

## PROJECT CONFERENCE 'FINDING THE LIMITS OF THE LIMES'

26-27 JANUARY 2017

VRIJE UNIVERSITEIT AMSTERDAM



### **VENUE**

Vrije Universiteit Amsterdam, main building  
De Boelelaan 1105  
1081 HV Amsterdam

Thursday 26 January 2017: room 14A33

Friday 27 January 2017: room 06A33

Route description: <http://www.vu.nl/en/about-vu-amsterdam/contact-info-and-route/index.aspx>

### **ORGANISERS**

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## **WELCOME**

Dear colleagues,

We are very happy to welcome you in Amsterdam for our two-day project conference '*Finding the limits of the limes*'. In this conference, we want to present the preliminary outcomes of our research, and to discuss the results within the broader framework of the application of computer modelling techniques to questions of subsistence economy, demography, transport and socio-economic networks. In this way, we not only hope to get useful feedback from all of you, but also to strengthen the network of researchers working on modelling approaches in (Roman) archaeology.

More background on the project, as well as the resulting presentations and publications can be found on our project website, <http://limeslimits.wordpress.com>.

We wish you a pleasant and productive conference!

Philip, Jamie and Mark

## CONFERENCE PROGRAMME

### THURSDAY 26 JANUARY 2017, ROOM 14A33

- 09:30 – 09:45 Welcome and introduction
- 09:45 – 10:15 Nico Roymans (Vrije Universiteit Amsterdam)  
*Setting the scene: characterising Batavian society at the edge of empire in the Dutch river area*
- 10:15 – 10:45 Philip Verhagen (Vrije Universiteit Amsterdam)  
*Modelling the cultural landscape of the Dutch Roman Limes: approach, results and prospects*
- 10:45 – 11:00 COFFEE BREAK
- SESSION 1 Modelling subsistence economy (chair: Mark Groenhuizen)**
- 11:00 – 11:30 Session keynote: Wim Jongman (University of Groningen)  
*What did the Romans ever do for us?*
- 11:30 – 12:00 Jamie Joyce (Vrije Universiteit Amsterdam)  
*Simulating the Roman farm: Investigating the limits and possibilities of the agricultural economy in the Roman Dutch limes zone via agent-based modelling*
- 12:00 – 12:30 Tilman Baum (University of Basel)  
*Models of Land-use in the Neolithic Pile-Dwellings of the Northwestern Pre-Alpine Forelands (4400-2400 BC)*
- 12:30 – 13:15 LUNCH BREAK
- 13:15 – 13:45 Antoni Martín i Oliveras (University of Barcelona)  
*The economy of Roman wine. Productive landscapes, archaeological data, quantification and modelling. Case Study Research: “Regio Laetana-Hispania Citerior Tarraconensis” (1st century BC-3th century AD)*
- 13:45 – 14:15 Tyler Franconi (University of Oxford):  
*Cultivating change: Roman agricultural production and soil erosion in the Thames River basin*
- 14:15 – 14:45 Maurice de Kleijn (Vrije Universiteit Amsterdam), pre-recorded presentation  
*Simulating land-use for the Lower Rhine-Meuse delta in the Roman period*
- 14:45 – 15:15 Eli Weaverdyck (University of California, Berkeley)  
*Farmers and Forts in Moesia Inferior: Modelling agricultural strategies on the Lower Danubian Frontier*
- 15:15 – 15:30 TEA BREAK
- SESSION 2 Modelling demography (chair: Jamie Joyce)**
- 15:30 – 16:00 Session keynote: Isabelle Séguy (Institut National des Études Démographiques, Paris)  
*Current trends in demographic studies in archaeology*
- 16:00 – 16:30 Philip Verhagen (Vrije Universiteit Amsterdam)  
*From population dynamics to settlement patterns. Linking archaeological data to demographic models of the Dutch limes*
- 16:30 – 17:00 Wim De Clercq (University of Ghent)  
*The Disastrous Effects of the Roman Occupation!? Population dynamics and rural development on the fringes of the Roman Empire: theories and models*
- 17:00 – 18:30 DRINKS

