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Solar influence on climate variability and human development during the Neolithic: evidence from a high-resolution multi-proxy record from Templevanny Lough, County Sligo, Ireland

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ABSTRACT

The relationship between climatic variations, vegetation dynamics and early human activity between *c.* 4150–2860 BC was reconstructed from a high-resolution pollen and geochemical record obtained from a small lake located in County Sligo, Ireland. The proxy record suggests the existence of a woodland with a largely closed canopy at the start of the fourth millennium BC. Only minor human disturbance is recorded. Following an episode of increased rainfall at *c.* 3990 BC, a decrease in the elm population occurred between *c.* 3970 and 3820 BC. This coincided with a period of warming and drying climatic conditions and an initial increase in anthropogenic activities. A second episode of high precipitation between *c.* 3830–3800 BC was followed by a steep increase in human impact on the landscape, which became most pronounced between *c.* 3740 and 3630 BC. At this time, the lake level of Templevanny Lough was at its lowest during the Neolithic.

The onset of wetter and cooler conditions after *c.* 3670 BC, representing the transition from the Early to the Middle Neolithic, coincided with a period of woodland recovery. The Middle Neolithic was characterised by pronounced climatic oscillations including periods of substantial rainfall between *c.* 3600 and 3500 BC and between *c.* 3500 and 3460 BC. A nearly century-long climatic amelioration between *c.* 3460–3370 BC facilitated a revival of human activity on a small scale around the lake. Abandonment of the area and full woodland recovery occurred after a period of particularly wet and cool conditions ranging from *c.* 3360–3290 BC. The pollen and geochemistry data suggest that the Late Neolithic was marked by a period of ameliorated conditions between *c.* 3110–3050 BC that was followed by two episodes of high rainfall at *c.* 3060–3030 BC and *c.* 2940–2900 BC.

The timing of the climatic shifts inferred from the Templevanny Lough record is in agreement with those of moisture/precipitation and temperature reconstructions from northern and western Europe and the Alps, suggesting that the studied period was characterised by a high-frequency climate variability. The results of the present study imply that human development during the Irish Neolithic was influenced by climatic variations. These climatic shifts correspond to variations in solar activity, suggesting a solar forcing on climate.

1. Introduction

Over the past decades, the Neolithic in Ireland has been the focus of a number of palaeoenvironmental and archaeological studies as this time period marks a rapid increase in human impact on the landscape (cf. O'Connell and Molloy, 2001; Cooney, 2007). The introduction of Neolithic practices including the construction of houses and other occupation sites, the erection of megalithic structures and the adoption of arable farming during the first quarter of the fourth millennium BC (Cooney, 2000; Cooney et al., 2011 and references therein) resulted in the widespread clearance of the primeval forest (O'Connell and Molloy, 2001).

Recent investigations suggest that climatic fluctuations had a major control on the intensity of human impact and societal developments during prehistoric and historic times (Magny, 2004; Mayewski et al., 2004; Turney et al., 2006; Büntgen et al., 2011). Palynological records from Ireland suggest that the notable

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increase in human activity during the Early Neolithic (4000–3600 BC; cf. Sheridan, 1995) broadly coincided with a period of climatic amelioration (Tipping, 2010; Stolze et al., 2012). Human impact was less intense during the Middle Neolithic (3600–3100 BC; cf. Sheridan, 1995) and declined noticeably during the Late Neolithic (3100–2500 BC; cf. Sheridan, 1995), facilitating woodland recovery in many areas (O'Connell and Molloy, 2001). This change was likely associated with a period of climatic deterioration (Caseldine et al., 2005; Verrill and Tipping, 2010; Stolze et al., 2012).

Based on the high-resolution multi-proxy record from Templevanny Lough in County Sligo, the present study confirms that climatic variability influenced human development in the region during the Neolithic. To test whether the observed variations correspond to large-scale climate patterns, the Templevanny Lough record is compared to high-resolution temperature and precipitation/moisture records from northern and Western Europe and the Alps. Following previous studies that established a link between climatic changes and fluctuations in the solar output during the Holocene (Bond et al., 2001; Mauquoy et al., 2002, 2008; Speranza et al., 2002; Blaauw et al., 2004; Magny, 2004), the established large-scale climate patterns are correlated to time-dependent variations in proxies of solar activity. Based on this comparison, it is argued that the climate during the Irish Neolithic was influenced by multi-decadal to centennial scale fluctuations in solar activity.

2. Study area

The study site is located in the southeastern Ballymote Lowlands in County Sligo (Fig. 1). This low-lying land is covered by glacial sand and gravel deposited on Carboniferous limestone (MacDermot et al., 1996). The Bricklieve Mountains, hills of cherty limestone, and the nearby hill of Keshcorran are prominent upland areas that rise to over 300 m above sea level (asl). To the south, the Ballymote Lowlands are bordered by the Curlew Mountains, a ridge of Devonian sandstone that reaches over 250 m asl (MacDermot et al., 1996).

