short sections of the core to produce flexible, robust chronologies. We modelled all cores to determine the age probability for each depth. Hereafter, all references to ages or years refer to the maximum probability age at a given depth, as determined from the age model, unless otherwise specified. We also used the age models to generate age error ranges for each depth.

3.3 Trend lines

A linear least-squares regression was carried out for each record for the period CE 1600-present to determine whether there was a drying or wetting trend over this timeframe. An F-test was used to determine whether each model provided a better fit to the data than a model containing no independent variables. A standard t-test was used to evaluate the slope and intercept coefficients. The analysis was completed using R version 3.4.1[39].

3.4 Data compilation analysis

All data were compiled within 4 groups: All sites; Britain and Ireland; Scandinavia and Baltics; and Continental Europe. A LOESS smoothing function[41] with an f-value (degree of smoothing) setting of 0.02 was calculated for the compiled regional datasets. Changepoint analysis[42] was performed on the compiled data to identify major changes in mean and variance over time (function cpt.meanvar) in the datasets using the package 'Package 'changepoint'[42] in R version 3.4.1[39]. The temporal span used in this analysis was 1000 cal. CE to present. The singular most likely changepoint in mean and variance was then identified using an "At Most One Change" (AMOC) method under default settings. In addition, multiple changepoints in mean and variance of the time series were then identified using "Pruned Exact Linear Time" (PELT)[43] method under default settings, with the number of changepoints limited to a maximum of 4.

3.5 Climate analysis

Temperature and precipitation data representing the period 1851-2010 were downloaded from KNMI Climate Explorer (https://climexp.knmi.nl/). We used the NOAA-CIRES Twentieth Century Reanalysis (V2c) dataset[19] – a comprehensive global atmospheric circulation dataset based on the assimilation of four-dimensional weather maps and their uncertainty from the mid-19th century to the 21st century. Data were downloaded at a monthly temporal resolution and at a spatial resolution of 2° latitude x 2° longitude for the spatial domain 40-70°N and 10°W-30°E. Maps showing change in summer temperature and precipitation across Europe were produced by first splitting data into two 50-year time periods from 1850-1899 and 1950-1999 respectively for the summer months of June, July and August. The difference between these periods was then calculated and kriging was used within ArcMap to interpolate between grid points to produce surface temperature and precipitation maps for Europe that represent the change in summer temperature and precipitation between the second half of the 19th and 20th centuries. Graphs showing temporal changes in temperature and precipitation across Europe were produced by first splitting data into four different spatial domains encompassing (1) Britain and Ireland, (2) Scandinavia, (3) Continental Europe, and (4) the three regions combined.

Changes for these four domains were then plotted as time series along with a smoothed line based on loess smoothing. Linear trends were calculated using linear regression. Using the years of the time series as the known x values and the climate data as the known y values, a linear regression equation was constructed and then used to predict y values (i.e. temperatures or precipitation) for the start and end years of the time series. The difference between the values for these years was then computed and expressed as a percentage of the temperature/precipitation value for the starting year.

Another set of time series for the same four regions was produced for the longer period of 1500-2000 based on temperature and precipitation reconstructions downloaded from KNMI Climate Explorer based on datasets from Luterbacher et al. (2004)[44] and Pauling et al. (2006)[45] respectively. Please also see Supplementary Section 6.

3.6 Human impacts

It is widely acknowledged that the majority of peatlands across Europe have been affected by human activity to at least some degree. Evidence of human activity for each site was recorded in several categories: cutting, drainage, burning, grazing, afforestation, and scientific activity (e.g. installation of scientific and monitoring equipment) within a matrix. The damage level for each individual category was noted as major (score 3), moderate (score 2), minor (score 1) and none known (score 0). A damage index for each site was calculated by summing the scores for each category (>4 = damaged site; 3-4 = minor damage; 0-2 = relatively undamaged).

