Multiscalar socio-ecological modelling of prehistoric and historic period human activities in the French Alps.

An assessment of human behaviour/activities at multiple scales, centering on the French Alps.

Patrick Thomas Russell Mayer

MA by Research

University of York

Archaeology

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Abstract

This dissertation applies a suite of coarse-grained formal models to the administrative departments four and five in South-Eastern France, the summed probability distribution of radiocarbon dates (SPD), the aoristic analysis of site counts (ASC), and pseudobiomization (PBM), evaluating the results against current landscape-scale interpretations from the Ecrins National Park to test their efficacy in elucidating our understanding of past human behaviour/activities. Previous research has incorporated elements of this methodology to this study area as a part of continental scale assessments of population density (Shennan et al. 2013; Crema et al. 2017), and changes in land-cover (Fyfe et al. 2015). Using these datasets, new SDP's were produced to include more radiocarbon dates from the Ecrins, previously reported PBM results were replicated to only include sites from within the study area, and ASC was additionally applied, primarily utilizing the PATRIARCHE database, as a multi-proxy analysis of human activity/population density and land-cover change. The results of this research was a broad correspondence between the landscape-scale interpretations from the Ecrins National Park, and the suite of models applied to the study area. Moreover, this dissertation ultimately concludes that the coarse-grained modelling approach employed was by itself only able to elucidate our understanding of broad-scale trends of human behaviour/activities across the study area, due to the scale of the approach taken. However, when combined as a part of a multiscalar analysis, it was a useful tool in integrating landscape-scale interpretations with their regional context.

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Declaration

I declare that this thesis is a presentation of original work and I am the sole author. This work has not previously been presented for an award at this, or any other, University. All sources are acknowledged as References.

Introduction

Research Question

To what extent can the application of formal models elucidate our understanding past human behaviour/activities in the French Alps?

Objectives

In order test the extent to which formal modelling can elucidate our understanding of human behaviour/activities in the French Alps, the following three objectives will be addressed. Please also refer to table one.

Table 1: List of objectives

1.	Review and assess how human-environment interactions are studied in archaeology and its cognates.
2.	Review and assess the current contribution of modelling approaches towards elucidating our understanding of human-environment interactions.
3.	To apply a suite of formal modelling techniques to a data set from the French Alps to test their efficacy in helping to integrate data from different spatial and temporal scales.

First objective one, how human-environment interactions are studied in archaeology and its cognates. The aim of considering this thematic question is to contextualise a number of key elements of critical thought that are pertinent to a modelling approach beyond a methodological engagement. Secondly objective two, the assessment of the current contribution of modelling approaches towards elucidating our understanding of human-environment interactions. This aims to build on the thematic arguments developed through objective one, while additionally incorporating discussions of methodological robustness. Finally, objective three, the application of a suite of formal modelling techniques to a data set from the French Alps, testing their efficacy in helping to integrate data from different spatial and temporal scales. Indeed, drawing on the previous discussions relating to objectives one/ two, it is through the interpretation of these results that will determine the utility of a formal modelling approach in elucidating our understanding of human behaviour/activities.

Rationale

Extensive programs of research in high altitude environments have lead to increasingly nuanced interpretations human behaviour/activities in mountain landscapes (Walsh et al. 2014, 52; Giguet-Covex et al. 2014, 1; Putzer et al. 2016, 136; Carrer et al. 2016, 1; Carrer and Angelucci 2017, 1; Cartier et al. 2018, 60; Fouinat et al. 2018, 1299); this dissertation aims to consider the efficacy of formal modelling in integrating both new, and previously reported archaeological and palaeoenvironmental data from the French Alps, in elucidating our understanding of how people interacted with these enigmatic landscapes at different spatial and temporal scales.

In recent years a suite of formal modelling techniques have been developed in seeking to further our understanding of past human population dynamics, changes in land coverage, and the relationship between the two, specifically: summed probability distributions (SPD) of radiocarbon dates (Shennan et al. 2013, 1; Timpson et al. 2014, 549; Crema et al. 2017, 1), pseudobiomization (PBM) (Fyfe et al. 2010, 1165; Woodbridge et al. 2014, 2080; Fyfe et al

2015, 1197), and aoristic analysis of site counts (ASC) (Orton et al. 2017, 1; Palmisano et al. 2017, 59). Although this analysis has been applied very successfully to regional, and indeed continental, scale questions of changing human behaviour/activities, most significantly in the wealth of publications concerning the Neolithic transition (Shennan et al. 2013, 1; Timpson et al. 2014, 549; Woodbridge et al. 2014, 216), it has been noted that discussions that deal with large-scale cultural questions rarely assess the same problems in terms of focused small-scale human-environment interactions, or give equal weight to archaeological and palaeoenvironmental data, risking the characterisation of human activities against a simple environmental backdrop, or indeed visa-versa (Walsh et al. 2006, 446; Walsh 2008, 548; Walsh et al. 2017, 1–3). Therefore, to answer calls that modelling offers an excellent means to make refined conclusions about human-environment interactions (Barton et al. 2012, 42; Izdebski et al. 2016, 5; d'Alpoim Guedes et al. 2016, 14483; Murphy and Fuller 2017, 8–9), these relatively coarse grained formal modelling approaches (SPD, PBM, and ASC) are applied to the administrative departments 4 and 5 in the French Alps, including the exhaustive interdisciplinary landscape-scale research program in the Ecrins National Park (France) (for example; Walsh et al (2014); Ali et al (2005); Court-Picon et al (2005); Court-Picon et al (2006); Talon (2010); Ponel et al (2011); Magny et al (2009a); Magny et al (2009b); Giguet-Covex et al (2014)), as a means of integrating it with its wider regional context, and testing our current interpretations.

Furthermore, as this analysis aims to integrate long-term palaeoenvironmental and archaeological data, it feeds into topics with a much wider significance regarding the contribution of archaeology to discussions of climate change (Redman 2005, 70; Jackson et al. 2018, 58). It has been highlighted that despite the societal importance of research focusing on climate change, there is relatively little attention paid to historical disciplines, such as archaeology, that are able to make a valuable contribution through the assessment of human adaptation to climatic variability at a temporal scale inaccessible to contemporary climate science (van der Leeuw and Redman 2002, 597; Redman 2005, 70; Jackson et al. 2018, 58; Robbins Schug et al. 2019, 1). Therefore, with the additional fact that mountain ecologies are particularly susceptible to changes in average temperature (Walsh et al. 2014, 53), attaining a deeper understanding of changing human behaviour/activities through the analysis of human population dynamics and changes in vegetation land coverage in a focused regional setting has the potential to inform us more generally about stability and resilience in socio-ecological systems (Fitzhugh et al. 2018, 1).

Summary of Methodology

This dissertation uses three complementary formal modelling techniques to assess past human behaviour/activities in the French Alps, summed probability distributions (SPD) of radiocarbon dates (Crema et al 2017, 1), pseudobiomization (PBM) (Fyfe et al 2015, 1197), and aoristic analysis of site counts (ASC) (Orton et al. 2017, 1; Palmisano et al. 2017, 59), investigating their efficacy as a tool in helping to integrate data from different temporal and spatial scales in assessing human population dynamics, and changes in land coverage. Fundamentally, this analysis entails the integration of archaeological and palaeoenvironmental data, and as such the approach taken in attempting to elucidate our understanding of past human behaviour/activities is one orientated towards the study socio-ecological systems, or moreover human-environment interactions (Butzer 1982, 5; Redman 2005, 71; Barton et al. 2012, 42; Kintigh et al. 2014, 880; Walsh et al. 2017, 3).

The analysis used a dataset collated from the administrative departments four and five, using 4501 sites, 78 radiocarbon dates, and 10 lake corese. See appendix for details of C14 dates and lake cores. The analysis was primarily conducted in the open source statistical programing software R 3.5.1 (El Capitan), specifically the packages rcarbon (Timpson et al. 2014, 549; Crema et al. 2017, 1) and archSeries (Orton et al. 2017), Microsoft Excel (2010), with additional processing within ESRI's ArcGIS (ArcMap 10.6).

Methods in Relationship Objectives

First, objective one: the assessment of how human-environment interactions are studied in archaeology and its cognates. Primarily, this consists of section one of the literature review, providing a robust theoretical backdrop regarding some of the complexities that are apparent when studying human-environment interactions, navigating various research biases in the concomitant study of the biophysical and social domains. Additionally, the importance of scale is discussed, a topic of particular importance in dictating the nature and extent of our interpretations. The result of these discussions is to build a critical backdrop against which the impact of modelling can be considered, while more importantly serving to develop an interpretive framework that will inform how the results of this dissertation are considered. Regarding objective two: the assessment of the current contribution of modelling approaches towards elucidating our understanding of human-environment interactions. This is addressed in section two of the literature review, considering the theoretical aspects of a modelling approach, and an in-depth discussion of the formal models used in this dissertation, SPD/PBM/ASC, in order to provide methodological robustness.

Finally, objective three: applying a suite of formal modelling techniques to a data set from the French Alps, testing their efficacy in helping to integrate data from different spatial and temporal scales. To reach this assessment, a multiscalar approach is taken, applying a suite of course grained formal models to departments four and five in the French Alps, seeking to test our current landscape scale interpretations from the Ecrins National Park, from within the study area, and also previous regional/continental scale interpretations in attempting to bridge the divide between these two different scales of analysis. Thus, section three of the literature review outlines the current interpretations of human-environment interactions in the French Alps, focusing on the research conducted in the Ecrins National Park, while also discussing previous research projects that have used similar methodologies, and encompassed the study area within their own. Within this discussion three periods are considered in depth: the Neolithic transition, 4.2 ka climate event, and the little ice age. Indeed, it is the interpretations of these periods that will be subsequently be tested against the results of this dissertation. Accordingly, this review provides the contextual backdrop against which the significance of the results can be considered. Secondly, chapter three specificies the the methodological steps taken for the modelling. This includes a detailed review of how the dataset used was managed within ArcMap 10.6, and the subsequent methodological processes. Indeed, the application of the pseudobiomization (PBM) approach (Fyfe et al. 2015, 1197), was initially conducted within R 3.5.1, and then subsequently within Microsoft excel (2010). Whereas both the summed probability distributions (SPD) of radiocarbon dates (Crema et al. 2017, 1), and aoristic analysis of site counts (ASC) (Orton et al. 2017, 1; Palmisano et al. 2017, 59), were conducted entirely within R 3.5.1, using the packages rcarbon (Timpson et al. 2014, 549; Crema et al. 2017, 1) and archSeries (Orton et al. 2017). Indeed, the SPD and ASC results were also statistically tested through the application of monte carlo simulations. The resulting plots were constructed using in R 3.5.1 using the package ggplot2. Finally, the results are discussed in chapter four, integrating the results of the formal modelling with our current understanding of human-environment interactions at a landscape/continental scale, providing a multiscalar perspective on the changing human behaviour/ activities in the French Alps.

Chapter One - Literature Review

Introduction

The aim of this dissertation is to test the efficacy of formal modelling in elucidating our understanding of human behaviour/activities in the French Alps, testing our current landscape scale interpretations against the results from a suite of coarse grained methodologies. Therefore, for this multiscalar socio-ecological analysis to be successful it is important that the subsequent discussions are well grounded in: 1) the inherent complexity regarding the integration of the biophysical and social domains, with specific reference to the scales of our analysis, 2) a strong understanding of the formal modelling approaches used for methodological robustness, 3) the characterisation of our current interpretations of human behaviour/activities in the French Alps.

However, to a certain extent these discussions concern thematic topics, establishing a theoretical and methodological framework of best practice, and as such it is useful to begin by reviewing the study area and research gap this dissertation aims to address in order to maintain a tight focus on these questions throughout the text.

A Question of Scale: The Study Area and Methodological Overview

The study area for this assessment is located in South-Eastern France within the administrative departments four and five (see figures 2 and 3), situated to the East of the Italian border, encompassing the South-Western edge of the Alpine arch, and including both mountainous zones and adjacent lowland plains. This geographical area has been subject to both intensive landscape scale analysis (Walsh et al. 2014, 52), while also being included in regional/continental scale research concerning human population dynamics and changes land coverage (Fyfe et al. 2015, 1197; Crema et al. 2017, 1; Roberts et al. 2018, 1). However, without being dismissive of the utility of these different scales of research, it has been noted that large scale assessments of human behaviour/activities rarely engage with the same questions with regards to landscape scale processes (Walsh et al. 2017, 1). Indeed, this critical point is certainly the applicable to the French Alps, and considering the rich dataset available for this study area, it is well suited for evaluating the efficacy of a modelling approach in testing our landscape scale interpretations.

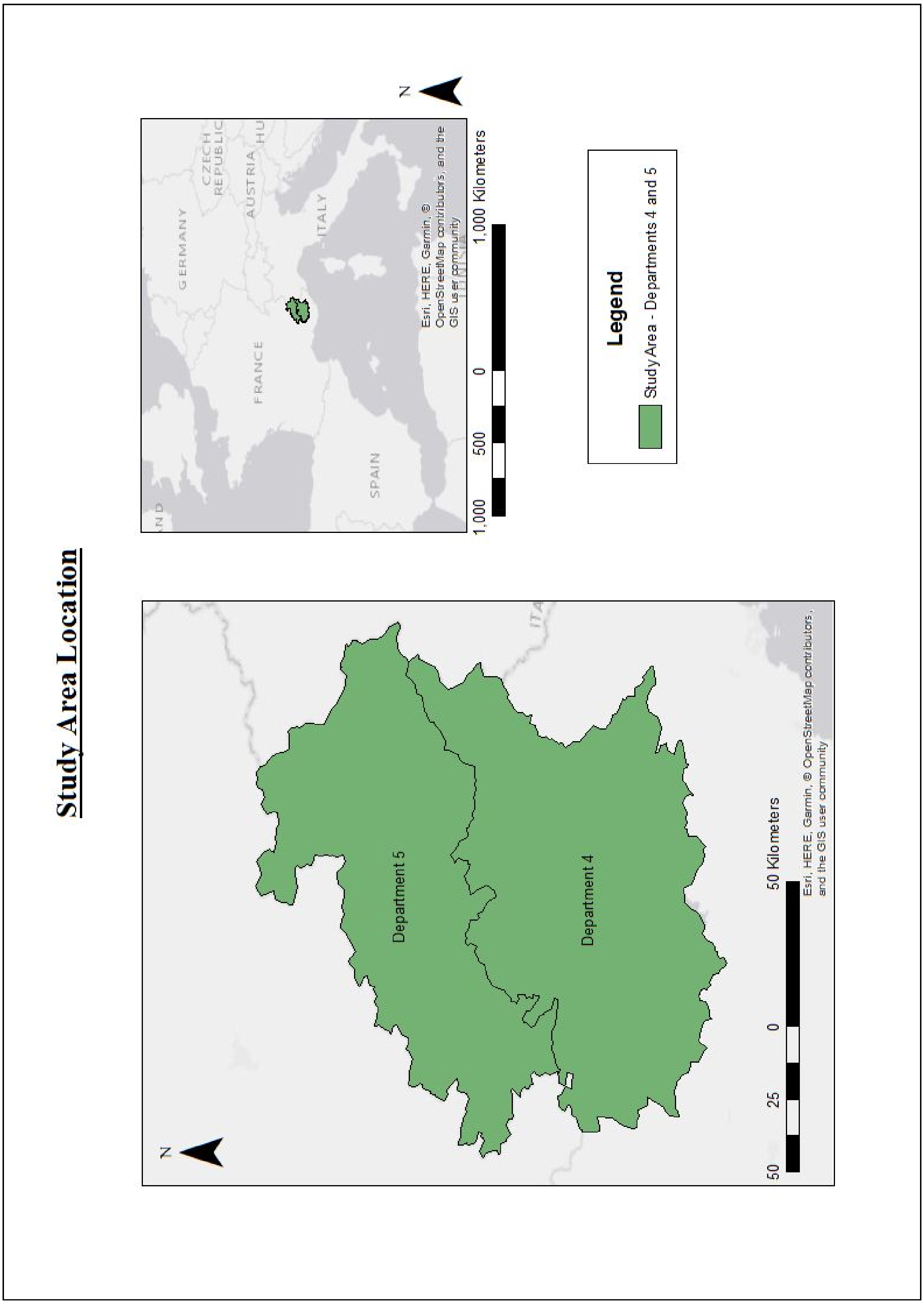


Figure One - Location of the study area.

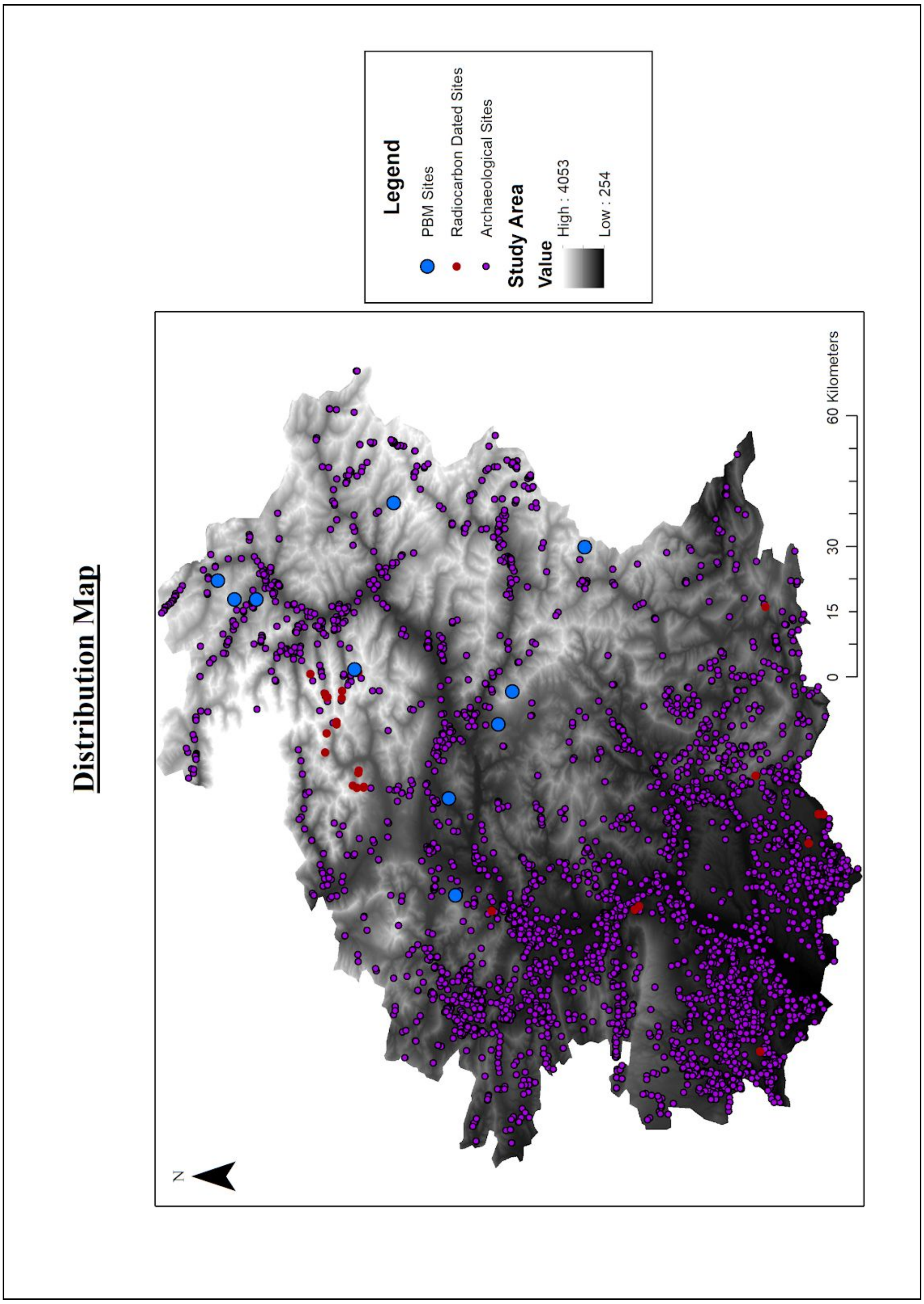


Figure Two - Distribution map of the data used.

