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Advancing archaeological computing and simulations in Classical and Roman Archaeology

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Despite the general feeling amongst academics of being overwhelmed due to ever-increasing duties, one of the remaining fun parts of being a researcher, and particularly so in Classical and Roman Archaeology, is trying new approaches and methods to explore theories and hypotheses developed from and compared against empirical data. This happens within a context of relatively limited adoption of computing and simulation methods in these disciplines, a trend that is nonetheless growing in research, despite the "resistance" of a sector of academia in the Humanities who still distrust these approaches. Much of their reluctance could be explained by the difficulties of establishing a fruitful conversation: on the one hand, more "traditional" researchers have limited knowledge of quantitative methods and computing science, resulting in a certain "illiteracy" when it comes to these methods; on the other hand, the frequent use of specialized jargon and a heavy emphasis on mathematics and computer programming by researchers specialized in modelling and simulations make grasping their meaning difficult for the non-initiated, thus severely limiting the possibilities of more researchers adopting and using these methods.

It is in this difficult context that the volume *Simulating Roman Economies: Theories, Methods, and Computational Models*, edited by Tom Brughmans and Andrew Wilson, makes a very valuable contribution as it seeks to foster this ongoing conversation within Classical and Roman Archaeology. It does so in three ways: firstly, by clearly defining the scope and nature of computer modelling and simulations; secondly, by presenting the diversity of topics and questions that could be further explored and the multiple methods that could be applied (including statistics, network analysis, and agent-based modelling, amongst others); and thirdly, by assembling a wide range of case studies where these approaches are applied, presented in a clear and well-structured style by a collection of specialists with solid trajectories in the field. In this way, *Simulating Roman Economies* successfully demonstrates the potential of these methods to invigorate past and current debates, to promote new questions and contrast competing hypotheses, and to exemplify how these approaches can be made accessible to a wider audience of researchers, including those in the early-career stages.

As for its structure, the volume is divided into three distinct parts: an introduction, setting out the context, aims and objectives; a section exploring different case studies from across the Roman Mediterranean with an (obvious) emphasis on economic and

demographic aspects (fully aligned with the theme of the book series in which this volume is published); and a section that brings the contributions made by the different case studies into focus within the general research context of archaeological computing and Roman studies. The final pages of the book comprise an index of the key topics, concepts, and places discussed across the volume, allowing the kind of intersectional inquiries that make it a useful reference work for specific applications, regions, and types of archaeological evidence employed. It should be noted, however, that the focus of this volume lies on the clear and well-structured presentation of the different methodological approaches, generally to the detriment of more extensive descriptive discussion and contextualization of the historical questions and processes under exploration. For these aspects, readers are encouraged to explore the extensive bibliographies accompanying each chapter, as well as (in many cases) the previous publications that illuminate these studies in more detail. The range of case studies is also quite diverse, from Empire-wide examples (e.g., chapter 3) to explorations of more local and regional dynamics and processes (e.g., chapter 8). More than half the contributions present case studies that have already been published elsewhere but with a less technical focus, an opportunity for the interested reader to deepen their understanding of these models in greater detail and complexity. The data supporting many of these contributions is often also openly available, allowing the studies to be replicated and used as teaching/learning examples.

Moving on to the actual content, quite a few of the contributions focus on trade and transport networks, with room also left for topics related to demography and population dynamics and agricultural production. These case studies are preceded by a superb introduction (chapter 1) by Brughmans ("Why simulate Roman economies?"), which sets the tone of the entire volume through a very clear and well-structured text. The author successfully contextualizes both the potential uses of simulations and the opportunities they offer for research in Classical Archaeology, whilst also focusing strongly on the importance of incorporating simulations into academic curricula and fostering interdisciplinary collaboration. However, it is interesting that despite a general description of simulation being included, much emphasis is placed on agent-based modelling and its potential to reveal diverse patterns emerging from systems as complex as the Roman economy. Other points of particular interest to the novice reader are Brughmans's discussions on ways to represent theoretical models and the usefulness of the "falsification" of theories and hypotheses; that is, trying to prove them wrong rather than right. More relevant is his assertion (made explicit also in other contributions) about how the process of model construction leads to increased focus and more explicit and deeper engagement with theories and hypotheses, an approach whose benefits are successfully demonstrated by all contributions in the volume.