3.7 Data sources

All published data sources are provided below:

Site	Region	Country	Latitude	Longitude	Reference
Ardkill	Britain and Ireland	Ireland	53.3653	-6.9532	46
Ballyduff	Britain and Ireland	Ireland	53.0807	-7.9925	47
Butterburn	Britain and Ireland	England	55.0875	-2.5036	48
Cloonoolish	Britain and Ireland	Ireland	53.1865	-8.2569	46
Dead Island	Britain and Ireland	Ireland	54.8862	-6.5487	49
Derragh	Britain and Ireland	Ireland	53.7667	-7.4083	50
Keighley	Britain and Ireland	England	54.4253	-2.0369	51
Malham	Britain and Ireland	England	54.0964	-2.1750	52
Slieveanorra	Britain and Ireland	Ireland	55.0848	-6.1921	49
Bagno Kusowo	Continental Europe	Poland	53.8078	16.5872	53
Barschpfuhl	Continental Europe	Germany	53.0558	13.8494	54
Combe des Amburnex	Continental Europe	Switzerland	46.5397	6.2317	55
Gązwa	Continental Europe	Poland	53.8726	21.2201	56
Izery	Continental Europe	Poland	50.8519	15.3602	57
Jelenia Wyspa	Continental Europe	Poland	53.5918	17.9821	58
Linje	Continental Europe	Poland	53.1880	18.3098	59
Mauntschas	Continental Europe	Switzerland	46.4900	9.8544	60
Mechacz	Continental Europe	Poland	54.3314	22.4419	61
Praz-Rodet	Continental Europe	Switzerland	46.5667	6.1736	62
Słowińskie	Continental Europe	Poland	54.3619	16.4785	63
Stążki	Continental Europe	Poland	54.4244	18.0833	64
Tăul Muced	Continental Europe	Romania	47.5739	24.5450	65
Akerlänna Römosse	Scandinavia and Baltic	Sweden	60.0167	17.3667	66
Ältabergsmossen	Scandinavia and Baltic	Sweden	59.9667	18.6833	67

Gullbergbymossen	Scandinavia and Baltic	Sweden	59.6333	18.4333	67
Kontolanrahka	Scandinavia and Baltic	Finland	60.4783	22.4783	68
Lappmyran	Scandinavia and Baltic	Sweden	64.1647	19.5828	69
Lille Vildmose	Scandinavia and Baltic	Denmark	56.8391	10.1896	70
Männikjärve	Scandinavia and Baltic	Estonia	58.8667	26.2500	71
Stordalen 1	Scandinavia and Baltic	Sweden	68.3568	19.0484	72
Stordalen 2	Scandinavia and Baltic	Sweden	68.3564	19.0441	73

Water-table reconstruction data are provided in Supplementary Section 7.

Data availability statement

The data that support the findings of this study are provided in Supplementary Section 7.

References

33. Woodland, W. A., Charman, D. J. & Sims, P. C. Quantitative estimates of water tables and soil moisture in Holocene peatlands from testate amoebae. Holocene **8**, 261–273 (1998).

34. Booth, R. K. Testate amoebae as proxies for mean annual water-table depth in Sphagnum-dominated peatlands of North America. J. Quat. Sci. **23**, 43–57 (2008).

35. Payne, R. J., Mitchell, E. A. D., Nguyen-Viet, H. & Gilbert, D. Can pollution bias peatland paleoclimate reconstruction? Quat. Res. **78**, 170–173 (2012).

36. Amesbury, M. J. et al. Development of a new pan-European testate amoeba transfer function for reconstructing peatland palaeohydrology. Quat. Sci. Rev. **152**, 132–151 (2016).

37. Swindles, G. T. et al. Testing peatland water-table depth transfer functions using high-resolution hydrological monitoring data. Quat. Sci. Rev. **120**, 107–117 (2015).

38. Swindles, G. T., Charman, D. J., Roe, H. M. & Sansum, P. A. Environmental controls on peatland testate amoebae (Protozoa: Rhizopoda) in the North of Ireland: Implications for Holocene palaeoclimate studies. J. Paleolimnol. **42**, 123–140 (2009).

39. R Core Team. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. http://www.R-project.org/ (2017).

40. Blaauw, M. & Christen, J. A. Flexible paleoclimate age-depth models using an autoregressive gamma process. Bayesian Anal. **6**, 457–474 (2011).

41. Cleveland, W. S. Robust locally weighted regression and smoothing scatterplots. J. Am. Stat. Assoc. **74**, 829–836 (1979).