Moreover, within the study area is the Ecrins National Park, which from 1998 has been the subject of an interdisciplinary landscape scale research project (Walsh et al. 2014, 53, 2016, 1). The results of this study have collected, and subsequently synthesised, a wide range of archaeological and palaeoecological data (see figure 4), providing extensive interpretations of the waxing and waning of human activity in a high altitude setting from the Mesolithic through to the Post-Medieval periods (Walsh et al. 2014, 52).

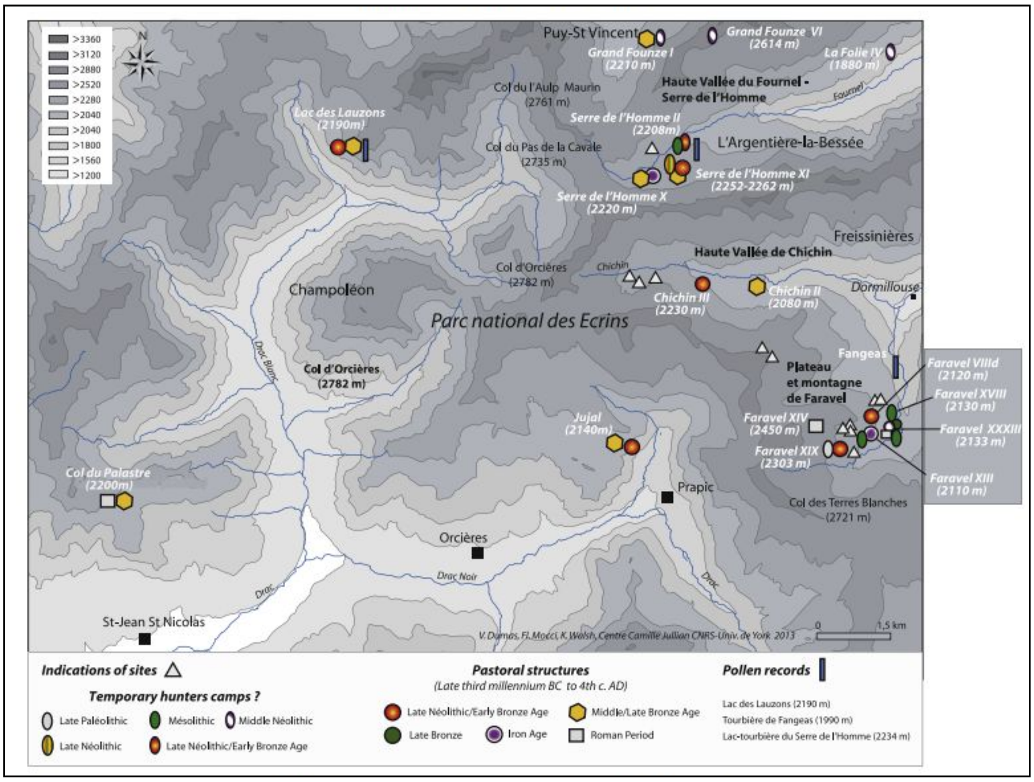


Figure Three - Distribution map from Walsh et al (2014, 54)

Conversely, data from this area has also been used in large scale regional/continental scale research projects (Fyfe et al. 2015, 1197; Crema et al. 2017, 1; Roberts et al. 2018, 1). From a palaeoecological perspective, data from departments four and five have been utilized in assessments of changes in land coverage through the Holocene, in order to elucidate our understanding of human-environment dynamics (Fyfe et al. 2015, 1197; Roberts et al. 2018, 1). From an archaeological perspective, data from the study area has been used in the analysis of continental scale human population dynamics across Europe (Crema et al. 2017, 1).

Thus, this dissertation aims to draw on this existing body of research to test the efficacy of a formal modelling approach to help in integrating data from different scales, evaluating our current interpretation of the study area against the results. Indeed, this is attempted through the application of the summed probability distributions of radiocarbon dates (SPD) (Crema et al. 2017, 1) and the aoristic analysis of site counts (ASC) (Orton et al. 2017, 1; Palmisano et al. 2017, 59) as a proxy for human population density, and pseudobiomization (PBM) (Fyfe et al. 2015, 1197) as a proxy for land cover change.

Chapter Overview

This chapter aims to review a number of critical points that are pertinent to the success of this endeavour. Indeed, as the methodological approach taken in this analysis is socio-ecological, aiming is to integrate palaeoecological and archaeological data, section one addresses the inherent complexity of this task, additionally making explicit the fundamental importance scale within these varying data types. With regards to ensuring methodological robustness, section two subsequently considers the suite of formal models applied to the French Alps, discussing best practice alongside any potential constraints. Finally, with the theoretical and methodological framework established, section three reviews current interpretations from within the study area, contextualising this with previous research projects that have operated at regional/continental scales. The focal point of this analysis is on the three following periods: the Neolithic transition, the 4.2 ka climatic event, and the little ice age.

Section One: Human-Environment Interactions

This section aims to answer objective one, reviewing and assessing how human-environment interactions are studied in archaeology and its cognates. The purpose of this discussion is to consider the complexity that comes with the study of both the biophysical and social domains, combining specialisms that traditionally conform to divergent research paradigms, and assessing data that operate at a multitude of scales. The utility of this review is to start building an interpretive framework for assessing the efficacy of the formal models applied to the French Alps. As such, this section can be broken down into the following two topics: 1) the traditional division between the natural and social sciences, 2) the significance of scale in our analysis.

Defining Human-Environment Interactions

Before entering into this discussion at greater length, it is imperative to offer a more precise definition of what is meant in this context by the term "human-environment interactions". This terms refers to the uni-directional relationship between humans and the environment, the environment consisting of the vegetative and geomorphic processes, as studied for example by an Ecologist or Physical Geographer, which combine as ecosystems that humans are an inherent part of (Evans and O'Connor 1999, 1; Walsh 2013, 1–5). However, although this definition is almost universally held as true in the natural sciences (Slaymaker 2017, 65), there has historically been significant theoretical tension regarding how we conceive of the environment and our place within it (Crumley 2007, 15). Therefore, the following discussion reviews the traditional theoretical division between the natural and social sciences, and how these different ways of understanding the world feed into our archaeological interpretations.

Two Cultures

The division between the natural and the social sciences has been termed the "two cultures", describing traditionally separate research agendas seeking to study either social or biophysical domains, or more simplistically the difference between relative and absolute knowledge (Walsh 2008, 547–549; Snow 2012, 1; Kristiansen 2017, 121). In an archaeological context, debates centering on the validity of these different forms of knowledge have been dominated by an often polemic and divisive discourse (Pollard and Bray 2007, 246), therefore rather than proceeding directly into the archaeological debates on this topic, a broader historical perspective is first taken in order to attain an overview of how and why more modern theoretical discussions came into being, subsequently drawing on theoretical musings from from archaeology's cognates, where the same fundamental questions have been addressed (Wylie 1992, 210; Johnson 2011, 48). The result of this approach is to ground archaeological theory in its contextual literature, providing a greater synthesis between disciplines that have considered the same theoretical questions, achieving an understanding of how this impacts our archaeological understanding of human-environment interactions, serving to remind researchers not to take a too anthropocentric/deterministic view of the archaeological record (Rae 2014, 56; Barrett 2013, 1).

A Brief History of the Nature-Culture Dualism

The division between natural and social sciences in embedded within the history of science, and is intrinsically linked to the notion of the nature-culture dualism (Smith 2009, 362). Therefore, to provide a detailed understanding of the deep rooted nature, and importance, of more modern discussions between the "two cultures" in archaeology and its cognates, a historical approach is taken in assessing development of the nature-culture dualism and its influence on more modern discourse. Due to the inherently large body of work that this review could draw upon, its focus has been confined to three periods of intellectual development, and subsequent reaction, that shaped contemporary discussions of dualistic and anthropocentric perceptions of the world (Rae 2014, 56), namely the renaissance, the enlightenment, and romanticism (Smith 2009, 362; Uggla 2010, 80; Piiroinen 2018, 64). Furthermore, it is worth remembering that when dealing with historical topics, particularly the history of science, it is important not to treat the subject as if it were a linear progression through time, but rather as contingent phenomena (Smith 2009, 345).

However, it is necessary to first define what the nature-culture dualism is, and its relationship with human-environment interactions. Indeed, the focus of this dissertation has thus far been presented as human-*environment* interactions, whereas the theoretical discussion outlined above concerns the *nature*-culture dualism, therefore a degree of terminological precision is necessary in defining the complexity that surrounds the terms "environment" and "nature" (Castree 2001, 6). The reason for this is that "nature" can have multiple meanings, both describing the physical world, but also a concept (Castree 2001, 6). Thus, "nature" can be divided into having three meanings; 1) as the external physical world not perceived as anthropic, and is inherently non-human, 2) as the intrinsic value of something, i.e. our conception of the inherent quality of something/someone, thus the somewhat clichéd phrase "it was in his/her nature…", 3) in opposition to number one, the notion that nature universally encompasses everything, whereby humans are biological organisms, and are intrinsically a part of the natural world (Castree 2001, 6–8). Although the definition of human-environment interactions outlined above is in clear alignment with number three, it is within the obvious tension between definitions one and three that embodies the central theoretical dichotomy of the nature-culture dualism, the notion that unlike other organisms which are intrinsically a part of the natural world, humans exist as a separate entity (Crumley 2007, 15; Walsh 2008, 547; Sutton and Anderson 2013, 1).

Thus with this semantic complexity highlighted, it is in the renaissance in which we can observe some of the foundational aspects of the nature-culture dualism begin to take shape (Johnson 2008, 9). The epicentre of the renaissance was in Florence, beginning at roughly 1400 AD, where there was active effort to emulate the intellectual achievements of the classical world (Haughton 2004, 229), giving rise to what we would now consider experimental science (Smith 2009, 345). The importance of these ideas was additionally magnified by technological advancements, specifically the introduction of the printing press, allowing the dissemination of ideas and knowledge like never before (Tebeaux 2018, 1). Fundamentally, the individuals at the centre of this development were not interested in understanding the world around them on a traditionally religious/superstitious level, but wanted to gain knowledge of the underlying mechanisms of the natural world (Smith 2009, 362). Indeed, this enquiry was not confined to the objective methodologies we associate with experimental science today, but also encompassed exploration of the natural world through the arts, a noteworthy example being the mathematical precision dedicated to artistic endeavours (Rees 1980, 60; Stork 2004, 77; Bullot et al. 2017, 453–546), and equally from a philosophical standpoint (Ribeiro 2018, 107). One of the most important philosophical thinkers in this context was René Descartes (1556 - 1650), who outlined the mind-body dualism (known commonly as Cartesian dualism), which argued that the mind and body (i.e. thoughts/ideas and the the physical world) are ontologically separate, in that each exist separately from the other (Ribeiro 2018, 107; Piiroinen 2018, 65). Therefore, it is the link between the mind-body dualism and the growth of experimental science that highlights the foundations of the nature-culture dualism in the renaissance; while the mind-body dualism set out the ontological basis for the nature-culture dualism, subsequently interpreted that if mind and body are ontologically separate then so to are humans and natural world (Vining et al. 2008, 1), the study of nature in scientific and artistic undertakings served to concomitantly reinforce the very same ideas (Hornborg and Crumley 2007, 3; Johnson 2008, 9).

Following on from the renaissance, it is next useful to discuss the enlightenment, a period in which most scholars agree marks the beginning of modern science (be that the natural or social sciences), triggering technological advancements, and the industrial revolution (Moravia 1980, 247; Mokyr 2015, 141; Arponen and Ribeiro 2018, 60). Scholars working during the enlightenment built very strongly upon the foundations laid down before them in during the renaissance, continuing to seek out the mechanisms behind natural processes, holding steadfast to the notion that through the application of objective methodologies can we understand the truth about the world, while at the same time drawing this body of work into a more coherent whole in attempting to systematise the knowledge of the world (Withers 1995, 139; Demeritt 1996, 485; Beiser 2000, 19). Indeed, it has been argued that this continuing wave of intellectual advance was intrinsically related to colonialism, where the discovery of new lands and peoples were a constant source of wonder, with exotic plants/animals, and people, brought back to western courts (Withers 1995, 148). Thus, there is a strong argument to suggest that advancements in science and technology were considered a civilising act over seemingly less developed cultures, and also by extension civilising nature (Wolloch 2016, 4–5). This was not just apparent in terms colonialism, but also significantly impacted the populations of wealthy nations through the industrial revolution, whereby technological advances led to the creation of factories, increasing urbanisation, and resulted with fewer people living in traditional rural settings (Vining et al. 2008, 1–2; Johnson 2008, 125; Mokyr 2015, 141). Contextualising this with modern debates around climate change, it is unsurprising that the 18th century has been marked out as a possible point of departure from the Holocene to the Anthropocene due to rampant industrialization during this period (Crutzen 2006, 17; Corlett 2015, 36). Therefore, to circle back to the development of the nature-culture dualism, it is during the enlightenment that we are able to perceive a sense of mastery over nature because of the perceived importance of scientific and technological advancements (Merchant 2006, 517; Vining et al. 2008, 1–2), additionally manifesting itself in a very physical separation and detachment from nature through urbanisation (Johnson 2008, 125).

Accordingly, it would seem that the developments of the enlightenment entrenched the notion that humans were somehow separate to nature; it is from this standpoint it has been argued that Romanticism was a direct reaction against the nature-culture dualism (Johnson 2008, 126; Uggla 2010, 80). Broadly speaking, Romanticism was a was a hugely influential cultural movement that occurred in reaction to the sweeping changes made by

Enlightenment/post-Enlightenment industrialization through the mid 18th and 19th centuries (Kohl 1998, 228; Uggla 2010, 80).In this way, Romanticism deplored the objective detachment to the world that scientific enquiry had fostered, instead striving for an "organic connection" with nature (Masson 2007, 117), favouring the ideals of untouched and remote wilderness (Head and Regnell 2012, 223). Nevertheless, despite this intellectual fervour regarding nature, it has been argued that Romanticism was fundamentally an empirical endeavour that nurtured the nature-culture dualism rather than dispelling it, highlighting how embedded it had become within western culture (Johnson 2008). Indeed, it is the emphasis between the domains of man, being that of newly formed industrial cities, and that of nature, as areas perceived as unsullied by sweeping technological advancements, which is of central concern in this argument (Uggla 2010, 80). To observe this in more detail it is important that we consider how nature was perceived in this work; one of the key themes in Romanticism was the sublime, the idea that the enormity and power of nature could evoke profound feelings within the minds-eye of the beholder, an idea that emphasized a hierarchical relationship between man and nature, rather than a dialectical relationship (Masson 2007, 127). Furthermore, there was an underlying empiricism to this work, whereby scholars aspired to let the landscapes they were depicting, be that within literature or art, speak for themselves, implicitly assigning them as a separate entity from man, accentuating the feeling of detachment (Johnson 2008, 27). Consequently, despite the fact that Romanticism denounced the objective and scientific thinking of Enlightenment period scholars, and the industrialization that followed, the way in which nature was perceived and depicted ultimately reinforced the cultural understandings nature-culture dualism (Haila 2000, 157; Masson 2007, 127; Johnson 2008, 27) and subsequently influenced modern perceptions of nature (Edmonds 2006, 167).

Therefore to conclude this brief historical overview, the theme that has been broadly traced out is the development of objective science through the renaissance and the enlightenment as a means of understanding the world, and consequently nurturing the nature-culture dualism (Smith 2009, 362). Indeed, this development arguably had a significant impact on the notion that nature is inherently non-human, in that the very nature of objectively studying the natural world, alongside the technological advancements that have been born out of it, promotes both a physical and ontological separation (Hornborg and Crumley 2007, 3; Johnson 2008, 9; Ribeiro 2018, 107). Additionally, romanticism was considered as an example of the broader social and cultural impacts of the nature-culture dualism, and how despite the fact that it deplored the objective detachment of the natural world, ultimately reinforced an already embedded cultural norm (Haila 2000, 157; Masson 2007, 127; Johnson 2008, 27).

Modern Theoretical Relevance

It is from this historical context it has been argued that the dominant way in which we perceive and study nature today is biased towards advancing a seemingly more scientific and objective understanding, placing too much emphasis on mechanistic processes, which undervalue social/cultural knowledge, furthering a dualistic conceptions of the world, or as summarized earlier as the "two cultures" (Woodgate and Redclift 1998, 4; Kidner 2000, 339; Demeritt 2001, 26; Walsh 2008, 547–549; Snow 2012, 1; Stedman 2016, 891; Slaymaker 2017, 70). Indeed, people have challenged this at a theoretical level under the broad banner of social constructivism (Castree 2001, 10). Although these arguments are apparent in archaeological thought, the very same theoretical dichotomy is apparent in all scientific spheres (Wylie 1992, 210; Pollard and Bray 2007, 246; Johnson 2011, 48), and therefore it is useful to first review such arguments within archaeology's cognates so not to confuse them as an isolated discussion. In a simplistic and generalised sense the underlying rationale behind social constructivist arguments is to challenge what is falsely thought of as fact, and highlight its social origins (Demeritt 2001, 22). However, the topic of social constructivism is somewhat more complex than this, in that it has a number of different themes, with different objectives, and although they have the same underlying rationale it is important not to get them confused (Demeritt 2002, 767). Accordingly, this can be broken down into two groups: social construction for the purpose of refutation, and social construction for the purpose of a philosophical critique (Demeritt 2002, 767).

The first group of social constructivist arguments to be considered are those with the purpose of refutation, that challenge a fallacy within modern thought and seek to disprove it as a social construction (Demeritt 2002, 769). Arguments of this type are not limited to discussions of nature (Demeritt 2001, 22), however the nature-culture dualism features heavily within the literature as a fallacy that is implicitly applied to a number of topics such as notions of pristine wilderness, and the ecologically noble savage (Grande 1999, 307; Denevan 2011, 576). Indeed, both of these examples are implicitly dualistic, assuming that western industrialised society exist as a separate entity to nature (Castree 2001, 6–8). Specifically, the notion of pristine wilderness is the idea that there are places on the planet that are devoid of modern industrialised/urbanised society, and therefore must be saved as pockets of nature as it was, before large scale human impacts (Grande 1999, 307; Denevan 2011, 576). Furthermore, the fallacy of the ecologically noble savage follows a similar trend in that it is centered on the notion that non-industrialized cultures, for the most part focusing on Native American populations, have a symbiotic relationship with the world around them, and do not/ did not exploit the environment in the same way that we do in a modern western sense (Raymond 2007, 178). As aforementioned, both of these fallacies have been refuted as examples of socially constructed knowledge: failing to engage with both the long-term nature of human impacts on the natural world (Proctor 1998, 352; Williams 2000, 28–29; Erickson 2008, 157), or additionally failing to engage with evidence regarding how ethnographic groups actually interact with their environment, with an incredibly rich understanding of natural processes, but often little regard for conservation (Raymond 2007, 184). Furthermore, these critiques often extend to how debates are politically situated, in this case as an example of conservation efforts, which has a important impact on how we manage natural and cultural resources (Demeritt 2002, 786; Castree 2003, 205; Head and Regnell 2012, 221). Thus, these examples highlight how social constructivist critiques can serve the purpose of refuting common fallacies regarding the nature-culture dualism, in demonstrating that information presented as fact is ultimately socially constructed for another, often political, means (Demeritt 2002, 769–769). However, it has also been noted that refuting such dualistic fallacies within a directly social constructivist framework may not be the most efficient form of argument due to its deeper philosophical implications (Demeritt 2002, 789).

