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Modelling Sustainability in the Past:

A Critical Evaluation of the Pillar Model and the Nested Model.

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Presented in fulfilment of the requirements for the degree of Master of Arts in Archaeology

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Preface

This paper was written with the aim of obtaining the degree of Master of Arts in Archaeology at the KU Leuven. Through a critical evaluation of the current literature, it studies if and how the concept of sustainability should be applied to archaeology. *Modelling Sustainability in the Past: A Critical Evaluation of the Pillar Model and the Nested Model* is the result of this investigation. The aim of this paper is not to say the final word on the application of the concept of sustainability in archaeology, but merely to offer a starting point for future research.

My appreciation goes out to my family and friends for their company. I would particularly like to thank Véronique Van der Voort for her endless support, Emmanuelle Groenen for her guidance in the process of academic writing throughout the years, Valérie Van der Voort for editing, and my promotor Prof. dr. Jeroen Poblome and co-promotor Prof. dr. ir. Bart Muys for their guidance, advice and introducing me to the vastly interesting field of socio-ecological systems.

Thank you all.

Samenvatting

Archeologen hebben in het verleden vaak, onder invloed van evolutionaire en neo-evolutionaire ideeën, sociale ontwikkelingen verklaard in lineaire termen. Een dergelijke lineaire beschrijving van sociale dynamieken verwaarloost veel van de culturele, economische en sociale variatie aanwezig in het archeologische bestand. Onder invloed van andere disciplines, zoals ecologie, is binnen archeologie een nood ontstaan om te onderzoeken hoe samenlevingen in het verleden veranderden op een cyclische wijze. Daarnaast is het belangrijk geworden om te kijken naar de manier waarop samenlevingen ontwikkelen in het verleden, en geleidelijk complexer worden, maar ook hoe en waarom ze vervallen. Wat maakt samenlevingen duurzaam? De volgende studie incorporeert deze ideeën, door te onderzoeken of de toepassing van het duurzaamheidsconcept op archeologie een meerwaarde kan bieden. Hiervoor moeten we eerst een conceptueel model adopteren om de structuur en de werking van een socio-natuurlijk systeem te evalueren, geschikt voor duurzaamheidsanalyse in het verleden. Vervolgens moeten we indicatoren selecteren op basis van archeologische data. Het concept van duurzaamheid heeft vele definities, maar toegepast op sociale dynamische processen kan het de volgende betekenis krijgen: "het vermogen van samenlevingen om hun orde en structuur te behouden doorheen de tijd, zonder verlies van complexiteit en welzijn." Het is in deze tijd een algemeen aanvaard idee dat samenlevingen niet op zichzelf staan, maar voorkomen in specifieke natuurlijke omstandigheden. De natuur is niet langer de onveranderlijke achtergrond waartegen de menselijke evolutie plaatsvindt. Integendeel, tussen het sociale- en natuurlijke systeem is sprake van een dialectische relatie. In het bijzonder evalueren we twee modellen om duurzaamheid te beschrijven: ten eerste het zuilenmodel, dat duurzaamheid ziet als een balans tussen economische-, sociale- en omgevingskwesties: ten tweede, het genestelde model dat de samenleving presenteert als een subsysteem van de omgeving; de economie is vervolgens onderhevig aan de samenleving en samenlevingen kunnen enkel bloeien onder de voorwaarden gesteld door de natuurlijke omgeving. Deze modellen worden geëvalueerd, onderling vergeleken en tegen een achtergrond van recente theoretische ontwikkelingen geplaatst, waaronder complexiteitstheorie, socio-ecologische systemen, complex adaptieve systemen en thermodynamica. Het duurzaamheidsconcept is nog niet grondig toegepast of uitgewerkt voor archeologie, daarmee is het een relatief nieuwe aanpak. Deze studie heeft op geen enkele manier de doelstelling om het laatste woord hierover te zeggen, maar ambieert het fundament te leggen voor verder onderzoek. Deze doelstelling wordt aangevat door de bestaande literatuur rond o.a. duurzaamheid kritische onder handen te nemen en toe te passen op bestaande archeologische case studies. In deze studie is geen sprake van een focus op één materiaalcategorie, regio of tijdsperiode. Desondanks is het spatio-temporele kader van deze studie te vinden in de periode tussen 1000 v. Chr. en 1000 na Christus in het Middellandse Zeegebied. De rode draad doorheen deze studie is het idee dat verandering de norm is in het archeologische bestand en dat we onze modellen bijgevolg moeten aanpassen.

Abstract

Archaeologists have often, under the influence of evolutionary and neo-evolutionary ideas, described societal dynamics in linear terms. This linear description of societal dynamics neglects much of the cultural, economic and social variation in the archaeological record. Under the influence of scientific disciplines such as ecology, a need has emerged within archaeology to investigate how societies in the past changed in a cyclical manner. The idea has arisen that we not only need to look at how societies gradually progress, and over time become more complex, but also how and why they decline. In other words, what makes them sustainable?

This paper aims to adopt these ideas to archaeology and investigate the application of the concept of sustainability to the study of the past. In order to do so, we first need to adopt a conceptual model for describing the structure and functioning of socio-natural systems, suitable for sustainability analysis in the past. We then need to select indicators for this model based on archaeological data.

The concept of sustainability has many definitions. Applied to society, it can be defined as: "the ability of societies to maintain order and structure over time, without loss of complexity and societal well-being." As is currently becoming apparent, societies do not exist on their own, they exist within a specific natural environment. Nature is no longer considered the static backdrop against which human evolution takes place, but instead has a dialectic relation with the societies that exist within it.

Specifically, we evaluate two models for describing sustainability: first, the pillar model, which considers sustainability as a balancing exercise between economy, social issues and environmental considerations; second, the nested model, which represents society as a subsystem of the environment; economy is at the service of societal well-being, and societies can prosper within the possibilities and limits offered by the natural environment. These models will be evaluated and compared with current theoretical developments, such as complexity theory, socio-ecological systems, complex adaptive systems and societal thermodynamics.

The concept of sustainability has not yet been thoroughly applied to archaeology and so it remains a rather new approach. This thesis in no way sets out to completely discuss the possibilities of the concept of sustainability, but merely to introduce the concept and lay the foundations for further research. This is set about by studying the scientific literature published on the subject and combining this with archaeological case studies. There is no focus on one material category, one region or a particular time period, albeit, that the spatio-temporal context of this paper can be found in the period 1000 BCE – 1000 CE around the Mediterranean Sea. The grand narrative of this thesis is the fact that we need to accept that change is the norm in the archaeological record and we should change our models of approaching the past accordingly. Hence, there exists a need to make visible change, explain it, model it, comprehend it and make it quantifiable for comparative purposes. Only then can we truly explain the dynamics of past socio-natural systems.

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1. Introduction

Archaeologists have often, under the influence of evolutionary and neo-evolutionary ideas, described societal dynamics in linear terms: society X has a fixed starting point A; overtime society X evolves, becomes more complex and ends up in point B; eventually it reaches point C, after which it declines and falls apart. This linear description of societal dynamics neglects much of the cultural, economic and social variation in the archaeological record. Under the influence of scientific disciplines such as ecology, a need has emerged within archaeology to investigate how societies in the past changed in a cyclical manner. The idea has arisen that we not only need to look at how societies gradually progress, and over time become more complex, but also how and why they decline. In other words, what makes them sustainable?

This paper aims to adopt these ideas to archaeology and investigate the application of the concept of sustainability to the study of the past. Can we – via archaeology – evaluate sustainability of past societies and does the idea of sustainability offer an added value to archaeological research? In order to do so, we first need to adopt a conceptual model for describing the structure and functioning of socio-natural systems, suitable for sustainability analysis in the past. We then need to select indicators for this model based on archaeological data. It is paramount to find scientifically grounded and robust indicators, or proxies, for modelling sustainability of past socio-natural systems. We otherwise run the risk of producing a noncommittal model. The concept and methods with which we evaluate sustainability of the past very much reflect how we think about sustainability in the present. Classical models have generally focused on economic performance and chose their indicators accordingly.

Sustainability is currently an often cited and discussed topic. The concept of sustainability has many definitions, but it can be best described as "the ability to sustain". Applied to society, this becomes: "the ability of societies to maintain order and structure over time, without loss of concomitant complexity and societal well-being." As is currently becoming apparent, societies do not exist on their own, they exist next to other societies and within a specific natural environment. Nature is no longer considered the static backdrop against which human evolution takes place, but instead has a dialectic relation – often in negative ways – with the societies that exist within it. This means, that as a species we are becoming more aware that our current economic model and way of living is harmful to the environment on which we rely to survive.

Specifically, we evaluate two models for describing sustainability: first, the pillar model, which considers sustainability as a balancing exercise between economy, social issues and environmental considerations; second, the nested model, which represents society as a subsystem of the environment; economy is at the service of societal well-being, and societies can prosper within the possibilities and limits offered by the natural environment. These models will be evaluated, compared and placed against current theoretical developments, such as complexity theory, socio-ecological systems, complex adaptive systems and societal thermodynamics.

In practice, this means that each of the two models will be discussed individually and their employment in archaeological research will be investigated. The first chapter discusses the pillar model on the basis of two articles: *In Search of Roman Economic Growth* (2009) by Walter Scheidel and *Indicators for Roman Economic Growth: A Response to Walter Scheidel* (2009). The second chapter discusses the nested model by looking more closely at a case study of the Middle Rhône Valley between 1000 BCE and 1000 CE, which is part of a study published in *The Model-Based Archaeology of Socionatural Systems* by T.A. Kohler and S.E. van der Leeuw (2007) and by looking at specific chapters (one, two and nine) of the book *Regional Pathways to Complexity* by P.A.J. Attema, G.-J. Burgers, P.M. van Leusen (2010). The third chapter comprises of a critical evaluation of both models and introduces potential alternatives for approaching sustainability in the past.

Many of the ideas put forward in this thesis have been inspired by the concepts found in*: Panarchy: Understanding Transformations in Human and Natural Systems* by Lance H. Gunderson and C.S. Holling (2003); *Complex Systems and Archaeology*, edited by R. Alexander Bentley and Herbert D.G. Maschner (2004); the idea of combining complex systems, thermodynamics and archaeology proposed by John Bintliff (2003, 2013); *The Archaeology of Time* by Gavin Lucas (2005); and in particular *Sustainable Development Within Planetary Boundaries: A Functional Revision of the Definition Based on the Thermodynamics of Complex Social-Ecological Systems* by Bart Muys (2013) and *The Economy of the Roman World as a Complex Adaptive System: Testing the Case in Second to Fifth Century CE Sagalassos* by Jeroen Poblome (2015).

The concept of sustainability has not yet been thoroughly applied to archaeology and so it remains a rather new approach. This thesis in no way sets out to completely discuss the possibilities of the concept of sustainability, but merely to introduce the concept and lay the foundations for further research. This is set about by studying the scientific literature published on the subject and combining this with archaeological case studies. There is no focus on one material category, one region or a particular time period, albeit, that the spatio-temporal context of this paper can be found in the period 1000 BCE – 1000 CE around the Mediterranean Sea. The grand narrative of this thesis is the fact that we need to accept that change is the norm in the archaeological record and we should change our models of approaching the past accordingly. Hence, there exists a need to make visible change, explain it, model it, comprehend it and make it quantifiable for comparative purposes. Only then can we truly explain the dynamics of past socio-natural systems.

2. The Pillar model - A centralised positioning of economy and GDP in historical research

2.1. Sustainable development and the three pillar model

The first model to be discussed is the *pillar model* or *three pillar model*. The pillar model considers sustainability as a balancing exercise between economy, social issues and environmental considerations. It is often represented as a Greek-style temple (figure 1) in which sustainability is visualised as the *fronton*, which is carried by *three pillars* (economic, social and environmental).[1] As this section sets out to prove, the three pillars do not receive an equal amount of attention and often a strong focus is placed on the economic area. As a result, the *pillar model* can also be represented as a *Micky Mouse figure* (figure 1). This model has, however, not shown "sufficient effectiveness for acting within planetary boundaries" - most visible in the current ecological degradation (see below) -, despite the fact that it is still commonly used.[2] This section sets out to explain the pillar model, its flaws, and its conscious or implicit application in historical and archaeological research.

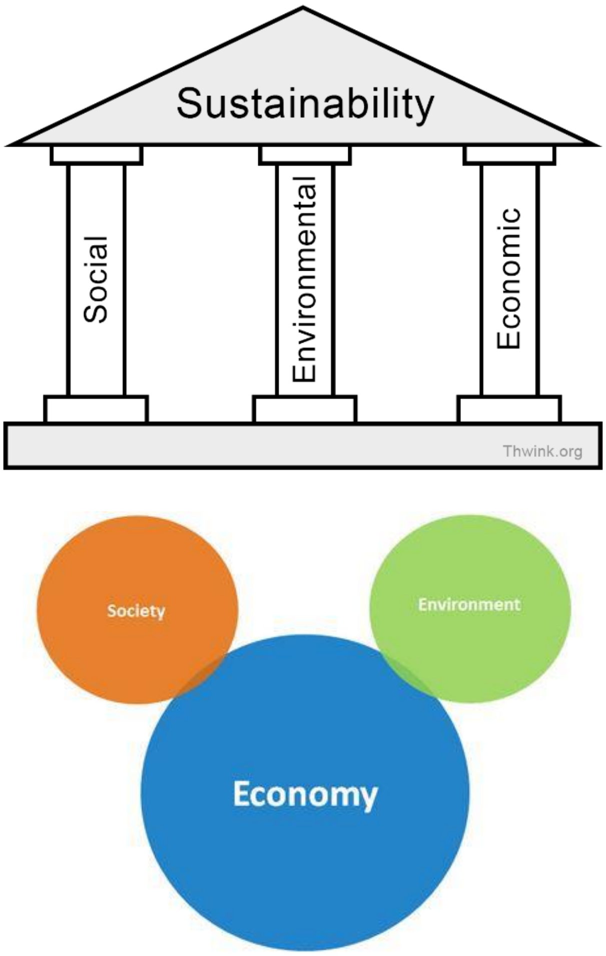

Figure 1: The Three Pillar Model. Source: http://www.thwink.org/sustain/glossary/ThreePillarsOfSustainability.htm and the Micky Mouse Model. Source: http://wikieducator.org/Sustainable_futures/ICSD/Learning.

[1] Muys 2013, 42.

[2] Ibid.

The central element of the pillar model is the concept of *sustainable development*. The idea of sustainable development was introduced in 1987 when the United Nations' World Commission on Environment and Development (also named 'Brundtland Commission', see below) published its report *Our Common Future*.[3] This report defined sustainable development as: "development that meets the needs of the present without compromising the ability of future generations to meet their own needs."[4] This idea of sustainable development was motivated by the notion of (intergenerational) solidarity, which translates into the benefit of sharing resources with future generations. This adds a social dimension to the economic and environmental dimensions of sustainable development and by doing so forms the third column.[5]

The definition of sustainable development supports strong economic and social development, in particular for people with a low standard of living. At the same time, it underlines the importance of protecting the natural resource base and the environment. In short, it proclaims that economic and social well-being cannot be improved with measures that destroy the environment.[6] For the first time, efforts were made, and policy was created on a global scale, that not only protected the environment but assured an economically viable life for the social beings which inhabit it. This definition shows why the concept of sustainable development could become so successful.[7] As a result, the report of the Brundtland commission, named after its chairperson Gro Harlem Brundtland, and with it the concept of sustainable development, made the 1992 United Nations Conference on Environment and Development (UNCED) in Rio de Janeiro an unprecedented success in global cooperation. It represented a milestone in the long trajectory of humanity's quest to increase and sustain prosperity in the long term without disrupting the natural resource base on which it has developed.[8] Since then, the tree pillar model has been one of the most dominant and politically accepted models of sustainability.[9]

The reason for the apparent success of the concept of sustainable development and the pillar model, lies in its vagueness.[10] Worldwide sustainable development acquired a common connotation of being something important and positive, while leaving a large flexibility of attributing very different meanings to it among different segments of society.[11] The weak scientific foundations of the definition has led to the often arbitrary selection of sustainability criteria and indicators, and consequently to poor monitoring

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[3] http://www.unece.org/oes/nutshell/2004-2005/focus_sustainable_development.html; Full name: The Report of the World Commission on Environment and Development: Our Common Future.

[4] Muys 2013, 42; http://www.un-documents.net/our-common-future.pdf.

[5] Howarth & Norgaard 1992; Muys 2013, 42.

[6] http://www.unece.org/oes/nutshell/2004-2005/focus_sustainable_development.html.

[7] Muys 2013, 42.

[8] Muys 2013, 4; Diamond 2006.

[9] Muys 2013, 42.

[10] Ibid.; Redclift 1991.

[11] Schellhuber & Kropp 1998; Muys 2013 42.

and compliance.[12] Several efforts have been made to build sustainability indicators on more scientific grounds, for example the well-known concept of an ecological footprint.[13] Similarly, this paper sets out to look for scientifically viable indicators in order to investigate sustainable development – in the past.

There are several reasons why the pillar model has not held its initial success, most importantly on the observation that several planetary equilibria have been passed.[14] An example is the current global rise in temperature, which is believed to be the result of greenhouse gasses, which in turn are the result of a strong focus on economic development next to - instead of within - ecological boundaries. In the past 250 years, humans have been artificially raising the concentration of greenhouse gasses in the atmosphere at an ever-increasing rate, mostly by burning fossils fuels, but also from cutting down carbon-absorbing forests. Since the industrial revolution began in about 1750, carbon dioxide levels have increased nearly 38 percent as of 2009 and methane levels have increased 148 percent.[15] Furthermore, there is an increasing understanding that global environmental quality is a non-negotiable boundary condition for the economic system.[16] Thus, something fundamental has to change in the overall strategies of production, consumption and organisation of markets.[17] This attested failure of the dominant pillar model has led to the need for a model of sustainable development which does sufficiently incorporate planetary boundaries.[18]

2.2. Archaeology and Economy

In the following section we look at how past societal development has been explained based on a strong focus on the economic segment - pillar - of society in archaeological research. This can refer to a literal replication, such as the direct application of the pillar model to archaeological research. In case direct application is less apparent, this section will also refer to archaeological studies which implicitly attribute great meaning to the economic segment. Such a focus is often at the expense of the social and the ecological segments as drivers of change. Despite a recent attention for ecological factors, these have generally been disregarded when trying to reconstruct development trajectories of past societies. As this paper sets out to prove, this approach to historical and archaeological research coincides with the pillar model. A field in which this is most visible, is the study of the Roman economy. It is not the aim of this paper to become enveloped in the study of the ancient economy or to review different approaches and methodologies. It is however impossible to study sustainability in the past without first exploring certain elements that pertain to the study of the ancient economy.

[12] Howarth & Norgaard 1993; Stern 2007; Muys 2013, 42.