42. Killick, R. & Eckley, I. A. changepoint : An R package for changepoint analysis. J. Stat. Softw. **58**, 1–19 (2015).

43. Killick, R., Fearnhead, P. & Eckley, I. A. Optimal detection of changepoints with a linear computational cost. J. Am. Stat. Assoc. **107**, 1590–1598 (2012).

44. Luterbacher, J., Dietrich, D., Xoplaki, E., Grosjean, M. & Wanner, H. European seasonal and annual temperature variability, trends, and extremes since 1500. Science **303**, 1499–1503 (2004).

45. Pauling, A., Luterbacher, J., Casty, C. & Wanner, H. Five hundred years of gridded high-resolution precipitation reconstructions over Europe and the connection to large-scale circulation. Clim. Dyn. **26**, 387–405 (2006).

46. Blundell, A., Charman, D. J. & Barber, K. Multiproxy late Holocene peat records from Ireland: Towards a regional palaeoclimate curve. J. Quat. Sci. **23**, 59–71 (2008).

47. Swindles, G. T. et al. Centennial-scale climate change in Ireland during the Holocene. Earth-Science Rev. **126**, 300–320 (2013).

48. Mauquoy, D., Yeloff, D., Van Geel, B., Charman, D. J. & Blundell, A. Two decadally resolved records from north-west European peat bogs show rapid climate changes associated with solar variability during the mid-late Holocene. J. Quat. Sci. **23**, 745–763 (2008).

49. Swindles, G. T., Blundell, A., Roe, H. M. & Hall, V. A. A 4500-year proxy climate record from peatlands in the North of Ireland: the identification of widespread summer 'drought phases'? Quat. Sci. Rev. **29**, 1577–1589 (2010).

50. Langdon, P.G., Brown, A.G., Caseldine, C.J., Blockley, S.P. and Stuijts, I. Regional climate change from peat stratigraphy for the mid- to late Holocene in Central Ireland. Quat. Int. **268**, 145–155 (2012).

51. Blundell, A., Holden, J. & Edward Turner, T. Generating multi-proxy Holocene palaeoenvironmental records from blanket peatlands. Palaeogeogr. Palaeoclimatol. Palaeoecol. **443**, 216–229 (2016).

52. Turner, T. E., Swindles, G. T. & Roucoux, K. H. Late Holocene ecohydrological and carbon dynamics of a UK raised bog: Impact of human activity and climate change. Quat. Sci. Rev. **84**, 65–85 (2014).

53. Lamentowicz, M. et al. Reconstructing climate change and ombrotrophic bog development during the last 4000 years in northern Poland using biotic proxies, stable isotopes and trait-based approach. Palaeogeogr. Palaeoclimatol. Palaeoecol. **418**, 261–277 (2015).

54. van der Linden, M., Broekens, P., Vickery, E., Charman, D., van Geel, B. Vegetation history and human impact during the last 300 years recorded in a German peat deposit. Rev. Palaeobot. Palynol. **152**, 158–175 (2008).

55. Sjögren, P. & Lamentowicz, M. Human and climatic impact on mires: A case study of les Amburnex mire, Swiss Jura Mountains. Veg. Hist. Archaeobot. **17**, 185–197 (2008).

56. Gałka, M. et al. Palaeoenvironmental changes in Central Europe (NE Poland) during the last 6200 years reconstructed from a high-resolution multi-proxy peat archive. Holocene **25**, 421–434 (2015).

57. Kajukało, K., Fiałkiewicz-Kozieł, B., Gałka, M., Kołaczek, P. & Lamentowicz, M. Abrupt ecological changes in the last 800 years inferred from a mountainous bog using testate amoebae traits and multi-proxy data. Eur. J. Protistol. **55**, 165–180 (2016).

58. Lamentowicz, M., Tobolski, K. & Mitchell, E. A. D. Palaeoecological evidence for anthropogenic acidification of a kettle-hole peatland in northern Poland. Holocene **17**, 1185–1196 (2007).

59. Marcisz, K. et al. Long-term hydrological dynamics and fire history over the last 2000 years in CE Europe reconstructed from a high-resolution peat archive. Quat. Sci. Rev. **112**, 138–152 (2015).

