S08 Modelling approaches to analyse the socio-economic context in archaeology II: Defining the limits of production

Philip Verhagen, Monica de Cet

At CAA2015, we organized a fruitful and stimulating session on spatio-temporal modelling of socio- economic processes in archaeology. At this year's conference, we want to continue the debate, and in particular focus on the issue of establishing boundaries of production. Past societies, whether they were hunter-gatherers or complex state societies, were all forced to deal with the problem of producing sufficient food and other resources to meet economic as well as social demands.

The debate on the limitations of socio-economic systems for the production of resources is currently more often based on educated guesses than on a good understanding of the processes involved. The interplay between the (potential) availability of resources, and the necessary workforce, technology and socio-economic structures (like land ownership, taxation or access to markets) is a complex field of study, in which significant steps forward are being made through the combined use of GIS, statistical simulation and dynamical systems and agent-based modelling.

We are, however, still far removed from a common modelling approach to these issues that will allow us to easily make cross-regional, multi-scalar and diachronic comparisons. In this session, we want to address questions such as: - what data sources and variables to include - what modelling techniques and analysis protocols to use - what theoretical frameworks to apply - how to model at different scale levels - and how to interpret the results of our models. We therefore specifically want to invite papers dealing with one or more of the following issues:

- demographic processes and their socio-economic impact - competition for resources at different scale levels, from the household to the state - settlement patterns, territories, accessibility and control of resources - the role of socio-economic and cultural constraints - the utility of ethnographic data and comparisons - sensitivity analysis of modelling approaches - modelling with large data sets

S08-01 Putting production landscapes into context: A multi-faceted case study from Upper Mesopotamia during the Early Bronze Age

Tuna Kalayci

Second half of the Third Millennium BCE (mid-to-late Early Bronze Age) in Upper Mesopotamia was signified by a rapid urbanization period and intensification of agricultural production. Settlement nucleation in tell-based settlements evidently created a new form habitation. Furthermore, developments in the politico-economics (e.g. secondary state formation, textile production as a high- commodity) must have had considerable impacts on agricultural landscapes. In combination of these two events, it is possible that the main determinants of the change in food production were due to the increased demographic pressure and the systematic integration of animal husbandry -as the source of wool.

In order to test this hypothesis, the study provides a quantitative model of the EBA agricultural production for highlighting the relationship between minimum biological requirements and estimates of food levels. Following this model, the discussion focuses on the anomalous variations in production levels under the axiom that high population levels required higher amount of foodstuffs, and thus, must have necessitated more input for the sustainment. Next, it evaluates these variations for different planting strategies (e.g. fallowing) so that a more realistic picture can be drawn. Finally, the model results are re-assessed for its ethnographic corollaries for the issues of agricultural surplus, storage and social stratification.

S08-02 Quantifying change: An evolutionary approach to interpret the amphorae production in the Roman Empire

Maria Coto-Sarmiento, Xavier Rubio-Campillo, José Remesal

The aim of this study is to explore the dynamics of change in amphoric production within the Roman Empire. In particular, an evolutionary framework is applied to understand the mechanisms of changes in olive oil amphorae [1].

This analysis can be developed by the fact that we detect differences in the amphorae production through time that allow us to quantify the rates of change. One of the main challenges of this approach is the high level of uncertainty associated to the archaeological chronologies. In addition, this problem is combined with the lack of a formal framework to apply on the conventional techniques for the analysis of the amphorae dataset.

In order to achieve this goal the study uses a quantitative framework based on cultural evolution theory. It provides a set of methods that can be used to account these changes in the production of olive oil amphorae. In this context, it will be presented a research where this methodology has been used to show its capacity to detect the culture trajectories. In particular, our case study has been focused to understand the dynamics of change of olive oil amphora production found in Baetica (currently Andalusia) during the Roman Empire (1st-3rd century AD). Specifically phylogenetic approach has been applied to quantify the morphological distance between pottery assemblages in order to identify discontinuities in archaeological and historical sequences. The phylogenetic tree created with this method will then be used to explore rates of change detected in the amphorae. In particular, we want to identify if these changes were produced by cultural reasons as it may be economical, political and social changes.