[13] Wackernagel e.a. 1999; Muys 2013, 42.

[14] Rockström e.a. 2009; Muys 2013, 42.

[15] http://earthobservatory.nasa.gov/Features/GlobalWarming/page2.php.

[16] Stevenson & Keehn 2007; Muys 2013, 42.

[17] Haberl e.a. 2011; Muys 2013, 42.

[18] Muys 2013, 42.

2.2.1. A short introduction to the study of the Roman economy

When studying the Roman economy, three things are necessary: determine what happened, explain why it happened, and assess these developments comparatively by relating these to other times, places, and contexts, thereby situating the Roman case in a global context of pre-modern economic performance. Explanations must be grounded in the empirical record, but do not directly emerge from it: the evidence never speaks for itself.[19] Or as one of the key agents of the New Institutional Economics approach and Nobel Prize winner Ronald Coase famously said: "If you torture the data long enough, Nature will confess." [20]

This paper is not primarily concerned with raw data, although data forms the basis of analysis, but instead it focusses on proxies. A proxy is, as defined by the Oxford English dictionaries: "A figure that can be used to represent the value of something in a calculation: e.g. '*the use of a US wealth measure as a proxy for the true worldwide measure*'."[21] In this way, this paper searches for proxies, which can serve as indications for sustainable or unsustainable past human-environment interactions. In other words, proxies are data which have been analysed and can usefully indicate one or more elements of a given system.

Studies of the Roman economic system tend to focus on performance. This analysis rests on the careful study of its visible manifestations, as is of course the case in archaeology. At the most basic level this requires the collection, analysis, and standardization of relevant data.[22] In other words, this requires a quantification of potential indicators. However, quantification studies of the Roman economy are not simply about counting and aggregating. Analysis of data ought to enable the measurement of change and variability, developments over time and variation across space.[23] A way out of this performance-centered approach is incorporating both comparative and causative approaches.[24]

Material remains are of crucial importance to acquire the data which is needed to perform an analysis of the Roman economy. Material remains - most frequently - consist of: consumer goods, technical devices and containers, remains of settlements, evidence of land use, building materials, human bones, plant and animal remains, coins, shipwrecks, and even traces of air pollution preserved in ice and sediment. All of these can be used to shed light on the economic life in the Roman world. In addition, information can be derived from literary accounts, stone inscriptions and other ancient written sources. When using ancient sources to reconstruct the Roman economy, the problem does not lie in the quantity

[19] Scheidel 2012, 1-2.

[20] Cios e.a. 2007, XI.

[21] Http://www.oxforddictionaries.com/definition/english/proxy.

[22] Scheidel 2012, 2.

[23] Bowman & Wilson 2009, 12.

[24] Scheidel 2012, 5-16.

of available sources, but in their interpretation. Records of how much was produced, traded and consumed are nearly absent. Therefore, modern observers commonly interpret different kinds of data, such as those listed above, and use them as putative proxies of Roman economic development. Proxies - in this case - are quantifiable data which, taken at face value, can indicate certain patterns or phenomena. When doing so, it is usually assumed that temporal or spatial variation in the quantity or quality of such proxies is taken to reflect economic change.[25]

Variation is an important theme in this paper, because it allows us to study temporal and spatial change. Archaeologists are determined to explain mechanisms of change. However, this is not an easy task, since variation is not easily or unambiguously elucidated. Because of the ambiguous meaning of variation, it is difficult to relate it directly to economic performance. For example, evidence suggestive of population growth might reasonably be interpreted as a proxy of growing economic output, but only if it was not offset by a reduction in per capita levels of consumption.[26]

2.2.2. The Roman economy – a theoretical debate

When looking at the study of the Roman economy, there appears to be a long tradition of opposing views. John Hatcher and Mark Baily point to the dominance of three competing 'supermodels': one that focusses on demography (a Malthusian perspective), one that focusses on class relations (a Marxist perspective) and one that focusses on commercialization.[27] With regard to this they conclude that: "[…] the discipline has barely advanced the stage of explicit model-building." [28]

Walter Scheidel declares that existing scholarship has primarily been concerned with establishing facts that are heavily indebted to contemporary modes of economic behaviour. Scheidel was certainly not the first author to indicate this trend, however, his recent declaration can be seen as a summary of this particular problem in the study of the Roman economy. Furthermore, he states that since the nineteenth century the debate on the Roman economy has been dominated by the contrast between 'primitivist' and/or 'substantivist' perspectives on the one hand and 'modernist' and/or 'formalist' ones on the other. Both perspectives are concerned with questions of scale - more or less economic development - but also, and crucially, with the structure of ancient economies. These positions therefore tend to focus on the variance of economic development, with formalists keen to document growth and integration and with substantivists pointing out constraints.[29] Both perspectives share a strong interest in the mechanisms and degree of economic integration, which is regarded as an index of economic development in general.

[25] Scheidel 2012, 2.

[26] Ibid.

[27] Hatcher & Baily 2011; Scheidel 2012, 7.

[28] Ibid.

[29] Nafissi 2005; Scheidel 2012, 7-8.

Both perspectives agree that for economies to grow, they have to become integrated.[30] Integration means that smaller economies would, through the improvement of existing networks of matter, energy and information, but also through the creation of new networks, become connected to other economies of varying size.

Very broadly speaking, the most recent generation of scholarship on the Roman economy has produced two competing approaches that focus on integration and with it the nature, scale and sustainability of economic growth. One vision privileges market relations, in which the Roman Empire created favourable conditions for production and trade. The other focusses on power relations, where integration was driven by tribute and rent collection and by the modes of exchange that effectively support it.[31] In practice, it would be a mistake to regard these perspectives as mutually exclusive causative interpretations.[32] This debate however underlines the pivotal role of comparison, theorizing and model-building in studies on the Roman economy.[33]

In 2002, Richard Saller revived the debate on Roman economic growth by emphasizing the necessity to distinguish gross or extensive growth from per capita or intensive growth (see below).[34] Peter Temin meets this demand by introducing alternative models for the nature of growth that are susceptible to empirical testing. He proposes two opposing visions: the first sees the Roman economy as having had a single spurt of productivity change whose effects were gradually eroded by Malthusian pressures; the second states that Roman productivity grew continuously until some unrelated (e.g. plague or natural disasters) factors inhibited it."[35]

The two competing and now dominant visions of Roman economic growth come down to a simple question: if and when attested, was economic growth terminated by endogenous or exogenous factors? In other words, was economic development the result of a limited and unrepeatable improvement in productivity that was gradually offset by population growth (i.e., by Malthusian pressures), or was productivity growth theoretically sustainable in the long run but in practice cut by shocks to the system such as political or military crises? In the former scenario, Roman expansion and eventual political unification of the entire Mediterranean and its hinterlands would have relaxed existing resource constraints by creating conditions that boosted agricultural output, trade, and the flow of information, thereby increasing the *Gross Domestic Product*. This, in turn, would have encouraged population growth that increasingly eroded these benefits by depressing real incomes and constraining further development. In the latter scenario, by contrast, economic growth might well have continued for longer than it actually

[30] Bowman & Wilson 2009, 15-53; Scheidel 2012, 8.

[31] Scheidel 2012, 8-9.

[32] Lo Cascio 1991; Scheidel 2012, 9.

[33] Scheidel 2012, 9.

[34] Saller 2002; Scheidel 2009, 46.

[35] Scheidel 2009, 46.

did had it not been interrupted by events (such as epidemics, political conflict, or invasions) that were not themselves a direct consequence of economic development.[36]

An example of a detailed study of the Roman economy is a project called 'The Economy of the Roman Empire: Integration, Growth and Decline', led by Alan Bowman and Andrew Wilson. The project attempts a detailed analysis of major areas of the economy where quantifiable bodies of archaeological and documentary data can be identified and compared. It looks at population, urbanization, agriculture, trade and commerce, mining and coinage. Examining for each a series of performance indicators which could track variation across space and time.[37] Remarkably, Bowman and Wilson remain modest about the results of their analysis: "[…] we cannot expect to derive a series of straightforward and unambiguous results from the data we have. At best, we may expect to identify a number of measurable indicators of trends that might tell us about different aspects of the economy."[38]

2.2.3. Problems with the study of the Roman economy

In general, the study of the Roman economy is accompanied by six considerations. First, recent years have witnessed a surge in publications that merely seek to demonstrate the existence of Roman economic growth and identify factors that are considered to have been conducive to this process. Some of this work draws on quantifiable proxy data taken to reflect economic growth. While this drive towards quantification is to be welcomed, Peter Temin remarks on the under theorization of these studies.[39] As with the definition of sustainable development (see above), weak scientific fundaments lead to the selection of arbitrary indicators.[40]

Second, a strong focus on economic performance and its consequences neglects what are perhaps the most interesting questions, those concerning the reasons for the observed outcomes.[41] This second consideration is the breeding ground for one of the main arguments presented in this paper, which petitions a multi-causal and systems approach to archaeological research and to sustainability in the past.

Third, the question arises whether or not it is meaningful to regard the Roman Empire as a single unit or entity, which includes episodes of growth, contraction, and political fragmentation, as well as greater or lesser degrees of administrative control. Can certain regions - pars pro toto - tell us something about the larger political or economic entity? An answer to this question is not easily given, but the question in itself again shows the need for a heuristic framework which is open to variation at different scales, be

[36] Scheidel 2009, 46.

[37] Bowman & Wilson 2009.

[38] Ibid., 12.

[39] Scheidel 2009, 46.

[40] Howarth & Norgaard 1993; Stern 2007; Muys 2013, 42.

[41] Nafissi 2005; Scheidel 2012, 5.

it local, regional of global. Bowman and Wilson address this issue by looking at the connections between the different geographical or structural parts of political or economic systems.[42]

Fourth, divergent modern reconstructions of the mechanisms of change of the Roman economy are ultimately shaped by analogies: with post-Roman Europe in the case of market-centered narratives or with other patrimonial empires in the case of otherwise centred narratives. One way forward that has the potential to bridge the gap between a neo-classical formalist approach, of comparative advantage and a benign state, and more substantivist or fiscalist models of commercial development is offered by the New Institutional Economics and Economics of Sociology. By demonstrating how social and cultural features shape economic activity, they alert to the overriding significance of historically specific 'rules of the game'. In other words, they focus attention on the incentives and constraints that were instrumental in determining Roman economic development.[43]

Fifth, the dialogue between the different kinds of evidence remains a problematic consideration. This is most visible when comparing archaeological and documentary (historical) evidence, as both often contradict one another. As we have seen, caution is advised when using documentary evidence without a critical perspective, although this can of course be said of all types of evidence. Due to this, Bowman and Wilson have argued to treat, where possible, the documents themselves as artefacts in their archaeological context. In addition, they suggest that the comparison of time series data for archaeological and documentary evidence for the same phenomenon can be instructive in illuminating possible biases in the data.[44]

Sixth, it is important to be specific about the limitations of the evidence. Different types of data converge in different distinctive ways, but it is safe to assume that they indicate at least the general direction of economic development. For example, the combination of more or higher quality goods being more widely distributed, of more or costlier infrastructure, and of more archaeologically visible settlements can all point to economic growth.[45]

2.2.4. GDP explained

In the previous section it was made clear that the study of the Roman economy has focussed on performance, growth and decline. In order to study the behaviour of the economic system as well as per capita wealth, GDP or Gross Domestic Product, was introduced into historical and archaeological research. The term GDP was conceived in the seventeenth century by the Englishman Sir William Petty,

[42] Bowman & Wilson 2009, 9.

[43] Scheidel 2012, 8-10.

[44] Bowman & Wilson 2009, 11.

[45] Scheidel 2012, 3.

who devised a calculation of GDP in order to properly shift the existing tax burden.[46] GDP is the sum of the value of total production and the sum of total income. Using GDP is an appealing approach since it ties income into the production structure and makes the connection between the standard of living and the efficiency of agriculture and manufacturing explicit.[47]

It is important to distinguish between two types of growth, and with it two different types of GDP. On the one hand there is aggregate or extensive growth, in which a simple increase in population growth leads to an increase in GDP.[48] This is not to be confused with extensive or aggregate GDP, which is the sum of the value of all goods and services.[49] On the other hand, there is intensive or per capita growth, which is achieved when greater efficiency in production means that every worker is producing more.[50] Like converging proxies of economic growth, it is not an easy task to distinguish between extensive and intensive growth,[51] and both may occur simultaneously.[52] Massive congruent changes in different indicators may well suggest not just the former but also the latter. Although changes on a large economic scale do not clearly translate to estimates of economic output in terms of per capita product or real incomes.[53]

Ancient economy studies do not only focus on the size of the GDP and what it can say about the behaviour of the any economic system. At least as important as its size, is the distribution of the GDP. In simpler terms: who had the money? If intensive economic growth could reliably be established, there would still be the need to ask how these gains were allocated. Indications of rising living standards in the general population are not incompatible with the notion of disproportionate elite enrichment: high profile trade and urban monumentalization can easily be read both ways.[54]

Historians are unable to establish a Roman GDP without relying on exceedingly schematic extrapolations from select data for prices and wages. More generally, GDP estimates are to a significant extent determined by what we expect to have happened rather than by empirical measurements. Scheidel sees GDP estimates as an unsurmountable constraint on the study of the Roman economy.[55] Estimates of GDP are useful mostly in establishing boundaries that constrain modern conjecture but are far less

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[46] Http://www.economist.com/news/finance-and-economics/21591842-meet-sir-william-petty-man-who-invented-economics-petty-impressive.

[47] Allen 2009, 327.

[48] Bowman & Wilson 2009, 28.

[49] Ibid., 12.

[50] Ibid., 28.

[51] Scheidel 2012, 3.

[52] Bowman & Wilson 2009, 28.

[53] Scheidel 2012, 3.

[54] Ibid., 4.

[55] Scheidel 2012, 4.

capable of supporting cross-cultural comparison, of distinguishing among regions, or of discerning change over time.[56] Per capita growth is more significant in demonstrating economic progress, and it is this issue which is most at stake in the debate on the Roman economy.[57]

Bowman and Wilson remain sceptical about estimating per capita GDP, on the grounds of the uncertainty concerning population figures. They therefore suggest to look at different proxies, which might offer some indications of per capita levels of income and expenditure.[58] Bowman himself, in a later chapter has put it as follows: "[…], it is difficult to see that we can make any sense of a GDP-based approach without putting considerable effort into generating more robust figures; this applies particularly to the derivation of useful per capita estimates […].[59]

Finally, a GDP-approach requires either a great deal of economic information that is either unavailable or not known with much accuracy, or it requires very strong equilibrium assumptions so that the small amount of available information can be used as proxy data for what we do not know about the economy. In addition, the population must also be known in order to calculate average income, and population estimates are still controversial. Consequently, while GDP calculations help organize what is known about the Roman economy, any calculation of per capita GDP is bound to be problematic.[60]

2.3. Scheidel vs. Wilson

2.3.1. Introduction

This section serves to illustrate the conscious application of the pillar model in archaeological research. As we have seen, this replication can be quite literal, but it can also refer to studies in which it is implicitly present. The selected studies have both focussed strongly - solely - on economic indicators to explain economic and wider societal trends. At first, this may seem logical, but as this papers sets out to prove, it would further motivate future research to include interdisciplinary proxies when trying to reconstruct development patterns of past societies. The two selected articles, *In Search of Roman Economic Growth* (2009) by Walter Scheidel and *Indicators for Roman Economic Growth: A Response to Walter Scheidel* (2009) by Andrew Wilson, shed light on the debate and proxies surrounding the calculation and, with it, the utility of the Roman GDP. Just as the pillar model focusses strongly on the economic sector, so do both articles focus on the GDP to understand the ancient economy as well. As a result, much temporal, cultural and chronological variation is not given a chance to emerge from the archaeological record.

[56] Scheidel 2009, 4.

[57] Bowman & Wilson 2009, 28.

[58] Ibid., 12.

[59] Bowman 2009, 182.

[60] Allen 2009, 327-328.

The extent and nature of economic growth achieved in antiquity continues to provoke debate. Keith Hopkins argued that the period from 200 BCE to 200 CE had seen some modest growth.[61] Some historians have tended to downplay the significance or extent of such growth, emphasizing stagnation over the *longue durée*.[62] Others are more optimistic about seeing growth in the material record.[63] The discussion between Scheidel and Wilson is about two competing hypotheses: one sees the Roman economic growth in the Late Republic and Early Principate as a single unsustained spurt of economic growth, the other supports the model of sustainable growth which was eventually checked by external factors.[64] The distinction between these different models of economic growth is a hypothesis first proposed by Peter Temin.[65] In order to distinguish between these opposing scenarios it is important to investigate whether the abatement of economic expansion occurred ahead of exogenous shocks, such as the Antonine plague of the late second century, or whether it coincided with these events.[66]

The main aim of Scheidel in his 2009 article is not solely to understand what the data reveals about economic change over time, but what we would need to know in order to determine whether these data reflect extensive or intensive economic growth (for distinction between the two concepts see above). Moreover, he investigates why any such growth occurred, abated and ceased and how it is related to the distribution of incomes.[67]

Some initial considerations have to be made clear: first, the difference between intensive or extensive growth is crucial to this discussion; second, and related to the first, the difference between a strong or weak reading of proxies. A strong or optimistic reading of the proxy data implies that they can be useful to explain the economic output in gross and even in per capita terms. This type of reading is opposed to a weak or sceptical reading that allows for the possibility that economical productivity cannot be straightforwardly inferred from proxy data.[68]

The discussion between Scheidel and Wilson is not only about which scenario of economic growth is most plausible, but also which proxies are to be considered sufficiently robust to be able to say something about the ancient economy.[69] In his paper Walter Scheidel chooses the following proxies: shipwrecks, levels of lead and copper pollution derived from arctic ice cores and lake sediments, deposits of domesticated animal bones at Italian sites, and data on personal income. According to

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[61] Hopkins 1978; Bowman & Wilson 2009, 28.

[62] Millett 2000; Bowman & Wilson 2009, 28.

[63] Hitchner 1993; 2005; Wilson 2002; Woolf 2000; Bowman & Wilson 2008, 28.

[64] Wilson 2009, 71.

[65] Temin (forthcoming)

[66] Scheidel 2009, 47.

[67] Ibid., 46.

[68] Scheidel 2009, 51-52.

[69] Wilson 2009, 71.

Scheidel, two separate issues are at stake: whether these distributions reflect economically relevant developments - such as trade volume in the case of shipwrecks or meat consumption in the case of animal bones -, and whether we are able to relate these to trends in gross or intensive economic growth, if we are indeed prepared to interpret these as reflections of economically relevant developments. The meaning of the different proxies in relation to economic performance shall be discussed in the following section.