The other, perhaps more complex, application of social constructivism is as a much broader philosophical critique of science (Demeritt 2002, 767). In this context, social constructivist criticism has focused on the dualistic relationship between the natural and the social sciences (Castree 2001, 16); as highlighted above, historically science has given more weight to objective methods as a way of understanding the world (Vining et al. 2008, 1), and as such some authors have taken issue with the perceived privileging in modern academia, and society as a whole, of the natural sciences over the more subjective social sciences (Castree

2001, 16; Demeritt 2002, 77). Thus, the philosophical critique of science from a social constructivist perspective contends that all scientific knowledge is socially contingent; it follows that although scientific enquiry seeks to gain an objective understanding of the world, it is impossible to ever achieve one because you can never truly separate science from social factors, and therefore science exists as a widely accepted social construct that achieves partial knowledge rather than an objective truth (Proctor 1998, 352; Klein 2002, 6; Demeritt 2002, 774). An interesting example to explore this premise is cartography, as the history of science is very closely tied to that of cartography, in that it is founded on the principle of attaining an object and scientific understanding of the world around us (Edney 1996, 186; Turnbull 1996, 5; Kitchin and Dodge 2007, 33; Kitchin et al. 2013, 1). However, in practice cartography, specifically the production of maps, is often not such an objective endeavour as it may appear, as theoretically objective documents are in fact socially contingent: as marxist theorists have highlighted, historically the creation of maps is intrinsically linked with a desire to exercise power by the ruling elites of the time, often censoring or manipulating them, sometimes for the purpose of generating more income through tax revenue, (Harley 1989, 1, 1988, 59; Biggs 1999, 374; Neocleous 2003, 409; Gizicki-Neundlinger et al. 2017, 37), or indeed in modern context with the creation of artificially divided nation states such as Iraq, Pakistan and India (Krishna 1994, 509; O'Leary 2002, 17). Although, this social constructivist critique of science is founded in logical philosophical thought, it has been criticized for treading a fine line towards relativism, in that if there is no objective truth to be known about the world, the "truth" can be manipulated in any way possible, undermining the study of the biophysical world, in what is termed hyper-constructivism (Castree 2001, 16; Demeritt 2002, 774; Klein 2002, 3). Accordingly, Crist has highlighted the political and ecological implications of this, as if concerns over climate change could so easily be played off as a social construction, then there is no political impetus to make substantive changes (2004, 5). The caveat to this criticism is that regardless of its validity, it is unclear, and indeed very unlikely, that anyone espousing a social constructivist critique of science actually believes in such an ontologically pure position as hyper-constructivism, but is more likely being polemic in order to simply address the dualism, and hierarchy, between the natural and social sciences (Demeritt 2002, 774; Castree 2001, 16). Therefore, social constructivist critique of modern science highlights the need to give more weight to social, or indeed cultural ways of understanding the world rather than just looking towards an objective understanding, however this being the case it has been noted that professionals working in the natural sciences appear to continue in a similar fashion regardless (Demeritt 1996, 485; Slaymaker 2017, 65).

Therefore, the two facets of social constructionism attempt to deal with fallacies that have developed out of the nature-culture dualism, by refuting faulty claims that humans are separate from the environment, but equally at a deeper more philosophical level addressing the hierarchy between the natural and social sciences (Demeritt 2002, 774; Castree 2001, 16). Ultimately, as Stedman highlights, such debates are not intended to spur on anarchic pluralism, or indeed relativism, but seek to encourage a greater integration and respect between the natural and social sciences, in working together to advance our understanding of the natural world (2003, 671).

Archaeological Relevance

Just as social constructivist arguments have played out in archaeology's cognates, so too have the same ideas been critically discussed within archaeology (Johnson 2011, 48), exemplified by the debates between processual and post-processual movements (Renfrew and Bahn 2007, 44; Hodder and Shanks 2007, 1–3). Aligned to a certain extent with the notion of social construction as a means of philosophical critique, the post-processual movement challenged the hierarchy between the natural and social sciences, a tension that is magnified within archaeology due to the ways in which primary data are gathered, but moreover because of the natural pluralism within a discipline that focuses on past human behaviour (Shanks and Tilley 1989, 42–53; Johnson 2011, 47; Barrett 2013, 1). Furthermore, these theoretical debates, particularly critiques of dehumanising/ deterministic narratives, which are still apparent in modern publications (Livingstone 2012, 564), remind us not to neglect cultural/ socio-economic interpretations of the past (Gaffney and Van Leusen 1995, 367; Miras et al. 2010, 933; Robbins Schug et al. 2019, 9).

Much in the same way that the earlier discussion in this chapter focused on the history of the nature-culture dualism to contextualise notions of social construction, so too must the debates within archaeology be placed in their correct historical context (Smith 2009, 362). The turn towards archaeologist's actively seeking to align themselves with the purported objectivity of scientific methodologies is often associated with the development of the "new archaeology", or indeed "processual archaeology", which was broadly speaking was an intellectual movement, emanating in the 1960s and 1970s, that sought to move away away from traditional culture-historical explanations of archaeological record (Trigger 1998, 694). In an American context, one of the key figures in this development was Lewis Binford, who argued the case that archaeology should more closely align its aims and objectives with that of anthropology, in trying to understand cultural differences (Binford 1962, 217, 1980, 4–5). Meanwhile, within a British context one of the key proponents of the "new archaeology" was the late David Clarke, who in his arguably seminal article on the subject (Malone and Stoddart 1998, 677), called for archaeology to embrace the new range of methodologies now at their fingertips rather than remain entrenched in traditional schools of thought (Clarke 1973, 6–7). Indeed, the criticism that followed this growth of objective methodologies, and indeed the functional/mechanistic interpretations coming to the fore that sought develop covering laws, was the self-styled "post-processual" movement, which shares some of the same aspects of critical thought that have already been touched upon with regards to social construction as a means of philosophical critique (Johnson 2011, 47). As such, the very same philosophical/sociological ideas regarding the fallacy of objectivity in the natural sciences was applied to an archaeological context (eg (Shanks et al. 1987)), where authors turned their attention to archaeology as a form of knowledge creation, honing in on the fact that the archaeological record is contingent upon an archaeologist recovering it, and that our understanding of what is found is intrinsically linked to the biases and knowledge of the individuals responsible for its recovery and interpretation (Hodder 1991, 7; Shanks and Tilley 1989, 44; Hodder and Shanks 2007, 3). Indeed, this critique also extended to functional/deterministic interpretations of past (Hulme 2011, 245), which were highlighted as overly simplistic and dehumanising ((Fleming 2006, 268; Barrett and Ko 2009, 276). Echoing the discussion pertaining to social constructionism, so too was post-processual archaeology accused of wanting to encourage hopeless relativism, while being fundamentally anti-science in their arguments (Shanks and Tilley 1989, 44). A parallel can be drawn here between similar discussions in archaeology's cognates, that post-processual archaeology was never an ontologically pure endeavour, in terms of being hyper-constructivist, but sought to challenge what was in their opinion the dogmatic and stagnant nature of archaeological discourse that focused too heavily on finding an objective truth, when in reality the archaeological record does not simply mean data, but is a relic of people, and as the very nature of the human experience is subjective, we should be open to giving more credence to subjective, or moreover social, explanations of the past (Tilley 1998, 692; Hodder and Shanks 2007, 3). Indeed, proponents of this critique argue that these debates seek to democratise archaeological knowledge (Shanks and Tilley 1989, 52–63).

However, despite the similarities between the post-processual movement and social constructivism, there are examples where these two thematically linked debates diverge, an example of this being phenomenology (Tilley 1994, 1). Indeed, the search for objectivity in processual thought often lent towards the pursuit of generalising covering-laws of the past, closely aligned with structuralism, a trend that was criticized (as aforementioned) as dehumanizing the archaeological record (Fleming 2006, 268; Barrett and Ko 2009, 276). In turn phenomenology has been applied to archaeological interpretations of the past, focusing on how people experienced landscape (Tilley 1994, 1; Cummings et al. 2002, 57). This has been most prevalent in the study of prehistoric monuments, where practitioners walk through an assumed prehistoric landscape, engaging with the topography, using their personal experience as a means of gaining an insight into how an area was experienced by the past people in question (Brück 2005, 48). As such, the application of phenomenology in archaeology has been termed as hyper-interpretive, as it seeks to construct a narrative that not so much supported by archaeological evidence, but more so by the subjective interpretation of the archaeologist (Fleming 2006, 267). It has been noted that this methodology brings us no closer to achieving an archaeology that explicitly populates our interpretations, as it remains entirely undermined by cultural relativism (Fleming 2006, 279). Therefore, within an archaeological context, the hyper-interpretive approach of phenomenology appears to bare similarities with the notion of hyper-constructivism within discussions outside of an archaeological context (Demeritt 2002, 774; Castree 2001, 16), and although it is unclear if the authors of this work really believe in its methodological validity, it is certainly an example of its application.

Therefore the theoretical discussions regarding how we study the archaeological record, and indeed the world in general, have been punctuated by a desire to achieve an objective knowledge of the past, and forced to face philosophical critiques of scientific knowledge, that illuminate the need to integrate the natural and social sciences rather than reinforcing an embedded hierarchy (McGlade 1995, 113; Demeritt 2002, 774; Castree 2001, 16).

Bridging the Divide

With this theoretical discourse in mind, it is necessary to discuss how researchers have attempted to move beyond the "two cultures", in the practical integration of of both the natural and social sciences (Stedman 2003, 671).

Although a range of approaches have been put forward as a way of integrating cultural and natural data, for example historical ecology/human-ecodynamics/coupled socio-natural systems/socio-ecology, the least prescriptive way defining them is to consider them as cluster of ideas that share the same values towards the study of human-environment interactions (Szabó 2015, 997; Crumley 2016, 1–4; Fitzhugh et al. 2018, 1). Linking back to the start of this section, despite the fact that all of these approaches grew out of varying disciplinary traditions, they share the view that human and natural systems are intrinsically linked (Folke et al. 2002, 447; Fitzhugh et al. 2018, 1). In practical terms, this means recognising dialectical relationship between humans and the environment (Balée 1998, 13, 2006, 75), endeavouring to take an inclusive approach that crosses disciplinary boundaries (Armstrong et al. 2017, 2), in aiming towards place based multidisciplinary/interdisciplinary research (Meyer and Crumley 2011, 109). One of the goals outlined for research of this nature is to create long term landscape scale narratives, that are validated by both natural and cultural data, which because of the diversity of the evidence employed serve as a means of testing the strength of our interpretations, helping to generate new hypotheses (Meyer and Crumley 2011, 110; Crumley 2016, 1–4; Isendahl 2016, 127).

Theoretically Informed Interpretations

Thinking about the practical significance of this theoretical review, it is useful to lastly consider the how this discussion will enable theoretically informed interpretations to be made in this dissertation.

Accordingly, the natural pluralism in archaeology has a significant impact on how we interpret the past, particularly in the study of human-environment interactions (Shanks and Tilley 1989, 42–53; Johnson 2011, 47; Barrett 2013, 1), which at times treads a fine line between functional/ deterministic narratives (Barnes et al. 2013, 542; Robbins Schug et al. 2019, 9), and culturally biased hyper-interpretive research (Tilley 1994, 1). With this in mind it is useful to return briefly to these ideas, specifically to the deterministic narratives that the post-processual archaeology rightfully critiqued (Fleming 2006, 268; Barrett and Ko 2009, 276), remembering the fundamental fact that correlation is not causation (Robbins Schug et al. 2019, 9), and that as humans we do not always act in a rational economic fashion but are instead subject to socio-economic and cultural norms (Walsh et al. 2006, 541; Miras et al. 2010, 933).

As aforementioned, the growth of the processual archaeology was met with a growing trend for scholars to emulate the natural sciences in looking for general covering laws applicable to archaeological observations (Fleming 2006, 268; Barrett and Ko 2009, 276), in some cases this lead to the idea of environmental determinism (McGregor 2004, 337; Hulme 2011, 245). The principle behind these interpretations was that human behaviour can be explained by the variations of an external force, namely changing climatic conditions (Gaffney and Van Leusen 1995, 367; Hulme 2011, 245; Robbins Schug et al. 2019, 9). Such was the popularity of this idea that numerous publications have proposed that the growth, and decline, of entire civilisations was mostly determined by how favourable the climatic conditions of the time were (Coombes and Barber 2005, 303). A classic example of this is the notion that the decline of the Roman Empire was caused by a climatic deterioration (Büntgen et al. 2016, 578). Indeed, as already touched upon in this review, interpretations of this manner have been highlighted as dehumanising the archaeological record (Fleming 2006, 268; Barrett and Ko 2009, 276). Considering this notion in a little more depth, it has been commented that it is perfectly valid to highlight correlations between environmental change and the archaeological record, however the presentation of these interpretations as fact should a be cautioned against, because correlations do not equal causation (Collins,Davis and Kaplan 2012, 1848; Robbins Schug et al. 2019, 9). Moreover, without a detailed understanding of the multitude of socio-economic and cultural factors that impact human behaviour, and a recognition that humans do not always respond to environmental stimuli in a rational economic way, we risk generating narratives that are overly simplistic and reductionist in the ways in which we conceptualise the complexity of human behaviour (Gaffney and Van Leusen 1995, 374; Walsh et al. 2006, 541; Miras et al. 2010, 933).

Two Cultures Conclusion

To conclude, the study of human-environment interactions is an inherently complex endeavour, as undercurrents of theoretical division have proven, and although this division is steeped in history, and crosses disciplinary boundaries, it has prompted a greater emphasis on interdisciplinary cooperation (Liu et al. 2007, 901; Walsh 2013, 1–5; Verburg et al. 2016/7, 328; Crumley 2016, 1–4). In the introduction to this chapter it was stated that the approach taken is socio-ecological, considering the focus on human-environment interactions with more clarity, and subsequently defining humans as an integral part of the earth system (Evans and O’Connor 1999, 1; Walsh 2013, 1–5; Verburg et al. 2016/7, 328). However, contextualising modern debates surrounding the inequity between the natural and social science with their historical context, it was highlighted that this has not always been the prevailing paradigm, an issue of particular importance to archaeology and its cognates that work with both cultural and natural data (Fitzhugh et al. 2018, 1). Therefore, translating this into a practical guide towards best practice when it comes to the interpretation of the formal modelling of human behaviour/activities in the French Alps, it is of critical importance that a balance is struck in the integration of archaeological and palaeoecological data, not least to avoid deterministic interpretations (Rae 2014, 56; Barrett 2013, 1).

Scale

If we are to be successful in integrating archaeological and palaeoecological data, learning from historical and theoretical debates alike, it is also of paramount importance that scale is considered (Walsh 1999, 5; Banks 2017, 272). As such, how successfully we engage with the scales of our data, and methodologies, defines our ability to ask appropriate and impactful questions (Walsh et al. 2017, 2).

Indeed, as already highlighted in the preceding discussion of the “two cultures”, the study of human-environment interactions is often an interdisciplinary endeavor (Schimel et al. 2015, 99; Chin et al. 2016, 1; Luterbacher et al. 2016, 2; Walsh et al. 2017, 2), accordingly there are an exciting array of different methodologies at our disposal to investigate them (e.g.(Torrence,Martinón-Torres and Rehren 2015/4, 1; Edwards et al. 2015, 117; Shahack-Gross 2017/3, 36) (please see Kintigh et al (2014) and Biondi (2014) for a review of some of these questions). However, just as we need to exercise care in integrating cultural and natural data, we also need to be mindful of the spatial and temporal scales they operate at to avoid mis-matching the resolution of the data and that of our interpretation (Armit et al. 2014, 17045). Thus, it is useful to next consider in more detail why a critical engagement with scale is necessary, reviewing why a consideration of mobility can help us achieve a human-scale interpretations, and finally the complementary nature of a multiscalar approach.

Mis-Matching: The Human Experience in Low Resolution

Linking back to the post-processual critique of the dehumanising of the archaeological record, vis-à-vis the creation of covering-law type explanations of the past (Fleming 2006, 268; Barrett and Ko 2009, 276; Chilton 2014, 36), so too has it been warned that if the scales of our interpretations are not carefully considered, there runs a risk of making generalised statements that do not sufficiently account for small scale human-environment interactions (Cumming,Cumming and Redman 2006, 1; Walsh et al. 2006, 446; Walsh 2008, 548; Armit et al. 2014, 17045; Walsh et al. 2017, 1–3; Banks 2017, 272; Veeramah 2018, 83). Critical thought of this nature is unsurprising considering multiplicity of the datasets used by archaeologists (Redman 2005, 70; Liu et al. 2007, 901; Verburg et al. 2016/7, 328), but also the fact that there is an interest both in producing long and short terms histories (Kristiansen 2014, 24). From the perspective of spatially extensive, long-term narratives, there is increasing optimism regarding the use of "big-data" driven approaches (Bevan 2015, 1473), utilizing of more powerful computational methods in helping us address large scale cultural questions such as migration, or population density (Kristiansen 2014, 14). A recent example of a big data driven project being Green et al, who consider population densities across England (2017). However, in a sense the criticism addressed towards such an approach can be thought of as another iteration of the post-processual critique, commenting on its dehumanisation of the archaeological record (Chilton 2014, 36), where large scale processes take primacy over our understanding of the lived human experience, highlighting the dichotomy between integrating global and local scale understandings of the past (Huvila 2014, 48). One of the root causes of this dichotomy is that methods from the natural sciences that are used to assess palaeoecological data very rarely operate at a human-scale (Walsh

1999, 5; Rohling 2016/9, 17; Contreras et al. 2018a, 54). Often such methods deal with regional variations in the environment, take pollen diagrams as an example: if the pollen taxa under investigation originated in a large lake, it is very likely the lake has a large catchment area, and is therefore more suitable for understanding regional vegetation trends, rather than local landscape scale changes that would be pertinent human-scale decision making (Walsh 1999, 5). However, it must also be noted that reaching a human-scale understanding is also hindered somewhat by the nature of the archaeological record, as although archaeological data can inform us about landscape scale human-decision making, it is a temporally patchy resource, in that an observed event (particularly in prehistory) may fall within a dateable range of a couple of hundred years (Contreras et al. 2018a, 55). An excellent example of this dichotomy is discussed by Armit et al, who highlight the continued publication of environmentally deterministic narratives, specifically towards human responses to rapid climate change (2014, 17045). The authors demonstrate that without high-resolution palaeoenvironmental and archaeological data, it is not possible to illustrate any form of reliable correlation (Armit et al. 2014, 17045). Therefore, as already highlighted, there is a very real challenge in reconciling human-scale decision making against regional palaeoenvironmental proxy data, and without an appropriate temporal resolution, we risk missing the human element of our interpretations (Gronenborn,Strien and Lemmen 2017, 54). However, advances in the application of stable isotope analysis, and equally within the field of aDNA are making significant headway in creating high resolution narratives of human activities/ behaviour (Hofman et al. 2015, 540; Veeramah 2018, 83), as discussed in more detail below. Moreover, there are local scale paleoenvironmental proxies, including the analysis of *Coleoptera* taxa, which are very sensitive to environmental conditions (e.g. (Kenward 1975a, 1975b; Carrott and Kenward 2001), or the use of anthracology/

pedoanthracology (e.g(Py et al. 2014; Allué et al. 2018; Novák et al. 2018), however both of these approaches are dependant on taphonomy, and indeed availability. Therefore, there is often a disparity between the resolution of paleoenvironmental proxies we use, and that of the archaeological record (Contreras et al. 2018a, 55). With this comes the danger of mis-matching these scales, smoothing over the complexities of local-environmental knowledge, and indeed the spatially/culturally contingent nature human behaviour/ activities (Walsh et al. 2017, 1–3). There is no one single solution to this issue other than a critical engagement/ alignment between our own research objectives, and the suitability of datasets we have at hand (Walsh et al. 2017, 1–3).

Mobility

Additionally, while it is important to be aware of the dangers of mis-matching the scales of our data, if we do not consider mobility in the past we risk further simplifying human-scale behaviour/ activities (Leary 2014, 4; Aldred 2017, 90). Mobility in this context refers to movement: be that the daily rhythms of human life, the seasonal movement of animals and people, or long distance travel for a cultural or economic purposes (Leary 2014, 3). The human experience is multiscalar, whereas the scales we divide the world into are a matter of convenience/ purpose (Evans and O'Connor 1999, 10), and it is our ability to look past this is an essential part of our understanding behaviour/ activities at a human-scale. (Leary and Kador 2016, 2).