60. van der Knaap, W. O. et al. A multi-proxy, high-resolution record of peatland development and its drivers during the last millennium from the subalpine Swiss Alps. Quat. Sci. Rev. **30**, 3467–3480 (2011).

61. Gałka, M. et al. Unveiling exceptional Baltic bog ecohydrology, autogenic succession and climate change during the last 2000 years in CE Europe using replicate cores, multi-proxy data and functional traits of testate amoebae. Quat. Sci. Rev. **156**, 90–106 (2017).

62. Mitchell, E. A. D. et al. The palaeoecological history of the Praz-Rodet bog (Swiss Jura) based on pollen, plant macrofossils and testate amoebae (Protozoa). Holocene **11**, 65–80 (2001).

63. Lamentowicz, M. et al. Climate and human induced hydrological change since AD 800 in an ombrotrophic mire in Pomerania (N Poland) tracked by testate amoebae, macro-fossils, pollen and tree rings of pine. Boreas **38**, 214–229 (2009).

64. Lamentowicz, M. et al. Climate change and human impact in the southern Baltic during the last millennium reconstructed from an ombrotrophic bog archive. Studia Quaternaria **28**, 3–16 (2011).

65. Feurdean, A. et al. Last Millennium hydro-climate variability in Central–Eastern Europe (Northern Carpathians, Romania). Holocene **25**, 1179–1192 (2015).

66. van der Linden, M., Vickery, E., Charman, D., van Geel, B. Effects of human impact and climate change during the last 350 years recorded in a Swedish raised bog deposit. Palaeogeogr. Palaeoclimatol. Palaeoecol. **262**, 1–31 (2008).

67. Schoning, K., Charman, D. J. & Wastegård, S. Reconstructed water tables from two ombrotrophic mires in eastern Sweden compared with instrumental meteorological data. The Holocene **15**, 111–118 (2005).

68. Väliranta, M. et al. High-resolution reconstruction of wetness dynamics in a southern boreal raised bog, Finland, during the late Holocene: A quantitative approach. Holocene **17**, 1093–1107 (2007).

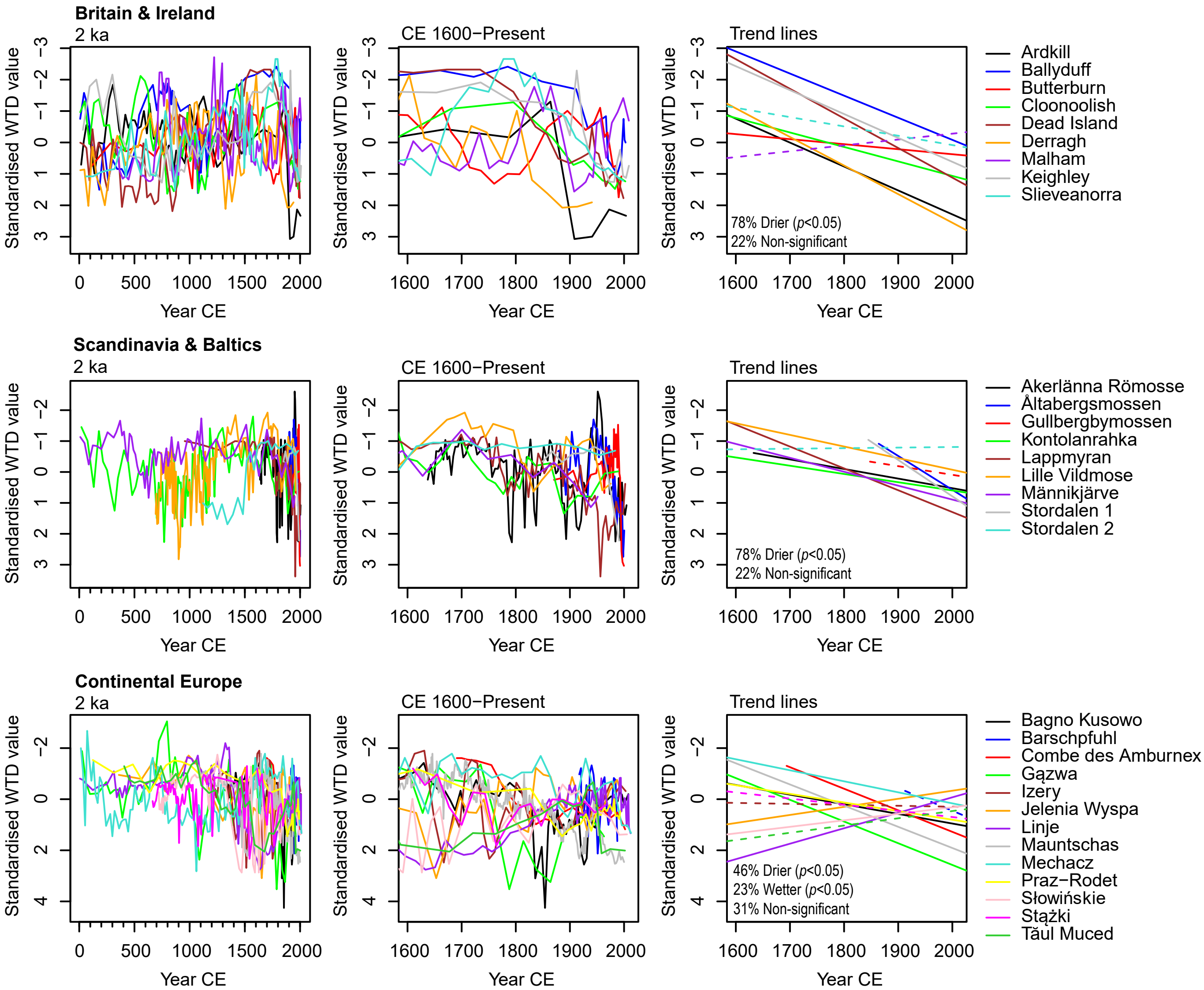
69. van der Linden, M., Barke, J., Vickery, E., Charman, D., van Geel, B. Late Holocene human impact and climate change recorded in a north Swedish peat deposit. Palaeogeogr. Palaeoclimatol. Palaeoecol. **258**, 1–27 (2008).