## FRIDAY 27 JANUARY 2017, ROOM 06A33

- SESSION 2      Modelling demography (chair: Jamie Joyce)**  
09:30 – 10:00    Chris Green (University of Oxford)  
*Modelling evidence densities: past population variation or modern structuring affordances?  
The case of England from the Iron Age to the early medieval period*
- 10:00 – 10:30    Antonin Nüsslein (École Pratique des Hautes Études, Paris)  
*A different vision of ancient settlement dynamics: creation and application of a model of  
evolution of the Antique habitat of the Plateau Lorrain*
- 10:30 – 10:45    COFFEE BREAK
- SESSION 3      Modelling transport (chair: Jamie Joyce)**  
10:45 – 11:15    Philip Verhagen (Vrije Universiteit Amsterdam)  
*Integrating detection and modelling of ancient pathways: towards a spatio-temporal,  
multiscalar approach*
- 11:15 – 11:45    Mark Groenhuijzen (Vrije Universiteit Amsterdam)  
*Diverse movement in a dynamic environment: modelling local transport in the Dutch part of  
the Roman limes*
- 11:45 – 12:15    Rowin van Lanen (University of Utrecht/Cultural Heritage Agency of the Netherlands)  
*Shopping for wood during the first millennium AD: modelling Roman and early-medieval  
long-distance transport routes in the Netherlands using a multi-proxy approach*
- 12:15 – 13:00    LUNCH BREAK
- 13:00 – 13:30    César Parcero-Oubiña (INCIPIIT - CSIC, Santiago de Compostela)  
*Postdicting Roman Roads in the NW Iberian Peninsula*
- 13:30 – 14:00    Katherine Crawford (University of Southampton)  
*Walking Between Gods and Mortals: reconsidering the movement of Roman religious  
processions*
- SESSION 3      Modelling socio-economic networks (chair: Philip Verhagen)**  
14:00 – 14:30    Session keynote: Tom Brughmans (University of Oxford)  
*Network science in Roman studies: the potential and challenges*
- 14:30 – 15:00    Mark Groenhuijzen (Vrije Universiteit Amsterdam)  
*Possibilities and challenges in the use of networks to study socio-economic relations in the  
Dutch part of the Roman limes*
- 15:00 – 15:15    TEA BREAK
- 15:15 – 15:45    Pau de Soto (Universidade Nova de Lisboa)  
*Network analysis to model and analyse Roman transport and mobility*
- 15:45 – 16:15    Angelo Castrorao Barba (University of Palermo)  
*Multi-scalar approach to long-term dynamics, spatial relations and economic networks of  
the Roman secondary settlements in Italy: towards a model?*
- 16:15 – 17:00    Final discussion

## ABSTRACTS

### SESSION 1: MODELLING SUBSISTENCE ECONOMY

#### ***What did the Romans ever do for us?***

*Wim Jongman, University of Groningen (keynote lecture)*

‘What did the Romans ever do for us?’ Few have nailed the fundamental question of Roman provincial history and archaeology with greater precision than the Monty Python team in their *Life of Brian*. For decades, the answer has been a pretty damning one, with a florid rhetoric of post-colonial scepticism. Similarly, even for its imperial core the success of the Roman economy has been seriously questioned by the overwhelming intellectual stature of its most perceptive analyst, the late Sir Moses Finley.

In my paper intend to argue that such scepticism has been unwarranted, once we take the vast quantities of new archaeological data into account. For a few centuries before and after the beginning of the modern era, the Roman Empire witnessed a remarkable growth of both population and standard of living, unprecedented levels of urbanization and truly urban life, more trade and connectivity than ever before and for a long time after, and favourable institutions.

I also want to argue that this prosperity was not the product of exploitation of the periphery by the imperial core, but was a genuine economic growth that extended to the provinces and benefiting large numbers of people.

#### ***Simulating the Roman farm: Investigating the limits and possibilities of the agricultural economy in the Roman Dutch limes zone via agent-based modelling***

*Jamie Joyce, Vrije Universiteit Amsterdam*

This paper presents the final results of an agent-based modelling approach to investigate the limitations on the agricultural economy of rural settlements in the Dutch *limes* zone between the late Iron Age and Middle Roman periods.

This research was undertaken under the remit of Finding the limits of the *limes* project specifically to understand the possibilities of agricultural production under the natural and cultural conditions present in the region in the Roman period. Specifically, we have used a spatial dynamic approach to reveal how the availability of land and labour affected agricultural productivity of farmers and possibilities of surplus production.

We have developed an agent-based model using NetLogo to analyse the principle determinants and limitations on subsistence and surplus farming in the region. The model simulates in unison the major tasks within a mixed agricultural economy: arable farming, animal husbandry and collection of wood for fuel and construction. Initial experiments were conducted to analyse the demand placed on land and labour by settlements undertaking these tasks within a subsistence-based economy. Further scenarios were simulated in which diverse agricultural strategies were undertaken to evaluate the feasibility of these different approaches in producing surplus.