The study of mobility in the past has recently seen a renewed surge of interest, challenging long held assumptions regarding mobile and sedentary lifeways, with particular reference to the neolithic transition (van Dommelen 2014, 478; Preston and Kador 2018, 321). However, it has been commented that one of the strengths of landscape scale analysis, that it is place based way of understanding landscape dynamics (Muir 1981, 15; Aston 1997, 9; Walsh 1999, 5; Meyer and Crumley 2011, 110), is also one of its limitations, as the humans we aim to study are not bound by the same spatial restrictions as our research (Banks 2017, 272). Arguably, this is accentuated by the static nature of the archaeological record, which relies on our interpretations going past a simple empirical record of the material recovered, but contextualising it with human practices (Leary 2014, 4). Accordingly, the human practices that we are able to interpret within a given area may well take place at a much larger spatial scale than we are able to view them at, take for example transhumant activities that operate on both a seasonal round but also in daily cycles (Cleary and Smith 1990; Jones 2005; Carrer 2013). As such if we do not fully engage with the human activities we are studying beyond a place based narrative, extending to a wider regional context, then we risk conflating human-scale interpretations with a local landscape scale (Leary and Kador 2016, 2).

A Multiscalar Approach

Therefore, it is significantly important we are attuned to the scales of of our data, but also to the human practices we aim to study, highlighting the importance of the need to reconcile these varying scales (Lucas 2015, 18; Johnson 2015, 62; Contreras et al. 2018a, 54). At a conceptual level, this means adopting a multiscalar approach to our research (Butzer 2008, 403; Tringham 2018, 6), while methodological advancements within archaeological science are increasingly developing multiscalar perspectives (Hofman et al. 2015, 540; Veeramah 2018, 83).

Harris has highlighted that amongst our varying discussions of scale, we should not lose sight of the fact that they are all interwoven, and that by adopting a multiscalar approach we are better equipped to navigate the integration of small and large scale data types (2017, 1–13). From this perspective, the multiplicity of the data at our disposal is a great strength, as only through a multiscalar dataset can we begin to assess a multiscalar world (Smith et al. 2012, 7617). This way of addressing archaeological questions has been very clearly discussed within geoarchaeology, where there has long been a tradition of taking a multiscalar approach (Edwards et al. 2017, 1). Karl Butzer termed this approach scale-switching (2008, 403): in practice this translates to using multiple methodologies that operate at varying scales, looking for any cross-correlation between them, enhancing our interpretive capability for understanding human-environment dynamics (Edwards et al. 2017, 1). Indeed, in her recently published paper on the future directions of archaeology, Tringham emphasised the importance of attempting to make these cross-correlations between different methodologies, and across multiple scales, highlighting that through this type of comparison we may find results that surprise us in their contradictory nature, warding off homogeny and creating a more complex picture of the world (2018, 1–6).

Furthermore, beyond the calls for more multiscalar perspectives, methodological developments in archaeological science are rapidly generating new ways of assessing archaeological material (Hofman et al. 2015, 540; Veeramah 2018, 83). For example, there has long been a growing strength in our ability to apply advanced spatial statistics within geographical information systems (GIS), in better understanding settlement patterns (Bevan and Conolly 2006, 1; Bevan and Lake 2016, 27; Palmisano et al. 2017, 59). Advancements in the study of aDNA (Hofman et al. 2015, 540) and stable isotopes (Henton et al. 2018, 1), are allowing us to understand mobility both on a population scale (e.g.(Allentoft et al. 2015), but so in terms of assessing the movements of individuals across space and time (e.g.(Sjögren et al. 2016). Specifically concerning human-environment interactions, the analysis of lake sediment DNA offers a particularly high-resolution looks at dynamical relationship between the natural and the cultural (Giguet-Covex et al. 2014, 1). While developments in the analysis of organic residues and dental calculus are reconstructing past human diets at both a regional and site based scale (Roffet-Salque et al. 2017, 1; Hendy et al. 2018, 1). Therefore, our ability to find correlations between different sources of data is expanding, and our ability to gain a multiscalar perspective is being steadily advanced by the development of scientific methods.

Conclusion

Therefore, the data that we use in the analysis of human-environment interactions operates at a wide range of scales, influenced by the methodological approach we take, and also by the nature of the human activities we aim to study (Contreras et al. 2018a, 55). One of the ways in which we can mitigate this issue by adpting a multiscalar approach to our investigations, engaging with different data sets appropriately, while maintaining the interrelated complexity of the world (Butzer 2008, 403; Tringham 2018, 6).

Section One Conclusion

To conclude section one of this literature review, it has been highlighted that the ways in which we integrate biophysical and cultural data is of great importance in the study of human-environment interactions, and can accordingly inform the methodological approach we take. Both the theoretical discussions relating to the traditional hierarchy between the natural and social sciences (Stedman 2003, 671), and also the challenges we have to face regarding the scales of our data (Contreras et al. 2018a, 55), demonstrate the inherent complexity in the study of human-environment interactions (Meyer and Crumley 2011, 110). The point of central importance that is interwoven in these discussions is the need to remain critical of overly simplistic interpretations of human behaviour/activities, while finding appropriate ways of integrating multiscalar data (Walsh et al. 2017, 1–3).

Section Two: Modelling

Introduction

Therefore, the study of human-environment interactions is fraught with complexity, and maintaining an engagement with this body of critical thought is significant in making informed interpretations of the formal modelling approach taken in this dissertation. Accordingly, it is next important that we review modelling and address objective two: reviewing modelling both more widely as an approach, the extent to which models elucidate our understanding of human-environment interactions, and giving a detailed account of the formal models employed hereafter to ensure methodological robustness.

This section can be broken into three constituent parts: modelling as a concept, its application to archaeological discussions of human-environment interactions considering its associated theory, and a review of the methods used in this dissertation: summed probability distributions (SPD) of radiocarbon dates (Crema et al. 2017, 1), pseudobiomization (PBM) (Fyfe et al. 2015, 1197), and aoristic analysis of site counts (ASC) (Orton et al. 2017, 1; Palmisano et al. 2017, 59).

The Concept

What is modelling? Indeed, it is with this most basic question that this section opens its discussion. Although this may seem from the outset to be relatively simple question, to reach an objective and comprehensive definition of modelling is an elusive goal, not least because of the semantic variety attached to the term (Moulines 2002, 1). For example, more philosophically minded readers may think of Tarski and pure model theory (Vaught 1986, 869; Keisler and Chang 1990, 142), whereas a linguists and computer scientists alike might think of formal semantics (Moulines 2002, 1). To this end, in the edited edition "Models in Archaeology", Clarke claimed that any definition of modelling would be either be "pointlessly narrow" or conversely "hopelessly broad" (1972, 2). However, at risk of falling into the latter category there is a general consensus from within the literature as to how we can broadly define modelling:

"At a basic level of agreement, a model is a simplification of something more complex to enable understanding" (Lock 2003, 6)

"Models are often partial representations, which simplify the complex observations by the selective elimination of detail incidental to the purposes of the model." (Clarke 1972, 2)

"...a model is some sort of simplified representation of a real system" (Grimm and Railsback 2005, 22)

"By a model we mean a representation of a group of objects or ideas in some form other than that of the entity itself." (Shannon 1998, 7)

"It is an imaginary system, represented in language, mathematics, computer code, or some other symbolic medium, that has useful similarities to aspects of a target system in the real world." (Kohler and van der Leeuw 2007, 3)

These definitions are undoubtedly very broad in their scope, nevertheless they serve to highlight the underlying concept of modelling: the attempt to somehow simplify and represent something from the real world, with the intention of elucidating our understanding of what is being modelled (Clarke 1972, 2; Shannon 1998, 7; Lock 2003, 6; Grimm and Railsback 2005, 22; Kohler and van der Leeuw 2007, 3). Thus, it is from this conceptual standpoint that modelling will henceforth be considered in this dissertation.

From Abstraction to Problem Solving

However, this broad definition stands as a somewhat abstract statement, and it is useful to draw upon how Kohler and van der Leeuw (2007) and Grimm and Railsback (2007) contextualise modelling with the way in which humans perceive the world, illustrating it as a problem solving approach (Grimm and Railsback 2005, 22; Kohler and van der Leeuw 2007, 2). Indeed, Kohler and van der Leeuw (2007) draw on the work of cognitive psychology where it has been argued (although it is not a settled debate, see (Markman and Dietrich 2000, 470) and (Reed 2012)) that the human mind is constantly constructing mental representations of the world around us in order to make sense of the vast amount of information we process on a daily basis, in essence creating simplified mental models

(Markman and Dietrich 2000/3, 138; Markman 2013, 27; Kohler and van der Leeuw 2007, 6; Spackman and Yanchar 2014, 48). Furthermore, Grimm and Railsback (2007) offer a similar but more specific analogy to modeling, illustrating how models are used as, an albeit simple, problem solving device in everyday life when "choosing a checkout queue" (Grimm and Railsback 2005, 22). In this instance modelling is applied to the everyday problem of minimising the time spent waiting to pay in a shop, accordingly we regularly pick the shortest queue after the application a of simple metal model, that the length of the queue is a strong indication of the amount of time spent waiting (Grimm and Railsback 2005, 22). It likely that this model has any number of often subconscious simplifying assumptions, a likelihood that is applicable to all modelling endeavours, for instance: that the staff are all equally efficient, or that all the customers require the same amount of time (Grimm and Railsback 2005, 22). Therefore, moving beyond the abstraction of the broad definition above, these examples highlight that modelling is the purposeful simplification of the real world, be that expanding our knowledge or solving everyday problems (Clarke 1972, 2; Shannon 1998, 7; Lock 2003, 6; Grimm and Railsback 2005, 22; Kohler and van der Leeuw 2007, 3).

Archaeological Modelling

With this basic conceptual outline of modelling established, we next need to consider how this applies to an archaeological context. Moreover, it is important that there is clarity on what is meant by the term formal modelling as employed in this dissertation, addressing how it has contributed to our understanding of human-environment interactions, and how this can be drawn together to assess the modelling of the French Alps. Accordingly, the following discussion has been divided into two parts: 1) seeking to define what formal modelling is, considering the complex variety of approaches this term encompasses, and important aspects of theoretical thought, 2) discussing the application of formal models to the study of human-environment interactions through by considering a number of approaches.

Formal Models

The term formal modelling in its broadest sense refers to the application of mathematical, statistical, or indeed other symbolic mediums such as coding, in the attempt to represent an aspect of the world (Lock 2003, 148; Kohler and van der Leeuw 2007, 6). However, returning to the important point made by Clarke, we must take great care in brandishing definitions of modelling or else risk imposing erroneous rigidity to our thinking, labeling such attempts as “hopelessly broad”, or moreover “pointlessly narrow”(1972, 2). Therefore, maintaining the point made above, that modelling in its *broadest* form is the simplified representation of the real world in order to elucidate our understanding of it, the term formal modelling can be considered as a means of differentiating between more ethereal conceptual models, moving beyond abstraction through the application of mathematical or symbolic methodologies (Kohler and van der Leeuw 2007, 6). This point is best illustrated by placing formal modelling within its contextual/historical setting.

Indeed, the use of formal models in archaeology can be closely associated with the notions put forward by the “new archaeology”, and the growing application of scientific approaches towards archaeological questions (Doran 1970, 291; Malone and Stoddart 1998, 677; Clarke 2014, 13; Lycett and Shennan 2018, 216). As discussed in section one, the impetus behind the new archaeology was an attempt to move away from culture-historical descriptions of the archaeological record, that relied too heavily on intuition alone (Doran 1970, 294), and move towards a more scientific approach (Johnson 2011, 15–20). One of the central tenants of this was that we should aim towards interrogating temporal, and indeed spatial, patterns in our data through the use of quantitative methods (Clarke 2014, 13; Lycett and Shennan 2018, 216). It is not to be forgotten however that closely interwoven to these ideas was systems theory, and the related discipline of cybernetics (Doran 1970, 294), which as mentioned above fostered a desire to seek generalising covering laws of the past (Leeuw 2004, 2; Clarke 2014, 16), and has routinely been criticised as a dehumanising approach (Fleming 2006, 268; Barrett and Ko 2009, 276). Nevertheless, it is out of this methodological diversification that the more widespread use of formal models came to pass, in an increased bid to apply mathematical/statistical approaches to archaeological questions (Doran 1970, 294; Lock 2003, 148; Kohler and van der Leeuw 2007, 6). This development was, and is, closely linked to the increased use of computers, of which archaeology has been noted as an early adopter (e.g.(Cowgill 1967)), allowing archaeologists to integrate a level of complexity into their research not thought possible before their introduction (Doran 1970, 289; Clarke 2014, 13; Perry et al. 2016, 2). Furthermore, in lieu of the accessibility of relatively user friendly software, it has been made significantly easier to for archaeologists to apply complex formal models to their work (Crema 2018, 20). Thus, from this context we can to draw together how formal models fit into an archaeological framework, and elucidate their differentiation. Returning to the discussion above regarding cognitive psychology, specifically the notion that the human mind is always constructing mental models of the world (Markman and Dietrich 2000/3, 138; Markman 2013, 27; Kohler and van der Leeuw 2007, 6; Spackman and Yanchar 2014, 48), so to is this perspective is useful in contextualising formal modelling (Kohler and van der Leeuw 2007, 2–3). It follows that traditional means of generating archaeological knowledge are reliant upon the creation of abstract mental models; our interpretations are based on observations from an inherently static and incomplete data set, thus in order to propose theories that explain these data we implicitly create abstract mental representations of the past as a heuristic device (Leeuw 2004, 118–122). Therefore, from this standpoint all archaeological interpretations are models to a certain extent, and the differentiation of formal models represent another tool for representing/explaining the past, albeit in a more quantitative manner (Kohler and van der Leeuw 2007, 6).

However, once again demonstrating Clarke's foresight in cautioning against defining modelling (1972, 2), the wide and complex range of formal models now at our disposals (Crema 2018, 20) means there is an opaque boundary between explanatory models and graphical/representational models (Lock 2003, 158). In this context it must be stressed that formal modelling refers only to those models that aim to be explanatory (Clarke 1972, 2; Shannon 1998, 7; Lock 2003, 6; Grimm and Railsback 2005, 22; Kohler and van der Leeuw 2007, 3). Thinking about this in more theoretical detail, it has been noted that if our models are not explanatory then there is a risk of circular reasoning (Perry et al. 2016, 3). Circular reasoning in this instance relates to the feedback loop that exists between our understanding and a model (see figure five); if the loop remains open then a model is doing nothing more than simply representing data within a computational environment, or *in silico*, which then holds the risk of merely obtaining a circular interpretation, or rather the interpretation that was held at the start of the exercise (Premo 2006, 29; Perry et al. 2016, 3). Whereas, a successful formal model explores something of interest through its representation, that then feeds back into our understanding, thus closing the feedback loop (Perry et al. 2016, 3). An example of this is application of approximate Bayesian computation (ABC), that allows users to conduct complex probabilistic analysis (Buck and Meson 2015, 567; Lintusaari et al. 2017, 66; Crema 2018, 22).

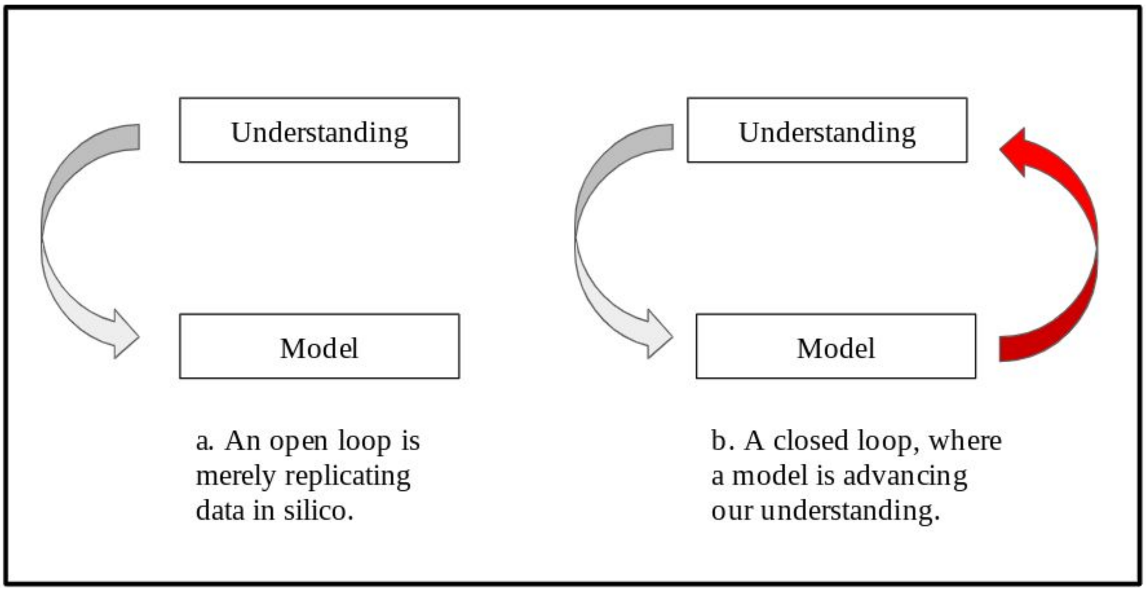


Figure Four - Diagram of the inferential feedback loop between a model and our understanding.

Therefore, with this point clarified we can easily define the difference between formal modelling and graphical/representational models (Lock 2003, 152) such as virtual reality (Jiménez Fernández-Palacios et al. 2017, 40). Indeed, for the most part these graphical/representational models are constructed using some form of computational application, and as such share this similarity with formal modelling, for example in the 3D modelling of ancient monuments (Jiménez Fernández-Palacios et al. 2017, 40), or indeed the widespread use of CAD applications (Scollar et al. 1999, 5). However, they cannot be categorized as formal modelling as their aim is not necessarily to be explanatory (Lock 2003, 152). This being so, an interesting case where the lines can be somewhat blurred between a representational model and a formal model is in the use of geographical information systems (GIS), in that they have the ability to used as a data management tool, producing simple distribution maps, but also apply complex spatial statistics (Conolly and Lake 2006, 3–7; Bevan and Conolly 2006, 217). Indeed for a review of these applications please see (Howey and Brouwer Burg 2017, 1). Therefore, as touched upon in the opening discussion of this section, the term modelling by itself carries certain amount of semantic variety (Moulines 2002, 1), encompassing a wide variety of approaches towards representing the past, however in this context formal modelling applies only to those approaches that aim to be explanatory (Clarke 1972, 2; Shannon 1998, 7; Lock 2003, 6; Grimm and Railsback 2005, 22; Kohler and van der Leeuw 2007, 3).

Furthermore, it is important that we are also aware of simulations as a widespread class of formal modelling (Lake 2015, 4). Simulations are very straightforward premise; they aim to mimic a cultural/environmental process, and thus generate a hypothetical model of what is being targeted (Kohler et al. 2005, 77). In this way, simulations often aim to create models that are analogous to an aspect of the real world within a computational environment (McGlade 2014, 1; Perry et al. 2016, 1), including the passage of time, which in this context is referred to as dynamical, running through a designated number of cycles (Lake 2015, 7). As highlighted by Lake, there is a long history of applying simulations to archaeological questions (Lake 2013, 258). It is useful to think about the varying aims of simulation studies in explaining their utility, which can be broken into the following three categories: 1) theory-building, these tend to aim towards exploring an aspect of human behaviour, generally testing a long held assumption about the decisions of past people, 2) method-development, this approach generally aims to generate an artificial dataset in order to assess the efficacy of a technique, 3) hypothesis-testing, these are built to mimic a historical/geographical context that can then be compared against real data (Crema 2018, 20). One of the most popular iterations of simulation modelling is agent based modelling (ABM), or as it is known more commonly in ecology, individual based modelling (Grimm and Railsback 2005, 1; Macal 2016, 144). ABMs are often constructed at a human-scale focusing on modelling decision making, therefore each individual “agent” equates to a human, and the variation in their decision making can be tested against changing cultural or environmental conditions built into the simulation, making them a form of experimentation (Madella et al. 2014, 2; Lake 2015, 11). Indeed, within these simulations feedback is often an important factor, in that the agents can respond to changes within the model (Whitley 2017), or equally be tested against a null model (Perry et al. 2016, 1). Therefore, ABMs aims to model past human behaviour (Doran 1970, 297), allowing us to test our theories and create a degree of conceptual unity (Lake 2015, 8). Accordingly, it is important to be aware of simulation studies as a branch of formal modelling, and that raison d'etre is to be somehow analogous to the real world, allowing us to experiment and test our current interpretations, and generate new theories (Lake 2015, 4).