To deal first with contributions focusing on trade, J. W. Hanson and Tom Brughmans's contribution "Settlement scale and economic networks in the Roman Empire" represents the further development of an earlier model by applying settlement scaling theory. This contribution explores the trade of ceramic tableware and the impact of estimated urban populations as a factor in the commercial and economic integration of towns in the eastern Mediterranean. In particular, the trade of tableware is simulated and explored through agent-based modelling across different chronological phases, then the results are compared with the known distribution of tableware. Such an undertaking allowed the authors to identify similarities and differences between the simulated and empirical contexts, some of them discussed in this text, which highlight the potential influence of factors not

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considered in these experiments in the phases showing divergences. Most interesting is the authors' provision of both dataset and scripts employed in this research, making it possible to replicate it, to adapt it for other purposes, or to expand it to consider other, additional factors. The chapter by Simon Carrignon, Tom Brughmans, and Iza Romanowska, "Copying of economic strategies in eastern Mediterranean inter-regional tableware trade," continues on the topic of tableware trade. Using the same dataset as the previous chapter, this study combines agent-based modelling and Bayesian inference to explore some diverging strategies amongst traders that could explain the varying archaeological distributions of Eastern Sigillata A, B, C, and D, the presence of which at sites at a regional level displays substantial differences. In so doing, this contribution tests (and rejects) hypotheses about the existence of a network of knowledge amongst traders active in the eastern Mediterranean, proposing instead a much lower degree of commercial integration of communities across this region, a result that will be further explored in the future by these researchers.

Still focusing on ceramics but moving on to amphorae production, Xavier Rubio-Campillo and María Coto-Sarmiento develop in their chapter "New approaches to old questions: The exploration of large-scale trade dynamics using hypothesis-testing frameworks" a very structured study exploring the characteristics and development of olive oil production and trade in the western Roman provinces. Focusing on both the formal characteristics of the amphorae and the stamps they bear, the authors test several hypotheses identifying the existence in Imperial times of a free market increasingly controlled by the wealthiest landowners through a process of property concentration. Not only because of its results but also due to the way this study develops, this contribution is particularly interesting for novice researchers as an example of how to structure and develop simulation approaches to answer archaeological questions.

Turning to contributions about transport systems, Pascal Warnking's chapter "Simulating Roman maritime trade: Modelling sailing times and shipping routes" explores and models maritime transport routes in the Roman Mediterranean. Combining literary and archaeological evidence and the modelling and analysis of maritime movement, it generates very interesting results and answers to a wide range of historical questions. Despite the use of an expensive piece of commercial software, potentially limiting the accessibility and replicability of these experiments, this chapter constitutes a welcome addition to a volume mostly focused on "terrestrial modelling" and mirrors the increasing attention the maritime and riverine contexts of the Roman Empire are now receiving in Classical and Roman Archaeology.[1]

Focusing on land, although the contribution by Pau de Soto and César Carreras, "The economic and social evolution of the Iberian Peninsula as revealed through analysis of Roman transport infrastructure," takes a more descriptive approach than other papers in this volume, it constitutes a highly successful study that clearly demonstrates the benefits of integrating diverse archaeological evidence with the analysis of connectivity. As a result, the reader gains a good understanding of the factors and historical contexts influencing the creation of the dense road network in Hispania between Republican times and Late Antiquity. However, no indication is provided as to how to access any of these datasets, limiting their practical use as simulation example.

[1] E.g., Horden and Purcell 2000; Leidwanger 2013; Safadi 2016; Moreno Escobar 2022.

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Finally, Mark R. Groenhuijzen ("Evaluating hypotheses about local transport systems through spatial and network analysis: The Dutch part of the Lower Rhine *limes* and its hinterland") explores both local and regional transport networks in terms of their efficiency for trade and supply and the potential role of intermediate distribution centers through a combination of least cost path and network analysis approaches. An interesting contribution in general, the apparent exclusion from this study of other types of transport (e.g., riverine) could potentially limit the interpretations it generates, given the important role of transport along waterways that has been demonstrated in regions nearby.[2] Also noteworthy is the absence of details about the software used and parameters applied in these analyses; although (in fairness) the author refers to his PhD thesis, this type of information should always be made explicit.

Other contributions focus on various topics. First is agricultural production and trade, in the chapter by Brian J. Dermody, Alexander Chiu-Smit, and Rens L. P. H. van Beek ("A model of grain production and trade for the Roman world"). By explicitly modelling environmental constraints across the Mediterranean Basin, the authors highlight how the reliability of crop yields in irrigated regions could have been an important factor in increasing the stable supply to large cities, whilst also showcasing both the wide availability and the limitations of datasets for modelling purposes. Demography is the focus of Philip Verhagen ("Modelling the basics of Roman demography: The case of the Dutch *limes*"), who (building on a previous study) explores whether local communities inhabiting the Batavian region could have supplied the Roman Army with enough soldiers through a model of local demographic dynamics built upon a relatively simple set of social and biological factors. Despite their simplicity, Verhagen's experiments show the unsuitability of previously considered assumptions (e.g., "stable population") and (more interestingly) the potential mechanisms of population control available to ancient communities, enabling them to adapt to changing environmental, political, and economic conditions. Epidemiology is explored in the contribution by Marek Vlach ("The Antonine Plague: Evaluation of its impact through epidemiological modelling"), who models the spread of smallpox through simulations accounting for population distribution densities, communication infrastructure (e.g., roads, navigable rivers), and environmental conditions (e.g., humidity, temperature). A novel approach to this topic, the results and discussion highlight the impact of diverging population densities in the degree of spread of this disease when combined with its characteristics (e.g., reproductive rate, time of incubation), as well as potentially showing how regions with more complex economic structures could have been "more susceptible." In a more general sense, this chapter makes a very valuable contribution to the wider debate on the complex developments of the 3rd c. CE, as it highlights the substantial impact of this disease even when considering "low count" scenarios of population densities within the Roman Empire.