70. Mauquoy, D., Yeloff, D., van Geel, B., Charman, D. & Blundell, A. Two decadally resolved records from north-west European peat bogs show rapid climate changes associated with solar variability during the mid-late Holocene. J. Quat. Sci. **23**, 745–763 (2008).

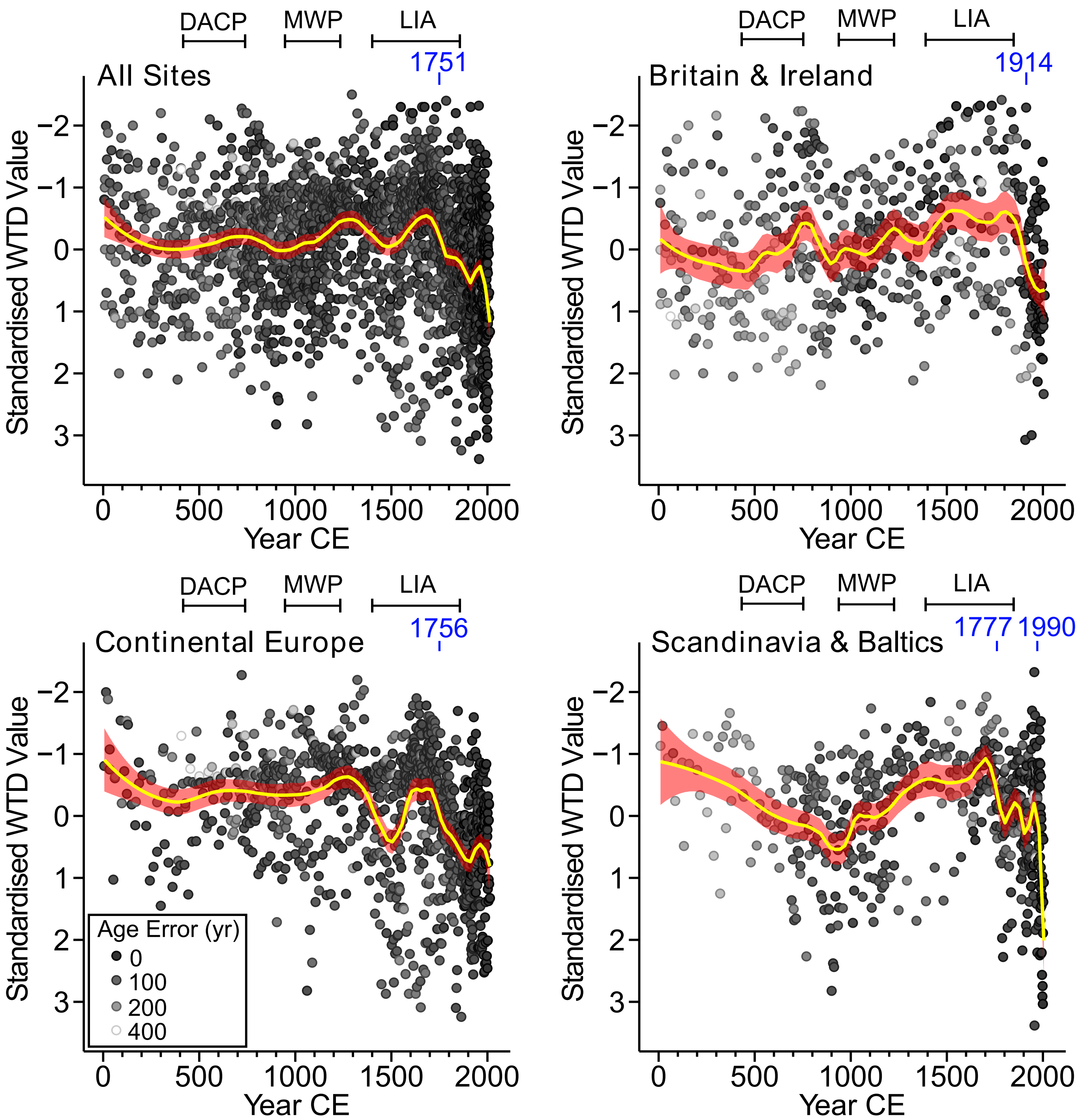
71. Väliranta, M. et al. Reconstructing peatland water tables using transfer functions for plant macrofossils and testate amoebae: A methodological comparison. Quat. Int. **268**, 34–43 (2012).

72. Swindles, G. T. et al. The long-term fate of permafrost peatlands under rapid climate warming. Sci. Rep. **5**, 17951 (2015).