This paper presents a detailed description of the simulation model including assumptions, behavioural rules and primary characteristics before presenting the results of key scenarios simulated, including both scenarios used as heuristic devices and those based upon data derived from archaeological data. Subsequently, the principle findings of this ABM approach to modelling the ancient rural economy of the Dutch limes zone will be shown and, in particular, how these findings impact on the current state of knowledge. Finally, the usefulness and limitations of our approach to the investigation of a complex system such as agriculture will be offered.

***Models of Land-use in the Neolithic Pile-Dwellings of the Northwestern Pre-Alpine Forelands (4400-2400 BC)***

*Tilman Baum, University of Basel*

In pre-alpine lakes and peat bogs, debris of wetland settlements provides information about past human activities in very high resolution. Crop and animal husbandry, dietary habits, and use of timber and firewood have been studied based on the archaeological remains. This data is interpreted in different ways, leading to two very different ideas on crop husbandry methods: shifting cultivation and permanent cultivation. I present a modeling approach that combines the existing hypotheses on economic and environmental conditions with spatial information. The aim is to understand the implications of the different crop husbandry methods, to assess their plausibility, and to learn more about Neolithic land use and the human-environment feedbacks in the wetland sites. In a first step, a modern agro-ecosystem model is used to provide information on potential Neolithic crop yields and the variability caused by different soil properties, husbandry methods, and the effects of weather and climate. This information is fed into an agent-based model that simulates crop husbandry of an idealized wetland settlement. Thus, the implications of various hypotheses on crop husbandry methods may be observed. The spatial extent of the related activities, the work load, and the productivity of the simulated hypotheses are analyzed. In a third step, further land use activities are included in the model in order to analyze the spatial demand for land use activities. This is strongly dependent on economic parameters as well as the composition of the landscape in terms of anthropogenic alterations. Therefore, different scenarios are compared that cover different ideas on cattle densities, wood cover, and husbandry methods. Using the information gained by analyzing the models, I develop a model that seeks to explain the existing data more consistently than previous models.

***The economy of Roman wine. Productive landscapes, archaeological data, quantification and modelling. Case Study Research: "Regio Laetana-Hispania Citerior Tarraconensis" (1st century BC-3th century AD)***

*Antoni Martin Oliveras, University of Barcelona*

The study of the Roman viticulture economy has multiple fields of knowledge and expertise with enormous possibilities for research. Most studies have in common to use the archaeological information and the written sources as a complementary support to confirm the absolute chronology of a settlement, a socio-economic phenomenon or an exact location of a wine production centre or a pottery activity in a specific territory.

Regional variability is a key point for understanding the changing patterns of rural settlement and its evolution as the specific interaction between intra-regional and extra-regional economic networks.

These studies can be conducted by geospatial and geoeconomic analyses in different territorial levels: macrospatial (regio) mesoespatial (territorium) and microespatial (torcularium atque figlina).

The level of dependence of the rural population in the regional market, respect for local urban centers and their subsequent screening in foreign markets (in our case study research: Western Europe, Italian Peninsula and Rome itself), responding to a series of socioeconomic patterns and behaviors that may be modeled and studied by different economic and econometrical ways.

The extensive use of mathematical models, statistical and linear programming to analyze, interpret and make predictions/regressions and reconstructions on the evolution of those complex systems, regarding, inter alia, different variables as the potential production of a region or territory, the regional consumption, the surplus production that could be traded in foreign markets, and other variables such as the sale prices, the market reactions, the production and transport costs, and the trends of consumption, is an increasingly widespread reality.

This paper present a PhD Research Project that try to analyse in four scenarios, the answers to this questions and the evolution of this complex economic system, related with the production processes, the long-distance trade and the consumption of Laeetanian wine in the Roman period, between the 1st century BC and the 3th century AD.

***Cultivating change: Roman agricultural production and soil erosion in the Thames River basin***

*Tyler Franconi, University of Oxford*

The environmental impact of Roman agricultural exploitation was significant and sustained. While Rome's relationship with its environment is often portrayed in a deterministic light, it is important to recognise the complex feedback mechanisms that linked people to their landscape. This paper examines the environmental impact of Roman farming practice in the Thames River basin of southern England in order to understand how provincial agricultural economies both shaped and were shaped by their landscape.

This paper uses the database of archaeological material compiled by the English Landscapes and Identities Project to examine the full range of known Roman activity within the Thames basin. These records are considered against a model of soil erosion susceptibility created using data from the European Soil Data Centre. This model demonstrates how factors like soil type, rainfall, slope, and wind combine to heighten soil erodibility.