Moving on to the final, discussion section, Shawn Graham ("Mapping the landscape of our ignorance") produces a new iteration of a previous paper wherein, by using agent-based modelling to study brick production in the Tiber Valley in Roman Imperial times, the author successfully exemplifies the ways in which models and simulations can be devised and implemented. More relevantly, the chapter highlights how the actual process of building the model leads to profound reflections about the implications of "translating" theoretical models into code and how the exploration and analysis of archaeological

[2] Bongers 2020.

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(empirical) data help us evaluate and structure what actual knowledge we have about the past. This chapter can be taken as a "non-official" expansion of the discussion initiated by Brughmans in the first chapter, whilst also reinforcing many of the points raised in the rest of the book. The volume is closed by Andrew Wilson ("Positioning computational modelling in Roman Studies"), with a contextualization of simulation approaches in the wider discipline of Classical and Roman Archaeology, improved thanks to the availability of software, training resources, and datasets. Wilson also reasserts (like the authors of other contributions) the benefits of these approaches, namely how models improve the ongoing debates and conversations in Classical Archaeology by making explicit our assumptions and by "testing" hypotheses and excluding the least plausible of them, whilst also drawing similarities with the adoption of other technologies (e.g., Geographic Information Systems, Network Analysis) by researchers in archaeology as ways to widen the application of modelling in Roman studies.

In general, the diversity of approaches and topics makes this book interesting (and fun!) for researchers seeking to expand their horizons through modelling and simulations, and its ideas could be easily applied to periods and regions other than the Roman Empire. However, several of the themes and questions raised in this volume deserve further attention, starting with the overwhelming evidence it provides to demonstrate the potential of computer modelling and simulations for exploring dynamics and processes on Empire-wide scales of analysis. Furthermore, although these contributions highlight the existence and characteristics of datasets at this extensive scale of analysis, the impact on results and interpretations of using alternative datasets remains unclear, particularly as some contributions use different datasets representing similar data (e.g., distribution of urban centers).

Another question refers to how to incorporate these methods into our "daily archaeological toolboxes." Regardless of the country, my personal contact with students and early career researchers has repeatedly demonstrated how curious, keen, and engaged they are when presented with new approaches and methods to help them explore the past. In this sense, it is relatively easy to nourish and grow this interest through specific lessons, practical sessions, and modules at their home universities. Despite lacking a parallel digital resource containing scripts and sample datasets (similarly to other publications and resources in network science by Brughmans),[3] this book has the potential to be part of this teaching, thanks to its well-structured content, the clarity of exposition when discussing (complex) questions and approaches, and the wide diversity of the examples. However, it is important to note that simulations and modelling still have a high "cost of entry" in relative terms, as computing and programming lies well outside the curricula of most undergraduate and postgraduate courses in Classical Archaeology. Luckily, later stages of academic development may offer students and early career researchers more specialized support, also fostering mobility across institutions (particularly easy within the EU) that promote the dissemination of these research attitudes and skills, although more institutional support (from both universities and funding bodies) should be invested to ensure the continuity of these ties and collaborations. More importantly, teaching these topics should be directed not only at producing specialists, but (more strategically) at providing researchers with a background on both the potential and the limits of these methods that would enable them to maintain and develop close collaborations with simulation experts

[3] Brughmans 2021; Brughmans and Peeples 2023.

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as the basis for true interdisciplinary research. As Brughmans and Wilson point out, an example of how this could be achieved is provided by the introduction of Geographic Information Systems, thanks to the popularization of introductory courses in higher education institutions and case studies at conferences, but also (undoubtedly) to the publication of GIS handbooks,[4] opening these approaches up to both a wider sector of consolidated academics and a younger generation of researchers. There is room for and previous experience of expanding interest in simulations and modelling through more recent tools, such as public repositories and examples openly available online, to complement traditional approaches to learning and teaching in higher education institutions.

To summarize, this volume constitutes a very good introduction to modelling and simulation in Classical Archaeology as its language is easy to follow and its approaches clearly stated and developed without resorting to specific jargon that might "terrify" non-specialized audiences. High-quality figures have been cleverly used to support arguments and interpretations (although in some instances labels could be difficult to read, e.g., chapter 2, or color images might have been easier to understand, e.g., chapters 8 and 9). The general readability of the book is very high, with very few typos and very good use of the English language, despite many contributors not having English as a first language. Thankfully, this volume makes use of footnotes instead of endnotes compiled at the end of each chapter (or worse yet, combined at the end of the book), thus making checking additional clarifications and sources very easy. In short, this volume is a solid, accessible (and fun) initiative that constitutes an important step for developing the critical mass of researchers who understand and apply simulations and modelling in Roman archaeology.

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[4] Wheatley and Gillings 2002; Conolly and Lake 2006.

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