Amongst discussing the framework of formal modelling, and some of its approaches, it is also useful to introduce the notion of equifinality (Crema 2018, 21). Equifinality describes the fact that it is possible for there to be many different ways of arriving at the same result, in essence causation (Graham and Weingart 2015, 248). This issue is particularly important when focus of a study is historical, no more so than within an archaeological context, where there are any number of possible processes that could have caused the formation of archaeological record as we study it today (Crema 2018, 21). Indeed, the same question has been considered within the context of hydrology (Beven 1996, 289, 2006, 1), taphonomic studies (Lyman 2004, 15), and indeed cultural systems (Barrett 2018, 1). Accordingly, it is widely understood that there is an inherent confirmation bias in the way we treat problems, which in the context of formal modelling, particularly hypothesis-testing simulations, where all of the parameters of a model are input by the researcher, there is a danger that if we are not attempting to falsify a hypothesis, then we may confirm our pre-existing theory and neglect the equifinality of processes we aim to study (Crema 2018, 21). Indeed, one of the ways in which this issue can be bridged is through the application of inferential statistics that allow us to test a multitude of possible outcomes, or their likelihood (Crema et al. 2016, 1; Crema 2018, 21). Thus, equifinality is a unavoidable limitation to the way we study the past, even more so in a formal modelling environment, and our awareness of it can help to limit the extent to which we simply aim to verify a pre-existing hypothesis, and seek rather to test it.

Finally, it is important to also recognise that formals models are not a are not a panacea, but are a tool, and are subject to similar criticism as discussed in section one (McGlade 1981, 1; Brouwer Burg 2017, 115). Accordingly, they are subject to the same critical points such as the integration of the biophysical and social domains, the impact of the scale of our data, and accounting for different human activities that involve varying degrees of mobility (Meyer and Crumley 2011, 110; Brouwer Burg 2017, 115; Contreras et al. 2018a, 55). As such, the use of models has often been prefaced by the phrase, “garbage in, garbage out” (McGlade 1981, 1; Schmidt 2004, 1; Conolly and Lake 2006, 11). Thus, as models are subject to what a practitioner chooses to include, we must remember to treat it like any other approach, with a critical eye towards the data set and indeed the methodological robustness (Pettitt and Zilhão 2015, 1–5).

Formal Modelling and Human-Environment Interactions

Therefore, with an outline of what formal modelling is, it is next necessary to discuss how it has been applied to the study of human-environment interactions, and thus answer objective two, assessing the subsequent contribution to our understanding. To achieve this three different approaches towards modelling human-environment interactions will be considered: 1) palaeoecological approaches, and how these are used to infer human activities, 2) the application of ABMs, considering the benefits and limitations of attempting to model socio-cultural processes, 3) a review of the recently published paper by Contreras et al (2018b), which allows us to examine limitations of simplifying human activities within a modelling environment. Indeed, this review is by no means intended to be comprehensive in terms of the number of methodologies considered, but rather illuminate a number of key approaches, from which more general trends can be inferred.

The first approach to be considered are those models that aim to study human-environment interactions from the perspective of palaeoecology (Edwards et al. 2015, 118). Invariably, the use of palaeoecological data to study human-environment interactions is inexorably linked to the application of palynology to archaeological questions (Edwards et al. 2015, 117; Richer and Gearey 2017, 2). In a somewhat traditional sense, these approaches have for the most part aimed to make inferences through the reconstruction of palaeoenvironments, using taxa that are associated with human activity as an indirect indicator for the activity itself, such as ruderal species indicative of agricultural/pastoral practices (Edwards et al. 2015, 117; Richer and Gearey 2017, 2). From this perspective, modelling has been viewed by many as a means of taking this a step further, enabling the quantitative reconstruction of of vegetation coverage (Caseldine,Fyfe and Hjelle 2008, 543; Edwards et al. 2015, 122; Perry et al. 2016, 1), an example of this being the REVEALS model, that accounts for the complexity of pollen productivity (Sugita et al. 2010, 2). Or moreover the less complex model used in this dissertation, pseudobiomization, which rather than attempting to model the complexities regarding the dispersal and taphonomy of pollen, groupes taxa into different land cover categories to infer changes through time (Fyfe et al. 2015, 119). However, just like other palaeoecological methodologies, these models are subject to the same limitations with regards to the scale of the data, in that these methods work well at a regional scale, but below this are not representative, and such the utility of modelling is that it makes it much easier to summarize data from large spatial and temporal ranges to infer general trends (Edwards et al. 2015, 122). Furthermore, one of the issues with this type of inference is the focus on assessing changes in land-cover, as a posed to land-use, in this way finding general evidence for human activity with little regard for the socio-cultural/economic processes that caused it (Robinson et al. 2018, 9). A good example of this are varying approaches towards assessing anthropogenic land cover change (ALCC) (Kaplan et al. 2017, 13–15; Hughes et al. 2018, 1). Kaplan et al illustrates this very effectively in their comparison of two ALCC models, KK10 and HYDE, against REVEALS (2017, 1). Without delving too far into the precise workings of these approaches, KK10 and HYDE are models that use data regarding human activities, population density, and the physical environment to create scenarios of anthropogenic land cover change at a country scale (Kaplan et al. 2017, 5). The authors highlight that these methodologies allow us to make very rough estimates about the rates at which ALCC occured, but at a very low resolution, and therefore do not equate to a better understanding of the socio-cultural processes that caused these changes (Kaplan et al. 2017, 13–15). In contrast to this, Hughes et al have recently published a methodology for quantifying land-use strategies, using the archaeological record as a proxy, aiming to go beyond the limitations of simply making inferences regarding land cover (2018, 1). Therefore, the application of palaeoecological models to the study of human-environment interactions has enabled a higher degree of analytical rigour, moreover the application of models has allowed a far better understanding of regional/continental changes in land cover, however the scale of this data has a tendency to focus research away from socio-cultural processes that drive these changes (Edwards et al. 2015, 122; Robinson et al. 2018, 896).

Conversely, at the other end of the modelling spectrum is ABM, which as discussed above is a form of simulation that aims to mimic a cultural/environmental processes, allowing researchers to experiment/explore the cause of patterns evident in palaeoecological/archaeological data, rather than aiming towards more analytical reconstructions (Kohler et al. 2005). One of the most famous applications of ABM is the work conducted considering the Long House Valley (Dean et al. 2000, 1; Kohler et al. 2000, 145; Axtell et al. 2002, 7275; Kohler et al. 2005, 77; Lake 2015, 4). In these models, individual household were considered as agents, choosing where to live in an environment that was reconstructed from palaeoenvironmental data in order to grow crops to survive, and had to make choices regarding changing environmental conditions (Lake 2015, 4). The result of these studies were then compared to the archaeological record, as a form of hypothesis testing (Crema 2018, 20), and it was concluded that climatic variation alone could not account for the human activity in the area, and that socio-cultural factors must have played an important role (Kohler et al. 2005, 77; Lake 2015, 4). Thus, in a simplistic way, the application of ABM in this context has allowed researchers to beyond simple reconstructions, and elucidate our understanding. Indeed, more recent applications have developed the application of ABMs to think about social organisation, not just the reaction to climatic variables (Chliaoutakis and Chalkiadakis 2016, 1072). However, the use of these methods is always cavetatted with the ever present notion of equifinality, in that although it is a means of addressing cause, we can never treat the findings as fact (Crema 2018, 21).

Lastly, the recent publication by Contreras et al (2018b, 1) is an interesting example in elucidating some of the limitations of modelling human-environment interactions, specifically in relationship to how we engage with the socio-cultural processes we are aiming to study (Walsh et al. 2017). The authors of this paper set out to evaluate how much climatic variability was a driver in societal change in Provence, France (Contreras et al. 2018b, 1). Indeed, the results of this research are particularly pertinent to this dissertation as their study area is directly to the South-West of modelling conducted for the French Alps. Moreover, to address this question Contreras et al use an agro-ecosystem model to assess agricultural productivity against climatic conditions through the Holocene (2018b, 1). To contextualise their results, the authors give a cultural history of the area, focusing heavily on demographic changes, and conclude that although agricultural productivity has a large impact of settlement patterns, it was not impacted by climatic variables (Contreras et al. 2018b, 1–21). However, by their own admission this methodology is only as useful as the importance of agriculture was in the study area (Contreras et al. 2018b, 4), which is a somewhat striking statement as there is very little discussion regarding the human behaviour/activities in question in their article. We can link this critique back to the earlier discussion of scale, particularly the extent to which we engage with the scales of the human activities we aim to study (Walsh 1999, 5; Leary 2014, 4; Aldred 2017, 90), as one of the main human activities in southern France through the Holocene has been pastoralism, an activity that involves a large degree of mobility (Walsh et al. 2014, 71). Therefore, this final example highlights that although modelling allows us to interrogate particular aspects of human-environment interactions at a large scale, if we fail to engage with human-scale activities then we risk creating models that are limited by our own engagement with the data.

Therefore, to answer objective two, contribution of formal modelling to our understanding of human-environment interactions has for the most part given researchers new quantitative/analytical tools that make it significantly easier to conduct large scale research projects, while opening new avenues to explore the causes of the process we observe (McGlade 1981, 1; Kohler et al. 2005, 77; Brouwer Burg 2017, 115; Robinson et al. 2018, 896). However, these approaches are not a panacea, but are limited by the same aspects of critical thought discussed in section one, and without care the validity of their application can be easily undermined.

Modelling the French Alps

Thus, with an understanding of how formal modelling can elucidate our understanding of human-environment interactions, the methods applied in this dissertation must now be reviewed to provide methodological robustness.

Indeed, the methodological approach taken is to apply is a multi-proxy assessment of human-environment interactions, appling summed probability distributions (SPD) of radiocarbon dates as a proxy for human activity/ population density (Shennan et al. 2013; Timpson et al. 2014, 550; Crema et al. 2017), the aoristic analysis of site counts (ASC) as another proxy for population density (Palmisano et al. 2017; Orton et al. 2017), and pseudobiomization (PBM) to assess changes in land coverage (Fyfe et al. 2015). Thus, this approach mirrors studies such as Woodbridge et al (2014, 216), and Lechterbeck et al (2014, 1297), in combining SPDs with PBM at 200 year time intervals, while additionally drawing on the approach taken Palmisano et al, in incorporating ASC as an additional means of assessing bias with the dataset (2017, 59). In this way the methodological approach taken here aims to assessment the extent to which there are cross-correlations between the different approaches (Tringham 2018, 1–6). The following discussion aims to provide a methodological overview, and highlight areas of critical thought, whereas the application of the methods is described in detail in chapter two.

Summed Probability Distributions (SPD)

SPDs of radiocarbon dates is a methodology first proposed by Rick, who set out the data as data approach it is built upon (1987, 55). Rick postulated that there is a monotonic relationship between the quantity of radiocarbon dates, and human activity/population density, and that they can therefore be used as a valid proxy (1987, 55). Indeed, to outline this core principle Rick set out an inferential chain (see figure six), highlighting that greater levels of occupation produce more material that can be radiocarbon dated, and that this material is subject to a number of

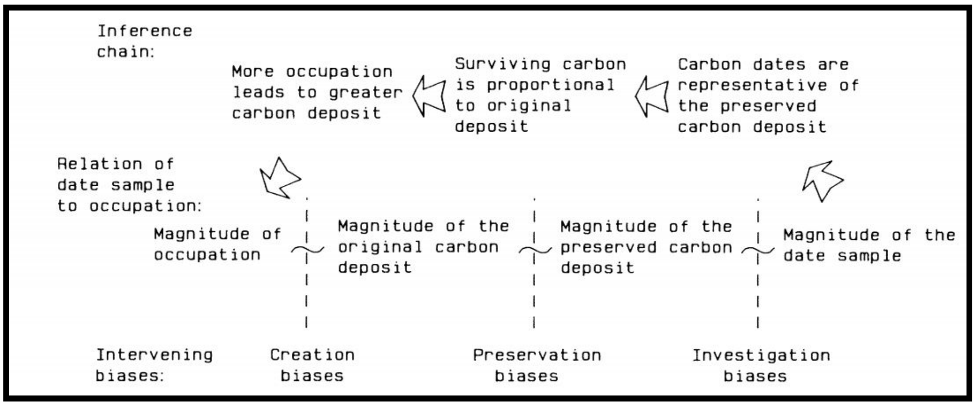


Figure Five - Rick's inferential chain (1897, 55)

biases (Rick 1987, 55; Shennan et al. 2013, 1). Specifically, that not all human cultures/activities will create the same amount of dateable material, varying taphonomic processes play a large role in what it is we recover, that our calibrations curves play a large role in the distributions of dates, and that the material we do recover is subject to our research designs, in that not all sites are sampled equally (Rick 1987, 55; Shennan et al. 2013, 1; Brown 2015, 134). To this end, it has been highlighted that the application of the dates as data approach is a first order approximation of human activities/population density(Rick 1987, 55; Gamble et al. 2005, 216; Shennan et al. 2013, 1; Brown 2015, 134; Timpson et al. 2015, 549). Linking the application of this approach to thematic interests in archaeological thought, SPDs have become very popular with scholars who argue we now have the tools to pursue the same questions culture historians proposed, but with new analytical rigour, highlighting its suitability as a demographic proxy (Shennan 2000, 881; Griffiths 2017, 1), and thus it is no surprise it has been used extensively to study the neolithic transition (Shennan et al. 2013, 1; Shennan and Edinborough 2007, 339; Collard et al. 2010, 886; Timpson et al. 2014, 550). Methodologically, a lot of attention has been paid to how we can overcome the various biases that are inherently a part of using radiocarbon dates as proxy material, particularly in regards to taphonomic processes (Rick 1987, 55; Surovell et al. 2009, 1715). Indeed, one of the concerns regarding the validity of the approach was that the probability distribution of radiocarbon dates only represented the taphonomic bias in the data, in that the older the material is the more likely it is that they will have been destroyed by taphonomic processes, resulting in an over representation of younger dates, and older dates being under-represented (Surovell et al. 2009, 1715). However, this is not the case, as it has been demonstrated that the relationship between the destruction of datable material and its age is not exponential, but instead decreases (Surovell et al. 2009, 1715). Additionally, the application of the dates as data approach now routinely includes the statistical testing of the SPDs, assessing their significance against a null model (Shennan et al. 2013, 1; Timpson et al. 2014, 550). This methodology was first introduced by Shennan et al, who worked from the assumption that the number of dates recovered will exponentially reduce through time, therefore they fitted monte carlo simulations of exponential population growth to their SPDs, allowing them to test where their results positively/negatively differed, demonstrating their statistical significance (2013, 1). Moreover, this approach was improved upon by Timpson et al, who filtered out the 5% false-positive results that the previous method was somewhat limited by, achiching this by assuming that false-positives are more likely to occur by themselves than in groups (Timpson et al. 2014, 550). Additionally, this publication also addressed criticism from Contreras and Meadows, who had argued that SPDs are not a reliable proxy when tested against more reliable demographic sources (Contreras and Meadows 2014, 591).However, it has been noted that in this analysis the time step used was at an inappropriate scale, below 200 years, and that anything below this is subject to wiggles that distort the results (Timpson et al. 2014, 551). Another methodological issues that has been addressed is the impact of sites phases, the notion that if the same site phase has been dated multiple times, it will sque the results, according this been dealt with in one of two ways, by binning each site phase together, or by binning the dates by chronological proximity (Crema et al. 2016, 6). Perhaps the most heated criticisms that this approach has been subject to has come from Torfing, who to a certain extent disagrees with the validity of Rick's premice, highlighting that not all cultures/ human activities produce the same amount of dateable material, and that our research biases have a large impact, using Jutland as a case in point in contrast to Shennan et al (Shennan et al. 2013, 1) (Torfing 2015b, 193, 2015a, 205). The response to this critique was twofold, that Torfing failed to make use of the statistical methodologies developed, reminded that it is only proxy, and a first order approximation at that, and although the criticism is valid, they stand by their original premise (Timpson et al. 2015, 549). Indeed, considering the subsequent application of SPDs against other proxies, such as Woodbridge et al (2014, 216) and Lechterbeck et al (2014, 1297), that highlight a general congruence between methods used, it perhaps seems that the premise holds true.

Aoristic Analysis of Site Counts (ASC)

Aoristic analysis is a methodology that was developed to deal with the issue of temporal uncertainty (Bevan and Lake 2016, 15), and produces a less formal, but equally comparable, probability density of relatively dated archaeological material, rather than the absolute values of radiocarbon dates (Crema et al. 2010, 1121). This approach was first developed within the field of criminology (Ratcliffe 2000, 669), and has subsequently been applied to an archaeological context (Johnson 2004, 448; Bevan and Lake 2016, 15), and aims to elucidate the probability that an event that occurs at an unknown point in a temporal window, in this context an archaeological site or artifactual material, falls within a series of temporal bins (Crema 2008, 99; Orton et al. 2017, 1121). Thus, it is assumed that the probability of an event in a specific time window is 1, denoting that that we have certainty that it is in this time span the event happened, the temporal range we are interested in studying is then divided into a series of uniform temporal bins, and the aoristic weight, i.e. the probability, that our event occured in these bin's is calculated (Palmisano et al. 2017, 63). Indeed, if we are using a 200 year time step, and an archaeological site falls between 1000 - 1800 BP, then it has an aoristic weight of 0.25. Accordingly, when all the aoristic weights for each temporal bin are then summed, the aoristic sum, the result is a probability distribution of our events (Palmisano et al. 2017, 63). However, the strength of this approach is also its main limitation; the ability to quantify relatively datable material is an excellent tool, however the very fact that it has been dated intuitively makes it more open to be impacted by bias, moreover there may be a homogenous distribution in the data, in that a large number or events may have the same start and end dates (Crema et al. 2010, 1121; Crema 2012, 448). Indeed, one of the ways this limitation has been dealt with is in the application of monte carlo simulations, which randomly picks a date out of every event being analysed, representing one possible distribution, which is them simulated a large number of times allowing for the creations of confidence intervals (Orton et al. 2017, 1121). Thus, ASC is a less formal means of assessing human activity/ population density than the creation of SPDs, but its utility in this context lies in the fact that the two can be compared, testing the validity of our interpretations (Palmisano et al. 2017, 63).