While it is widely apparent that much of the landscape of southern England was cleared of forest by the Roman period, the scale of production within this landscape changed with the advent of Rome to support a growing urban population tied into Empire-wide networks of exchanged. This intensification of land use had noticeable effects within the landscape, evident through the formation of field lynchets and increased alluvial deposition along the course of the Thames. We are now able to model this activity through space and time to move beyond an anecdotal, site-based narrative of environmental change.

### ***Simulating land-use for the Lower Rhine-Meuse delta in the Roman period***

*Maurice de Kleijn, Vrije Universiteit Amsterdam*

This paper presents a methodological framework for understanding and simulating past land-use developments. As a case study, the framework is applied for the Roman period in the Lower Rhine-Meuse delta region. The arrival of Roman soldiers in the Lower Rhine delta in the first century AD brought great change for the local inhabitants and their surrounding landscape. First, Roman armies were (partially) reliant on the local population to produce cereals and meat for them. Second, the fortification structures required timber for construction and maintenance. Additionally, wood was required as fuel. This research simulates the impact of these changes and tests various scenarios on the demand for various land-use types by applying a quantitative modelling approach.

### ***Farmers and Forts in Moesia Inferior: Modelling agricultural strategies on the Lower Danubian Frontier***

*Eli Weaverdyck, University of California, Berkeley*

This project analyzes changing rural settlement patterns in the Lower Danubian Plain from the Late Iron Age through Late Antiquity in order to elucidate the role played by garrison settlements in the economic strategies of peasants living near the Roman frontier. Using GIS, univariate statistical analysis and multivariate equation-based modeling, I interrogate rural landscapes for evidence of agricultural intensification and ancient marketing systems.

Settlements are the most durable traces left behind by rural, non-elites and the landscapes around settlements fundamentally shaped the opportunities and constraints these people faced. By identifying the features that attracted and repelled ancient settlers we can begin to understand the conditions under which settlement decisions were made. Using data collected from published and semi-published archaeological investigations in northern Bulgaria, I compare the productive potential of settlement territories to randomly distributed territories of the same size. I investigate the rural marketing through the concept of market potential – a measure of the total accessibility of marketing opportunities from any given location. I create market potential variables that include forts, exclude them, and include them as a negative influence. I then create a series of logistic regression models, varying only the market potential variables used. By comparing the goodness of fit of these models with one that excludes market potential altogether I can determine whether marketing opportunities influenced rural settlement and, if they did, which variable best approximates the ancient marketing system.

I come to the following conclusions: 1) the security provided by the Roman frontier allowed rural agriculturalists to settle in the most productive locations within the Danubian plain while the collapse of Imperial control at the end of the fourth century drove settlers to occupy less productive, but more defensible landscapes; and 2) Roman peasants sold their produce in small towns and cities, but not military bases.

## SESSION 2: MODELLING DEMOGRAPHY

### ***Current trends in demographic studies in archaeology***

*Isabelle Séguy, Institut National des Études Démographiques, Paris (keynote lecture)*

Demographic studies mainly focus on populations with statistical, or pre-statistical data for historical demography. Ancient census and other written documents allow historian-demographers to reconstitute the size, the spatial distribution, the sex-age structure and the evolution of some particular populations, mainly urban ones. In this way, demographers are able to determine demographic behaviors (in terms of mortality, fertility, and migration) of graeco-roman populations.

On other hand, most of ancient populations have no written documents and only archaeological evidence can be used to know a tiny bit of their demographic events. Depending on the kind of available sources, such demographic approaches aim to reconstruct spatial distribution of the population, its dynamics and, when possible, its components. I'm used to distinguish two different approaches (using cultural data versus biological ones) : « Archaeological demography » which investigates the distribution, the density and the dynamics of past populations using traces of human activities (like artefacts and settlements), and « palaeodemography » which uses buried human remains for reconstructing mortality patterns, genetic relationships and migratory behaviours. The first one is the main field of archaeologists and geographers who apply specific qualitative models linked to ecology and resource availability (carrying capacity) ; the second one is closer to forensic medicine (even if goals are basely different) and demography, and develops new methodologies for the estimation of demographic parameters from skeletal populations and the understanding of the populations' history. Of course, both approaches cover not only Roman times, but all periods from Prehistory to the Twentieth century.

I will present some case studies, may be covering more than Roman period. In those times, some populations already have written sources, that can be locally merged with archaeological evidence, some not. And of course, what we know from the first ones is not directly applicable to the « pre »-historic populations of antique Europe. Demographic approaches in archaeology are mainly realized in collaboration with historians, geographers, even economists or statisticians, and more rarely in association with demographers or historian-demographers. I'll try to point out current -or future- demographic topics which are -or could be- studied in the next few years.