The analysis explores how the framework provided by evolutionary archaeology can provide a useful base for understanding change in production processes using material culture. Finally, the results suggest that different factors can influence rate of change and thus different speeds can be identified with distinguishable patterns of social behaviour.

References [1] Mesoudi, A. (2015) Cultural Evolution: A review of Theory, Finding and Controversies, Evolutionary biology

S08-03 Boundaries of agrarian production in the Bergisches Land in 1715 AD

Irmela Herzog

The boundaries of agrarian production for the Bergisches Land east of Cologne in 1715 AD can be deduced from historical sources including maps created in the years up to 1715 AD and modern topographic data. The historical maps indicate the settlement sizes ranging from mills and single farmsteads to towns with walls. The maps are complemented by images of the two towns in the study area and a text describing the economy of each administrative unit covered. According to this additional information, in 1715 AD the towns were quite small and the economy relied mostly on agriculture (oat, pigs, and cattle). This applies even to the town controlling a bridge of an important trade route. Moreover, the maps show a large proportion of today's settlements, hardly any additional settlement locations can be found in the maps created in 1848. For this reason it seems plausible to assume that the study area was nearly full in 1715 AD. Different approaches to allocate territories to the settlement locations shown on the 1715 AD maps are discussed, based both on straight-line and least-cost distances. For allocation methods ignoring the settlement size the quality of the result is assessed by checking the relationship between territory size and settlement size. The paper also presents approaches for predicting the location of patches where additional settlements were founded after 1715 AD.

S08-04 Factors of production: Investigating land and labour as limiting factors in agricultural production in the Dutch Roman limes zone via agent-based modelling

Jamie Joyce, Philip Verhagen

In this paper, we investigate the role of land and labour availability in the rural economy of the Dutch Roman limes region via agent-based modelling. The availabilities of land and labour pose limits on agricultural production and are regarded in economics as two of the primary factors or inputs in the production process determining the quantity of output. Although recent research has now prompted a departure from the previously held view that surplus production in the region was not possible (see Kooistra et al. 2013; van Dinter et al. 2014), we still don't know how the shift from subsistence farming to surplus production occurred. The likely methods of surplus production undertaken by local farmers, the limiting factors in agricultural production within different temporal and geographic scales and possible mitigation strategies have hitherto only been dealt with in generalist terms. To investigate these topics, we have produced an agent-based model in NetLogo to simulate the rural economy of the region with land and labour costs as primary outputs. We have simulated methods and strategies in the three most significant elements of this economy: animal husbandry, arable farming and wood-fuel acquisition. By comparing the model results against archaeological data of the natural and cultural landscapes in the region, we are able to test the scenarios for plausibility. In addition, the model has enabled us to investigate the elements of the rural economy not only as separate activities but in combination, reflecting the mixed agriculture practiced in the region in this period. Lastly, we are able to simulate a dynamic economy both temporally and geographically by imposing on agents conditions known from the region. We present here therefore the initial results from the model and our conclusions in defining the limits of production in the Dutch Roman limes zone.

S08-05 Socio-economic analysis and GIS modelling: A pilot study from rural society in Northeastern Italy

Monica De Cet

Rural society from the second half of the XIX century CE in the mountain area of Northeastern Italy showed interesting dynamics of subsistence production. Products from land were one of the main sources of subsistence and cereals were largely consumed. This poster illustrates a pilot study of socio- economic analysis through GIS technology. It shows how a socio-economic approach, previously developed in De Cet, in press for the Mediterranean island of Menorca (Spain) can be reapplied in a mountain region. The study area is now the piedmont region of Alps, in the National Park of Dolomites-province of Belluno, Italy (Unesco site), characterized by an important natural and historic heritage. The geographical framework is a small scale area of around 150 hectares, nearby the city of Feltre and the chronology considers the second half of the XIX century CE.