Pseudobiomization (PBM)

Unlike SPDs and ASC, PBM is a semi-quantitative methodology for reconstructing past land coverage from pollen taxa (Fyfe et al. 2015, 1197; Roberts et al. 2018, 2). This approach was designed to be a methodology of intermediate difficulty, between AP/NAP ratios of landscape openness, and more complex methodologies such as the mechanistic model REVEALS (Fyfe et al. 2015, 1197; Roberts et al. 2018, 2). PBM is based upon research that sought to group pollen taxa into plant functional types (PFT) according to different biomes, accordingly PBM modifies this methodology by grouping pollen taxa into land cover classes (LCC), creating a first order approximation of land coverage through time across Northern Europe (Fyfe et al. 2010, 1166). Indeed, Lechterbeck et al have further developed this methodology creating land cover classes that reflect the vegetation surrounding Lake Constance (2014, 1297). The contents of the LCCs was developed further through the comparison with remotely sensed data, to ensure a better goodness of fit (Woodbridge et al. 2014, 2080). Accordingly, the Northern European LCCs were applied in this study. To achieve this pollen taxa are initially grouped into five separate LCCs, including forested land cover, and culturally created landscape such as pastures, to make a modified pollen sum for each class (Fyfe et al. 2010, 1166; Fyfe et al. 2015, 1197). A limitation of this approach is that each taxa is only assigned to a single LCC, whereas in reality multiple taxa are apparent across multiple LCCs (Fyfe et al. 2010, 1166). From this an ‘affinity score’ is generated by subtracting the sum of the ‘open’ LCCs from the ‘closed’ LCCs, which is then used alongside a number of threshold values to determine if a period falls under either the mixed forest, semi-open, or mixed open LCCs (Fyfe et al. 2015, 1197). Thus, the application of PBM can give a spatially explicit approximation of how land coverage changed through time at a regional scale (Woodbridge et al. 2014, 2080). Importantly for the context of this dissertation, there are two examples where it has been used in conjunction to SPDs to assess the relationship between vegetation and population density, and has served as a useful proxy for understanding human-environment interactions (Woodbridge et al. 2014, 216; Lechterbeck et al. 2014, 1297). There are however a couple of limitations to be aware of. Firstly, on a more general note, that the relationship between pollen taxa and vegetation coverage is non-linear, and when tested against the more accurate REVEALS methodology, PBM routinely underestimates the extent of forest coverage, and overestimates the extent of open landscapes (Woodbridge et al. 2014, 2080; Roberts et al. 2018, 2). Furthermore, the relationship between pollen and vegetation is also significantly impacted by taphonomy, and that the context of the site itself is essential in accounting for these issues (Fyfe et al. 2010, 1166). Nevertheless, the authors of this method make very clear that its purpose is to be a first order approximation, at a regional scale, and warm against its application at a finer resolution (Fyfe et al. 2010, 1166; Fyfe et al. 2015, 1197). Thus, PBM is a very useful methodology to assess changing land coverage at a regional scale.

Section Three: The French Alps

The preceding two sections of this chapter have reviewed a number of key aspects of critical thought that are important in developing interpretations that are well grounded in theoretical thought, alongside methodological rigour. Therefore, the final section in this chapter aims to characterise how human behaviour/activities have been interpreted in the French Alps, so they can be tested against the results of this dissertation in evaluating the efficacy of formal modelling to elucidate our understanding. Rather than simply assessing this throughout the entirety of the Holocene, the focus of this analysis is on three periods, the Neolithic Transition, the 4.2 ka event, and the little ice age.

This discussion has been broken down into three parts: 1) an overview of the interdisciplinary landscape-scale research program in the Ecrins National Park, 2) an overview of previously reported regional/continental scale research that has encompassed the study area, specifically those which share a similar methodology to this dissertation, 3) the evaluation of the current interpretations in the study area of the Neolithic Transition, the 4.2 ka event, and the little ice age.

The Ecrins National Park

Research into human-environment interactions in the Ecrins National park has a long history, however since 1998 it has been subject to intensive fieldwork as a part of the Southern French Alps Landscape Project (Walsh et al. 2014). The purpose of this research has been to elucidate our understanding of human activities over the the longue durée in a mountainous landscape, specifically focusing on how people have interacted with high altitude zones, between 1600-3000m (Walsh et al. 2014, 53). Furthermore, this work has been conducted within an interdisciplinary framework, integrating the results of archaeological fieldwork (Walsh et al. 2006, 436; Walsh et al. 2007, 9; Walsh and Mocci 2011, 88; Walsh 2013, 257; Walsh et al. 2014, 52, 2016, 1), alongside a detailed program of palaeoecological research (Ali et al. 2005, 1659; Court-Picon et al. 2005, 13, 2006, 151; Magny et al. 2009a, 823, 2009b, 102; Touflan et al. 2010, 45; Talon 2010, 35; Ponel et al. 2011, 565).

In summary, the results of this study have highlighted the increasing impact on the environment by the waxing and waning of human activities through the Holocene (Walsh et al. 2014, 52). Beginning in earnest around the Neolithic, palaeoecological evidence suggests the opening of the landscape for pastoral activities (Walsh et al. 2014, 61–64). This activity appears to increase dramatically in the Bronze age, with a surge in the number of stone structures being built at altitude, with charcoal evidence suggesting significant land clearance through the use of fire, lowering the timber line, indicative of pastoral use (Walsh et al. 2014, 64–65), line with beginning of the secondary products revolution (Greenfield 2010). During the Iron Age and Roman periods there appears to a continuation of activity at high altitude, evident only in further deforestation via palaeoecological evidence and increases in lead levels, but very little in the way of archaeological evidence (Walsh et al. 2014, 68). One interpretation for this is that there was away shift from dairying, towards more ephemeral transhumance aimed towards the production of meat and wool (Carrer 2015, 17). In the Medieval periods there was a large boom in activity in the Ecrins, supported both in the archaeological and in the palaeoenvironmental record, with increases in transhumant pastoralism and mining (Walsh et al. 2014).

Regional/Continental Research

Alongside this landscape-scale research project focusing on the Ecrins, departments 4 and 5 have also been incorporated as a part of regional/continental scale analysis (Shennan et al. 2013, 1; Fyfe et al. 2015, 1197; Crema et al. 2017, 1; Roberts et al. 2018, 1). Indeed, an understanding this work is particularly important to this dissertation, as two of the methodological approaches taken here use the same methodology, albeit with an updated dataset, where the spatial extent is clipped to the study area. Thus, previous publications have used SPDs of radiocarbon dates as a proxy for human activity/population density across Europe (Shennan et al. 2013, 1; Crema et al. 2017, 1), and PBM to assess changes in land-cover (Fyfe et al. 2015, 1197; Roberts et al. 2018, 1). Please see section two of this chapter for a methodological overview, and chapter two for the methodologies themselves.

The application of SPDs of radiocarbon dates at a continental scale, which include the study area, has for the most part been a part of the EUROEVOL project directed by Professor Stephen Shennan, aiming to study the patterns of change across Europe that were brought with the onset of the Neolithic, and indeed the established ment of farming (Manning et al. 2016, 1). As such, the temporal extent of this research focuses on the period between 8000 BP and 4000 BP (Shennan et al. 2013, 1; Manning et al. 2016, 1). In brief, the results of this work has established patterns of boom and bust in population density associated with the adoption of farming across multiple regions, including a similar pattern in the region including the study area (Shennan et al. 2013, 1; Crema et al. 2017, 1). However, because of the coarse-grained nature of this work, it has been suggested that although it is very likely there there different population trends across different regions, it is difficult to assess them due the marked variation in sample sizes (Shennan et al. 2013, 1; Timpson et al. 2014, 549). Nevertheless, recent methodological advances have tested this with the use of "spatial permutation tests", which has highlighted population increases in the South-West of France between 5000 BP and 5500 BP (Crema et al. 2017, 5). Although this work is very informative regarding the general trends during Neolithic transition in the study area, the temporal focus in this context is a slight limitation, as there is not the same quality of interpretation through the other periods of interest. Nevertheless, Contreras et al summarize demographic changes in Provence, directly to the South-East of the study area, highlighting the relatively modest population levels increase up until a boom during the late Bronze Age, between roughly 3300-2700 BP, followed by a subsequent decline during the early Iron Age, and another population surge during the Gallo-Roman periods from 2070 BP through too roughly 1800 BP (Contreras et al. 2018b, 4).

Conversely, the use of PBM to assess land-cover change gives us a first-order approximation across the entirety of the Holocene (Fyfe et al. 2015, 1197; Roberts et al. 2018, 1). This research used data from the European pollen database (EDP), and included the Western Alps as a part of their analysis (Fyfe et al. 2015, 1197–1203). This research highlights that the study area would likely have stayed forested up until about 4000 BP, which saw a decline of broad-leaf tree, and an increase in needle-leaf forest (Fyfe et al. 2015, 1203). However, similar to the interpretations from the Ecrins, the authors highlight significant deforestation at the end of the Iron Age, 2200 BP, which saw the dominant land cover shift to grasslands, with the amount of arable/disturbed land at its highest during the Medieval periods (Fyfe et al. 2015, 1203).

Current Interpretations of the Study Area

In an attempt to go beyond interpreting the results from a general diachronic perspective, three periods are assessed in depth, considering the current interpretations from the study area as well as the extent to which they impact regional regional trends.

The Neolithic Transition

The data from the Ecrins National parks, and indeed regional interpretations of land cover and population density, seem to suggest that the Neolithic Transition only had a relatively small impact on the study area (Shennan et al. 2013, 2; Walsh et al. 2014, 61; Fyfe et al. 2015, 1203). Indeed, it would appear that at a local landscape-scale, that there is no archaeological evidence for agricultural activity in the Ecrins, however this being so, charcoal analysis yielded evidence of burning during this period, which may be indicative of early landscape management practices for pastoral activity (Walsh et al. 2014, 61). This small scale impact of the vegetation cover on the region as a whole is echoed in the regional PBM results, that highlight only a small decline in forest cover around 4000BP (Fyfe et al. 2015, 1203). Furthermore, the regional SPD results indicate a similar trend, in that human activity/population density only appears to increase slightly earlier around 5000 BP, but only modestly (Crema et al. 2017, 5; Contreras et al. 2018b, 5).

The 4.2 ka Event

The "4.2 event" is a period of supposed aridification, which it is argued to have caused long dry summer conditions (Zanchetta et al. 2016, 5). Within the Ecrins there appears to be a complex picture, with palaeoecological data suggesting some form of climatic event (Brisset et al. 2013, 1863; Cartier et al. 2015, 1231, 2018, 73) alongside a wealth of evidence suggesting that during the Bronze age there is significant intensification of human activity (Walsh et al. 2014, 61–65). Lake sediment analysis, from lakes Petit and Allos in the study area (and included in the results of this dissertation), suggest that around 4200 BP there is short pulse of detrital material, which it is unclear from this evidence alone if it is the result of humans activity, a climatic event, or indeed both (Brisset et al. 2013, 1863; Cartier et al.

2015, 1231, 2018, 73). Anthropogenic evidence is however abundant during this period , reflected in large amounts of burning that reducing the timberline, alongside the construction a large number of stone built structures, tentatively interpreted as animal pens, all indicative of increased pastoral activity coinciding with the secondary products revolution (Walsh et al. 2014, 61–65). Regionally, the decline in forest cover at roughly 4000 BP seems correspond with this trend in human activity, rather than being directly impacted by the 4.2 event (Fyfe et al. 2015, 1203), whereas in the surrounding area in Provence, this increase is also reflected in the a population rise at around 3300 BP (Contreras et al. 2018b, 5). Thus there is no clear consensus as to what happened during during the 4.2 event, however there is undoubtedly an increase in human activity.

The Little Ice Age

Lastly, the little ice age, a period of climatic cooling that occurred throughout the Medieval periods (Matthews and Briffa 2005; Luterbacher et al. 2016, 1). At a landscape scale, this period of cooling appears to have little impact on the use high altitude areas in the Ecrins, it seems that this was the point in time that study area was at its busiest, with a large increase in the number of stone stone structures being built, alongside further evidence for forest clearing, both for grazing historically large numbers of livestock, additionally supported by palaeoecological data, as well as supporting mining in the area (Walsh et al. 2014, 60–71). Regionally, this trend in increasing livestock practices in is also picked up on by the PBM results, that highlight that through the Medieval periods the predominant land-cover type is arable/disturbed land (Fyfe et al. 2015, 1203).

Section Three Conclusion

Therefore, considering the varying scale of analysis in the study area, there appears to be a broad correspondence between the interpretations made at a landscape-scale, and those at a regional-scale. Overall, this data seems to broadly indicate two pronounced periods of intensification of human activity, in the Bronze Age, which is seemingly followed by a period of more ephemeral, but consistent, activity in the Ecrins, in contrast to rises in population in Provence, and a relative boom in activity in the Medieval periods.

Chapter One Conclusion

To conclude, this chapter has attempted to discuss a range of topics that are pertinent to the interpretation of the results of this dissertation, and subsequently evaluate the utility of formal modelling to elucidate our understanding of human behaviour/activities. This has been considering in through a range of theoretical and methodological discussions: tracing through the complexities of integrating data from the the biophysical and social domains, thinking explicitly about the scales of our data and the utility of a multiscalar is approach, introducing the formal models used in this dissertation at both a theoretical and methodological level, and reviewing the current interpretations of the study area at both a regional and landscape scale.

Chapter Two - Methodology

Introduction

This chapter outlines in detail the three methodologies used in conjunction within this dissertation, the Pseudobiomization (PBM) approach (Fyfe et al. 2015, 1197), Summed Radiocarbon Probability Distributions (SPD) (Crema et al. 2017, 2; Palmisano et al. 2017, 59), and aoristic analysis of site counts (Orton et al. 2017, 1), in seeking to assess the extent to which modelling can elucidate our understanding of human-environment interactions in the French Alps.

Accordingly, the application of three methodologies required a range of data to be collated, with the bulk of the data management performed in ESRI's ArcMap 10.6, with the analysis performed within the open source statistical programing software R 3.5.1 (El Capitan), and Microsoft Excel (2013).

Dataset and Study Area

The dataset used within this dissertation is a combination of radiocarbon dated pollen percentage data, radiocarbon dates from archaeological sites, and a database of archaeological sites. Indeed, as aforementioned in chapter one, this methodology employ the use of a number of previously published datasets, namely the EUROEVOL dataset (Manning et al. 2016) for radiocarbon dates, and the pollen data used within Fyfe et al (2015). Indeed, additional radiocarbon dates was added to this dataset from Walsh et al (2014), whereas the results from Fyfe et al (2015) are replicated to only include the study area.

The various sources of this data is as follows (also see table 2): the pollen percentage data was extracted from the European Pollen database (Davis et al. 2013) by Dr Jessie Woodbridge, who additionally removed all rare taxa from the data set prior to sharing (Dr Jessie Woodbridge, pers. Comm. October 2017), and contained georeferenced radiocarbon dated pollen sequences from 59 sites in 200 year time steps from across southern France as Excel spreadsheets. The bulk of the archaeological site data was was extracted from the PATRIARCHE database by Dr Kevin Walsh in October 2017 from departments 4 and 5, which before processing contained over 8000 georeferenced archaeological sites ranging from the Palaeolithic to Post-Medieval periods. Additionally, sites were also extracted from the Bilan Scientifique de la Region Provence-Alpes-Côte d'Azur, by Dr Alessio Palmisano who kindly shared it, containing georeferenced absolute calendric dates of 3070 site phases, from the French Alps, as CSV files. Finally, the radiocarbon dates originated from the published literature regarding the archaeology of the high-altitude zone in the Southern French Alps, namely Walsh et al (2014, 55-57), containing the details of 57 radiocarbon dated archaeological sites, and was copied into an Excel document. Additionally, radiocarbon dates were downloaded from the EUROEVOL database (Manning et al. 2016, 1), as CSV files.

Table 2: Sources of the Dataset.

Data Type	Original Source/Repository	Contributor
Pollen Percentage Counts	European Pollen Database (EPD)	Dr Jessie WoodBridge
Radiocarbon Dates	Walsh et al (2014, 55-57) EUROEVOL database (Manning et al. 2016, 1)	Georefencened with spatial data shared by Dr Kevin Walsh
Archaeological Site Data	Bilan Scientifique de la Region Provence-Alpes-Cote d'Azur PATRIARCHE	Dr Alessio Palmisano Dr Kevin Walsh

As aforementioned, the study area chosen for the following analysis combines departments 4 and 5 (Alpes-de-Haute-Provence and Hautes-Alpes) within the Provence-Alpes-Côte d'Azur region of France, therefore if was first necessary to clip the extent of the data to only include sites from this area. This initial data management was performed within ESRI's ArcMap 10.6, with all data projected in the Geographic Coordinate System WGS84. First, a shapefile specifying the departmental boundaries of France was downloaded from the open online repository"Diva-GIS" (Anon. nd), which contained polygon's for each boundary, with the departmental name and number listed in the attributes table. Once read into ArcMap, Departments 4 and 5 were selected using the selection function, and used to create a new layer containing only the study area, which could then be used to manage the extent of the data used in rest of the analysis. Additionally, as the dissertation focuses on a mountainous landscape, it was particularly important to know the height above sea level for all of the sites in the study area. Therefore, digital elevation models (DEM) were downloaded from the United States Geological Survey's (USGS) "EarthExplorer" repository (Anon. nd), which contained data from the Space Shuttle Radar Topography Mission (SRTM), which would then be used to obtain the altitude, and contextualise the topographical position of the sites. In total, a mosaic of six tiles were downloaded to cover the full extent of the study area, these were then processed using the raster processing tool "clip", with the output extent set to departments 4 and 5. Once the geographical extent of the study had been specified, it was next possible to clip the dataset to this extent. The pollen, site count (both from PATRIARCHE and Bilan Scientifique)l, and EUROEVOL data all had latitude and longitude specified, whereas the radiocarbon data from the published literature (Walsh et al. 2014, 55-57) did not contain this information, and therefore it was necessary to georeference it. Indeed, Dr Kevin Walsh, one of the directors of the Southern French Alps Landscapes Project which generated the data (Walsh et al. 2014, 53), kindly shared the associated spatial data as ESRI shapefiles. Once imported to ArcMap, the Conversion tool "Table to Excel" was called upon the spatial data, which importantly contained the X and Y coordinates. To then georeference the radiocarbon dates a simple "IF" statement was called in Excel, where if the radiocarbon data and the spatial data shared the same site name, then the coordinates would be populated (see figure X). With the data fully georeferenced the three data sets were imported into ArcMap, using the "Display X and Y" function, and exported into the appropriate geodatabase. The tool "Clip" was then used to remove all points from the dataset that fell outside of the study area. Finally, the "Table to Excel" tool was used to convert the dataset to Excel documents ready for analysis.

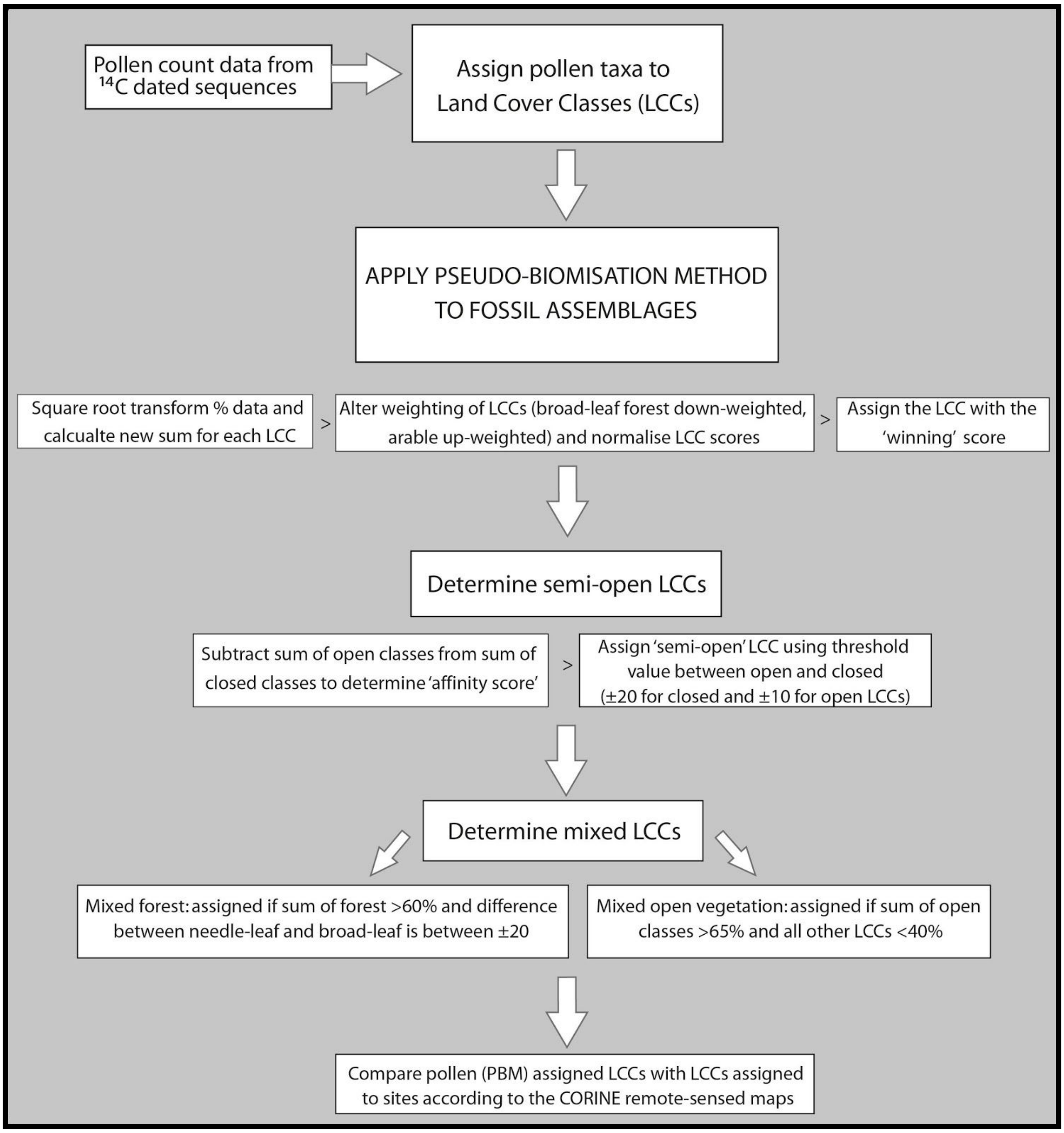
Data Analysis

The following sections detail the application of the Pseudobiomization (PBM) approach (Fyfe et al. 2015, 1197), Summed Radiocarbon Probability Distributions (SPD) (Palmisano et al. 2017, 59), and aoristic analysis of site counts (ASC) (Orton et al. 2017, 1), to the dataset. The rationale behind this approach is, to a certain extent, to replicate and combine the research designs of publications such as Palmisano et al (2017), and Lechterbeck et al (2014), in comparing the correlation between Demography, and changes in land coverage over the Longue durée, while thinking more specifically about vertical space. For a detailed discussion on the advantages/disadvantages of these methods, please see chapter two.