### ***From population dynamics to settlement patterns. Linking archaeological data to demographic models of the Dutch limes***

*Philip Verhagen, Vrije Universiteit Amsterdam*

Even while the Dutch river area is among one of the most intensively researched regions in the world, when it comes to estimating its population in the Roman period, the available evidence is difficult to interpret. Previous approaches have departed from either estimates on the basis of settlement densities, or on idealized models of army recruitment and the size of the occupational forces and urban settlement. The demographic processes themselves however have hardly been the subject of study, leading to a largely unexplained model of substantial population increase in the late 1st and early 2nd century, followed by decline in the 3rd century AD.

We have tried to tackle this from two different angles: firstly, we have created a generalized simulation model of household demographics, taking into account historical evidence on mortality

and assumed army recruitment rates; and secondly, we have analyzed the archaeological data for chronological accuracy, in order to better understand the population development trends. The simulation models point to various scenarios that can influence long- and short-term population dynamics, in which the biological factors of mortality and fertility are not the only drivers. On the other hand, the archaeological data suggests that the earlier postulated patterns of population growth and decline are real, at least as far as it concerns the observed presence of settlement. Some features in the data may obscure more subtle patterns, such as the abundance of chronologically undistinctive 'native' pottery, the lack of well-dated metal finds in many surveys and the scarcity of Late Roman finds that may not just be related to a lower number of people living in the area, but also to reduced material wealth.

Even so, it seems that the observed increases and decreases in settlement density are difficult to explain by natural demographic processes, and hence simulation modelling can be used to further explore possible scenarios.

***The Disastrous Effects of the Roman Occupation!? Population dynamics and rural development on the fringes of the Roman Empire: theories and models***

*Wim De Clercq, University of Ghent*

In a seminal paper, the palaeo-botanist Groenman-Van Waateringhe described in 1983 what she called the “*Disastrous Effects of the Roman Occupation*”: a rural crisis on the sandy landscapes near the most northern fringes of the Roman Empire, now located on the territory of the Southern Netherlands and Northwestern Belgium. While one could argue that Groenman-Van Waateringhe had a rather eco-deterministic view upon Roman rural settlement patterns and economy, she basically did bring to the foreground the vulnerable equilibrium of a fast growing population and rural economy on the one hand, and its potentially disturbing effects on the landscape and the carrying capacity on the other.

These basic, profoundly intertwined aspects of rural and societal development have off course been debated before in many regions and for many periods. The theories developed by Malthus and Boserup for instance, but also those of Chayanov and Ricardo, have been most influential in trying to grasp the fundamental mechanisms of the interaction between population growth and economic intensification. In more recent years, valuable insights emerged from panarchy theory, which evolved from biology and life-systems analysis.

Building on these theoretical models and on new data emerging from preventive archaeology, we will assess the “*Disastrous Effects of the Roman Occupation*” and try to provide in an interpretative framework that allows to understand the relationship between population dynamics and agriculture. Amongst others the concept of resilience adds to our understanding how growth paths and crises evolved in a cyclic way through time and space.

***Modelling evidence densities: past population variation or modern structuring affordances? The case of England from the Iron Age to the early medieval period***

*Chris Green, University of Oxford*

This paper is based upon the work of the English Landscapes and Identities Project (EngLaId) at the University of Oxford (2011-2016; ERC funded), covering material recently published as Green

et al. 2016. EngLaId was a project that took a long-term approach to understanding the archaeology of the English landscape from the Middle Bronze Age (1500 BC) to the Domesday survey of AD 1086. It was a legacy data project that collated a massive amount of material from existing repositories and then used that as the basis for modelling continuities and differences across England across c. 2,500 years.

In particular, this paper will discuss differences in relative densities of evidence between (the modern country of) England in the Roman period (AD 43 – 410/1) as against the preceding Iron Age (c. 800 BC – AD 42) and succeeding early medieval periods (AD 411 – 1065). In particular, it will question the degree to which these differences (and similarities) are due to differences in past population density or due to differences in both modern recovery practices and past usage of archaeologically durable material culture. Inevitably, the answer is a little bit of both.

References:

Green, C., C. Gosden, A. Cooper, T. Franconi, L. ten Harkel, Z. Kamash & A. Lowerre. 2016. "Understanding the Spatial Patterning of English Archaeology: Modelling Mass Data, 1500 BC to AD 1086." *Archaeological Journal* [online first] <http://dx.doi.org/10.1080/00665983.2016.1230436>

***A different vision of ancient settlement dynamics: creation and application of a model of evolution of the Antique habitat of the Plateau Lorrain***

*Antonin Nüsslein, École Pratique des Hautes Études, Paris*

Research concerning settlement dynamics is mainly based on data from archaeological field survey. This method of investigation provides researchers with a lot of information that can help to identify trends and to model the evolution of settlement structure at different scales.

