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E-mail: Eurasia@archaeology.nsc.ru

C. Lemmen
Institute for Coastal Research, Helmholtz-Zentrum Geesthacht,
Max-Planck-Straße 1, 21502, Geesthacht, Germany
E-mail: carsten.lemmen@hzg.de

MECHANISMS SHAPING THE TRANSITION TO FARMING IN EUROPE AND THE NORTH AMERICAN WOODLAND

Despite the fact that Europe and Eastern North America both have similar woodland environments, the emergence of agriculture in these areas proceeded very differently varying in timing, speed, and mechanism. To analyze the different subsistence paths the Global Land Use and Technological Evolution Simulator was used, a numerical model for simulating demography, innovation, domestication, migration and trade within the geoenvironmental context. I demonstrate how Europe receives a large package of foreign domesticates and converts rapidly. In contrast, trajectories relating to Eastern North America exhibit a gradual transition in which hunting and gathering and agropastoralism coexist for a long period of time, and agriculture is integrated slowly into the existing subsistence scheme. I deduce from this a qualitative economic difference in the two regional transitions: limited population size in Europe, limited resources in Eastern North America.

Keywords: *Early agriculture, Neolithic package, pre-Columbian population, adaptive dynamics, sociotechnological model, human ecodynamics.*

Emergence of farming in woodlands

In the Levant and along the Chinese Yellow and Yangtze rivers, the first green revolution occurred between 10,000 BC and 8000 BC when the predominant hunter-gatherer life style was replaced by agriculture and pastoralism (Willcox, 2005; Kuijt, Goring-Morris, 2002; Londo et al., 2006). Subsequently, this new method of procuring food resources took hold in almost every society around the globe, at different times, at different speeds, and via different mechanisms. Where agriculture did not arise independently, or where the local domesticates where insufficient to serve as staple crops, agriculture was imported from founder regions either via prehistoric trade networks or by migrants (e.g., (Wen et al., 2004; Fuller, 2011; Lemmen, Gronenborn, Wirtz, 2011)). Europe and Eastern North America (ENA) are prime examples of regions in which non-independent agriculture emerged (for ENA see (Price et al., 2001; Zeder, 2008; Smith, 2011)).

In most of Europe, the transition to farming occurred between 6000 BC and 4000 BC, marking a continuous temporal gradient from the southeast (earliest agriculture in Greece and the Balkan (Perlès, 2001)) to the northwest (southern Scandinavia (Price, 2003) and Britain (Whittle, Cummings 2007)). The most prominent example of a large-scale homogeneous agricultural complex is the Linearbandkeramik culture of central Europe (Lüning, 2005). None of the crops used had been domesticated locally in Europe, being imported from the west Asian founder regions; everywhere, the emergence of agriculture was associated with the appearance of ceramic artifacts. The Neolithic package which was delivered to Europe is comprised of food crops and animals that have their origins in the wider region of the Fertile Crescent (Flannery, 1973), and is comprised of wheat, barley, rye, lentils, peas, cattle, sheep, goat, and pigs (Willcox, 2005; Luikart et al., 2001; Edwards et al., 2007; Larson et al., 2007; Zeder, 2008). Genetic analyses (Haak et al., 2010) provide evidence of a

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demic process, i.e. people carrying the Neolithic package into Europe but diffusion-only scenarios are equally likely in expansion model studies (Ackland et al., 2007; Lemmen, Gronenborn, Wirtz, 2011).

The transition to farming occurred much later in North America, between 1000 BC and 1000 AD, a period denoted as the Woodland stage in ENA. Local domesticates like amaranth and sunflower had been cultivated alongside a predominantly hunter gatherer economy, but gradually corn and beans were introduced from Mexico and became the staple crops; domesticated animals were absent (Piperno, 2011). The Woodland period is characterized by continuous pottery artifacts and a gradual increase in the dependence on agriculture (Anderson, Mainfort, 2002). In contrast to Europe, crops were diffused by trade rather than via migration from the founder regions into ENA, and their cultivation was adopted by the resident population (Hart, 1999).