2.3.2. Proxies

2.3.2.1. Shipwrecks and long distance trade

Scheidel first looks at the number of shipwrecks found in the Mediterranean.[70] He states that "[i]n principle, increases in the volume of maritime trade can be expected to be positively correlated with economic growth, at the very least with extensive growth and - if the increase is rapid - with intensive, per capita growth as well."[71] Despite this optimistic view, Scheidel also gives three confounding variables related to the use of shipwrecks as proxies of economic growth.[72] He states that the attested peak (figure 2) is in fact an underestimation of the expansion of the amount of traded goods in this particular period. The reason for this is that merchant ships had most likely grown in size, which means that their cargo, and the amount of traded goods had grown.[73] Furthermore, merchant ships most likely took direct routes across the Mediterranean, making them travel across deeper waters. If a ship had sunk in deeper waters, instead of near the coastline, it is harder for archaeologists to discover it.[74] At the same time, changes in the nature of the cargoes - most notably in the presence of ceramic containers and marble - render wrecks from this period more visible and thus more likely to be found, compared to those that had carried organic products, which may arguably have happened more often in later centuries. This of course causes an overestimated variation in the actual amount of shipping. It is however not possible to ascertain to what extent these countervailing factors cancelled out each other.[75] Indeed, changes in the use of barrels or sacks may obscure actual trends, and shipwrecks only remain visible if they contain durable cargo.[76] Wilson also argues against the use of shipwreck data as a reflection of economic performance. He states that the number of shipwrecks over time are so demonstrably at variance with the evidence from terrestrial sites that the evident biases in the maritime data question its utility for the purpose of tracking economic performance over time, and especially within the Roman period.[77]

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[70] Scheidel 2009, 49-50.

[71] Ibid., 49

[72] Ibid.

[73] Parker 1992, 26; Scheidel 2009, 49.

[74] Arnaud 2005, 98-148, 217; Scheidel 2009, 49.

[75] Scheidel 2009, 50.

[76] Scheidel 2012, 3.

[77] Wilson 2009, 71.

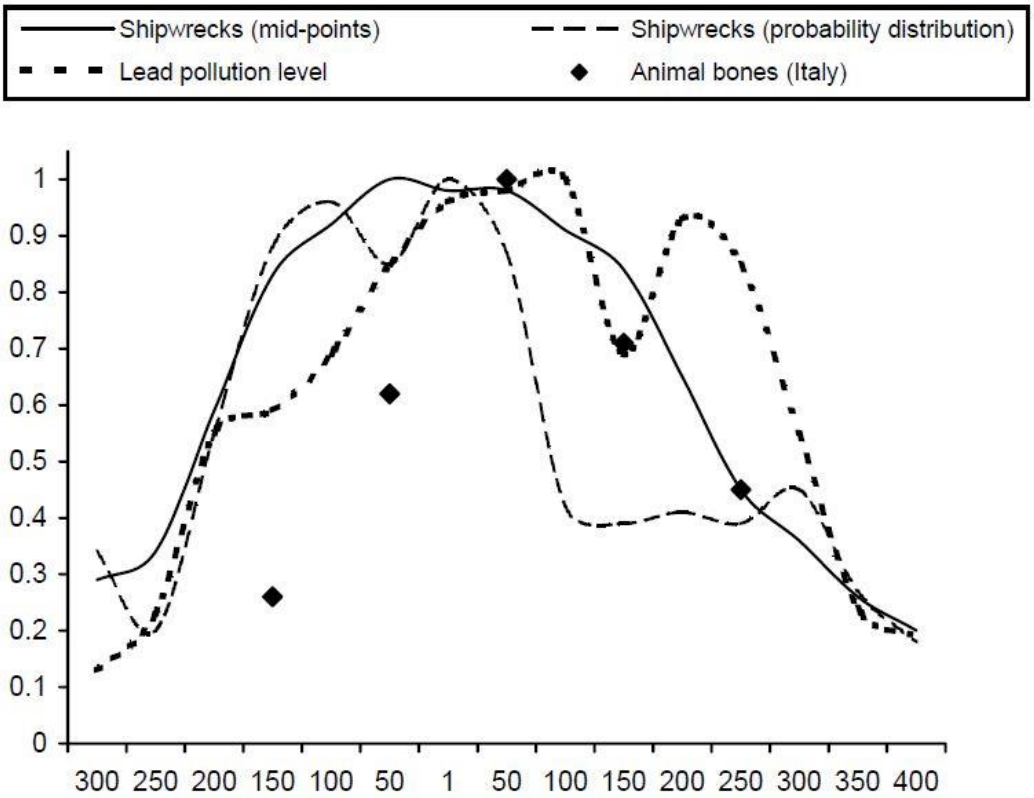

Figure 2: Standardised distribution of Mediterranean shipwrecks, lead pollution caused by Iberian mining, and animal bone deposits in Italy. Source: Parker 1992 fig. 3, Wilson 2009 fig. 9.4, Kylander e.a. 2005 fig. 3, Jongman 2007 fig. 22.1, Scheidel 2009, 48.

Wilson gives the following example of a shipwreck analysis: "The decline in number of wrecks after A.D. 100 is a bias peculiar to the wreck data set, and is not reflected in the evidence of long-distance maritime exports from 1st- and 2nd c terrestrial sites; ARS exports from N Africa really take off and the harbour at Portus receives a major upgrade under Trajan just as the graph shows wreck numbers halving. The overall wreck graph is a graph of known cargoes on the seabed as much as (or even rather than) wrecks, as such, it is highly sensitive to cargo durability and visibility, and it is dominated by patterns of amphora usage. If one looks instead at the numbers of wrecks of stone cargoes, rather than the overall wreck numbers or the amphora cargoes, these continue increasing through the 2nd and even into the 3rd c. This is the picture we would expect from archaeological and epigraphic evidence for building activities on land. The drop in overall wreck numbers must be a combination of such factors as changes in cargo visibility resulting from the increased use of barrels, the current under-exploration of the N African coastline, and perhaps larger shipping routes across open water. These factors demonstrate that the wreck evidence cannot bear a straightforward relationship to the volume or intensity of maritime trade, and is unusable as a proxy for reconstructing economic performance in the Roman period."[78]

[78] Wilson 2009, 71 -72.

2.3.2.2. Lead pollution and mining

Remains of lead and copper pollution in the Greenlandic ice cap and in peat bogs and lake sediments in Western Europe are caused by the deposition of windborne contaminants generated by smelting of mineral ores, most notably in the Iberian Peninsula.[79] Atmospheric lead pollution from Roman silver extraction has been registered as far away as Greenland.[80] The mutual consistency of different data samples confirms that this evidence may be considered as a reliable index of variation in the scale of Roman mining activity.[81]

The Roman Empire made extensive use of coin, and bullion supply was crucial to the highly monetized Roman economy. Mining studies therefore focus on the output of coinage metals (gold, silver, copper), but also other metals whose extraction was important for production of tools, weapons, and other artefacts.[82] In these studies of Greenland ice core data and peat bogs, atmospheric pollution can be seen as a proxy measure of diachronic production of copper, silver and lead.[83] Walter Scheidel plotted this pollution data on a graph together with shipwreck data and meat consumption data in Italy (figure 2). By doing this, he wanted to visualize converging proxies, in order to be able to speak about general economic trends.[84] His use and visualisation of all of these proxies were dismissed by Andrew Wilson. In the scope of this paper, however, we will not go into detail about the specific elements of their discussion.

The relevance of this type of data in understanding Roman economic growth is less clear. Strictly speaking, remains of lead and copper pollution measure change in metal extraction and processing rather than economic growth. While these pollution levels and economic performance might be related, as they clearly are in the case of modern increases in air pollution levels, this relationship is less straightforward in earlier economies. So, if changes in the pollution record can be assumed to reflect changes in mining activity, do changes in mining activity reflect economic performance? Further still, does economic growth reflect sustainable per capita growth of GDP? Finally, should these signals be uniquely connected to Rome?

Bowman & Wilson collate archaeological and documentary evidence for mining with numismatic data, to test the hypotheses that the exploitation of new sources of metal was to a significant degree responsible for economic growth from Augustus onwards, and that the abandonment or loss of these sources created or intensified fiscal problems in the late second and the third century CE. [85]

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[79] Scheidel 2009, 49.

[80] Lowe 2009; Bang 2012, 201.

[81] Scheidel 2009, 49.

[82] Bowman & Wilson 2009, 64-65.

[83] Hong e.a. 1994; Bowman & Wilson 2009, 64-65.

[84] Scheidel 2009, 48.

[85] Bowman & Wilson 2009, 65.

As this paper proposes, such a monocausal approach is outdated. Not only is it becoming more apparent that the performance of the economy cannot be inferred from a single proxy, but also that the general societal performance cannot be inferred from the economy alone. Recent academic interest in climatic variation has already begun to generate a growing amount of data pertaining to the Roman period. An enormous variety of proxies has been brought forward, including tree-ring width, tree-line movement, glacier movement, analysis of stable isotopes and mercury deposits as well as pollen, algae, and molluscs recovered from ice cores and stalagmites and peat and lake sediment deposits. While no synthesis currently exists, a substantial series of data sets indicate an impressive convergence of trends all over Eurasia. Although the respective ranges vary by location and type of data, on average, this warmer period commenced in the second century BCE and ended in the third century CE.[86]

Roman mining in the Iberian Peninsula abruptly ceased at the end of the second century CE. Several explanations for this have been put forward, such as an incapacity of military forces to protect these ventures or a simple cessation of the use of these mines, but these are hypotheses that have yet to be proven. Most remarkable is that - most often - the minerals were not yet depleted, so it is not a question of sustainable management of resources, but rather of sustainable economic or societal performance.[87] To explain this further, if mining activity was of vital importance - and this is an important question on its own - then why would the Roman government cease to exploit these mines? Walter Scheidel proposes a simple cost-benefit analysis: the ratio of investment to profit ceased to be satisfactory. This would either mean that the economy was already declining in the second century CE and/or that the state was not as dependent on mining as suggested by Andrew Wilson.[88] The former means that the Roman economy was somehow not functioning in a sustainable fashion. This strengthens the idea of unsustainable growth in the first centuries CE, possibly being eroded by Malthusian pressures.

2.3.2.3. Income and well-being

A final proxy to be discussed is data about income. As Scheidel puts it: "[t]he study of intensive economic growth in the Roman period acquires meaning only if it can be related to the question of the development of real incomes, which are a critical determinant of well-being. In order to assess the performance of the Roman economy we would need to know three things: how gross GDP changes over time; how per capita GDP changed over time: and how the distribution of income changed over time."[89] The problem here however, is that there is very little direct evidence of income data in the Roman period, let alone any series of which gives a consistent diachronic view. Income and well-being seem to be both inversely related to population: a larger economic output was likely to produce more people rather than more

[86] Scheidel 2012, 12.

[87] Scheidel 2009, 55-56.

[88] Ibid., 55-56.

[89] Ibid., 63.

income per person.[90] Yet, the visible remains often tell a different story. Roman archaeologists encounter signs of innovation and expansion: more and larger cities, more advanced technology, bigger ships, more writing, new crops, more metal and more consumer goods of any kind. It would be perverse to doubt Roman growth and prosperity given the abundance of evidence for innovation and expansion. However, it seems that this growth only furthered inequality. This coincides with a Malthusian model in which income gains are not merely unevenly distributed but increasingly absorbed by a growing population.[91]

It is particularly striking that while the Roman Imperial period witnessed stagnation, increases in body height in both the Mediterranean and Central/Western Europe coincided with episodes of demographic contraction. Thus, in a sample of 1,021 skeletons from 74 sites in Central Italy, body height was greater both in the Iron Age (1100 – 700/600 BCE) (166.6 cm for 220 males, 154.3 cm for 181 females) and in the Middle Ages (eight to sixteenth century CE) (166.9 cm for 187 males, 154.5 cm for 150 females) than in the Roman period (753 BCE – 476 CE) (164.4 cm for 153 males, 152.1 cm for 130 males). 1,867 specimens from 61 sites in Britain reveal increases in mean body height of 5.7 cm for males (n=773) and 4.4 cm for females (n=557) between the Roman and Early Medieval period.[92] All these observations would strongly support a Malthusian scenario in which Roman intensive economic growth, to the extent that it occurred after the beginning of the Common Era, failed widely to disseminate gains in well-being and only substantial population losses generated palpable benefits. This data should, however, be complemented with sufficiently wide-ranging skeletal isotope analysis of changes in diet, which can then serve as proxy of variation of income and well-being.[93]

2.3.3. Sustainable vs. Unsustainable growth

In this section the main points of argument given by Walter Scheidel to underpin his hypothesis of unsustainable growth, curtailed by Malthusian pressures, will be summarised. It seems important to reiterate these arguments, as they are a window to an economically founded hypothesis of societal development. This section also serves as a culmination of the points which are discussed in earlier sections of this paper.

The model of *one-off growth* curtailed by Malthusian pressures entails a different look at Roman economic growth and society. It is generally assumed that the empire - as a whole - experienced unprecedented growth in the first centuries CE as a result of stable political, social and military circumstances. If we assume that the evidence put forward by Scheidel can in fact be regarded as economic proxies, then these proxies actually point to a stagnation of growth in the first centuries CE.[94]

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[90] Scheidel 2009, 63.

[91] Ibid. 63-64.

[92] Giannecchini & Moggi-Cecchi 2008, 290; Stephan 2008; Scheidel 2009, 66.

[93] Scheidel 2009, 66-67.

[94] Ibid., 67.

Based on shipwreck data, lead pollution, fish salting installations and body size, Scheidel concludes that Roman economic growth stagnated and ceased in the first century CE, and even earlier in the core areas of the West Mediterranean compared to the Roman East. He explains this by proposing the concept *centrifugally staggered growth*: the idea that growth stagnates earlier in the core and in more densely populated areas, and later in the peripheral areas. As an additional example, Scheidel points to the economic situation in Roman Britain during the second century CE. He states that for what these indicators are worth, they are uniformly consistent with a Malthusian model of one-off unsustainable growth.[95]

The reason for the economic growth in the last two centuries BCE is, according to Scheidel, the result of its incorporation in a more developed economic system, in this case the Hellenistic Eastern Mediterranean and Near East. He argues that modern economies have undergone a *demographic transition*, meaning that they decoupled population growth from output growth, allowing sustainable development to continue at lower, but positive levels. In a pre-transition environment, such as the Roman Empire, incorporation into a more mature system will deliver benefits in per capita terms, but will eventually encounter the countervailing force of population growth driven by rising real incomes.[96]

Scheidel recognizes this model of pre-transition environments in the Hellenistic and Roman period. Roman conquests merged the political-military systems of the Eastern and Central Mediterranean, with profound consequences for economic integration and capital allocation. The violence and dislocation (wars and mass enslavement) that attended this process constrained population growth and mobilised free-floating resources, thereby generating growth and income gains, most of all among core beneficiaries of this process in Italy. In Late Republican Italy (147 BCE – 30 BCE) the combination of checks on free population growth through war and emigration warded off Malthusian pressures. The inflow of capital and slaves, the externalization of costs of war by conducting much of it in the provinces and the distribution of the fruits of expropriation among commoners can all be expected to have sustained income growth that was potentially substantial but necessarily unsustainable in the long run.[97] What matters here is that growth ceased in the core areas, thereby predicting similar, if delayed, outcomes in the periphery. This model assigns critical importance to the state, with its tributary mode of surplus mobilization that ultimately underwrote urbanization, monetization, and exchange, and ensured a base-line level of stability, not to be confused with ongoing growth, into Late Antiquity.[98]

[95] Scheidel 2009, 67-68

[96] Ibid., 68.

[97] Ibid., 68; Scheidel 2007.

[98] Scheidel 2009, 68-69.

2.4. Conclusion

Walter Scheidel can clearly be categorised as a historian who focusses on economic performance. Furthermore, he supports the scenario of unsustainable growth where a single spurt of productivity was gradually eroded by population pressures, e.g. the Malthusian/demographic perspective. Scheidel employs an optimistic reading of the different proxies, but also points to the future. As clarified by this progressive point at the end of his paper: "[p]rogress in the study of Roman economic growth will critically depend on the expansion of the range of proxy data and on the adoption of a more explicitly comparative perspective."[99] As has become clear, it is impossible to determine whether economy and society as a whole were (un)sustainable by looking solely at economic proxies. As we have seen, this approach regards economy as an almost independent variable - or pillar - of sustainable development in the past. Paradoxically, economic behaviour cannot be explained by simply looking at - arbitrarily selected - economic proxies. This perspective coincides well with the earlier explained *pillar model*. As is becoming apparently clear in our current day and age, so too does a central focus on economy not deliver the necessary results for the study of sustainable development in the past. This paper proposes to look at different proxies, such as ecological and social, not as independent elements, but as co-dependent variables. The lack of success of these one-dimensional approaches clarifies the need for a more integrated approach. The next chapter will look at economy, not as a separate pillar but as an element of - or an element within - the ecological environment.

[99] Scheidel 2009, 67.

3. Nested Model – Going beyond the Pillar Model

3.1. An introduction to the Nested Model

The second model to be discussed is the so-called nested model. This model was conceptualized, because of a dissatisfaction with the initially popular pillar model.[100] As mentioned in the previous chapter, the commonly adopted three-pillar model of sustainable development has not shown sufficient effectiveness for acting within planetary boundaries.[101] This observation is based on the fact that several planetary thresholds have been passed.[102] As for approaching sustainability in the past, the pillar model also comes short, specifically - but not entirely - because of its strong focus on the economic segment of society. For these reasons, a nested sustainability model, considering society and economy as a subsystem, nested in the ecosystem seems a more adequate basis for approaching sustainability.[103] The following chapter will investigate the viability of the nested model in historical-archaeological research.

Even though the nested model can be seen as - or in fact is - a reaction to the pillar model, both share a similar architecture: they are made up of the same three elements: society, economy and environment. In this regard, the nested model can even be considered as an improved version of the pillar model. However, as opposed to the pillar model, the nested model does not see its three elements as separated or even as equal parts. The nested model proposes to conceptualize the three elements hierarchically: the economic system is nested in society, which in turn is nested in the environment.[104] The Greek style temple of the pillar model (see previous chapter) is therefore replaced by three concentric circles (figure 3): the largest of which represents the environment, in which a smaller circle is placed, representing society, in which an even smaller circle is placed, representing the economy segment. This model is applicable at any different scale (local, regional and global), and is therefore not reserved for explaining large scale global events.

The main difference between the pillar model and the nested model is the interaction and positioning of the three elements. As was made clear in the previous chapter, the pillar model sees economy as an independent element, or *pillar*, on which a strong and singular focus is placed. Societal performance, and with it (societal) sustainability, is straightforwardly inferred from economic performance (see the discussion between a Malthusian vision of the Roman economy *versus* the vision that the Roman productivity grew continuously until some unrelated external factor inhibited it). The nested model sees economy (its smallest circle) as being at the service of societal well-being (the medium circle), and societies can prosper within the possibilities and limits offered by the natural environment (largest

[100] Muys, 2013, 42.