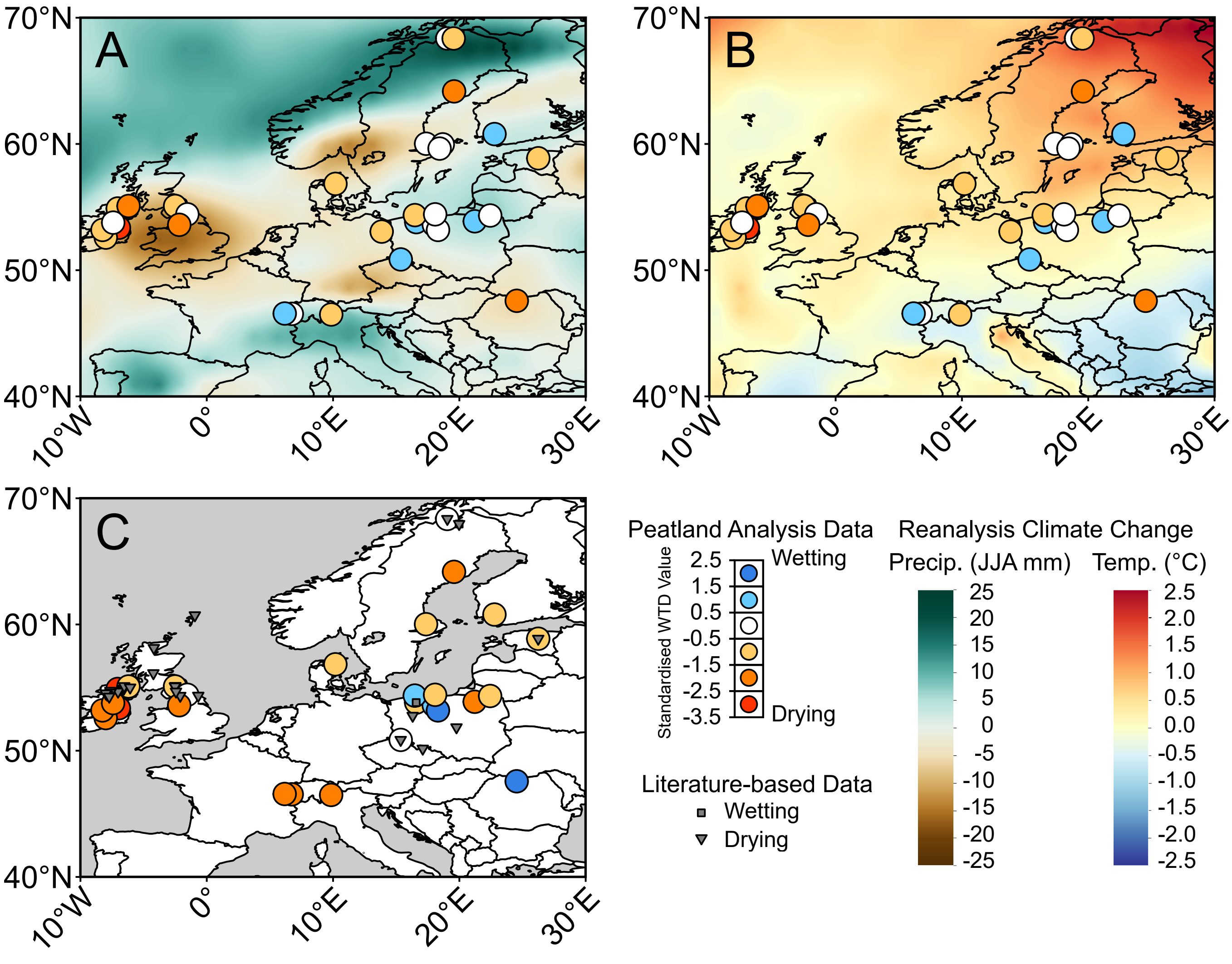
73. Gałka, M. et al. Vegetation succession, carbon accumulation and hydrological change in subarctic peatlands, Abisko, Northern Sweden. Permafr. Periglac. Process. **28**, 589–604 (2017).

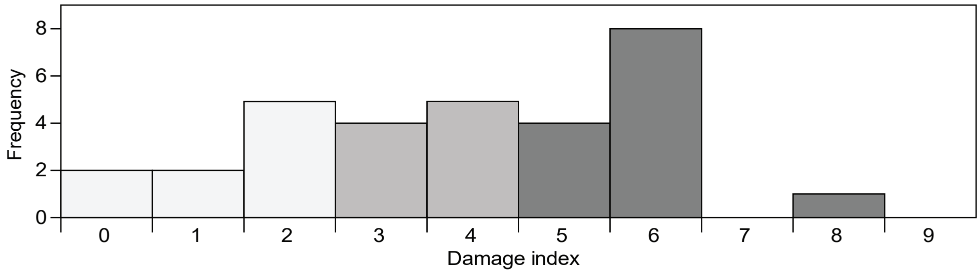


Britain & Ireland
2 ka
CE 1600−Present
Trend lines
Standardised WTD value
Year CE
78% Drier (p<0.05)
22% Non-significant
Ardkill
Ballyduff
Butterburn
Cloonoolish
Dead Island
Derragh
Malham
Keighley
Slieveanorra
Scandinavia & Baltics
78% Drier (p<0.05)
22% Non-significant
Akerlänna Römosse
Åltabergsmossen
Gullbergbymossen
Kontolanrahka
Lappmyran
Lille Vildmose
Männikjärve
Stordalen 1
Stordalen 2
Continental Europe
46% Drier (p<0.05)
23% Wetter (p<0.05)
31% Non-significant
Bagno Kusowo
Barschpfuhl
Combe des Amburnex
Gązwa
Izery
Jelenia Wyspa
Linje
Mauntschas
Mechacz
Praz−Rodet
Słowińskie
Stążki
Tăul Muced



All Sites
Britain & Ireland
Continental Europe
Scandinavia & Baltics
DACP
MWP
LIA
1751
1914
1756
1777
1990
Standardised WTD Value
Year CE
Age Error (yr)
0
100
200
400