The success of growing crops is restricted to suitable climatic conditions and sufficient soil and water resources. With the exception of the dry plateaus along the Western Cordillera, North America and Europe exhibit similar climatic conditions, vegetation types and topography, both with a variety of landscapes and features like large rivers, mountain ranges, plains, and rolling hills. The natural vegetation type on the majority of North American and European area is temperate forest (Williams et al., 2000; Thompson, Anderson, 2000; Cheddadi et al., 1997).

In this study, I employ the Global Land Use and Technological Evolution Simulator (GLUES) which resolves the diffusion of local innovation, migration and cultural values (Wirtz, Lemmen, 2003; Lemmen, Gronenborn, Wirtz, 2011). I demonstrate that the model is capable of explaining the global onset of agriculture for many world regions very reasonably; here, I restrict my analysis of the global model to North America and Western Eurasia. I elaborate on the differential processes leading to agriculture in Europe and the Eastern North American Woodland region, and I estimate the pre-Columbian population in the Woodland region.

Material and methods

GLUES (Wirtz, Lemmen, 2003; Lemmen, 2010; Lemmen, Gronenborn, Wirtz, 2011; Lemmen, Wirtz, 2012) describes the evolution of regional sociocultural traits constrained by a biogeographical setting. Available resources exploited by regional societies are based on regional net primary production, derived for the past by applying Climber-2-simulated temperature and precipitation anomalies (Claussen et al., 1999) on the IIASA climatological data base (Leemans, Cramer, 1991), and a bioclimatic limit vegetation model (Lieth, 1975). The conceptual model is outlined below (for details on the algorithms used and the mathematical implementation see (Wirtz, Lemmen, 2003; Lemmen, Gronenborn, Wirtz, 2011)).

Sociocultural model. The sociocultural realm is described by three characteristic traits of a population and its demographic density. The temporal evolution of each trait follows the gradient of increased benefit for success (i.e., growth) of its associated population (Dieckmann, Law, 1996; Wirtz, Eckhardt, 1996). The evolution of the distribution of each trait in terms of its moments, not a single realization of the trait values is simulated. A short description of the characteristic traits is given below.

(1) Technology is a trait which describes the efficiency of food procurement and the effectiveness of basic health care. In particular, it describes the availability of tools and weapons, storage and organization of labor. Included in this trait is writing as a means for administration and cultural preservation, and transport.

(2) The relationship of farming and herding activities (energy or time or manpower) with respect to the total food sector.

(3) The number of agropastoral economies available to a regional population; though I do not attribute named plants and animals to each economy, as an example, a number of four is obtained when pig farming, barley and wheat harvesting, as well as goat herding are present in one population. With this setup I follow Shennan (2001) by directly coupling population dynamics with the process of cultural evolution.

Model parameters are constrained by requiring that the emergence of agropastoral centers in five founding regions be successfully simulated by appropriate timing as suggested by Smith (1998: 12): these are the Fertile Crescent (7500 BC), central Mexico (7000 BC), South China (8500 BC), North China (7800 BC), south central Andes, (7000 BC), and the eastern United States (4500 BC)*. For each simulation with random parameter variation, a score is calculated considering the spatiotemporal distance from these centers. The highest scoring parameter set from one million simulations was selected for the hindcast study in this paper.

The conceptual basis of the mathematical model is as follows. Within each biogeographically defined region (average size $127 \cdot 10^3$ km^2), a Mesolithic hunter-gatherer population is incubated at simulation start. The Mesolithic population grows with a speed constrained by sociocultural traits, and is limited by natural resources. As technologies become more powerful, resources are more efficiently exploited and first domesticates are brought under control. Demographic density and technologically advanced exploitation put pressure on the environment and reduce usable resources. Only when the combination of technologies and domesticates outweighs the hunter-

*In this paper, I use present day names to refer to approximate geographic location.