[101] Howarth & Norgaard 1992; Muys 2013, 42.

[102] Rockström e.a. 2009; Muys 2013, 42.

[103] Muys 2013, 42.

[104] Ibid.

circle).[105] This approach not only relinquishes the dominant role of the economic element as a proxy for the well-being of the social system, but it completely turns the formula around: economy is no longer the most viable indicator of societal prosperity or performance, but it is now placed at the service of society. Economy is constituted by society, which is constituted by the environment.

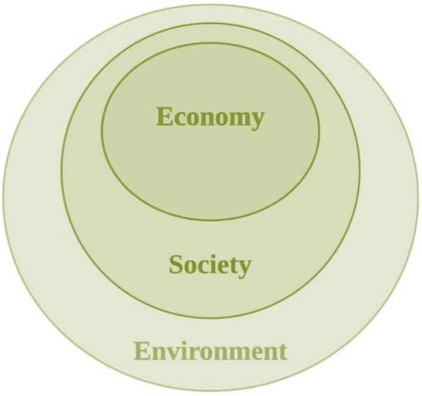

Figure 3: Representation of the nested model as a sphere made up of three concentric circles (environment, society and economy). Source: https://www.missouristate.edu/Sustainability/default.htm.

The difference between the pillar model and the nested model can be summarised as a difference in the relation between the three elements (environment, society and economy). Instead of being separated, they are now heavily co-dependent. In other words: people and society create the abstract and intangible economic system on which they themselves depend. These economic systems then shape society and society shapes the environment. Unlike the economic system, the environment however is a non-negotiable and tangible system. In other words: it is a physical determining factor for all living creatures in a certain time-space context. Mankind has no other choice but to live in the current physical world and this world, to a high degree, governs our actions and our possibilities. A modern example to illustrate this recursive relation between environment, society and economy: loss of marine biodiversity and fish populations are a direct consequence of unsustainable fishing. Fishing - besides a means of procuring food - is an economic activity, which is governed by the larger economic system, which is a human creation. Unsustainable fishing leads to a concomitant loss of fish populations and this serves a direct blow to the environment. The environment in turn negatively affects the economy, which in turn negatively affects society.[106] This example serves to clarify that one element (economy, society and environment) does not stand alone. In fact, by setting limits and creating possibilities, they highly influence each other.

[105] Unpublished presentation Prof.dr.ir. Bart Muys.

[106] Http://sustainabilityadvantage.com/2010/07/20/3-sustainability-models/

In conclusion the nested model is a framework for understanding the limitations put on society and economy by the environment. On top of that, economy is no longer the main indicator for societal performance or sustainability. Economy is now caught up in a relation of servitude with society; it is now considered to exist in service of society.

3.2. The nested model and archaeological research

As in the first chapter, this section serves to illustrate the (un-)conscious application of the nested model in archaeological research. This application can be quite literal, but it can also refer to studies in which the nested model is implicitly influential. Two research projects will be discussed: First, a case study of the Middle Rhône Valley between 1000 BCE and 1000 CE, which is part of a larger research project investigating the spatio-temporal aspects of resilience in complex social systems. The study was published in *The Model-Based Archaeology of Socionatural Systems* by T.A. Kohler and S.E. van der Leeuw; Second, we will look at specific chapters (one, two and nine) of the book *Regional Pathways to Complexity* by P.A.J. Attema, G.-J. Burgers, P.M. van Leusen. These chapters were selected because of the comparative value and because they were deemed representative for the lay-out of the larger research project. Both studies, the Middle Rhône Valley and Regional Pathways to Complexity, are characterised by a view in which economy and society are embedded within the environment. This idea may seem self-evident, but as the first chapter of this thesis has set out to prove, this has not always been the case.

The study of the Middle Rhône Valley and the case studies presented in *Regional Pathways to complexity* will be analysed comparatively, in order to highlight differences, but most importantly to prove the hypothesis that these are working within the nested model. Both studies cover a comparable time frame (Bronze - and Iron ages to Late Antiquity), but they do not cover the same region. This can be seen as an advantage, as both offer a window into the complex system of the Mediterranean region. Both studies have been broken down into three segments: (1) environment, (2) settlement pattern (3) and economic aspects. The amount of information about these different aspects may differ from study to study, resulting in a smaller or larger body of text. Where possible, these studies have been augmented by other archaeological, historical or palaeoenvironmental data.

3.3. Introduction

3.3.1. Modelling the Role of Resilience in Socioenvironmental Co-evolution – Middle Rhône Valley between 1000 BC and AD 1000

This first study, by Jean-François Berger, Laure Nuninger and Sander van der Leeuw, has been selected because of its holistic approach to reconstructing past events, particularly because of the manner in which environmental proxies have been integrated. It is not only the integration of these environmental proxies which serves this paper, but the importance given to them when reconstructing past settlement dynamics. In simple terms, Berger *et al.* state that the environment is one of the main determinants of societal evolution. If then society evolves according to certain environmental conditions, then the economy evolves with it.[107]

The hypothesis of the environment determining human evolution may sound familiar. It is very similar to the ecological determinism of the *New Archaeology* or *Processual Archaeology,* where (material) culture was seen as mankind's adaption to his surroundings. The study of the Middle Rhône Valley is no revival of 1960's or 1970's archaeological thought, however, because of the recursive relation between the subsystems (see above): nature and culture (or society) evolve together; hence the title *socioenvironmental co-evolution*.[108]

The larger research project, in which the study of the Middle Rhône Valley has its place, "aims to develop a conceptual model of the dynamics that drive the trajectories of regional socioenvironmental systems by looking at three case studies." [109] This conceptual model will combine elements of four different research domains, each with their own body of theory: (1) natural sciences and complex systems theory, (2) organizational and information science and dynamics of social organization, (3) ecology and resilience theory (4) and social anthropology and culture theory. The starting point of this project is the hypothesis that the continued existence of socioenvironmental systems depends on the adequacy of the interaction between their social and environmental dynamics.[110]

According to Berger *et al*., the adequacy with which society and environment interact varies through time and is dependent on the development of both these domains. In other words, systems with an adequate socioenvironmental interaction are more resistant to external shocks (war, social-, political or economic crisis,…) compared to systems with a lesser degree of socioenvironmental interaction.[111] In order to investigate this rather abstract interaction between social formations and their environment, Berger *et al.* propose to focus on the following aspects: (1) the periodicities of the climate dynamics over the long term, (2) the natural dynamics of the landscape in the area, (3) the societal dynamics (4) and the technologies enabling the interaction between the societies and their environments. An understanding of these aspects should lead to an understanding of both the societal and the environmental dynamics. By looking at the long-term co-evolution, the interactive relation between both should become visible.[112]

[107] Berger e.a. 2007.

[108] Ibid.

[109] Ibid., 41.

[110] Ibid.

[111] Ibid., 42.

[112] Ibid.

3.3.2. Regional Pathways to Complexity

Regional Pathways to Complexity is the short title for a project, which ran from 1997 to 2010. The project covered the long-term archaeology of three regions in Italy (figure 4): The Pontine region in Lazio, the Salento Isthmus in Apulia and the Sibaritide in Calabria. This paper will only discuss the study of the Pontine region, since the concepts and methods applied to all three regions are virtually the same. The full title of the project was *Regional Pathways to complexity, Landscape and Settlement Dynamics in Early Italy from the Bronze Age to Republican Period*. The project's primary aim was a multidisciplinary and comparative assessment of processes of centralization and urbanization in three Italian landscapes during the first millennium BCE. Particular attention was given to the internal social dynamics of the investigated regions and, correspondingly, to local responses and interaction with the process of Greek and Roman colonialization.[113] Greek and Roman colonialization will not be systematically discussed in this paper, but it does nonetheless remain an important factor when reviewing the first millennium BCE in Central Italy. The project also aimed at demonstrating both the complex nature of the archaeological reality, and the significant perspectives offered by regional archaeological landscape studies. This was done by comparing the development of indigenous societies in Central and Southern Italy throughout the first millennium BCE until and including their incorporation into the Roman state system.[114]

Figure 4: Locations of the three core research areas of the RPC project in Italy: The Pontine region, the Salento Isthmus and the Sibaritide. In this paper we only focus on the Pontine region. Source: Attema e.a. 2010, 2 (fig. 1.1).

The project approached the aims stated above by constructing and testing dynamic settlement models.[115] "Regional settlement models built by archaeologists are typically based upon both a review and assessment of all the available archaeological information for the region, and on theoretical models of the structure and development of past societies."[116] The research was organised around two main themes,

[113] Attema e.a. 2010, 1.

[114] Ibid., 1-3.

[115] Ibid., 2-7.

[116] Ibid., 11.

each comprising two complementary topics: on the one hand, settlement and land use studies based on archaeological and ethnographical research; on the other hand, landscape and technology evaluation founded on palaeo-environmental research and technological studies (including pottery studies). Attema *et al.* then integrated these different studies, with the aim of both constructing and testing dynamic settlement models.[117]

Just as with the Middle Rhône Valley-project, the principle point of departure for this study is a systematic and intensive regional survey. The RPC project in the Pontine region includes transect surveys, urban surveys and surveys of the rural catchment area of ancient settlements. Archaeological field survey is: "a prospection technique that is typically used when undertaking an inventory of archaeological remains within a defined study area".[118] Although this definition is restricted to archaeological research, it can be widened to include geomorphological, sedimentological and pollen analysis.

A study of Central and Southern Italy between the end of the Bronze Age and the end of the Roman Republican period presents several major challenges: (1) the size of the region, (2) the length of the period under investigation, (3) the difficulty to effectively investigate the long-term processes operating at a certain space-time context. The processes that involved the growing complexity of indigenous societies, and the transformation of traditional rural and pastoral ways of life into urbanism during the period of 'external' Greek and Roman colonization.[119]

In the archaeology of Italy from the Bronze Age to the Roman period, the study of the internal development of indigenous Italic societies and landscapes has remained a relatively underdeveloped area. This is due to the emphasis on explanations relying on external factors (the influence of non-Italic cultures), dominant historical processes (the Greek and Roman colonisations), and a traditional culture-historical view of society (stages of growth, flowering and decline).[120]

At the same time, issues ranging from methodological details to problems of data analysis and interpretation are continuously and fervently debated - a critical attitude which demonstrates the health of the discipline. However, macro-regional interpretative schemes have not yet been widely employed: regional archaeological projects are all too often inward-looking. Projects may therefore evaluate basically similar dynamics from different perspectives and, consequently, explain them in rather different terms. This is an unhappy incongruence, and it precludes the analysis of patterns and dynamics in supra-regional framework.[121]

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[117] Attema e.a. 2010, 11.

[118] Ibid., 15.

[119] Ibid., I.

[120] Ibid., 1.

[121] Ibid., 7.

Intermezzo: Different timescales in Archaeology

First, the idea of different timescales shall be defined. There have been various approaches to timescales in archaeological research. Here we will discuss the concept of 'non-linear time'. To put it in simple terms, a non-linear time approach means that history/time is no longer seen as a simple and singular process from A to B. Since the 1980's there have been two approaches to historical time that diverted from the dominant linear view of time. Although inspired from quite different sources, both share the basic idea that different historical phenomena or processes work at different temporal scales. The first approach borrows from French historical theory developed by the *Annales* school. The *Annales* school was very critical of traditional history which can be termed a simple sequence of events. One proponent of the *Annales* school, Fernand Braudel (1902-1985), proposed to distinguish three timescales (figure 5) over which history unfolded: the long-, medium- and short term. The long term, or *longue durée*, covered very slow-moving processes such as the environment; the medium term referred to social or structural history, such as persistent forms of social or economic organization; and finally, the short term referred to events or individuals, usually the main focus of traditional history.[122]

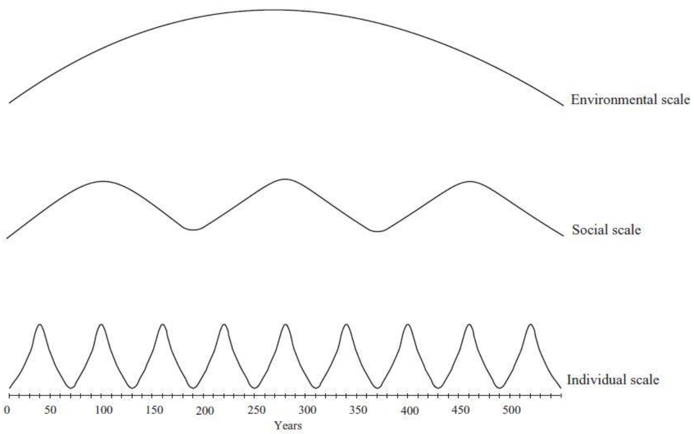

Figure 5: Different timescales: The slow moving environmental scale (long term), the social scale (medium term) and the fast moving individual scale (short term). Source: Lucas 2005, 18 (figure 1.3).

The second approach is similar to the first and can be defined as an early attempt to develop a non-linear model of change that draws upon catastrophe theory, which was developed in the natural sciences. Later attempts replaced catastrophe theory with chaos theory as a theoretical framework for change. These later attempts broaden their perspectives by taking on the idea of different scales (or rates of change) as employed by the *Annales* school, but provide a more mathematical model of the relationship between these different scales (McGlade 1987, 1999, van der Leeuw and McGlade 1997). This second approach agrees with the *Annales* school that history involves different rates of change, from geological processes to human events, and suggests that much of the discontinuity in history can be seen as the product of a conjuncture between different temporalities. Thus history is not a linear process but one punctuated by cycles or periods of rapid transformation.[123]

[122] Lucas 2005, 15-17.

[123] Ibid., 16-17

3.4. The Environment

3.4.1. The Middle Rhône Valley

The Middle Rhône Valley is located on the northern edge of the Mediterranean morpho- and bioclimatic system, in what is current day southern France. The Mediterranean system itself can be characterised as a transitional zone between a temperate and tropical climate and a humid and arid climate. Within the Middle Rhône Valley two regions are looked at in more detail: the Valdaine and the Tricastin. The Valdaine is characterised by the close proximity of the pre-Alps and consists primarily of large detrital fans and numerous hills.[124] Since the Late Neolithic, this region has seen intense human occupation.[125] The Tricastin consists of Holocene floodplains and fans, deposited by the Rhône and its tributaries, surrounded by lower alluvial terraces.[126]

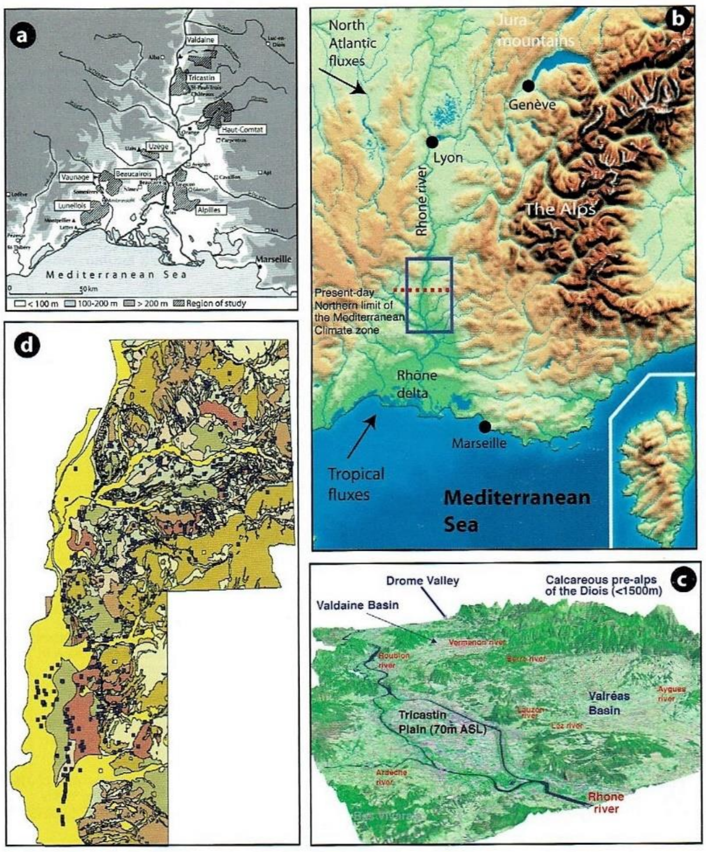

Figure 6: The middle and lower Rhône Valley: (a) location of the study areas in the Archaeomedes project, including the Tricastin and the Valdaine region; (b) regional localization of the study areas and the main bioclimatic characteristics; (c) three-dimensional view of the Middle Rhône Valley from the southwest: in dark green, the spread of the forest cover since the beginning of the Twentieth century, which is strictly located on plateaus, hills around the Rhône River, and more distant mountains; and (d) map of the sites in the Tricastin and Valdaine projected on the nine landscape units. Source: Berger e.a. 2007 (Plate 1) .

[124] Berger e.a. 2007, 43.

[125] Notebaert e.a. 2014, 1333.

[126] Berger e.a. 2007, 43.

The current landscape in the Middle Rhône Valley is the result of centuries of co-dependent evolution. In general, the beginning of the Holocene (9000-6500 cal. BCE) is marked by diffuse erosion under expanding vegetation cover, dominated by bioclimatic parameters. During the Atlantic and the *climatic optimum*, the first human-induced crises of the landscape occurs. Later prehistory (3200-120 cal. BCE) is characterized by strong contrasts between human and climate dynamics. The end of the Iron Age and the Roman period (100 BCE – 100 CE) show an important and extensive weakening of the soil system. The period between 100 CE and 600 CE appears more stable until the Early Middle Ages (600 CE – 1000 CE), which witness the return of landscape instability. The High Middle Ages (1000 CE - 1500 CE) are marked by a relative stability in the landscape, followed by delayed morphogenetic activity due to earlier human pressure on the vegetation. Finally, the modern and contemporaneous periods (1500 CE - now) see the conjunction of a secular climatic deterioration (the Little Ice Age) and the Holocene maximum in human pressure on the environment.[127]

As people need soil and water to survive, positive hydrological and pedological conditions are prerequisites for societal well-being. Based on three hundred soundings and cores in six river basins of the Middle Rhône Valley, dated between 1000 BCE and 1000 CE, three main stages of the landscape have been distinguished. The first stage is associated with a stable optimum in which the soils are naturally well-drained which causes good agricultural potential. Frequent wildfires occur, both natural and anthropogenic in origin. Many Neolithic to Bronze Age sites in the plains are associated with this kind of environment.[128] The second stage corresponds to maximum instability of the landscape, with a dominance of North Atlantic air currents. The annual and multiyear water balance is often positive. This leads to high instability of the river systems and rising water tables. Before people knew how to drain the landscape, these phases strongly limited subsistence in the lower plains and humid areas as only herding was possible. As a result, from the Neolithic to the Gallo-Roman period there are very few settlements on the plains in these phases.[129] The third stage is associated with short periods of high instability, dominated by tropical air currents. Flash floods and fires were common, but the alluvial plains do not show much evidence that these conditions imposed serious constraints on the prehistoric and early historic economies.[130] These three stages should not be interpreted as a chronological sequence, but rather as three potential states in which the landscape system can find itself.

