ARTICLE IN PRESS

Journal of Archaeological Science xxx (2012) 1–8

Contents lists available at SciVerse ScienceDirect

Journal of Archaeological Science

journal homepage: http://www.elsevier.com/locate/jas

On the sensitivity of the simulated European Neolithic transition to climate extremes

Carsten Lemmen*, Kai W. Wirtz

Helmholtz-Zentrum Geesthacht, Institute of Coastal Research, Max-Planck Straße 1, 21501 Geesthacht, Germany

ARTICLE INFO

Article history:
Received 1 March 2012
Received in revised form
10 August 2012
Accepted 26 October 2012

Keywords:
Europe
Climate events
Extreme events
Neolithic transition
Adaptation
Modeling

ABSTRACT

Was the spread of agropastoralism from the Fertile Crescent throughout Europe influenced by extreme climate events, or was it independent of climate? We here generate idealized climate events using palaeoclimate records. In a mathematical model of regional sociocultural development, these events disturb the subsistence base of simulated forager and farmer societies. We evaluate the regional simulated transition timings and durations against a published large set of radiocarbon dates for western Eurasia; the model is able to realistically hindcast much of the inhomogeneous space-time evolution of regional Neolithic transitions. Our study shows that the consideration of climate events improves the simulation of typical lags between cultural complexes, but that the overall difference to a model without climate events is not significant. Climate events may not have been as important for early sociocultural dynamics as endogenous factors.

1. Introduction

Between 10 000 and 3000 cal BC, western Eurasia saw enormous cultural, technological, and sociopolitical changes with the emergence of agropastoralism, permanent settlements, and state formation (Barker, 2006). Human population experienced a dramatic increase (Bocquet-Appel, 2008; Gignoux et al., 2011), and people, plants and animals moved or were moved great distances (e.g., Zohary and Hopf, 1993).

While the Holocene possibly defines the start of major anthropogenic global environmental change (Lemmen, 2010; Kaplan et al., 2011), it also marks the period where climatic shifts could have affected human subsistence more severely than ever before: reduced mobility after investments in settlement infrastructure most likely increased the sensitivity of the novel farmers to environmental alterations (Janssen and Scheffer, 2004). There remains, however, considerable uncertainty on whether and how climate instabilities had influenced the development and spread of agropastoralism in Eurasia (Berglund, 2003; Coombes and Barber, 2005).

1.1. *Origin and spread of western Eurasian farming*

The Neolithic originated most probably in the Fertile Crescent, between the Levantine coast and the Zagros ridge. In this region, almost all European food crops and animals—wheat, barley, cattle, sheep, pigs—had been domesticated and inserted into a broad spectrum of foraging practices during the tenth millennium cal BC (Flannery, 1973; Zeder, 2008). Neolithic (farming based) life style emerged not before the 9th millennium BC in this core region (Rosen and Rivera-Collazo, 2012), and expanded to Cyprus by 8500 cal BC (Peltenburg et al., 2000); around 7000 cal BC, agropastoralism appeared on the Balkan and in Greece (Perlès, 2001). Propagating in a generally northwestern direction, agropastoralism finally arrived after 4000 cal BC on the British isles and throughout northern Europe (Sheridan, 2007); in a western direction, the expansion proceeded fast along the Mediterranean coast to reach the Iberian peninsula at 5600 cal BC (Zapata et al., 2004).

1.2. *Transitions and climate*

It has been argued that a precondition of agriculture was the relatively stable environment of the Holocene (Feynman and Ruzmaikin, 2007), and that only in this stable environment active cultivation and establishment of infrastructure such as fields and villages was favored (van der Leeuw, 2008). Within its relative stability, however, the Holocene climate exhibited variability on many spatial and temporal scales with pronounced multicentennial and millennial cycles (Mayewski et al., 2004; Wanner et al., 2008). In addition, non-cyclic anomalies have been identified (Wirtz et al., 2010), most prominently the so-called 8.2 and 4.2

* Corresponding author. Tel.: +49 4152 87 2013; fax: +49 4152 87 2020.
E-mail address: carsten.lemmen@hzg.de (C. Lemmen).

0305-4403/$ – see front matter
http://dx.doi.org/10.1016/j.jas.2012.10.023

events (around 6200 and 2200 cal BC, respectively, von Grafenstein et al., 1998; Cullen et al., 2000). Although the regional scale and intensity of the 4.2 event has been strongly questioned (e.g., Finné et al., 2011), the event had evoked the formulation of hypotheses on the connection between climatic disruptions and societal collapse (Weiss et al., 1993; DeMenocal, 2001). Similarly, the globally documented 8.2 event has been linked to the abandonment of many settlements in the Near East and simultaneous appearance of new village structures in southeast Europe (Weninger et al., 2005).

It might be coincidental that the 8.2 and 4.2 events define the time window of the Neolithic expansion in Europe, but the general view that environmental pressure on early Neolithic populations may have stimulated outmigration has been put forward since long (Childe, 1942). Dolukhanov (1973), Gronenborn (2009, 2010), or Weninger et al. (2009) suggest that climate-induced crises may have forced early farming communities to fission and move in order to escape conflicts. Berger and Guilaine (2009), to the contrary, see the role of climate events rather in creating opportunities: the rapid farming expansion into the Balkan could have been stimulated by an increase of natural fires after the 8.2 event, which opened up the formerly forested landscape.