Pseudobiomization (PBM)

The application of the PBM method below has been rigorously followed from the methodology provided within Fyfe et al (2015, 1197), which demonstrates the updated and refined PBM approach following its original publication in Fyfe et al (2010, 1165), with modifications from Woodbridge et al (2014, 208). The basic premise behind the PBM approach is that fossil plant taxa can be assigned to "Land-Cover Classes" (LCCs) designed to produce a representative summary of the "dominant land-cover type" of a spatially explicit area through time (Fyfe et al. 2010, 1166). Thus, this methodology, of an intermediate level of complexity, provides an interesting means through which to assess changing patterns of land coverage against the archaeological record (Lechterbeck et al. 2014, 1298), and in turn investigate how modelling can elucidate our understanding of human-environment interactions. See figure 7 for a schematic flow diagram of the PBM method, from the supplementary information within Fyfe (2015). Additionally, see chapter one for a more detailed methodological overview.

Figure Six - Schematic flow diagram of the PBM method from the supplementary information in Fyfe et al (2015).



The first step in applying the PBM methodology to pollen dataset from departments 4 and 5 was to assign the pollen taxa to their varying LCCs (see table three for a description of the categories, and table four for the pollen assigned to each LCC), discarding any taxa that did not fall within an LCC (Fyfe 2015, 1200). Although, the LCC categories used here are generally applicable to Northern Europe at continental scale, their broad nature can be seen as a potential constraint within the methodology, as different regions, and indeed sites, will have varying vegetative patterns, resulting in a risk of overlooking smaller scale patterns from within the data (Woodbridge et al. 2014, 2087–2088). This initial subsetting of the data was conducted in R, using the “dplyr” package, with the

Table Three: Table from Fyfe et al (2015, 1200) defining land cover classes (LCC)

	Land Cover Class	Description
	Closed LCCs	
LCC1	Needle-leaf forest	Defined by a small number of needle-leaf trees (typically high pollen producers)
LCC2	Broad-leaf forest	Defined by a large number of broad-leaf trees (e.g. deciduous Quercus), including a small number of epiphytes (e.g. Hedera), and some fruit trees (e.g. Olea)
LCC3	Mixed forest	Dominated by a mix of needle-leaf and broad-leaf forest Defined by thresholds between different forest types
	Semi-open LCC	
LCC4	Semi-open vegetation	Mixed land cover including both forest and open vegetation Defined by thresholds between other classes
	Open LCCs	
LCC5	Heath/scrubland	Defined by a mixture of heath/scrub type taxa, including evergreen Quercus.
LCC6	Pasture/natural grassland	Predominantly defined by a large mixture of grassland herbs including a number of taxa associated with pasture

LCC7	Arable/disturbed land	Defined by a large number of herbaceous taxa indicative of arable and disturbed land (excluding fruit trees)
LCC8	Mixed open vegetation	Dominated by a combination of heath/scrubland, pastures/natural grassland and arable land Defined by thresholds between open classes

Table Four: Table from the supplementary information in Fyfe (2015) specifying the pollen taxa within each LCC

	Land Cover Class	Pollen taxa assigned for PBM
	Closed LCCs	
LCC1	Needle-leaf forest	*Abies, Cupressaceae, Larix, Picea, Pinaceae, Taxus*
LCC2	Broad-leaf forest	*Acer, Aesculus, Alnus, Amygdalus, Anacardiaceae, Arceuthobium, Betula, Buxus, Carpinus, Castanea, Celtis, Cercis siliquastrum, Corylus, Crataegus, Daphne, deciduous Quercus , Euonymus, Fagus, Frangula, Fraxinus, Hedera, Ilex, Juglans, Liquidambar, Liriodendron, Lonicera, Malus, Morus, Myrica, Myrtaceae, Nyssa, Olea, Parrotia, Platanus, Populus, Prunus, Pulmonaria, Pyrus, Rhamnaceae, Robinia, Robinia, Salix, Sambucus nigra, Sorbus, Staphylea, Tilia, Ulmaceae, Viscum, Vitaceae*
LCC3	Mixed forest (dominated by a mix of needle-leaf and broad-leaf forest)	Defined by thresholds between different forest types
	Semi-open LCC	
LCC4	Semi-open vegetation (mixed land cover including both forest and open vegetation)	Defined by thresholds between other classes
	Open LCCs	
LCC5	Heath/scrubland	*Aellenia, Alkanna, Anagallis, Arctostaphylos, Argania spinosa, Asphodelus, Astragalus, Ballota, Beta, Bongardia, Calluna, Carex, Casuarina, Centaurea sclerophyllus, Ceratonia, Chaenorhinum, Chamaerops, Chrozophora, Cistaceae, Citrus, Colchicum, Colutea, Convolvulaceae, Coriaria, Cynoglossum, Cyperaceae, Cytisus, Echium, Empetrum, Ephedra, Erica, Fagonia, Genista, Hippophae, Hypericum pulchrum, Hyphaene, Juniperus, Laurus, Lotus, Melampyrum pratense, Moltkia, Narthecium, Onosma, Parnassia, Phlomis, Pistacia, Polygonum heath types, evergreen Quercus, Rhynchospora, Rosmarinus, Rutaceae, Salvia, Sapotaceae, Sarcobatus, Scheuchzeria, Tamarix, Trachycarpus, Ulex, Valerianaceae heath types, Verbena*
LCC6	Pasture/natural grassland	*Actaea, Agrimonia, Anemone, Anethum, Anthyllis, Apiaceae, Asperula, Asteraceae (subfamily Lactucoides), Asteraceae undifferentiated, Bunium,*

		Bupleurum, Calendula, Caltha, Campanulaceae, Centaurea grassland types, Coronilla, Dipsacaceae, Epilobium, Filipendula, Galega, Galium, Gentianaceae, Geum, Knautia, Lithospermum officinale, Ornithopus, Paliurus spina christi, Papaveraceae, Plantago alpina, Plantago coronopus, Plantago lanceolata, Plantago tenuiflora, Poaceae, Polygala, Potentilla, Ranunculaceae, Rhinanthus, Rumex acetosa, Rumex acetosella, Ruppia, Sanguisorba, Senecio, Sherardia arvensis, Sisyrinchium, Stachys, Succisa, Thalictrum, Trifolium, Urticaceae, Valerianaceae grassland types, Veronica, Viciaceae
LCC7	Arable/disturbed land	*Allium, Anagallis arvensis, Anchusa, Aphanes, Arctium, Artemisia, Asparagaceae, Asteraceae (subfamily Asteroideae), Borago, Brassicaceae, Calligonum, Cannabaceae, Carduus, Caryophyllaceae, Cassia, Centaurea arable types, Centaurea undifferentiated, Cerealia, Chenopodiaceae, Cirsium, Cucurbitaceae, Fagopyrum, Galeopsis, Humulus, Hypericum calycinum, Jurinea, Lamiaceae, Lappula, Lathyrus, Leguminosae, Linaceae, Lithospermum arvense, Medicago, Melilotus, Noaea, Ononis, Pastinaca sativa, Phaseolus, Pisum, Plantaginaceae, Plantago albicans, Plantago atrata, Plantago cylindrica, Plantago major, Plantago maritima, Plantago media, Plantago montana, Plantago ovata, Plantago psyllium, Polygonaceae arable types, Prosopis, Punica, Rheum, Ribes, Ricinus, Rubus arable types, Rumex type, Scorzonera, Sideritis, Silenaceae, Solanaceae, Spinacia, Valerianaceae arable types, Zea*
LCC8	Mixed open vegetation (dominated by a combination of heath/scrubland, pastures/natural grassland and arable land)	Defined by thresholds between open classes

data imported as a CSV file. Please see the appendix for a copy of the code used. Indeed, the following code is an example of how taxa was assigned to LCC1:

```
LCC1_Needle_Leaf_Forest <- Pollen_Taxa %>% select(Site.code, Cal.yr.BP, Abies
Cupressaceae, Larix, Picea, Pinaceae, Taxus)
```

Once this was complete for all LCCs, the data was then written as a Excel document using the “writre.xlsx” function within the “xlsx” package, as all of the remaining steps in the PBM method were conducted in Excel. Again, the following code is an example of how this was achieved for LCC1:

```
write.xlsx(LCC1_Needle_Leaf_Forest, file = "LCC1_Needle_Leaf_Forest", sheetName =
"LCC1_Needle_Leaf_Forest", append = FALSE)
```

With all the data written in an Excel format, they were subsequently combined within a single Excel document for ease of analysis. Indeed, as shown in figure one, the data was then square root transformed, and a modified pollen sum was calculated (Fyfe et al. 2015, 1200). Additionally, as specified in Woodbridge (2014), broad-leaf forest was was down weighted by approximately x0.6, whereas arable/disturbed land was up weighted by x1.3 to give the highest possible match to remotely sensed land cover maps (2084). The data was then normalised to allow for between sample comparison, and allowing for the "winning" category to be established for each period (Fyfe et al. 2015, 1200). Defining the winning category was a simple two step process: first a new column was added to excel document containing the "MAX" function to establish the highest LCC percentage, whereby the variables within the function were specified as the initial five LCC categories. This winning score was then used as variable within a nested "IF" function, where if one LCC score's was the same as the winning score, that category's name was printed in a new column. The next step was to determine if the any of the samples fell into LCC4, semi-open vegetation, by calculating a "affinity score" , then assessing it against two threshold values, ±20 for closed LCCs, and ±10 for open LCCs (Fyfe et al. 2015, 1200). This was achieved in Excel by using the following steps: the "affinity score" was determined by subtracting the sum of the open LCCs from the sum of the closed LCCs, as indicated in the following example:

Affinity Score of sample x = (LCC1 + LCC2) - (LCC5 + LCC6 + LCC7)

Next, to establish if the winning LCC was either open or closed, thus defining the threshold value to be used, a nested "IF" function was used, whereby if the winning LCC was in LCC1/LCC2, then "Closed" was printed, and conversely if the winning LCC was in LCC5/LCC6/LCC7, then "Open" was printed. Therefore, with this information established, it was used as a variable in a nested "IF" "AND" functions to determine if the sample fell into LCC4 as follows:

LCC4 Semi-Open Vegetation = IF (AND (Open/Closed Column = "Closed", Affinity Score Value <= 0.2, Affinity Score Value <= - 0.2), "TRUE", IF (AND (Open/Closed Column = "Open", Affinity Score Value >= 0.1, Affinity Score Value <= - 0.1), "TRUE", ""))

The next step in the PBM method is to determine which of the samples fall into LCC3/LCC8, mixed forest and mixed open vegetation. LCC3 (mixed forest), was assigned to sum of LCC1 and LCC2 was greater than 60%, and the difference between LCC1 and LCC2 was ±20. Whereas, LCC8 (mixed open vegetation) was assigned when the sum of LCC5/LCC6/LCC7 was >65%, and the sum of all other LCCs was <40% (Fyfe 2015, 1200). Both of these LCCs were calculated using the "IF" "AND" functions as demonstrated in the following examples:

LCC3 Mixed Forest = IF (AND (Open/Closed = "Closed", (LCC1 +LCC2) <= 0.2, (LCC1 + LCC2) >= - 0.2), "True", "")

LCC8 Mixed Open Vegetation = IF (AND (Open/Closed = "Open", (LCC5 + LCC6 + LCC7) > 0.65, (LCC1 + LCC2 + LCC5 + LCC6 + LCC7) < 0.4), "True", "") Finally, the “winning” LCC per sample was assigned using a nested “IF” function, that worked back from the mixed categories, semi-open vegetation, and the then the five pure LCCs.

Summed Radiocarbon Probability Distributions (SPD)

The next methodology applied to the radiocarbon dated material from departments 4 and 5 was the summed probability distributions approach, which was conducted in R using the “rcarbon” package as outlined in Crema et al (2017, 2), and Crema and Bevan (2018). As discussed in chapter two, this methodology builds on the “dates as data” approach, first proposed by Rick (1987, 55), and has developed into a popular means of assessing shifting population dynamics through time (Shennan et al. 2013, 2; Crema et al. 2016, 1; Bevan et al. 2017, 1; Crema et al. 2017, 2; Edinborough et al. 2017, 1). As mentioned above, the application of this methodology is intended to partially emulate publications such as Lechterbeck et al (2014, 1297), and Woodbridge et al (2014, 216) in comparing human population dynamics against changing patterns in land cover. Furthermore, please see the appendix for a full copy of the scripts used in this analysis.

First, the radiocarbon dates were read into R as a CSV, and the dates were calibrated using the “calibrate” function from the “rcarbon” package (Crema and Bevan, 2018). This function was called twice over the data, once normalising the radiocarbon dates using the default setting for the logical argument “normalised” within the “calibrate” function, and a second time changing the argument “normalised” to equal “FALSE”, so not to normalise the dates, as seen in the example below:

```
Calibrated_Normalised <- calibrate( x = Radiocarbon_Dates$BP, errors =
Radiocarbon_Dates$Error, ids = Radiocarbon_Dates$DateID)
```

```
Calibrated_Not_Normalised <- calibrate( x = Radiocarbon_Dates$BP, errors =
Radiocarbon_Dates$Error, ids = Radiocarbon_Dates$DateID, normalised = FALSE)
```

This follows the argument put forwards by Weninger et al (2015, 543) that normalisation causes artificial spikes in the SPDs that are subsequently generated. As such only non-normalised results are reported in the following discussion.

The next step in applying the SPD methodology was to bin the data, for which the “binPrep” function was called (Crema and Bevan, 2018). In this instance the “binsense” function was called to assess the the most appropriate h value to be used in “binPrep”, however following the example of Lechterbeck et al (2014, 1297), and Woodbridge et al (2014, 216), a value of 200 was chosen to allow for direct comparison between the SPD and PBM results. Following on from this, the resulting binned data was used as within “spd” function that generates the SPD curve, as per the following code:

```
SPD_Normalised <- spd(RD, bins = SPD_bin, timeRange = c(8000, 450))
```

```
SPD_Normalised_False <- spd(RD_false, bins = SPD_bin_False, timeRange = c(8000, 450), datenormalised = TRUE, spdnormalised = TRUE)
```

Additionally, the SPD curve was tested against a number of Monte-Carlo simulations using the “modelTest” function, to assess the goodness-of-fit against a uniform, linear, and exponential model (Crema and Bevan, 2018), as demonstrated in the following code:

```
SPD_Exp <- modelTest(RD, Radiocarbon_MA$Error, nsim = 100, timeRange = c(8000, 450), model = "exponential", runm = 200)

SPD_Lin <- modelTest(RD, Radiocarbon_MA$Error, nsim = 100, timeRange = c(8000, 450), model = "linear", runm = 200)

SPD_Uni <-modelTest(RD, Radiocarbon_MA$Error, nsim = 100, timeRange = c(8000, 450), model = "uniform", runm = 200)
```

Aoristic Analysis of Site Counts

Furthermore, as an additional means of testing human population dynamics, as well as testing the SPD curve against sampling biases, an aoristic analysis of site counts was conducted in R using the package “archSeries” which was downloaded from github (Orton et al. 2017, 1). Again, please refer to chapter 2 for a more detailed overview of this methodology. However, this approach shares similarities with that used with in Palmisano et al (2017, 59), whereby relatively dated site phases based on artifactual evidence may have a high level of temporal uncertainty associated with them, particularly when a site phase may span more than 1000 years, which is not likely to be representative of the true occupation of a site (Palmisano et al. 2017, 59). The aoristic approach counters this issue by treating site phases in a probabilistic manner, giving a higher probability to phases with a smaller temporal range, and a lower probability to those with a higher temporal range. From this, an aoristic sum can be calculated for each time step considered within the analysis (Palmisano et al. 2017, 59).

There were two sources of data for this analysis, the PATRIARCHE database, and the Bilan Scientifique de la Region Provence-Alpes-Cote d'Azur. The data from the Bilan Scientifique had the start and end date of each site phase clearly available and ready to use, however this was not the case for the PATRIARCHE data and thus required some processing before it was suitable for the aoristic analysis. Indeed, the PATRIARCHE data was originally formatted as follows: every site was assigned a start and end date code, that corresponded to the start and end dates of different chronological periods in time (see figure X), while if a more precise dates was known from within these period they were given in a BC/AD format. Therefore, before the data could be used, each site had to be correctly assigned to a chronological period, using the more precise BC/AD dates where possible. Kindly, Dr Daniel Contreras (University of Maryland) shared an R Script detailing the conversion of the start and end date codes into Before Present (BP) dates. This chronological information was then input into an Excel document, and a simple if statement was used to convert the codes into BP dates as shown in the example below and additionally in table five:

Example IF statement from Chronological assignment =IF(AND(E21="",F21<=$N$3, F21 >= $O$3),$N$3,IF(AND(E21="",F21<=$N$9, F21 >=

$O$9),$N$9,IF(AND(E21="",F21<=$N$12, F21 >=

$O$12),$N$12,IF(AND(E21="",F21<=$N$15, F21 >=

$O$15),$N$15,IF(AND(E21="",F21<=$N$16, F21 >= $O$16),$N$16, E21)))))

Table Five - Chronological Assignment of PATRIARCHE data

Period	Start_BP	End_BP
Neolithic	7950	4050
Early_Neolithic	7950	6650
Middle_NeoLithic	6650	5450
Final_Neolithic	5450	4250
Recent_Neolithic	4250	4050
Early_Bronze_Age	4050	3750
Bronze_Age	4050	2850
Middle_Bronze_Age	3750	3350
Late_Bronze_Age	3350	2850
Iron_Age	2850	1977
Early_Iron_Age	2850	2430
Late_Iron_Age	2430	1977
Gallo_Roman	1977	1500
Middle_Ages	1500	497
Low_Middle_Ages	1500	951
High_Middle_Ages	950	650

The next step in processing the PATRIARCHE data was to use to the more precise BC/AD dates, over the re-coded chronological periods where possible. First, for ease of comparison the BC/AD dates were converted to BP, this was performed manually in excel with an IF statement (see supplementary information). With the dates converted, an if statement was used to populate the start and end date columns for each site, prioritising the precise dates, and if not defaulting to the broader chronological periods.