[127] Berger e.a. 2007, 43.

[128] Ibid., 45.

[129] Ibid.

[130] Ibid.

3.4.2. The Pontine region

The Pontine region (figure 7), which lies between 60 and 80 km south of Rome, can be divided into three main physiographic units: (1) the Pontine plain, an almost flat coastal area with ancient beach rides. Towards the north-west this plain is bordered by (2) the volcanic area of the Alban Hills and towards the north-east by (3) the limestone mountain range of the Monti Lepini.[131]

The study area comprises the southern part of the volcanic formation of the Alban Hills down to the Tyrrhenian coast, the south-western and western slopes of the limestone massif of the Monti Lepini and Ausoni, and the Pontine plain itself. The region is situated in the southern part of the present-day province of Lazio in Central Italy. The toponym ‘Pontine Region’ is no longer in use today. There are three main geographical units in the study area itself: (1) undulating volcanic landscape, (2) limestone mountain range, (3) low pontine plain. These three units form a complex system that, in the *longue durée* (see above: intermezzo time scales) of the Pontine region, were used differently and with varying intensity. Archaeology, history and ethnography reveal that these land systems have been socio-politically interlinked in various ways through time (see below). In order to evaluate land-use dynamics of the Pontine region, one of the main focal point of the RPC-project, they also took into account all environmental changes that would have had a significant impact on the physical landscape, regardless whether the causes were natural or human.[132]

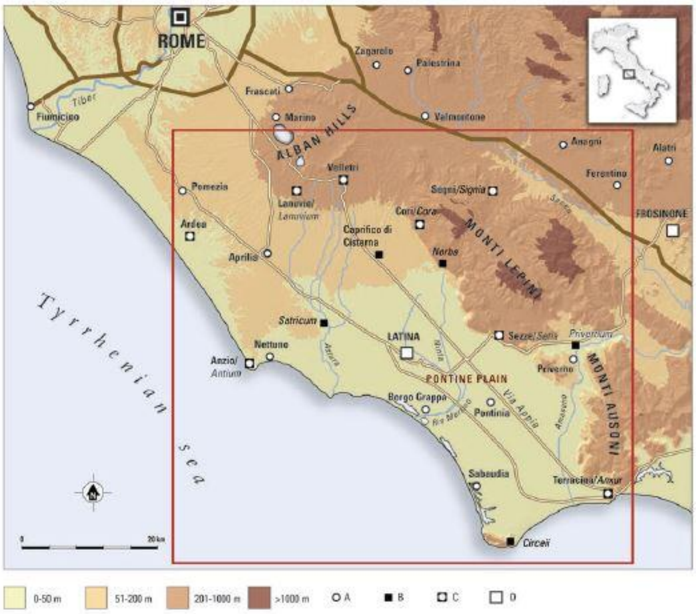

Figure 7: Geographical and Topographical map of the Pontine region in relation to Rome and the Tyrrhenian sea. The box indicates the study area of the RPC project. Source: Attema e.a. 2010, 204 (fig. 1.2)

[131] Attema e.a. 2010, 4.

[132] Ibid., 32.

3.5. Society

3.5.1. Settlement patterns in the Middle Rhône Valley

With exception to Berger *et al.*'s study, the Middle Rhône valley has not been the subject of an extensive regional archaeological study. The main objects of study were more frequently centred around the larger cities, Lyon (*Lugdunum*) and Nîmes (*Nemausus*). Analysing the landscape offers an enormous potential for acquiring scientific knowledge. It is however the coupling of this landscape data with human - archaeological - data that offers the most valuable perspectives. One way to adhere long-term human activity is through settlement dynamics: the changing in size and location of attested settlements. Both settlement location and settlement size can be seen to reflect past anthropogenic choices about the landscape.[133] Based on field walking, soundings and rescue excavations, Berger *et al*. discovered eight hundred sites in the Middle Rhône Valley, dating from the Late Bronze Age to the beginning of the Middle Ages. It is common archaeological knowledge that certain periods are more visible than others, even more so when conducting surface surveys.[134] Palaeolithic fragments, for example, are not as easily detected as Roman amphora sherds. Because of this, Berger *et al*. corrected the biases of the surface surveys with respect to certain cultural horizons, by taking into account soil erosion and deposition.[135]

Next, Berger *et al*. statistically calculated the probable settlement number for the Middle Rhône Valley. The results of their analyses indicate variation in settlement density between 800 BCE and 800 CE (figure 8), marked by several peaks, almost always followed by a substantial drop. The first peak is reached at the end of the Bronze Age (ca. 800 BCE), followed by an abrupt decrease during the seventh century BCE, followed by another peak between 600 and 400 BCE and a second drop in numbers during the fourth and third centuries BCE. The third and most important peak in occupation density begins around 200 BCE and culminates during the first century CE. It thus begins before the arrival of the Romans in Gallia Narbonensis (ca. 120 BCE). A major restructuration occurs in the course of the second century CE, when more than a third of the settlements are abandoned in less than a century. This decrease in settlements continues during the following centuries, be it at a slower pace. A brief break in this trend can be observed in the fifth and sixth centuries CE and it continues throughout the seventh century. Finally, a minimum settlement density is reached in the eighth and ninth centuries CE.[136]

[133] Berger e.a. 2007, 45.

[134] Ibid., 45.

[135] Ibid.

[136] Ibid., 45-46.

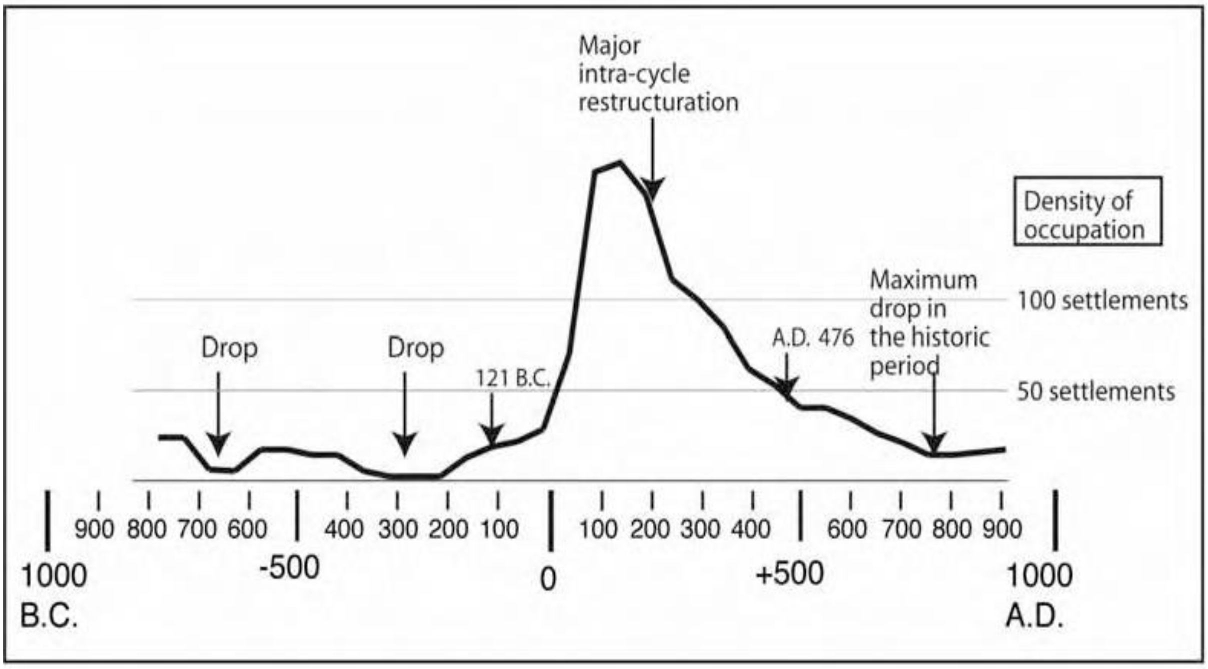

Figure 8: The evolution of settlement density between 800 BCE and 800 CE. Source: Berger e.a. 2007, 46 (fig. 3.1)

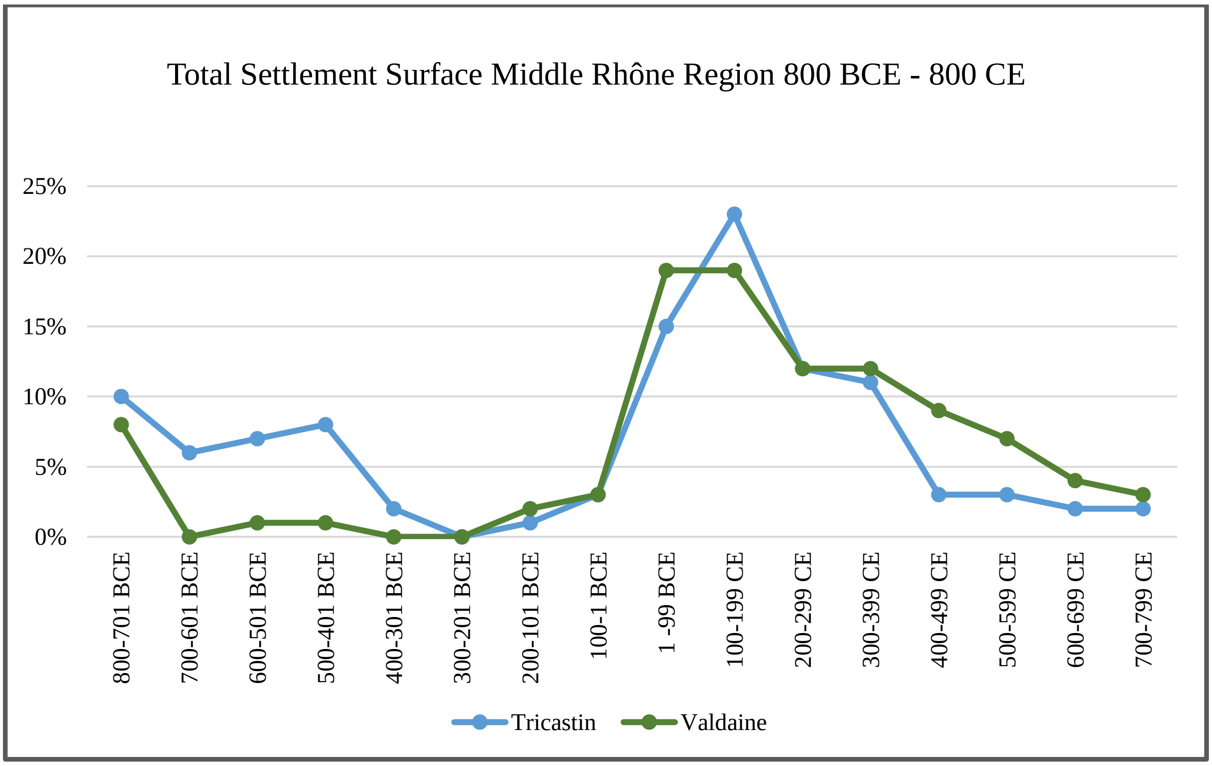

Figure 9: Total surface of all settlements in the Middle Rhône Region. Green line represents Valdaine region and blue line represents Tricastin region. After: Berger e.a. 2007, 41 (fig. 3.5 a)

The number of settlements per period does not assess the real impact of settlements on the landscape or the impact of the landscape on the settlement pattern. Therefore, Berger *et al.* identified the total surface occupied by all settlements, per region, for every century (figure 9).

For the Iron Age, the occupied total surface for the Valdaine and Tricastin is relatively variable, pointing to an unstable settlement system. Moreover, there are considerable differences between the two areas: The Tricastin shows a relatively large total surface in the first Iron Age, but a low number of sites. This could mean that the settlements must have agglomerated or the remaining settlements grew in absence of others. In the sixth century BCE, the Valdaine region has a relatively significant number of establishments, but a low total surface. This, in turn, means that most individual sites must have been very small.[137] There appears to be a discrepancy between the regions in the Bronze Age and early Iron Age.

In the third century BCE the number and surface of settlements for both areas is relatively low. To the point that the area almost seems depopulated. Many hill-top sites are temporarily abandoned and only a few small settlements are found. It is not clear what caused this break in the settlement system. To put this in perspective: in the northwest Mediterranean region, an apparent decline in trade in the fourth and third century BCE is also observed. The following centuries are marked by a progression in the number of settlements, even though the total settlement surface increases very little. This could mean that Roman colonization, which started in the second century BCE, apparently began in small, relatively dispersed settlements.[138] It should be noted that the subject of Roman colonization or annexation of southern Gaul is in itself an object open for scientific discussion, with many more research opportunities.

At the height of the Roman Empire, the total settlement surface and the number of settlements increases hand-in-hand in both the Valdaine and the Tricastin. In spite of a general reduction in the number and surface of settlements, the Valdaine Basin seems to be doing a little better than the Tricastin in Late Antiquity (second to fifth centuries CE) and at the beginning of the Middle Ages (fifth to eight centuries CE). In the Tricastin, the major reduction in total settlement surface accompanies a much less marked decrease in the number of settlements, suggestive of a dispersal of settlements.[139]

3.5.1.1. Soil exploitation in the Middle Rhône Valley

Berger *et al.* created a map (figure 6.d, 10) of landscape units, based on the lithology, soils, geomorphology and pedosedimentary data of the Middle Rhône Valley landscapes. They then positioned the known settlements in their landscape and calculated their relation to the surrounding soils, the hydrology, and the lithological, morphostructural, and topographical parameters of their

[137] Berger e.a., 46-47.

[138] Ibid., 47.

[139] Ibid., 47-48.

environment. This enabled them to compile regional diagrams, showing principal tendencies in soil exploitation. The diagrams show a clear preference for fluvial soils and wetlands during the Late Bronze Age (800-700 BCE). During the Early Iron Age (700-500 BCE) the total exploited surface reduced. In the Late Iron Age (ca. 200 BCE) an expansion of settlements begins. This settlement expansion reaches its maximum in Roman Antiquity (1-500 CE). At that time, a wider range of soils is exploited than ever before. In the third and fourth centuries CE, a restructuring of the settlement system occurs, which manifests itself in a brief period of increase in the number of hilltop settlements. It is followed by two centuries of partial recolonization of settlements in lower areas, which had been abandoned a few centuries earlier.[140]

The data collected by Berger *et al.* is subsequently presented in cumulative diagrams (figure 10a,b). These show a complete settlement cycle of fifteen centuries. They are able to highlight two abrupt breaks in the organization of the settlements in the Valdaine and Tricastin: The first around 700 BCE, the period of Bronze Age to Iron Age transition. The new cycle is marked by a progressive descent of settlements from the top of the hills to the fluvial soils of the lower plains. The largest number of sites, the largest total settlement surface, and the widest range of exploited environments are reached in the middle of this cycle (first and second centuries CE). At the beginning of the Middle Ages, people move back to the hilltops and similar locations. But the new settlement pattern is different: rather than scattered, it is now nucleated.[141] The second major observed rupture occurs in a much more progressive way during the second part of Classical Antiquity. It begins in the second century CE with a slow but constant reduction in the settlements on alluvial plains and in humid areas, together with an increase in the number of settlements on Pleistocene terraces, alluvial fans and hill slopes bases. From the fourth century CE, the settlements are mainly distributed on higher grounds, hills and plateaus. This tendency culminates during the eight century CE, marking the end of this cycle of settlement.[142]

[140] Berger e.a. 2007, 49.

[141] Ibid.

[142] Ibid., 50.

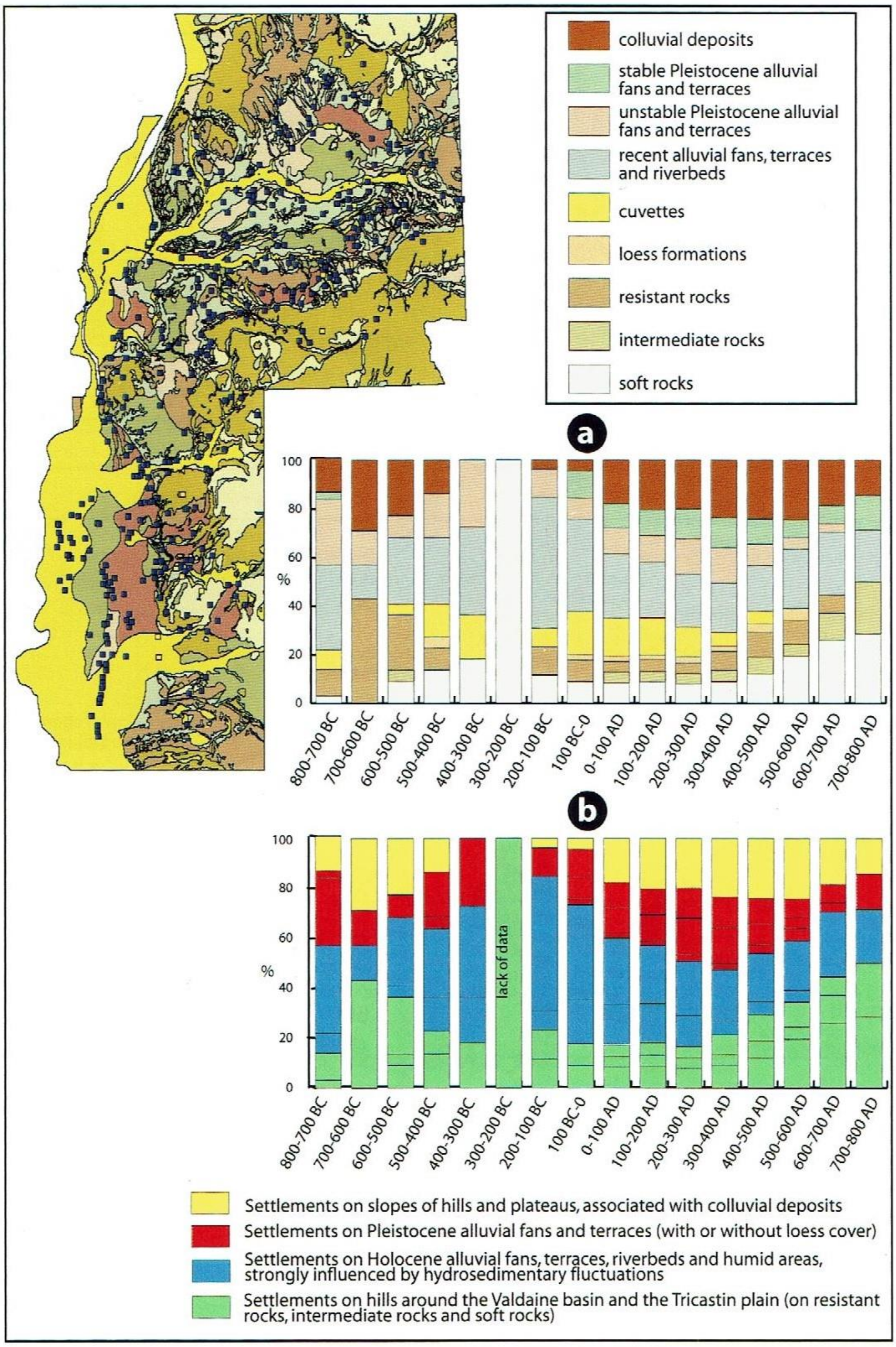

Figure 10: Landscape and site distribution: (a) calculation (per century) of the site distribution over the nine landscape units of the Tricastin and Valdaine, from 800 BCE to 800 CE, and (b) reclassification of settlement locations in the main physiographic units of the region. Source: Berger e.a. 2007 (Plate 4)