A series of some twenty passage tombs, referred to as the Carrowkeel–Keshcorran megalithic complex, is located in the largely blanket bog covered Bricklieve Mountains and on Keshcorran (McGloin and Moore, 1996). A cluster of 153 hut sites was recognised on the limestone plateau of Mullaghfarna in the northeastern Bricklieve Mountains (Fig. 1) dating from between 3200 and 1100 BC (S. Bergh, pers. comm.).

At present, mild and moist climatic conditions with an average annual precipitation of 1150 mm and a mean annual temperature of 9 °C prevail. The predominant wind direction is west to southwest (online data of Met Éireann, 2012).

The study site, Templevanny Lough (54°02.10′N, 08°24.35′W) represents a glacially formed lake of oval shape (Fig. 2). Its small size of 2 ha allows the reconstruction of changes in the vegetation

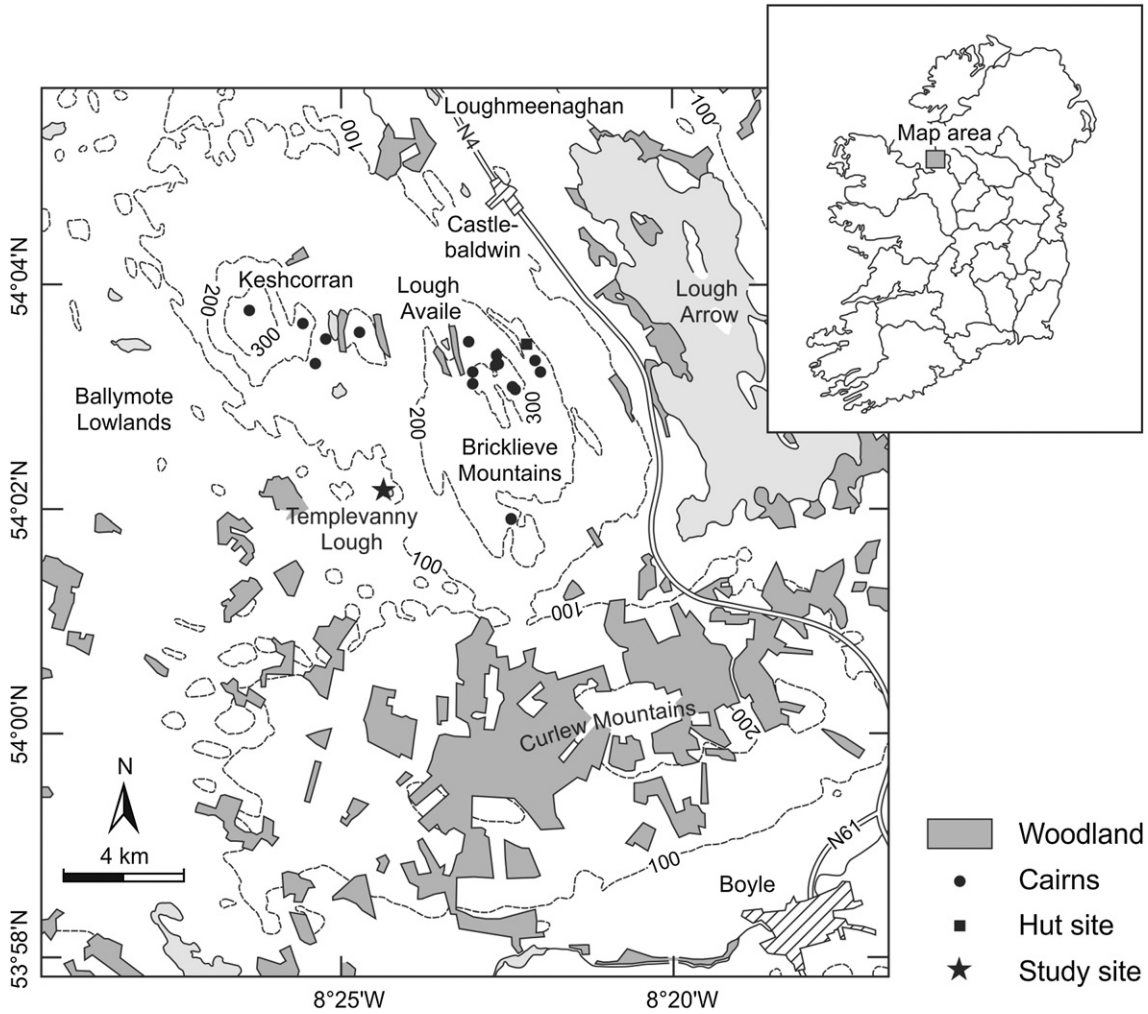

Fig. 1. Regional map of southwestern County Sligo, Ireland, showing the location of Templevanny Lough with respect to the locations of the passage tombs of the Carrowkeel–Keshcorran megalithic complex and hut sites at Mullaghfarna. Also shown are the previously studied sites of Lough Availe and Loughmeenaghan (Stolze, 2012a,b; Stolze et al., 2012).