This research illustrates the boundaries of subsistence production, where are involved the following variables: a. demographic sample (c. 1000 people), b. diet based on wheat and barley, c. rudimental technology, d. isolated mountain area, and d. political system focused on patriarchal structure. I illustrate the results as multi-scalar maps, where human exploitation of agrarian resources is observable. These outputs have been obtained from historical cadastral maps through spatial analysis techniques (e.g. Kernel densities) combined with palaeo-agrarian calculations (e.g. cereal harvest per person). Maps have highlighted an economic strategy with self-sufficient families, land fragmentation, and direct political control of farmers on land (De Cet, in press-b). In fact, historical sources point out the difficulty of finding a balance between available land, subsistence needs, and manpower. The final aim is to contribute to the discussion on the resolution of socio-economic results obtained using GIS-based modelling, multiscalar approach, and ethnographic data.

S08-06 Co-evolution of culture and trade : Impact of cultural network topology on economic dynamics

Simon Carrignon, Jean-Marc Montanier, Jerome Michaud, Xavier Rubio-Campillo

Trace of the economic activity in the archaeological record are scarce which make the understanding of past economy difficult. Nowadays economic studies could bring new tools and models that could help to fill that gap, however such models badly incorporate cultural aspect of past society.

In this study we want to mix those approaches by mixing cultural and economical model to look at how the local cultural environment of individuals in a society could influence the global dynamics of the economy of this society.

To do so we use a trade model that has been shown to converge to an optimal market without central authority. In this model, individual have to trade a good they produce in order to get other goods they need, and can change their trading strategies by imitating the strategy of the most successful individuals.

In this previous model the cultural environment of the individual was made of every other agents in the system, i.e. all agents were able to know the success of all the other agents and imitate anyone of them. With this imitation mechanism and the simple trade system, all were quickly able to exchange the good they produce in a way that allows us to get the other goods, without the need of a central coordination.

In the current paper we want to study in what extend the capacity of this model to converge to an optimal and decentralized market depends on the properties of the cultural network of the individuals. To do so we change the cultural environment of the agents by creating a wide variety of different typologies of networks with different properties leading to different cultural environment. For each cultural environment, we then run simulations and observe and measure the properties of the resulting economic dynamics.

We thus aim to model the coevolution of both components (cultural and economic) and how different trade networks (based on knowledge of the Roman Empire) affect their dynamics. In coming study we hope to fruitfully apply this approach to evaluate the probability that this kind of economy evolved during the Roman Empire, using trade network reconstructed via Archaeological and Historical evidence.

S08-07 Defining boundaries: A GIS-based approach to the Sardinian Bronze Age

Francesca Cadeddu

This paper introduces a spatial statistical analysis in a GIS environment on the settlement patterns of the Nuragic civilisation, a long-lasting culture that existed in Sardinia (Italy) from the Middle Bronze Age (ca. 1600 BC) to the First Iron Age (ca. 800 BC). The aim is to perform a test of the major theory proposed by scholars concerning the Nuragic civilisation, the cantonal system theory, a hierarchical settlement organisation according to which, during the Bronze Age, Sardinia was divided in regional polities, partitioned in districts called cantoni. In this paper the focus will be especially on settlement patterns with the purpose to assess the existence of these polities finding their territorial boundaries, as a necessary first step for the reconstruction of the socio-economic context of the Nuragic civilisation. GIS and spatial statistical analyses (i.e. Thiessen Polygons and Viewshed Analysis) are used to examine a sample area, represented by the historical region of Gallura, located in the northeastern part of Sardinia. The method created allows for the first time to validate the existence, during the Sardinian Bronze Age, of territorial systems formed by interconnected communities, and to identify defined boundaries for these systems. The results provide new data on the Nuragic civilisation through the identification of overall common attributes in the settlement and economic strategies of these territorial systems, with some specific variances

according to different environmental conditions. This research builds the foundation to analyse and reconstruct the exploitation strategies of the natural resources carried out by these Nuragic communities, creating also a provisional model of their demographic capacity.