3.5.2. Pontine Region

The settlement data available for these areas is made up out of four datasets: A first dataset consists of inventories of incidental finds, the second consists of topographical data, the third set is made up out of excavation results and the fourth set includes systematic survey results.[143]

The archaeological record and the pollen evidence indicate that proto-urbanization and rural infill in the Iron Age (1020 – 580 BCE) and the Archaic period (580 – 480 BCE) were particularly strong in the Alban hills and adjacent volcanic areas, with their excellent settlement locations, fertile soils and large crater lakes.[144] A similar process, although much less evident for the Bronze Age (ca. seventeenth to tenth century BCE) than for the Iron Age (ca. tenth to first century BCE), has also been attested for the foothills and slopes of the Monti Lepini. Increasing settlement density and pressure on the available agricultural land in the volcanic land system, may have triggered proto-urban settlement in the Monti Lepini. A provisional dividing line between this proto-urban landscape and the remaining less developed landscape may be drawn at the edges of the low-lying Pontine plain. This plain was especially suitable for grazing flocks of cattle and sheep in short transhumance between the nearby Lepine uplands and the plain. Near the coastal lagoons and on the coast itself, most of the recorded protohistoric sites may be connected with the exploitation of lake and marine resources as well as with the inland (salt) trade.[145]

In the Archaic period, the Pontine region can be seen as carved up in small territories around urban settlements of more or less equal rank. In this period the Pontine plain and the southern coastal area remained marginal relative to the main settlement developments. It is only with the advent of Roman colonization that the Pontine plain became part of the 'urban' infrastructure that had already developed in the proto-urban landscape of the Archaic polities. This was the outcome of a long process of Roman interference in the Pontine region, in a transitional period (the fifth and fourth century BCE) referred to as the post-Archaic. This period is historically characterized by the protracted power struggle between Romans, Latins and Volsci. It is reflected in the archaeological record by the destabilization of the Archaic polity system, the general impoverishment of material culture, and the first signs of Roman colonization on the Lepine margins. These early Roman colonial towns stimulated the growth of an agricultural economy that by the late fourth century BCE extended over most of the Pontine region, with the exception of the marshy areas that were to remain a marginal element in the Roman agricultural economy. Although the colonies were mostly established on previously settled locations, they were essentially new towns planted with a population sent in by the Roman administration. Intensive survey of Roman platform villas in the surrounding landscape has started to reveal that most of these farms were built on land that had already been farmed before, and in many cases will have continued on top

143 Attema e.a. 2010, 4.

144 Ibid., 57.

145 Ibid., 57-58.

of pre-existing Archaic farms. After ca. 300 BCE, a villa landscape developed in the already proto-urban part of the Pontine region and spread into those parts of the Pontine plain that appear to have been only marginally settled previously. This would have been made possible primarily by the new Roman infrastructure of roads and drainage works, of which the Via Appia must have been the centre piece.[146]

3.6. An economic perspective

3.6.1. The Middle Rhône Valley

The period between 200 BCE and 500 CE is better documented than previous ones, and this allows for a more detailed analysis. The settlement data shows the passage from a clustered settlement pattern to a dispersed settlement pattern in the beginning of the second century CE. The Valdaine region however, is marked by relative stability, when the Tricastin region shows a more dynamic development. This change accompanies the peak in new creations of agricultural establishments in the Rhône Valley during the first century CE. The return of the settlement system to a form close to that of its early days occurs in two stages: the first occurs in the first half of the third century CE and the second in the second half of the fourth century CE. In Late Antiquity, the settlement pattern is clustered again, and that tendency continues into the Middle Ages, until the creation of the typical villages of the High Middle Ages (tenth to twelfth centuries CE).[147]

The differences between the two regions, small as they may be, can be explained by looking at their geo-economic history. The Tricastin plain is nearer to the regional capital, *Augusta Tricastinorum*, and to the major communication routes of the Rhône Valley - the Via Agrippa and the river Rhône -. Its soils are favourable for the establishment of vineyards - on the vast alluvial terraces -, and viticulture led to large financial investments - wine-growing villae - during the first century CE. The area thus felt the full force of a crisis in viticulture that hit most of Gallia Narbonensis at the end of the second century CE.[148] The Valdaine, farther from the main economic networks and with more contrasted landscapes, is less dependent on viticulture. Its economic profile is polycultural and less sensitive to economic fluctuations. Hence, during the Roman period it maintains stable settlements networks.[149] Although this is a feasible hypothesis, it remains a hypothesis and this requires further testing of comparable regions. What this is actually saying is that the less integrated a region is into a larger economic system, the more resilient this smaller system is in time of large scale shocks. Although this is logical, caution is advised when extrapolating this to other regions.

[146] Attema e.a. 2010, 57-58.

[147] Berger e.a. 2007, 48.

[148] Jung e.a. 2001; Berger e.a. 2007, 48.

[149] Berger e.a. 2007, 48.

Although historical information about Roman agriculture and land management strategies exist, such information does no take the specifics of this region into account. Hence, Berger *et al.* base their arguments on both on-site and off-site palaeo-environmental data. There have been three periods of climatic degradation: (1) around 700-600 BCE, (2) around the beginning of our era and (3) around 550 CE. Other, shorter or more localized phases of degradation appear around 350-300 BCE, 200-250 CE, and 750 CE. Stable phases - in which soils were regenerated, streams cut deeper into sediments, and fluvial plains were exploited - appear around 900-800 BCE, 200-150 BCE, 350-450 CE, and after 900 CE. The Gallo-Roman expansion cycle is then coinciding with the middle of a stable hydroclimatic phase.[150]

3.6.2.‘Pontine Region

By now, it should be clear that economic activities in the Pontine region during the first millennium BCE were to a large degree determined by the environment. The RPC project however did not focus on investigating economic activity in the Pontine Region. As has been stated above, the focus lay more on processes of urbanisation and centralisation. Although changes in urban and rural lay-out reflect economic factors as well, they are no straightforward reflection of economic phenomena. Nonetheless some points relating to the settlement pattern can be reiterated.

Pollen analysis shows that between ca. 2000 and 1000 BCE a decline in woodland occurred that can be contributed to early farmers, but also to drier conditions resulting from climatic change. The Pontine pollen record shows that from the later Neolithic to Roman periods there appears to be a gradual decline of forest cover on the Alban Hills and the Monti Lepini (figure 7), resulting in a gradual opening up of the landscape. All pollen cores indicate an intensification of farming, but the evidence is more consistent for the Alban Hills than for the Pontine Plain. Several cores indicate that the volcanic area shows evidence for cereal farming in the Early (3000 BCE) and Recent Bronze Age (mid second millennium BCE). In combination with the evidence from cores taken in the crater lakes, the picture is suggestive of the widespread introduction of wheat cultivation in the volcanic area.[151]

In the Bronze Age, wheat was apparently not only cultivated in the fertile volcanic areas, but even in the coastal margins. The evidence for agriculture continues into the Iron Age, with indications of barley and wheat/rye cultivation in the volcanic area and farming activities in the coastal area. For the Roman period, evidence for cereal cultivation and an expansion of chestnut, walnut and olive in the area of the volcanic lakes is attested. From the fourth and third century BCE onwards, evidence for olive cultivation on the foot slopes of the Monti Lepini appears in pollen cores. This evidence can be connected to

[150] Berger e.a. 2007, 51-52.

[151] Lowe e.a. 1996; Attema e.a. 2010, 39.

farmsteads along the Lepine margins in the Republican period, believed to have been involved in the production of olive oil.[152]

As we saw above, in the Bronze Age to Archaic period, the lower Pontine Plain and Lepine uplands would have been very suitable for grazing flocks of cattle and sheep. The coast and nearby regions may have been connected with the exploitation of lake and marine resources as well as with the inland trade. In the fourth century BCE the roman colonial towns stimulated the agricultural economy, with the exception of the marshy areas. [153]

3.7. Co-dependent subsystems, or Nested Model

3.7.1. The Middle Rhône Valley

To fully understand the co-dependency of the different systems, it is best to look at the long term perspective. The various kinds of information obtained from independent sources point to a coherent picture that reinforces the hypotheses of landscape change in terms of human impact, climate impact, and/or the combined impact of climate and human population. For example, the spatial reorganization of the settlement pattern in the seventh century BCE is accompanied by a decrease in the agricultural exploitation of riverine and marshy environments during a phase of high hydrosedimentary activity associated with braided river systems. These are probably transformed into pastures, while other landscape units continue to be cultivated.[154] Never is there a total retreat from the exploitation of the landscape. Activities shift to those parts of the landscape that are better protected from fluctuations in the hydrosedimentary equilibrium, or they change in nature (reduction of cultivation and increase in herding) in periods of major restructuring, such as the seventh century BCE and the eight-ninth centuries CE. [155]

In the early Holocene, major climatic and anthropogenic factors have to act in conjunction to have effect on the landscape. But from the end of the protohistoric period (which saw an increasing intensification of societal impact on the environment), the slightest fluctuation in either climatic or societal dynamics had major effects on the landscape. In ten thousand years, the combined system has become hypercoherent, and its tolerance highly compromised.[156]

The data on the Middle Rhône Valley presented in this chapter points out a break (figure 11) in the resilience of the agrosystems in the Middle Iron Age (600 – 400 BCE). Berger *et al.* state that: "[t]his crash leads to major transformations in all aspects of social organization. In the following centuries, we

[152] Attema e.a. 2010, 35-39.

[153] Ibid., 57-58.

[154] Berger 2003, Delhon 2005; Berger e.a. 2007, 52.

[155] Berger e.a. 2007, 52.

[156] Ibid., 44.

see the development of protourbanism, […], the extension of tree cultivation, and the introduction of Roman water-management technology in southernmost Gaul."[157] They go on to state that these reorganizations allow the system to exhibit resilient behaviour in the face of environmental perturbations (hydrosedimentary crises, see below), as well as societal ones (political, military, and socioeconomic changes). These environmentally induced changes therefore affected the sustainability of the social system. [158]

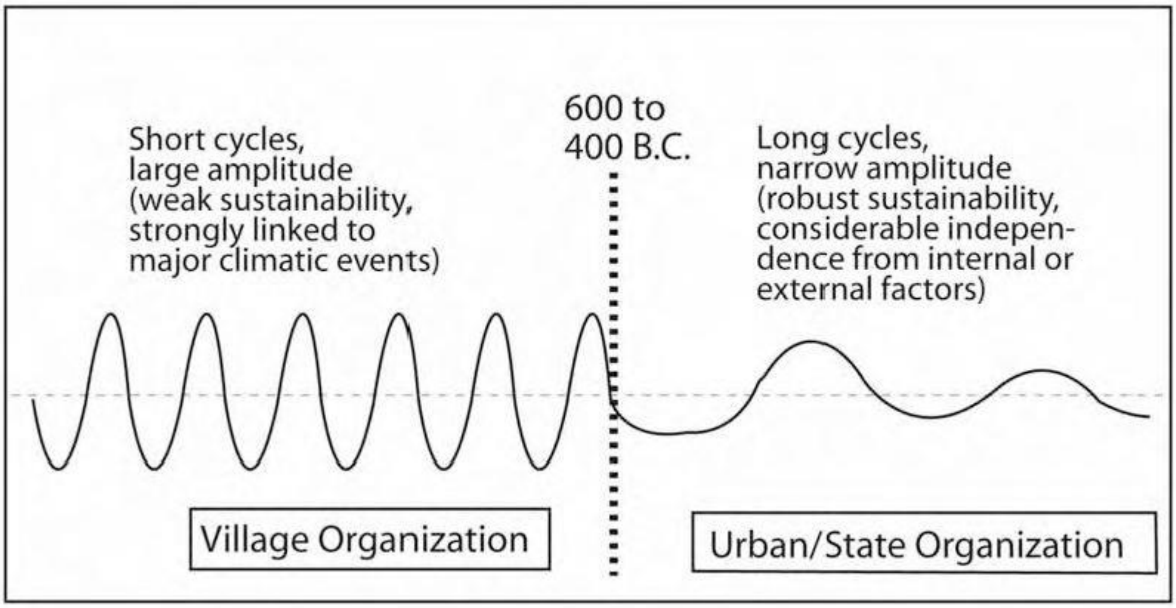

Figure 11: schematic presentation of the environmentally induced break of the agrosystems, which cause societal changes. Effecting the sustainability of the system. Source: Berger e.a. 2007, 58 (fig 3.5)

Despite this assumed social sustainability, and the fact that recent geoarchaeological studies show that there appeared to be no indications of a major climatic crisis in the Roman period, the pedosedimentary sequences observed in southern France seem to indicate that the landscape - the environmental system - at this time was highly unstable. From the Roman period onwards the environment witnesses an important deterioration of the drainage systems of the lower Rhône Basin. Its impact seems almost equivalent to that of the Early Iron Age (800-600 BCE) or the little Ice Age (1500-1900 CE). This deterioration in Roman times seems principally due to human activity, in particular, to the very wide-spread and rapid transformation of the countryside from predominantly forest and grassland to intensively cultivated agricultural land.[159]

[157] Berger e.a. 2007, 57.

[158] Berger e.a. 2007, 57-58.

[159] Berger e.a. 2007, 44.

3.7.2. The Pontine region

As we have seen, the aim of the study of the Pontine region was to delineate the long-term settlement history from the Bronze Age to the Roman period in the context of the natural environment. The settlement pattern and concomitant economic activity made clear that specific environments (mountains, marshlands, river valleys, etc.) reflect different archaeological records, only highlighting the micro-regional differentiation and the importance of the environment on the nested society and nested economic system. What this section will further highlight is, not only the way in which the environment shaped society, but also the way society shaped the environment. [160]

First, there undoubtedly exists a close spatial relationship between land use, towns and infrastructure. A relationship that will have been closer in the past given the, for example, more limited means of transport.[161] This is of course, if we think about it, very logical. To put it in more extreme terms: sites that develop in for instance the Nile Delta or in the highlands of Peru are going to be different to those in the British Isles or southern France. What the RPC project has successfully proven, is that the effect of the environment can and should also be taken into account for macro-, but also for micro regional studies. Moreover, the environment is seen as an important agent in shaping societal evolution.

Secondly, pollen analysis and sedimentation studies have shown that human impact changed the appearance and the potential of the landscape from the Neolithic period onwards to the extent that it is no longer possible to accept the idea of the ancient landscape as a static backdrop to settlement development and land use. This is especially true in the Pontine Region where natural processes and human interferences combined to change the conditions of settlement and cultivation during proto- and early history. Both climate change (changing precipitation), human- (deforestation) and animal interference (pastoralist activities) are expressed in the pollen record of the region, and in its regime of erosion and sedimentation.[162]

It is hard to distinguish human and natural factors of change in the landscape. The pollen record shows this difficulty in distinguishing between human or climatic factor. In the Pontine region pollen cores were taken from former lagoons and combined with the results from cores taken in northern Lazio and the Alban Hills (outside of the study area).[163] Barker concluded that around 6000 BCE the increased rainfall and temperature resulted in a dense forest cover in the uplands of the Italian peninsula. Furthermore, between 2000 and 1000 BCE, a decline in woodland occurred that can be attributed to either drier conditions or human clearance.[164] The available data points to the climate as the main agent

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[160] Attema e.a. 2010, 31.

[161] Ibid., 33.

[162] Ibid. 34.

[163] Attema e.a. 2010, 35.

[164] Barker & Rasmussen 1998, 38-41.

for change, but this does not rule out a contribution from early farmers in the process, since indicators for arable farming and pasture are present in pollen diagrams of cores from the Pontine region. It is therefore plausible that a combination of climatological and human factors led to a more open landscape that characterised central Italy during the protohistoric and early historical periods.[165] Above (section economic perspective) we already noted the evidence for agricultural activity in the pollen record of the Pontine region from the Roman period onwards. Some human interventions, however, can be straightforwardly deduced. One of the largest human interventions in the Pontine region was the almost complete elimination of wet areas. Since the period of early urbanization, wetlands were perceived as unproductive, which led to the reduction of the extent of seasonal inundation of valleys in the volcanic areas, using underground drainage channels, as early as the first half of the first millennium BCE.[166]

Third, erosion and sedimentation can shed light on the human-environment interactions. Physical geographic studies, via drillings and a comparative approach, have shown that the silting-up of parts of the plain between the Bronze Age and the Middle Age affected the living conditions and the agricultural potential of the area. Whereas the protohistoric landscape in the Pontine region should be seen as a wetland, which by Roman times had become dry cultivable land.[167] This work demonstrates how agricultural characteristics and agricultural potential of parts of the landscape were subjected to considerable change. Even the more stable landscape in the western part of the Pontine region had undergone considerable environmental change which not only affected the land-use potential in the past, but also the visibility of the archaeological record in the present. These studies have shown that any reconstruction of land use in the hills of the volcanic area and the slopes and upland regions must take into account substantial erosion, just as sedimentation was a major agent of landscape change in the lower parts of the Pontine plain.[168]

[165] Attema e.a. 2010, 35.

[166] Ibid., 32-33.

[167] Attema e.a. 1999, 111-116; Attema e.a. 2010, 40.

[168] Attema e.a. 2010, 40.

3.8. Summary

This chapter has set out to prove that there are indeed archaeological studies which - unconsciously - work within the nested model. The nested model states that economy is at the service of societal well-being, and societies can prosper within the possibilities and limits offered by the natural environment.[169] Both studies looked at the archaeological evidence, specifically placement and size of settlements and referenced this to specific landscape units. Settlement size and distribution are here used as proxies for societal dynamics and sustainability. Both studies continuously refer to peaks and drops in settlement size and distribution, nucleated or more scattered settlement patterns, etc. Therefore, even though the word sustainability is not always explicitly mentioned, it is clear that sustainability forms part of the research subject of both the RPC-project and the Middle Rhône Valley study.