A
B
C
70°N
60°N
50°N
40°N
10°W
0°
10°E
20°E
30°E
Peatland Analysis Data
Standardised WTD Value
2.5
1.5
0.5
-0.5
-1.5
-2.5
-3.5
Wetting
Drying
Literature-based Data
Wetting
Drying
Reanalysis Climate Change
Precip. (JJA mm)
25
20
15
10
5
0
-5
-10
-15
-20
-25
Temp. (°C)
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
-1.0
-1.5
-2.0
-2.5



	Cutting	Drainage	Burning	Grazing	Afforestation	Scientific activity	Damage index	Country	Latitude	Longitude
Britain & Ireland										
Ardkill[RB]	2	1	2	1	0	0	6	Ireland	53.3653	-6.9532
Ballyduff[RB]	2	2	1	1	0	0	6	Ireland	53.0807	-7.9925
Butterburn[RB]	1	1	1	1	2	0	6	England	55.0875	-2.5036
Cloonoolish[RB]	2	1	2	1	0	0	6	Ireland	53.1865	-8.2569
Dead Island[RB]	1	1	1	1	0	0	4	Ireland	54.8862	-6.5487
Derragh[RB]	2	1	1	1	0	0	5	Ireland	53.7667	-7.4083
Keighley[BP]	1	1	2	1	0	0	5	England	54.4253	-2.0369
Malham[RB]	1	1	1	1	0	0	4	England	54.0964	-2.1750
Slieveanorra[RB]	1	1	1	1	2	0	6	Ireland	55.0848	-6.1921
Continental Europe										
Bagno Kusowo[RB]	2	2	1	1	2	0	8	Poland	53.8078	16.5872
Barschpfuhl[RB]	0	0	0	1	2	0	3	Germany	53.0558	13.8494
Combe des Amburnex[PF]	1	1	1	2	1	0	6	Switzerland	46.5397	6.2317
Gązwa[RB]	1	2	1	1	1	0	6	Poland	53.8726	21.2201
Izery[RB]	0	1	1	1	0	0	3	Poland	50.8519	15.3602
Jelenia Wyspa[PF]	0	0	0	0	0	0	0	Poland	53.5918	17.9821
Linje[PF]	1	2	0	0	0	2	5	Poland	53.1880	18.3098
Mauntschas[PF]	0	0	0	1	0	0	1	Switzerland	46.4900	9.8544
Mechacz[RB]	0	1	0	0	1	0	2	Poland	54.3314	22.4419
Praz-Rodet[RB]	0	0	0	1	0	0	1	Switzerland	46.5667	6.1736
Słowińskie[RB]	1	2	0	1	0	0	4	Poland	54.3619	16.4785
Stążki[RB]	1	2	0	1	0	0	4	Poland	54.4244	18.0833
Tăul Muced[RB]	0	0	0	1	2	0	3	Romania	47.5739	24.5450
Scandinavia & Baltics										
Akerlänna Römosse[RB]	1	1	0	0	0	0	2	Sweden	60.0167	17.3667
Åltabergsmossen[PF]	0	1	0	1	3	0	5	Sweden	59.9667	18.6833
Gullbergbymossen[RB]	1	1	0	1	3	0	6	Sweden	59.6333	18.4333
Kontolanrahka[RB]	0	1	0	0	1	0	2	Finland	60.4783	22.4783
Lappmyran[PF]	0	0	0	0	0	0	0	Sweden	64.1647	19.5828
Lille Vildmose[RB]	1	1	1	1	0	0	4	Denmark	56.8391	10.1896
Männikjärve[RB]	0	1	1	0	0	1	3	Estonia	58.8667	26.2500
Stordalen 1[PP]	0	0	0	0	0	2	2	Sweden	68.3568	19.0484
Stordalen 2[PP]	0	0	0	0	0	2	2	Sweden	68.3564	19.0441

3	Major
2	Moderate
1	Minor
0	None known

	>4 Damaged
	3-4 Minor damage
	0-2 Relatively undamaged

RB = Raised bog (ombrotrophic)
BP = Blanket peatland (ombrotrophic)
PP = Permafrost plateau (ombrotrophic)
PF = Poor fen