Nonetheless, field survey data, even when dated, is incomplete and only shows a snapshot of the settlements. This static information lacks a certain number of parameters which are essential to perceive the inherent evolution of the habitats and therefore to visualize their own evolution within the dynamics of the settlement trajectory networks. On the other hand, data from archaeological excavations enable us to detect those phenomena.

This paper aims to propose a methodological approach to try to resolve this lack of parameters : the creation of an evolutionary model of the habitats from the information collected during excavations. Applied to the sites discovered by prospection, and combined with other analytical tools, the model allows for a better understanding of the diversification phenomena of the habitat and the modalities of spatial development of the settlement.

For now, this tool that offers solutions to balance the static approach provided by surveys data, was designed for the study of Antique settlement of the Plateau Lorrain, but the concept can be applied to other periods and to other regions as well.

### SESSION 3: MODELLING TRANSPORT

#### ***Integrating detection and modelling of ancient pathways: towards a spatio-temporal, multiscalar approach***

*Philip Verhagen (Vrije Universiteit Amsterdam) & Laure Nuninger (Chrono-Environnement UMR 6249, Université de Bourgogne-Franche Comté)*

Pathway detection and modelling operate from different perspectives that seem to have little in common apart from using the same base data. Material traces of pathways can be detected from LiDAR and fieldwork, but they are usually fragmented and are difficult to date, interpret and connect to other elements in the landscape. Path modelling on the other hand is usually hindered by a severe lack of material evidence to test models of ancient movement, and therefore often remains speculative.

In order to better understand past movement and the development of ancient pathways, it is necessary to consider all the relevant spatial and historical dimensions of movement, the connectivity of the resulting networks, and the material traces left behind. We suggest that such an analysis should start by considering the full historical trajectory of pathways, from their construction and associated practices up to their development during their use and after their abandonment. Such a spatio-temporal, multi-scalar perspective on ancient pathways is crucial to enhance our ability to detect and interpret structures, and to link the detected elements to their modelled counterparts.

In this paper, we will present a state of the art and develop some ideas to build a framework for such an approach.

#### ***Diverse movement in a dynamic environment: modelling local transport in the Dutch part of the Roman limes***

*Mark Groenhuijzen, Vrije Universiteit Amsterdam*

This paper presents part of the research on local transport in the Dutch part of the Roman *limes* that was carried out in the context of the 'Finding the limits of the *limes*' project. Research on transport has traditionally focussed on long-distance connections, often related to historical and archaeological evidence. We know very little of local scale transport, perhaps precisely because of the lack of material to work with. Least-cost path models have often been applied in archaeology to bridge this gap, for example to investigate possible routes or to look into the factors that have governed movement in the past.

Reconstructing transport movements through least-cost path models is not straightforward: there are many dynamic parameters that change the way in which local transport materialises. The role of the natural environment must firstly be considered, particularly in the dynamic river landscape of the Dutch Roman *limes*. Secondly, transport can utilise multiple modes such as regular walking, ox-cart transport and water-based transport, and a single movement can potentially use more than one mode of transportation. Finally, there are many different functions available in path modelling as well as a distinction between energy-based and time-based models, each having its own applications and assumptions. How these aspects are considered and integrated in our research will be the core of this paper. The next step is then to move from reconstructed transport paths to transport networks, which will be briefly alluded to but be dealt with in greater detail in another paper.

***Shopping for wood during the first millennium AD: modelling Roman and early-medieval long-distance transport routes in the Netherlands using a multi-proxy approach***

*Rowin van Lanen, University of Utrecht/Cultural Heritage Agency of the Netherlands*

Wood was imported into the current Netherlands throughout the first millennium AD. The exact nature of these import patterns and to what extent they changed between Roman and early-medieval periods is unclear. The transition from Roman time to Early Middle Ages in many parts of north-western Europe coincided with severe demographic decline, changing natural setting and the collapse of trade routes. These changes must have greatly influenced long-distance transport in the region. The reconstruction long-distance transport is difficult since few historical sources are available and the existing archaeological records often are unclear and sometimes conflicting. Additionally, research on long-distance exchange of Roman and early-medieval goods has traditionally focussed on either (1) the spatial analysis of luxury goods or very specific commodities such as pottery and rotary querns or (2) essentially theoretical models explaining trade and exchange networks.