To give a more accurate reconstruction of past sustainability, the scale of the research has to be both enlarged, looking beyond the region and at the state or even continent as a whole, and made smaller, looking at short term fluctuations and specific sites, or even parts of sites. An example: the ancient city of Sagalassos grew smaller from the fifth century CE onwards, yet the eastern suburbia in which the potters quarter was settled does not disappear. On the contrary, it keeps up production, export and even import of ceramics. The small scale (household, partial site, site,…), medium scale (region) and large scale (state, empire, continent, global) need to be combined in order to be able to unambiguously speak about past sustainability.[170]

Both studies were not without difficulties and this was most adequately put into words by Attema *et al*.: "We are aware that the validity of our reconstruction of these patterns of settlement and land use is hampered by problems relating to the question of whether our archaeological dataset is representative. We have stressed the various processes by which natural and human-induced changes in the landscape (erosion and sedimentation, land use, land cover), field methodology (generic topographical research versus highly intensive survey), intensity of research, and the variable diagnostic nature of artefacts for different periods all result in significant biases in this dataset. We know as yet very little about the archaeology of two of our land systems: […]. The broad patterns derived from the archaeological record that were discussed in this chapter should therefore be understood within the context of these limitations."[171] Although this paragraph refers to the RPC-project, the same can to a certain degree be said of the Middle Rhône Valley as well.

4. Comparison and critical evaluation of both models

[169] Unpublished presentation Prof.dr.ir. Bart Muys.

[170] Poblome 2015

[171] Attema e.a. 2010, 58.

In this third and final chapter we will look more closely at the value of the nested model and the pillar model. Where the first two chapters served as an introduction to the workings of these models and a recognition of their existence in archaeological research, these will now be evaluated separately and afterwards compared. A final section will look to the future and introduce concepts and models which may serve as valuable alternatives for approaching sustainability in the past.

4.1. Evaluation and comparison: Pillar Model

The pillar model considers sustainability as a balancing exercise between economy, social issues and environmental considerations. It is motivated by the intergenerational benefit of sharing resources and has been the globally and politically dominant model for sustainability since 1992. However, the model has often been adopted with an emphasis on the economic pillar and it therefore reinforces the idea that a successful economy is the best guarantee for social and environmental benefits.[172]

Despite the fact that the pillar model has been proven insufficient in the first chapter of this thesis, it is not without assets. This paragraph will discuss both the strengths and weaknesses of the pillar model after first providing a general overview.

STRENGTHS	**WEAKNESSES**
1. Simplicity	4. Oversimplified
2. Lays foundation for approaching sustainability	5. Unbalanced focus on economic development
3. (theoretically) Easy to calculate trade-offs between economic, social and environmental indicators	6. Suggesting that economic development is unconstrained by social and environmental issues
	7. Hard to determine scientifically founded determinants or proxies

Table 1: overview of strengths and weaknesses of pillar model.

Based on: Unpublished presentation Prof.dr.ir. Bart Muys.

We will first discuss the strengths of the model, before moving on to the weaknesses. Some points will be familiar, as these have been touched upon in chapter one. (1) The model is simple: sustainability is conceptualized as being determined by economic, social and environmental aspects. This makes the

[172] Muys 2013, 42.

model easily accessible and understandable, since it does not rely on overly complex schemes and theories. (2) The model has laid the foundation for approaching sustainability. Most likely due to its simplicity, it has been widely accepted and has therefore been the dominant global and political model for approaching sustainability. (3) In theory, the model allows for an easy calculation of trade-offs between the economic, social and environmental segments. In practice this exercise is harder. The pillar model has determined that economy, society and environment are the key factors for approaching sustainability. This achievement alone has made the model successful. The idea that the economy is related to social or environmental sustainability, and that society and economy are no longer human achievements against the static backdrop of the environment is a scientifically valuable statement.

Despite apparent strengths, the pillar model is not without equally apparent weaknesses: (4) although simplicity is its key feature, this has also accredited to its downfall. First, the model is an oversimplification of reality. It has been successful in propagating that sustainability relies on economic, social and environmental factors, but this statement also denies the complexity of reality. 'economy x society x environment = sustainability' is an overly simple equation and cannot explain variation and change at different scales of time and space. Secondly, economic, social and environmental entities are not always clearly distinguishable, but are instead heavily intertwined. (5) Chapter one demonstrated that the model shows an unbalanced focus on economic development. Therefore negating the role of society and environment and with it deconstructing the original architecture of the model itself (see the Mickey Mouse figure). (6) A weakness made more clear when comparing the pillar model to the nested model; the model as it is, suggests that economic development is unlimited by social and environmental issues. Both studies of the past and the present have shown that the economy should be viewed as part of a larger socio-natural system (see below). (7) When approaching sustainability through the pillar model it is hard to determine which proxies are both scientifically warranted and what these proxies can actually say about the past. One of the examples in chapter one showed that roman shipwrecks in the Mediterranean Sea are not an unambiguous reflection of economic performance. On top of questioning the validity of investigating economic performance, it was not clear whether the attested phenomena indicated intensive or extensive - per capita - growth.[173]

4.2. Nested model

[173] Saller 2002; Bowman & Wilson 2009.

Because of the inherent flaws of the pillar model, it has been altered to provide a more suitable framework for approaching past sustainability. It can be concluded that the weaknesses of the pillar model have therefore paved the way for the nested model. The nested model sees economy at the service of societal well-being, and societies can prosper within the possibilities and limits offered by the natural environment. The nested sustainability model considers human society and its economy as a subsystem nested in the planetary ecosystem.[174] The strengths and weaknesses of the nested model are fairly similar to those of the pillar model. An overview:

STRENGTHS	WEAKNESSES
1. Simplicity	5. Oversimplified
2. Solved negative economic focus	6. Not adequate for explaining change (undynamic)
3. Subsystems nested within environment more closely modelled to reality	7. Could be perceived as environmentally deterministic
4. Applicable to different spatio-temporal scales	8. Hard to determine proxy-data

Table 2: overview of strengths and weaknesses of nested model.

Based on: Unpublished presentation Prof.dr.ir. Bart Muys.

Strengths: (1) Like the pillar model, one of the main features of the nested model is again its simplicity, which makes it understandable and accessible for modelling sustainability. (2) By modelling the economic factor as a subsystem of society, which in turn is a subsystem of the environment, the nested model has moved beyond the strong economic focus of the pillar model. (3) The subsystem architecture is more closely modelled after reality and therefore more adequate for studying sustainability in the past. (4) The nested model, compared to the pillar model, is more easily applied to different spatial (local, regional, global) and time scales (short term, medium term and long term). In other words, it can be applied to the Roman Empire during the third century CE, in the same way it can be applied to a specific region in southern France between 800 BCE and 800 CE.

[174] Griggs e.a. 2013; Giddings e.a. 2002; Muys 2013 42.

Weaknesses: (5) Just as the pillar model, the nested model is an oversimplification of reality. It does not account for the modelling or quantification of flows of energy, matter or information which make up all three systems (economic, social and environmental). Moreover, it does not take into account the existence of more and different (sub)systems. Society for example could be seen as a system with multiple subsystems (religious subsystem, cultural subsystem, technological subsystem).[175] (6) As the model does not calculate trade-offs between the different subsystems, it is not easy to explain temporal variation of a given system. (7) Just as the pillar model has the inherent flaw of favouring an unbalanced focus on the economic segment, so too does the nested model accommodate an unbalanced focus on the environment as a driver for change or sustainability. The misuse of both models does however depend on its applicator - the researcher in question. (8) Suitable proxy-data for speaking about sustainable economies, societies or the environment are not easily determined and are highly dependent on current advancements in various other scientific disciplines. An example from the second chapter: settlement numbers in the Middle Rhône Valley during between 800 BCE and 800 CE could be taken at face value as reflection of societal prosperity. Yet when including settlement size, the picture changes drastically.

4.3. Importance of proxies

Again the importance of proxy-data becomes clear. To repeat, proxies are archaeological phenomena which, depending on the model, are able to distinguish and explain past events - in this case societal sustainability. The problem regarding the use of proxy-data in archaeology can best be summarized by the following statement by Andrew Wilson: "Before we reach the point where we can use proxy series to test hypotheses, we need to think further not only about what proxies are to be considered sufficiently robust for this purpose, but also how to present and compare them."[176]

There is no standardized set of proxies, as these are dependent on both the model to be tested and the available data. The pillar model, with its strong focus on the economic segment, looked at the problem of determining economic performance based on: shipwrecks (trade), lead pollution and mining (coinage) and income and well-being (per capita GDP). When you look at the nested model, suddenly proxy data about the environment receive more attention. Chapter two discussed (changing) settlement size and location, in combination with data about soil, hydrology, lithological, morphostructural, and topographical parameters of a given land unit. These datasets were combined to model long-term societal dynamics by integrating economic-, social- and environmental data.

The difference between the studies of chapter one and two are of course also related to scale: chapter one discusses large scale studies - the Roman economy as a whole -, whereas chapter two focusses more on regional archaeological studies - the Middle Rhône Valley and the Pontine region -, for which

[175] Clarke 1968.

[176] Wilson 2009, 71.

environmental data are more easily acquired. This however does not excuse a complete lack of environmental proxies in large scale studies.

In conclusion to the use of proxy-data: proxies are to be carefully selected, based on the available data, to create a comprehensive and holistic reconstruction of past societies. Even when focusing on economic performance, not an easy subject on its own, environmental proxies are a valuable addition to reconstruct the patterns of growth, variation and spatio-temporal change. Proxies should always be comparable and quantifiable. As the proxies become quantifiable, so too do the models which aim to prove these, become comparable and quantifiable.[177]

4.4. Future

The starting point of every academic endeavour is to know what has come before. Getting to know the position of sustainability in archaeological research is precisely what this paper has set out to do. This paper proposes to look at the pillar model and the nested model as past attempts at approaching sustainability. Even though these models are inadequate, the evolution of the pillar model into the nested model is a step in the right direction. There is no longer an unbalanced focus on the economic segment and society is now embedded within the environment. The nested model is only a first step in a larger movement of approaching the complexity of past realities. The last decades have seen the emergence of concepts, models and a new body of theory which, if applied right, could prove invaluable for future archaeological research. We will introduce some of these concepts below.

The pillar and nested model have not proven sufficient for modelling and studying sustainability in the past. The nature of past phenomena is more complex and multivariate than can be explained by these 'simplistic' models. We must therefore look for other models to apply to the study of past sustainability. These models need to meet certain demands: first, they need to be quantifiable; second, they need to be comparable; third, they need to be applicable to different spatio-temporal scales; fourth, they need to model society and nature as part of a single system and not separately; finally, they need to model flows of energy, matter and information between the different entities of a given system. Based on these criteria, several models can be put forward.

4.4.1. Complex systems theory

Complex systems theory, and its derivatives such as *complex adaptive systems* and *socio-ecological systems*, can deliver a way out of the impasse created by previous inadequate models. Defining these concepts is not without difficulty, however the potential of these models should become clear as this section progresses.

[177] Poblome 2015, 110.

Complex systems theory represents a conglomerate of converging theories from ecology and social sciences.[178] It focusses on non-equilibrium systems of many interacting agents and thus applies naturally to human societies. Societies are non-equilibrium systems because they are open, in the sense that through them there is a flux of matter and energy. Agents within this system can be defined at any scale (individual, group, household, …) and are interconnected in a way that they influence each other. This interconnectedness renders a complex system vulnerable to abrupt change. And it is because of this that complex systems theory has the potential to explain sustainability.[179]

Complex adaptive systems are complex systems which are open to change. In other words, they adapt to both internal and external stimuli. The main characteristics of complex systems are: (1) they are made up out of separate elements; (2) between these individual elements - or agents -, or between these agents and their environment, there exists an exchange of energy, matter and information; (3) this interaction creates unexpected behaviour; (4) the behaviour of these agents adapts to that of other agents and the environment; (5) as a consequence, the system as a whole changes through time.[180] To this can be added: (6) that a certain hierarchy exists both in the network of agents and in the network of relations; (7) emergent properties develop. This means that the characteristics of the system are not reducible to the characteristics of one element. In other words, the sum of the parts does not equal the whole. What this also means is that complex adaptive systems are self-organizing and they do not behave in a predictable or a linear fashion (similar to points 3 and 4).[181] Examples of complex self-organizing adaptive systems can be forest ecosystems, but also human societies.[182] Applying complex adaptive systems can explain the visible change in the archaeological record and if there is one structural determinant in the archaeological record, it is constant change. Not only in physical terms, but in how to understand it or to model it as to better understand the past.[183]

Socio-ecological systems are best explained by looking at the relations of exchange we described above. Society has relations in which it exchanges energy, materials and information with the environment. These kind of relations are called ‘socio-ecological’. An organized ensemble of socio-ecological relations is called a ‘socio-ecological system’.[184] Socio-ecological systems can be viewed as a coming together of two complex adaptive systems, human society and nature, into one. By using the socio-ecological model, the trade-offs between society and environment become visible and as a result sustainability of past societies can be approached. For the socio-ecological system of the Roman Empire

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[178] Poblome 2015, 105.

[179] Bentley 2003, 9.

[180] Bentley 2003, 9-23; Forrest & Jones 1994; Bogucki 2007, 98.

[181] Gunderson & Holling 2002; González de Molina & Toledo 2014, 34.

[182] Holling 2001; Poblome 2015, 106.

[183] Lucas 2012; Poblome 2015, 105.

[184] Ostrom & Cox 2010; González de Molina & Toledo 2014, 34.

to develop in sustainable ways and for the system to be successful at any analytical scale, energy was needed.[185] To put it in simple terms: "Roman farmers had a healthy breakfast in order to have sufficient energy to work their lands, the produce of which supplied sufficient energy for landlords or urban councils to capitalize and invest in urban building projects."[186]

4.4.2. A thermodynamic approach, the exergy model

In order to explain the discrepancy between the dominant model of decline of the Roman Empire in Late Antiquity and the evidence in the archaeological record, John Bintliff proposed to look for a model which was founded on both complexity theory and thermodynamics. With regard to thermodynamics, especially the second law was of special interest. The second law of thermodynamics, or entropy principle, states in general terms - and with regard to open systems - that all complex systems of energy inevitably run down. Bintliff applied the theory of entropy to the decline of the Roman Empire, that when confronted with reducing energy levels, due to increasing complexity, started looking for new forms of energy, in the form of fresh lands and people, in order to maintain order and stability.[187]

The entropic-principle was later combined with socio-ecological theory.[188] This resulted in a new model for studying the energetic relations of both nature and society and is based on the principle that thermodynamics are suitable for explaining the behaviour of open complex living systems (such as an ecosystem or human society).[189] Roman society was an open system, which interacted with other systems within the socio-ecological framework. It requires high energy to maintain its societal complexity, while at the same time releasing low energy in the form of waste.[190]

In order to explain the *exergy model* we must first explain the concept of *exergy*. Exergy is useful energy, which in contrast to energy, cannot be consumed - first law of thermodynamics. An ecosystem exergy concept for describing the behaviour of complex living systems was described by Schneider and Kay. These complex systems have the following characteristics: 1) complex living systems are open systems, exposed to external exergy fluxes; 2) complex living systems can buffer exergy (order from disorder);[191] product specialisation can be seen as a form of exergy buffering, as specialization allows producers to improve their skills, increasing efficiency and labour productivity, therefore creating sufficient margin to increase output and engage in exchange;[192] 3) ecosystems with a higher exergy content are more

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185 Tainter e.a. 2003; Homer-Dixon 2006, 36-42; Poblome 2015, 106.

186 Poblome 2015, 106-107.

187 Bintliff 2004, 189-192; Bintliff 2012, 73.

188 Muys 2013, González de Molina & Toledo 2014.

189 Dewulf e.a. 2008.

190 Poblome 2015, 107.

191 Muys 2013, 43; Schneider & Kay 1994; Schrödinger 1994; Unpublished presentation Prof.dr.ir. Bart Muys.

192 Poblome 2015, 137.

effective dissipative structures and have a higher resistance to shocks to the systems and therefore higher stability; 4) complex living systems have the ability to maintain and increase their exergy storage and dissipation through memory and learning (order from order).[193]

There appears to be a remarkable parallel between the structure of an ecosystem and a human system (figure 12), as larger societies with more complex institutional organizations lead to stronger collective protection against human suffering. The ecosystem exergy concept therefore proves a powerful model to describe the relationship between the structure and function that ecosystems and human systems have in common with Carnot's law for closed systems: the higher the exergy availability of a system, the higher its potential to perform work. Complex systems can then - with Kay's law in mind: 1) store exergy, 2) use exergy for maintenance, 3) use exergy for buffering, and 4) use exergy for consumption. Buffering leads to better fitness and function of the systems and is therefore a fundamental principle of self-organization.[194] Roman society was an open system receiving external exergy fluxes, mainly as solar radiation. This complex adaptive system used part of that external exergy to increase its internal exergy levels, such as those contained in the institutions and structure of society, aimed at improving order in the system through selection and learning processes.[195]

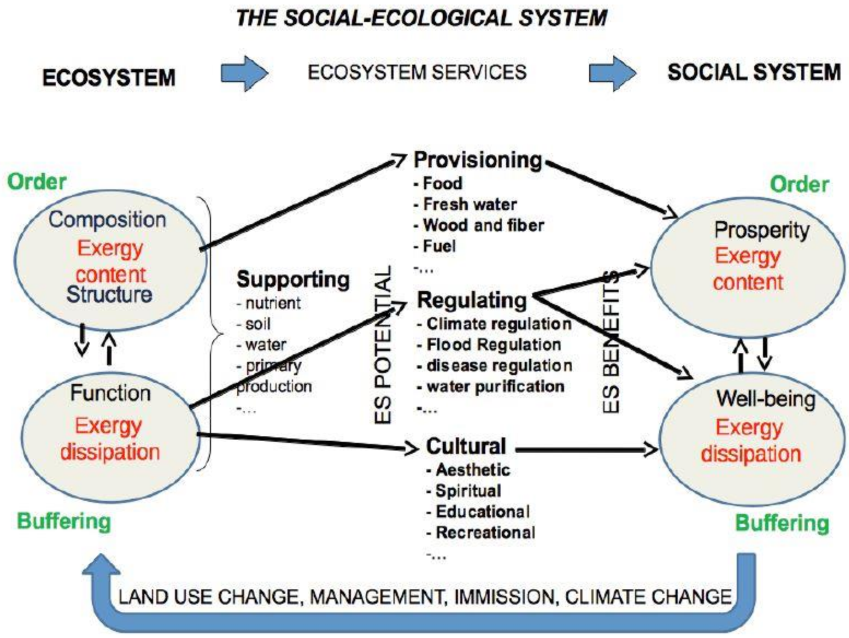

Figure 12: Conceptual scheme showing the relationships between ecosystems and social systems as closely interlinked subsystems exchanging exergy, matter and information. Source: Muys 2013, 46 (fig.3).