1.3. How sensitive was the Neolithization to climate?

The relevance of climate variability and external triggers for prehistoric agricultural dynamics has been severely questioned (e.g., Erickson, 1999; Coombes and Barber, 2005). Alternative theories of the Neolithic transition underline the agency of early societies (Shanks and Tilley, 1987; Whittle and Cummings, 2007). On the other hand, the development of technological, social, and cultural complexes can hardly be thought to evolve independently of their variable environments; and the spatio-temporal imprint of the Neolithization in Eurasia requires a geographic approach which resolves how people and/or goods and practices migrated over long distances. Berglund (2003), e.g., suggested a stepwise interaction between agriculture and climate but found no strong links for northwest Europe.

The dispersal of agriculture into Europe has long been mathematically formulated based on Childe's (1925) observation on the spatio-temporal distribution gradient of ceramics that Ammerman and Cavalli-Sforza (1971) formulated as the 'wave of advance' model. This simple—and also the later more advanced ones (Ackland et al., 2007; Galeta et al., 2011; Davison et al., 2006)—diffusion models received support from linguistic (e.g. Renfrew, 1987) and archaeogenetic work (e.g. Balaresque et al., 2010). The dispersal of agriculture in these models occurs concentrically, and can be modulated by topography and geography. This dispersal model is not able to describe the inhomogeneous spatio-temporal distribution of radiocarbon dates, which are, e.g., apparent in regionally different stagnation periods ('hypothèse arythmique', Guilaine, 2003; Rasse, 2008; Schier, 2009).

Stagnations are visible in the simulation by Lemmen et al. (2011), who integrate endogenous regional sociocultural dynamics with the dispersal of agriculture. Their approach connects social dynamics—as optimally evolving agents—to regionally and temporally changing environments; in addition, they account for the spatio-temporal spread of populations and technological traits. Their Global Land Use and technological Evolution Simulator (GLUES) has proven to produce realistic hindcasts of the origin and distribution of agropastoralism and concomitant cultures around the globe (Wirtz and Lemmen, 2003; de Vries et al., 2002), for Eastern North America (Lemmen, Unpublished), the Indus valley (Lemmen and Khan, in press), and western Eurasia (Lemmen et al., 2011). Using GLUES and a globally synchronous climate forcing signal, Wirtz and Lemmen (2003) found a general delay of the simulated regional Neolithic due to climate fluctuations; at a global scale, differences in hindcasted sociocultural trajectories proved to be largely independent of temporal disruptions.

We here use temporal disruptions that are defined as excursions of a climate variable far from the local mean climate, i.e. extreme climate events; we do not consider rapid climate shifts that abruptly alter the climate mean state (e.g., Dakos and Scheffer, 2008). The hypothesis that extreme climate events had significant impacts on the Neolithization of Europe is critically examined: we employ GLUES as a deductive tool to reconstruct the Neolithic transition in Europe and evaluate the simulated reconstruction against the radiocarbon record of Neolithic sites in two experiments: (1) one including climate events, represented by a pseudo-realistic spatially resolved climate event history for the period 9500–3000 cal BC; and (2) another without climate events.

2. Material and methods

2.1. Reconstructing climate event history

We used a data collection of 134 globally distributed, high-resolution (<200 a) and long-term (>4000 a) palaeoclimate time series collected from public archives and published literature. The collection only contains studies where the respective authors indicated a direct relation to climate variables such a precipitation, temperature, or wind regime (e.g. Bond, 1997; Wick et al., 2003; Chapman and Shackleton, 2000; Gasse, 2000). A large part of this data set (122 time series) was previously analyzed by Wirtz et al. (2010) for extreme events; a complete overview of time series in this collection is provided in the supporting online material (Table S1). Due to the different types of proxies originating from both marine and terrestrial sites (mostly $\delta^{18}O$, see Table 1) the relation to climate variables is often ambiguous, also in sign. This ambiguity does not affect our analysis, as we are only interested in the spatio-temporal characterization of extreme events: a drastic excursion from a climate mean state stressed regional habitats and human populations regardless of its direction.

Our data set comprises 134 palaeoclimate time series, all of them long-term and high-resolution, and provides the best spatial and temporal coverage of any study we are aware of. Previous collections used 18, 50, 60 or 80 records (Wanner et al., 2008; Mayewski et al., 2004; Holmgren et al., 2003; Finné et al., 2011, respectively), mostly limited to the last 6000 years. The coverage we use here is sufficient to represent climate variability in almost all land areas of the world (with sparsest regional coverage in central Australia, Saharan Africa, and Northern-Central Eurasia), considering the spatial coherence of climate signals within 1500 km distance found by Wirtz et al. (2010) for their similar data set.

From the global data set, 26 time series are located in or near our focus area western Eurasia (Table 1). For these time series we analyzed the non-cyclic event frequency according to the procedure in Wirtz et al. (2010): time series were detrended with a moving window of 2000 years and smoothed with a moving window of 50 years, then normalized (Fig. 1b). Events were detected whenever a time series signal exceeded a confidence interval with threshold $p = 1 - 1/n$, where n is the number of data points (Thomson, 1990), and where each event is preceded or followed by a sign change in the time series.

For each simulation region, events from spatially overlapping or nearby proxy locations were used to construct an aggregated event time series specific to this region (Fig. 1a–c): (1) a Gaussian filter with $\tau = 175$a (corresponding to the dating uncertainty in many records) standard deviation was applied to each event; (2) the distance of the proxy location to the simulation region was used to assign exponentially decreasing weights to each event; (3) all event

Please cite this article in press as: Lemmen, C., Wirtz, K.W., On the sensitivity of the simulated European Neolithic transition to climate extremes, Journal of Archaeological Science (2012), http://dx.doi.org/10.1016/j.jas.2012.10.023