This contribution presents a quantitative approach to the reconstruction of long-distance transport of oak (a common good) during the first millennium AD. By applying a dendroarchaeological approach we were able to analyse long-distance transport routes of imported timber in the Roman and early-medieval Netherlands. By combining the provenance of exogenous timbers with data on modelled Roman and early-medieval (interregional) route networks, we were able to reconstruct: (a) Roman and early-medieval trade networks in structural timbers, (b) changing transport routes in structural timbers and (c) model spatially shifting frequent-travel zones, i.e. sections within the route network frequently used in a specific period. To establish the significance of these patterns for the first millennium AD we compared the findings with import patterns of other commodities for daily use: pottery and stone household goods.

***Postdicting Roman Roads in the NW Iberian Peninsula***

*César Parcero-Oubiña, Alejandro Güimil-Fariña, João Fonte (INCIPIT - CSIC, Santiago de Compostela) and José Manuel Costa García (University of Santiago de Compostela)*

GIS-based digital modelling tools, such as the well-known least cost paths (LCP), have been widely used in archaeology in the recent years as ways to approach the forms of mobility in the past. Quite frequently they have been used as tools to reconstruct (predict) the routes of ancient paths and roads, especially in prehistoric contexts. However they can also be used within a “postdictive” perspective where the aim is not to reconstruct lost parts of evidence (the missing route of a road) but rather to find a logic in the pieces of evidence we actually know about (the archaeological record). This approach is especially useful when we have a significant amount of evidence available, in highly formal archaeological contexts.

This is usually the case of the Roman roads, as in the NW Iberian Peninsula. Here, in the Roman province of Gallaecia, a number of scholars have contributed extensively to the reconstruction of the likely routes of the main Roman roads in the last decades. In this paper we will show a complementary approach that, based on a LCP analysis, tries to tackle the question of why the roads follow those particular routes. By doing so, we will try to understand the influence of topographic factors in the road network, and the role of some particular sites in the social, administrative and political organization of the territory.

***Walking Between Gods and Mortals: reconsidering the movement of Roman religious processions***

*Katherine Crawford, University of Southampton*

Movement was a central component of Roman religious processions. While scholars acknowledge the regularity of processional activity, studies have traditionally focused on major processions such as the Roman triumph rather than considering the wider occurrence of religious processions. The nuances of how a procession traversed a city's streets and its urban impact are not easily revealed due to the paucity of information from ancient literary sources. As a transient event with their occurrence largely held in the memory of those who attended or heard about them, processions leave little standing trace within the archaeological record. This paper applies a network analysis and agent-based modelling approach to consider new ways of studying the movement patterns of religious processions at Ostia, Rome's ancient port. Focus is transitioned from trying to reconstruct routes based off of a fragmented archaeological and historical record to questioning the ways in which a cityscape affected a procession's direction. This approach considers processions as dynamic events that engaged with both the people and built environment of a cityscape. By re-examining approaches to studying processional movement, we can gain new insight into how religious movement shaped social and religious interactions within the ancient city.

## SESSION 4: MODELLING SOCIO-ECONOMIC NETWORKS

### ***Network science in Roman studies: the potential and challenges***

*Tom Brughmans, University of Oxford (keynote lecture)*

As far as the application of network science in Roman studies is concerned, the low-hanging fruit has almost all been picked. We have created networks of the Antonine itineraries and of Cicero's letters, and many more networks of large datasets of Roman material culture. Network science has recently become more commonly applied in archaeology and Roman studies in particular have seen a diverse and creative use of network science techniques, thanks to the availability of both written and material sources as well as long-running debates on theoretical models. Roman studies now face the challenge, not of copying network science techniques from sociology and physics, but to develop original network science models and methods that explicitly address its key research themes. Such work should take the unique strength of network science as its starting point: the formal representation and study of (theories about) relational phenomena and data. In this presentation I will review the use of network science in Roman studies and make some suggestions of how the potential of network science can be explored in the future. The review reveals theoretical and methodological challenges that Roman studies share with archaeology and history more broadly in their application of network science. How to deal with material data in network approaches? How to explore long-term change in social systems with network methods that have traditionally been applied to study more short-term changes? How to address sampling issues and missing data? Addressing these challenges and thinking through the relational phenomena underlying key research themes in Roman studies will reveal ways forward.

### ***Possibilities and challenges in the use of networks to study socio-economic relations in the Dutch part of the Roman limes***

*Mark Groenhuijzen, Vrije Universiteit Amsterdam*

Network theory and network analysis have become integral components in our research on the cultural landscape of the Dutch part of the Roman *limes*, particularly concerning local-scale transport. The application of network analysis on reconstructed transport networks has provided avenues for approaching both old and new archaeological questions, yet there are many considerations and reservations that have to be made in the process. Both sides of the coin will feature in this paper.