193 Muys 2013, 43; Schneider & Kay 1994; Schrödinger 1994; Unpublished presentation Prof.dr.ir. Bart Muys.

194 Muys 2013, 43.

195 Muys 2013; Poblome 2015, 107-108.

To translate all of this into sustainability of past societies, would sound like this: past societies would be deemed sustainable if and when the increase in human prosperity (exergy content) and human well-being (exergy buffering) is achieved without the loss of ecosystem structure (exergy content) and ecosystem buffering (exergy buffering). This definition of sustainable development is valid and applicable for socio-ecological systems at different scales of time and space, e.g. over a decade at the level of a community or over a century at the level of an empire.[196] With this in mind the exergy concept could be translated into the question whether communities, regions or the entire Empire were successful at buffering exergy and matching its exergy needs with those of the supporting ecosystem.[197]

By mapping flows of exergy as well as how much work a given system contains, thermodynamics can be considered very appropriate for capturing the global properties of complex systems.[198] In spite of this, the exergy model has disadvantages. The principles of thermodynamics in combination with complexity theory were developed by, among other, Belgian scientist Ilya Prigogine.[199] These natural laws were first conceived for closed systems and later applied to open systems as well, such as the Roman Empire.[200] One of the main advantages of a model which assumes a constant exchange of exergy between systems, is it that it recognizes that these systems are not - or even never - in an equilibrium state. They need a constant input of exergy to maintain their operational level, and even more so the more complex they become. Providing a constant exergy input implies adaptive strategies and this changes society. In complex adaptive systems, therefore, change is the norm and stability is unassured.[201] This does not mean that stability is not present in the archaeological record, because it is. It, however, means that it depends highly on the given spatio-temporal scale and the research focus. Stability cannot be a general and expected state of socio-ecological systems.

When studying complex systems by means of thermodynamics, and therefore by studying exergy sources, the *arrow of time* is introduced. Exergy flows only allow one path of exergy, its dispersal – or entropy.[202] But time moves in a linear fashion, so why is the linear progression - or decrease - of exergy unsuitable for archaeological sustainability studies? Because it denies the random process of history.[203] Socio-ecological systems do not pass through different evolutionary stages,[204] solely based on their exergy flows or entropic value. Random events, which could even be the actions of a single agent, could

196 Muys 2013, 45.

197 Poblome 2015, 108.

198 Poblome 2015, 107.

199 Bintliff 2013, 73.

200 Muys 2013, 43; Poblome 2015, 107.

201 Poblome 2015, 108.

202 Bintliff 2004; 189.

203 Unpublished presentation Prof.dr.ir. Bart Muys.

204 Lucas 2005, 12.

influence the entire system. The underlining neo-evolutionary scheme of a general societal evolutionary pattern undermines the fact that societies regress as much as progress, and that they develop at different rates and through different causal mechanisms.[205] Furthermore, time is not a fixed structure in which changes simply take place, it is as multi-layered as these changes, and it is affected by them as much as it affects them.[206] Time can no longer be seen as an independent or linear dimension in which archaeological events take place.[207] The next model, the *resilience model*, will try to come to terms with the cyclical manner in which societies, or socio-ecological systems, behave.

4.4.3. Adaptive cycles, the resilience model

The resilience model also builds upon the concept of socio-ecological systems but combines this with the concept of adaptive cycles of renewal in human and natural systems. The idea of linked adaptive cycles, or *Panarchy theory*, was introduced by Gunderson & Holling. Panarchy is a tool for understanding economic, social and environmental systems, and explains how these three interact. By doing so, these often abstract and intangible concepts become visible in the archaeological record and additionally become units for analysis. Panarchy becomes a framework for investigating change: it places agents, institutions, natural and human systems in adaptive cycles, which are governed by three factors: the limit of change (*potential)*, the internal control and variability (*connectedness*) and sensitivity for change (*resilience*). These adaptive cycles (figure 13) run through four stages: growth (r), stability (K), catastrophic change (α), and reorganization (Ω). This model shows incremental growth from r to K. Increased connectedness in K leads to a more rigid system with less resilience for disturbances in Ω. This results in the reorganization of existing and newly integrated elements in α, therefore creating a new cycle. These individual cycles are caught in larger and slower cycles. Larger cycles dominate the behaviour of smaller cycles, but like all complex systems, the non-linear behaviour of the dynamics of the system, allows smaller cycles to also influence the larger ones. This concept allows for the study of short, medium, and long term developments and is therefore very effective for studying societal changes against a wider economic, social and environmental background.[208]

[205] Johnson & Earle 1987; Lucas 2005, 12.

[206] Lucas 2005, Poblome 2015, 103.

[207] Lucas 2005, 19.

[208] Gunderson & Holling 2005, 27-47, 68-77.

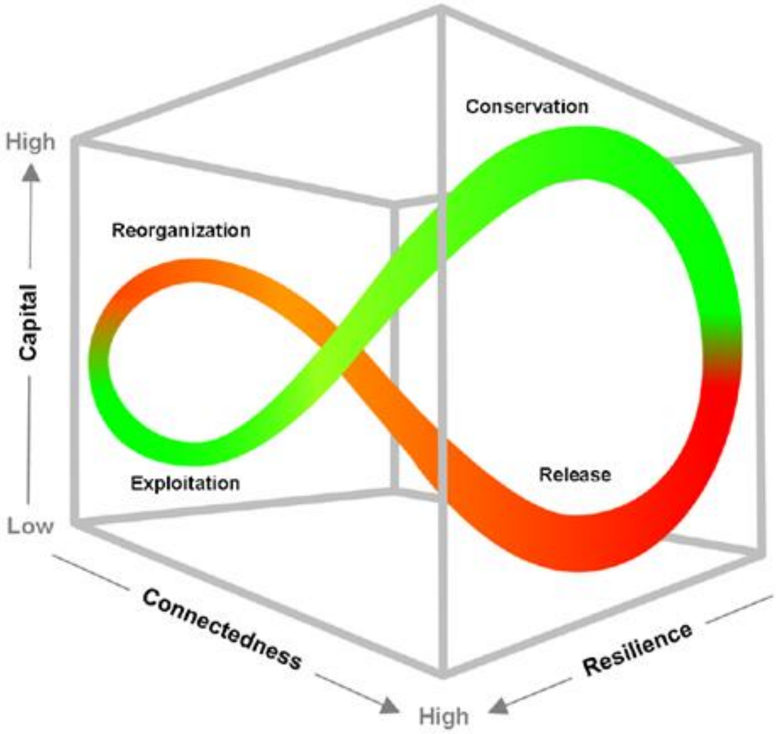

Figure 13: The adaptive cycle of renewal showing the four stages: exploitation, reorganization, conservation and release framed within different dimensions of connectedness, resilience and capital.

After: Gunderson & Holling 2002, 41.

A case study to elucidate the abstract model of adaptive cycles can be found in the analysis of the productive landscape of the ancient site of Sagalassos (southwest Turkey, ancient *Pisidia*) between the second and fifth century CE, where the concept of regional complex adaptive systems was explored considering interdisciplinary indicators for *potential*, *connectedness* and *resilience*. The studied time frame is part of the so-called Beyşehir Occupation Phase, identified between 1000 BCE and 800 CE at various locations in the Eastern Mediterranean. This phase is characterized by signs of intense human impact, represented by an increase in arboriculture (mostly oak tree) and secondary anthropogenic indicators, which can be connected to agriculture, in the pollen record.[209]

In late Roman times, macro botanical remains show a slight decrease in fruit trees compared to Roman Imperial times, but an increase in pulses and barley. Especially barley, which is more resistant to bad conditions and which can be grown in marginal areas, can be seen as a shift towards a more *resilient* system. Furthermore, the attested grain and olive cultivation can be seen as important indicators of stability, and therefore *resilience*, in the productive landscape.[210]

[209] Van Zeist e.a. 1975, 55-143; Poblome 2015, 115.

[210] Poblome 2015, 119-123.

The Beyşehir Occupation Phase represented the optimal *potential* for the regional vegetation pattern and *resilient* human use and maintenance of the landscape. In terms of *potential*, a heavy human hand is visible in the vegetation pattern from the third century CE onwards: managing cereal and olive cultivation; and also the maintenance of oak woodlands, which could reflect human measures against soil erosion on top of harvesting wood. Furthermore, since the Beyşehir Occupation Phase, different landscape pockets seem to have been characterized to some degree by different vegetation patterns, invoking local change and *connectivity*.[211] At least from the third century BCE onwards, ancient Sagalassos became the most prominent settlement in the wider region. By early Imperial times, it had established a territory of approximately 1.200 km^2, drawing resources and *potential* from the wider region.[212] This period saw the highest *connectivity* of the system, not only in local and regional terms, but also in terms of state-wide networks.

The analysis of faunal remains seem to agree with the general trend derived from the pollen record. In terms of *exergy*, meat yield is a better indicator than counts and proportions of animal bones. Cattle produced proportionally more meat than pig, sheep or goat. Therefore beef clearly formed the majority of the consumed meat between the early Roman Imperial and early Byzantine times. In general, cattle at Sagalassos were slaughtered at an older age in late Roman times, and this is seen to reflect the *potential* of the regional economy.[213] Despite the growing consumption of beef in this period, it implied that cattle in Sagalassos had an important role as working animals, for transport or as milk providers. In the course of the fourth century CE, amphora- and *oinophoroi* production was introduced in and around Sagalassos, which previously only produced pottery within the Eastern Suburbium. This is a sign of specialization of craft production and the diverse content of these containers could possibly imply the same for agricultural production.[214]

Based on the pottery analysis, fabric and type, of the Ağlasun Valley around Sagalassos, two different degrees of development - or change - can be recognized: one for the urban centre of Sagalassos and one for the surrounding Ağlasun Valley. Although there is no straightforward connection between sherds and people, it seems that in late Roman times there is an increase in people in the Ağlasun Valley compared to the urban centre, especially when comparing these numbers to earlier centuries. This could imply that the late Roman times saw the emergence of more valley farms, focussing on agriculture and herding livestock. During this time, the rural settlement pattern was at its densest and this could result in a high demographic total. This positive demographic evolution and degree of specialization associated

[211] Poblome 2015, 119.

[212] Poblome e.a. 2013; Poblome 2015, 119-128.

[213] De Cupere, 2001, 139; Poblome 2015, 121-123.

[214] Poblome 2015, 123-126.

with late Roman times can be considered to reflect successful strategies in *exergy buffering*, resulting in increased *resilience*, *order* and *complexity* in society.[215]

This example demonstrates the usefulness of the concept of adaptive cycles and resilience in approaching the development of nature-society interaction, regional analysis and diachronic comparison.[216] In order to fully understand the cycles of resilience this region went through, the general trends mentioned above need to be diachronically widened and compared with available data on earlier Hellenistic, early Roman, Imperial Roman, and later Byzantine times.

The addition of the concept of resilience allows for the explanation of the inherent tendency of internal destabilization in systems of increasing complexity, where fine-tuning of the status-quo prevails over the adaptive capacity to upcoming changes. Resilience is therefore the ability to keep potential and connectivity high over the long-term.[217] The resilience model is akin to the exergy model when it comes to modelling flows of energy, matter and information. However, it more thoroughly explains the inherent and cyclical change of complex open systems. The socio-ecological system of the Roman Empire for example needed energy to develop in sustainable ways. Access to energy made it resilient, adaptive and capable of solving problems, such as those caused by the level of its own complexity.[218]

The focus on resilience and sustainability of socio-ecological systems makes this model most compatible with interdisciplinary approaches of past regional development and of course with past sustainability itself.[219] It integrates the exergy flows of the thermodynamic model of socio-ecological systems and combines this with a multi-layered approach to time. The Panarchy concept facilitates the idea of smaller adaptive cycles, being connected to larger adaptive cycles, continuously influencing and changing one another (see above). One cycle, for example a region in south-east Turkey in the second century CE, may change at a different speed than the larger cycle to which it is connected, for example the Roman Empire. Yet, the connection remains. The resilience model therefore allows a multi-scalar approach to archaeology, meaning that it can be applied to different spatial (household, region, empire) and temporal scales (short term, medium term and long term processes). Another advantage of mapping flows of matter, energy and information is that the system becomes quantifiable and therefore comparable. The comparison of different spatio-temporal scales is adamant to archaeological research. Adaptive cycles can work as heuristic tools to describe sustainability of past societies, with archaeological phenomena

[215] Poblome 2015, 133-139.

[216] Ibid., 140.

[217] Unpublished presentation Prof.dr.ir. Bart Muys.

[218] Poblome 2015, 106.

[219] Poblome 2015, 106.

as proxies for the potential, connectedness and resilience. Archaeological regions could be seen as panarchies, with linked adaptive cycles represented by households, communities and empires.[220]

The downside of this, and other model(s), is the definition of quantifiable and robust proxies. What kind of archaeological data is suitable for being applied to this model? There will always be inherent biases in the data. Furthermore, the nature and quantity of the data will be dependent on not only the region, but the excavator, researcher and funding. This does not mean that all previous datasets should be thrown overboard, on the contrary: all datasets are valuable, but their positioning and influence should be thoroughly revised. This does also not mean a radically different approach to archaeological excavation, for example: ceramic analyses together with pollen analysis and diet reconstructions can still form the basis of an archaeological enquiry. But these investigations should, and this is crucial, be put together and not be viewed separately. Environmental proxies should be viewed next to economic and social ones in order to recognize and explain the different mechanisms of change.

4.5. Conclusion

In this chapter we evaluated the use of the pillar and the nested model for approaching sustainability of past societies. To this purpose, both models have their strengths and weaknesses, which are relatively similar. The nested model however, as an improved version of the pillar model can be seen as a step in the right direction. We framed both models as the earliest attempts at modelling sustainability of past societies. Several more recent attempts at modelling sustainability were subsequently presented as food for thought. We look at complexity theory and explained the structure of socio-ecological systems and complex adaptive systems. Two new models were put forward, which could potentially replace the pillar and nested model: the exergy model and the resilience model. Both models can be termed multi-scalar, both model fluxes of energy, matter and information and both represent nature and society as two parts of the same system. All of which makes these models quantifiable and comparative. Despite positive virtues, these models have yet to be thoroughly applied to archaeological research. One of the reasons this has yet to happen is the inherent problem with finding suitable proxies. In short, these models need to be fine-tuned before they can be applied to archaeology. The larger narrative of this chapter was the recognition of a need to assume, explain and model change in order to study sustainability of past societies.

[220] Poblome 2015, 110.

5. Final conclusion

The aim of this paper was to investigate the use of the concept of sustainability in archaeology. In order to approach this research question we had to first look for a conceptual model describing the structure and functioning of socio-natural systems, suitable for sustainability analysis in the past. Secondly, it was important to identify and select indicators for these models, based on archaeological data. This paper reviewed two models which took into account economic, social and environmental considerations to assess sustainability: the pillar model and the nested model. In the first two chapters these models' structure was explained and subsequently applied to carefully selected archaeological studies in order to prove their employment in archaeological research.

The simplicity of the pillar model made it accessible, comprehendible and made it, in part, responsible for it becoming the globally dominant model for sustainability. However, this simplicity proves to be both its strong point as well as its weakness. The pillar model fails to offer a scientific basis for selecting accurate indicators or proxies. Furthermore, it tends to focus on economic performance, resulting in the selection of indicators for economic growth. This focus on economic performance suggests that economic development is unconstrained by social and environmental issues. As a result, overall sustainability of the socio-natural systems is not explicit. Despite its weaknesses the model has laid the foundations for evaluating sustainability, both in the present and the past.

The nested model can be seen as an improved version of the pillar model, as it solved the focus on economic performance, by representing the economy as a subsystem of the social system. The social system itself is then modelled as a subsystem of the environment. The economy now facilitates societal well-being, and societies can only prosper within the possibilities and limits offered by the natural environment. In part, due to its similar architecture to the pillar model, the nested model can be termed as oversimplified. Just as with the pillar model, it proves difficult to determine robust and scientifically founded proxies for evaluating sustainability in the past. Furthermore, the model does not account for the dynamic nature of past societies. However, by both relinquishing the focus on economic performance and by providing a framework of co-dependent subsystems, the nested model has proven to be a step in the right direction.

The third chapter presented a new body of theory that, in initial terms, proves useful for modelling and evaluating sustainability in the past. Complex systems theory, complex adaptive systems and socio-ecological systems were introduced. Next, we moved forward with these concepts and proposed two new models which could replace the models of the first two chapters. The first of which was the exergy model, which combines the ideas of complex systems theory with thermodynamics, in order to model the flows of energy, matter and information in a socio-ecological system. This not only proves valuable for selecting proxies, but also makes the models themselves quantifiable and therefore comparable. Furthermore, the modelling of fluxes allows for an application to different spatio-temporal scales. On top of that, it assumes that socio-ecological systems are never in equilibrium, since these systems need a continuous input of energy to maintain order and are therefore continuously changing and adapting. Although the exergy model seems to solve the problem of explaining societal dynamics, the entropic principle on which the model is based only allows for one energy path – its dispersal. The exergy model is therefore faced with an insurmountable one-directional approach to time, which proves ineffective for explaining patterns of change.

The second model, the resilience model, continues to build on the idea of socio-ecological systems and fluxes of energy, but adds the Panarchy concept. Like the exergy model it presents socio-ecological systems as continuously changing complex adaptive systems, but these are now connected to other - larger of smaller - complex adaptive systems. These systems go through a continuous cycle of exploitation, reorganization, conservation and release. The position of the socio-ecological systems in this resilience cycle is determined by fluctuating levels of capital and connectedness. These additional dimensions - resilience, interlinked complex adaptive systems and flows of energy - provide the necessary framework to overcome the arrow of time. By accommodating change, as increasing and decreasing complexity, at different spatio-temporal scales, the resilience model proves most suitable for modelling sustainability in the past.

The concept of sustainability has proven a valuable framework for archaeological studies. It not only requires the researcher to model the environment and society as one socio-natural system, but also comes to terms with the growing need in archaeology to explain the attested variation in the archaeological record. Furthermore, it distances itself from linear interpretations of social dynamics and offers a cyclical approach instead. By integrating fluxes of energy, matter and information in a given system, both the proxies and the models become quantifiable and comparable.

This academic venture was not without its difficulties: combining the vast amount of literature on complex systems theory with the relatively new concept of sustainability, in order to apply this to archaeological studies, proved challenging. For all that, I hope that this paper can serve as a stepping stone for further research into sustainable archaeological systems.

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