The first part will present the application of formal network analysis on reconstructed transport networks, and what we can interpret from the results, for example related to existing archaeological hypotheses on the socio-economic structure of the region. Using the extensive site dataset and chronological information available, networks of various modes of transport can be compared, the development of transport networks through time can be studied, and the role of individual sites within the network, ranging from rural settlements to Roman *castella*, can be examined

The second part of the paper will present some challenges that were encountered and considered during our research using network analysis to study transport networks. Firstly, a number of network construction techniques and their merits for building transport networks will be discussed. Secondly, the stability of networks and the robustness of network analysis results under the influence

of uncertain information will be presented, showing that a significant part of the results are unreliable, and how that can be used in the interpretation of the network. Finally, the application of an alternative approach to chronological uncertainty in the archaeological site dataset and how that changes the networks is shown.

### ***Network analysis to model and analyse the Roman transport and mobility***

*Pau de Soto, Universidade Nova de Lisboa*

The analysis of Roman infrastructures to understand the transport costs and the commercial routes and processes is an indispensable way to know the benefits and shortcomings of the transportation system created in Roman times. It is well known that the Roman Empire built the first big transport network in Western Europe and also in parts of Eastern Europe, the Middle East and Northern Africa. This overwhelming task included not only the construction of roads with their correspondent bridges, but also the building of river ports and maritime harbours. Such a huge effort aimed to create an integrated economy covering all the Roman provinces on the Mediterranean Sea and Atlantic Ocean.

In the last years, we have attempted to reconstruct the Roman transport conditions by modelling travel costs and times with the help of GIS and Network Analysis applications. The main geographical focus of this project was the NE of Hispania. It was necessary devote a significant effort to the gathering, documentation, analysis and digitisation of Roman communications with high precision. With the aim of using these methodology in a much broader geographic frame, the entire Iberian Peninsula and other European territories were analysed with less detailed transport networks. It allowed us to discover very interesting patterns. The results of such applications provide us with new information to understand the distribution of commodities, product competition and problems of stagnation in ancient economies such as that of Ancient Rome.

The ability to see graphically and numeral those costs values which until now they could only be guessed, can open new perspectives and justifications to the speeches made on the work done until today. In fact, the comparison between these results and the analysis of archaeological and historical interpretations should complement each other, clarifying and offering more elements for a global vision.

At the same time, it has been possible to observe how the construction of a complex communication network, especially based on the creation of land routes, meant an important element for the integration of new territories to the Roman provincial model. To understand the morphology of these networks, we have applied some Social Network Analyses to understand the configuration and performance of the Roman mobility in these territories.

The same methodology can be used to analyse other historical periods and therefore to elaborate comparisons of the same territories along the centuries. This is the main focus of our current project, named Mercator-e and will allow us to explore the transport network evolution of the Iberian peninsula from Roman times to the XIXth Century.

**Multi-scalar approach to long-term dynamics, spatial relations and economic networks of the Roman secondary settlements in Italy: towards a model?**

Angelo Castrorao Barba (University of Palermo), Stefano Bertoldi (University of Pisa), Gabriele Castiglia (Pontifical Institute of Christian Archaeology)

In Roman landscapes particular sites defined as secondary settlements, (known also as *vici/villages*, minor centers, *agglomération secondaire*, *stationes/mansiones*) have played an 'intermediary' role between the cities and the other rural structures (*villae/farms*), linked to the medium- and long-distance economic and commercial trajectories. The aim of this paper is to apply a multi-scalar approach to modelling the long-term spatial relations and the connectivity with the Mediterranean exchange network of the Roman secondary settlements. On a macro-scale we have analyzed a sample of 219 edited sites to understand the diachronic trends and the spatial dynamics of attraction / proximity to the significant elements of the landscape as towns, roads, rivers and coastline. The Ombrone Valley (Tuscany – Italy) represented a micro-scale case study of a complex systems in which the imported pottery (*amphorae*, ARS, *ingobbiata di rosso*) found in the *vicus/mansio* of Santa Cristina in Caio, the Roman villa of La Befana and the town of Siena (Saena Iulia) held diagnostic 'macro-economic' perspectives. The results showed how the secondary settlements played a nodal position in the Roman landscape in terms of resilience (long period of occupation until the Early Middle Ages), spatial organization with a close relationship to natural and anthropic infrastructures and trade functions linked to the Mediterranean routes.