The next step in the processing was to remove any sites that were not wanted for analysis, this included all sites from before the onset of the Holocene, and any site that had not been assigned a start or an end date. The reason some sites resulted in having no dates is twofold, the database was incomplete, or if a site fell outside of the chronological period of interest, i.e. post-medieval and modern sites. At this point some sites had only been assigned either a start date, or conversely only an end date. To rectify this an if statement was used to assign the corresponding start or end date to a site. The penultimate step in preparing the data was to remove any duplicates in the PATRIARCHE dataset. This is can be seen as a potential constraint of the data, to a certain extent questioning its reliability. Lastly, the PATRIARCHE and Bilan Scientifique datasets were combined, with any duplicates again removed.

The site data was loaded into R as a CSV file, and the "aorist" function was called on it with a bin width of 200 to match the PBM and SPD data, as follows:

```
Aorist  <- aorist(Sites_Data_BP, 10000, 450, end.date = NULL, bin.width = 200)
```

Additionally, as with the SPD results, the aoristic results were tested against a Monte-Carlo simulation testing the goodness-of-fit against uniform distribution, calling the "date.simulate" funcion at the default of 100 repetitions, as shown in the following code:

```
Simulate_Sites  <- date.simulate(Aorist_BP, bin.width = 200)
```

Potential Constraints

Although some constraints of these methodologies have already been touched upon in chapter one, there are a number of critical points that are useful to reiterate.

Potential Constraints of the Pseudobiomization (PBM) Approach

First, when considering the results of the PBM approach it is important to consider more general points surrounding the interpretation of pollen data (Woodbridge et al. 2014, 2089). Indeed, the relationship between the pollen and vegetation coverage is non-linear, which highlights a degree of speculation in the interpretation of any results, in that they are bound by the fact that correlation is not causation (Woodbridge et al. 2014, 2089). Moreover, any detailed analysis of pollen taxa must always be grounded in the local site taphonomy, and the importance of lake size should not be underestimated due to the significance this has on the geographical extent of interpretations (Fyfe et al. 2010, 1169; Hjelle and Sugita 2012, 1). However, authors of the PBM methodology have from its first publication been very clear on the limitations of the approach, highlighting that it is a first-order approximation of land cover change, that is not quantified (Fyfe et al. 2010, 1169; Woodbridge et al. 2014, 2080; Fyfe et al. 2015, 1210). Accordingly, PBM is only effective at a macro/regional/continental scale, and does not give accurate results when down-scaled to a local site based scale

(Woodbridge et al. 2014, 2080). Furthermore, a degree of caution must be exercised when considering the affinity score generated, as they are not an empirically tested means of assessing landscape openness (Fyfe et al. 2010, 1169). As such it is important to remember that PBM is an approach of intermediate difficulty (Fyfe et al. 2015, 1197), and a range of more sophisticated methodologies are available (e.g. (Trondman et al. 2015; Zanon et al. 2018)).

Potential Constraints of Summed Radiocarbon Probability Distributions (SPD)

In regards to the potential constraints of SPD methodologies, there has been a wider debate regarding its validity as a proxy of population density (Torfing 2015b, 193). It has been argued that the very nature of a "dates as data" approach is fundamentally inappropriate when it comes to considering palaeodemography, as the density of radiocarbon dates is strongly biased towards sampling strategies/ research focuses/site taphonomy, and is only representative of changes in human activities that produce more or less material that is suitable for radiocarbon dating (Torfing 2015b, 193, 2015a, 205). As such, one suggestion has been it is a more suitable proxy for energy consumption (Freeman et al. 2018, 454). However, the rebuttal to this criticism has been to accept that to certain extent all of these critical concerns are valid, but that they does not undermine the overall validity of the endeavour, as its underlying purpose is not to be an exact representation of population density, but simply be used as a proxy towards elucidating our understanding (Timpson et al. 2015, 200; Smith 2016, 214). Going some way to bridge these concerns is the advancement in the statistical testing of the SPD curves, as highlighted in the application of Monte-Carlo simulations in this methodology (Timpson et al. 2014, 550; Crema et al. 2017, 1; Brown 2015, 134; Contreras and Meadows 2014, 591). Additionally, it has been noted that the strength of any interpretations of SPDs are greatly increased when they are combined with other proxies (Palmisano et al. 2018, 59), as applied in this methodology. In regards to the appropriate temporal scale, there is no correct value for which to cluster SPDs, the time intervals used in the interpretation of results, however below a 200 year interval fluctuations in the calibration curve may cause spurious wiggles that are irrelevant over a period of thousands of years, and as such a rolling mean of 200 years is plotted to avoid the over enthusiastic interpretation of very small scale changes (Timpson et al. 2014, 550). While small sample sizes are not thought to be an issue, still resulting in reliable outputs (Timpson et al. 2014, 550), it must be firmly noted that only 78 radiocarbon dates have been used in this analysis, and even though this dataset is growing, it is a very small number for a large geographical area with unfortunately only a limited prospect of gauging significant results. Finally, on a more general level, it has been stressed that due to the increase in accessibility in simulations, it is of paramount importance that all practitioners are critically engaged with the methodologies in question, otherwise they risk becoming black-boxes (Buck and Meson 2015, 1).

Chapter Three - Results and Discussion

Introduction

In this penultimate chapter the results of this dissertation are assessed, addressing objective three, the assessment of the efficacy of formal modelling to integrate data from different spatial and temporal scales. Moreover, this chapter will also begin to discuss how successfully the research question has been answered, the extent to which formal models can elucidate our understanding of past human behaviour/activities.

Before entering into the interpretation of the results, it is useful to first reflect on a number of the critical points raised in chapter one, mainly the importance of scale, considering the extent to which this can help directly inform our interpretations, and furthermore aid in the evaluation the success of this approach in answering the research question. It was highlighted that one of the most important aspects of asking impactful questions was the extent to which we engage with the scales of our data/methodologies, and ensuring that these are aligned with our research questions (Walsh et al. 2017, 1–3). Indeed, these points were discussed, highlighting that the methodologies employed in this dissertation are all first-order approximations (Shennan et al. 2013, 2; Fyfe et al. 2015, 1197), and as such can only elucidate our understanding at a very coarse-grain. As such, a limitation of this approach is that by itself it is of limited value in elucidating our understanding of human behaviour/activities beyond general trends. However, returning back to the discussion regarding the utility of a multiscalar approach (Butzer 2008, 403; Edwards et al. 2017, 1), and additionally the use of models as a form of hypothesis-testing (Crema 2018, 20), the utility of this methodology is it enables us to consider cross-correlations between coarse-grained models, and the landscape-scale processes they are indicative of, testing the strength of our interpretations (Tringham 2018, 1–6). Thus, to tentatively begin answering objective three, and the overarching research question, the extent to which formal models can elucidate our understanding of human behaviour/activities in the French Alps is heavily reliant upon way in which we employ them in our research designs.

Results

The results of the three modelling approaches employed in this dissertation are now considered separately, and then as a spatially aggregated whole, discussing their combined significance against the previous interpretations from the study area, and finally discussing their efficacy in integrating data from multiple scales.

SPD Results

The SPD results appear to show a high level of correspondence with the landscape-scale interpretations from the the Ecrins National Park, however some caution is required here in regards to the sample size and location. Indeed, most of the C14 dates that were used in this analysis originated from the Ecrins dataset, see figure eight, and as such there is a risk of there being a high degree of confirmation bias between these results, and how the dates have been previously interpreted in Walsh et al (2014, 59).

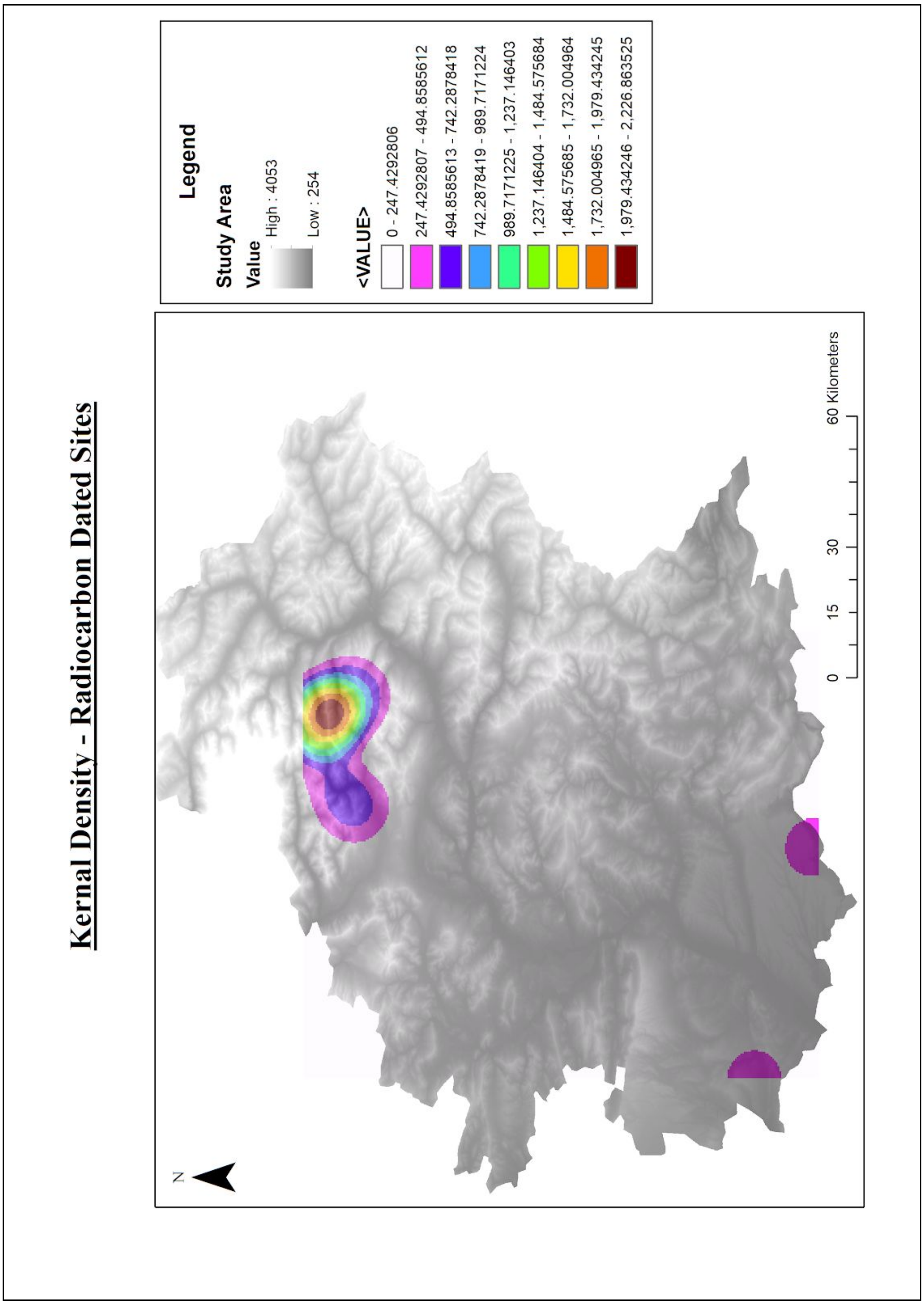


Figure Seven - Kernal Density Map of C14 dates

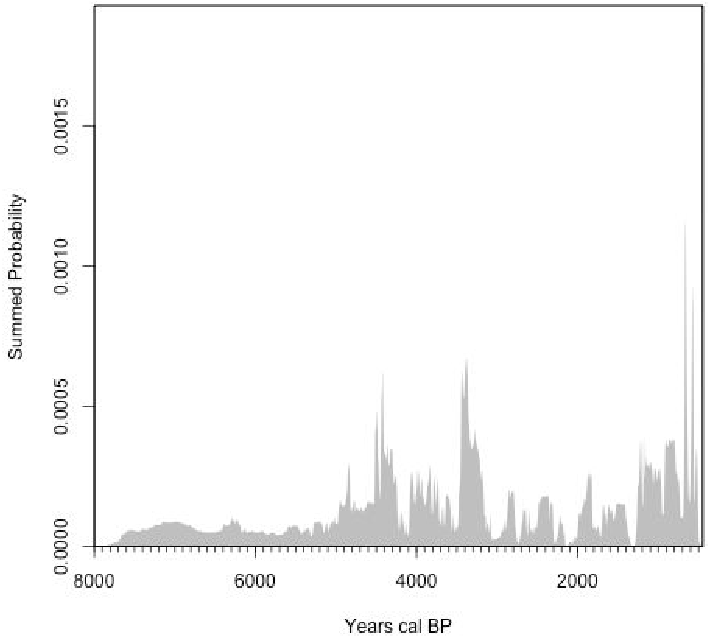


Figure Eight - Spatially aggregated SPD Results

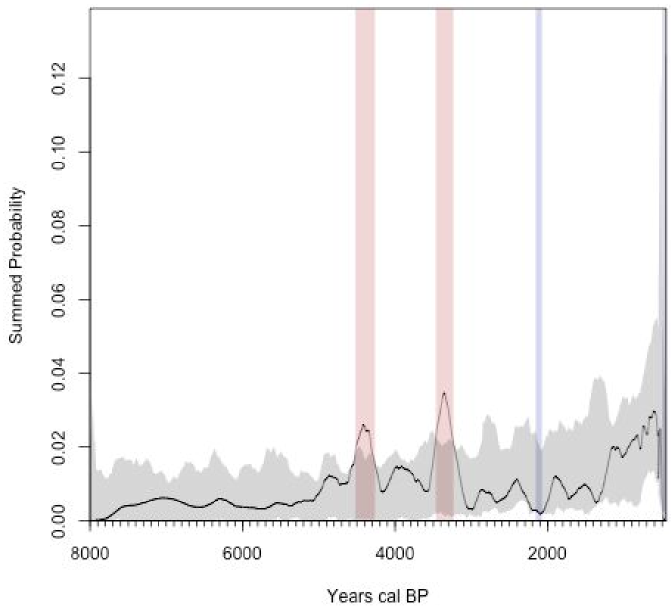


Figure Ten - Spatially aggregated SPD results plotted against exponential null model

Nevertheless, visually inspecting the spatially aggregated SPD results, see figure nine, there appear to be two increases either side of 4000 BP, one at approximately 3600 BP and the other at approximately 4700 BP. Indeed, both of these increases appear to be valid increases in human activity as they both positively deviate from the null model of exponential growth, see figure ten. Indeed, this appears to highlight that there was an increase in population during the end of the Neolithic, and then again during the Bronze Age. Subsequently, there appears to be a period of fairly stable activity, until there is a negative deviation from the null model just before 2000 BP, suggesting a down turn in human activity during the Iron Age/ Gallo-Roman periods. Indeed, during Medieval periods there are not further deviations from the null model, however the results seem to indicate is a general increase in activity. However, as aforementioned these results have been derived from a very small dataset, and as such must not be over interpreted, or indeed too much weight.

ASC Results

Visually interpreting the ASC results, see figures eleven and twelve, there appears to be a general increase in population density through during the middle of the Neolithic, followed by a more dramatic rise in the Bronze Age. Indeed, the results seem to indicate that after this period there was a drop off in activity, and then a large boom during the Gallo-Roman period. The Medieval periods by comparison do not appear to suggest the same levels of intensity as the Gallo-Roman periods, but rather drop off to the same density at around the same level as the peak in the Bronze Age. However, it is very important to remember that as these site have all only been relatively dated, and there is a strong chance that it is biased towards material more easily dateable, such as distinctive Roman wares. Indeed, considering these results

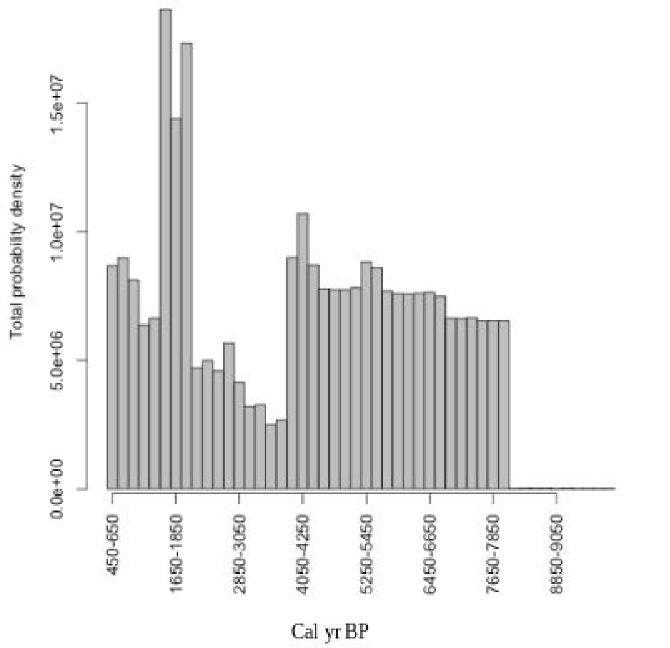


Figure Ten - ASC results

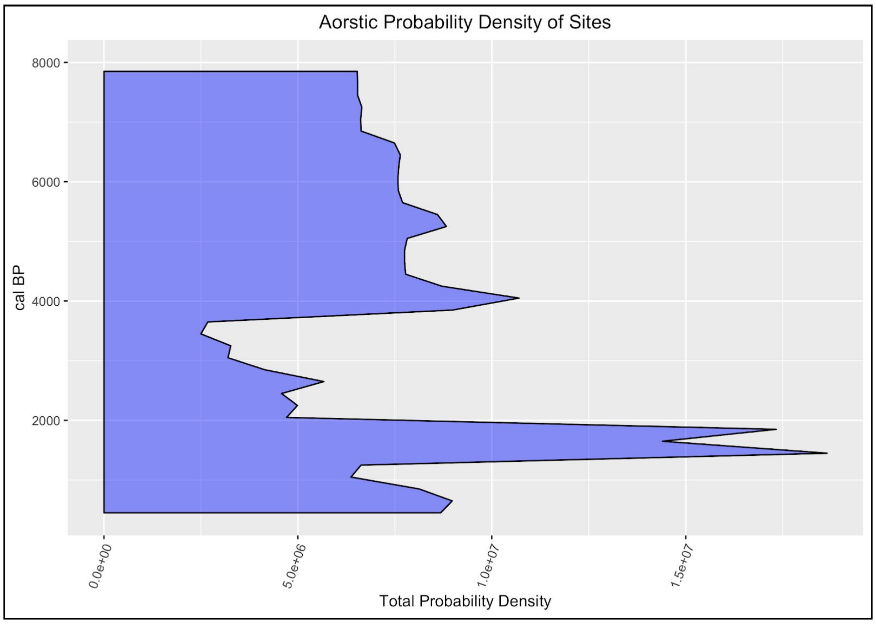


Figure Eleven - ASC results density plot

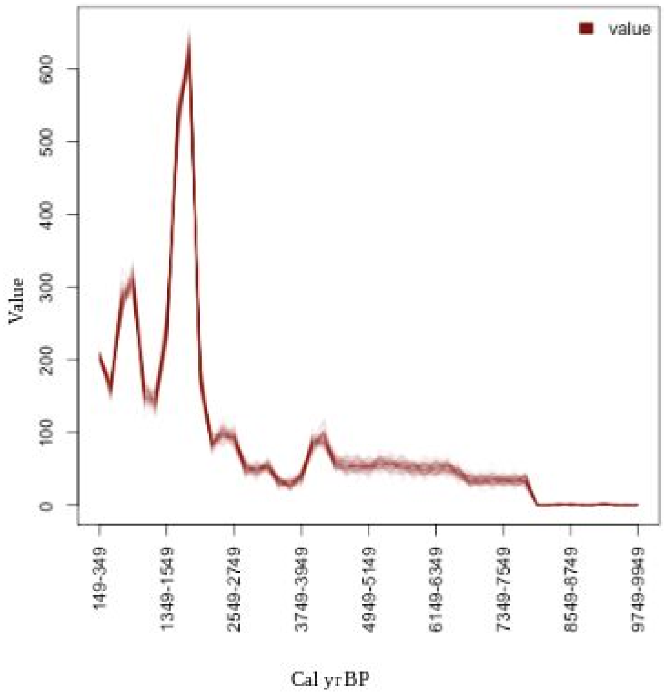


Figure Twelve - ASC monte carlo results line graph

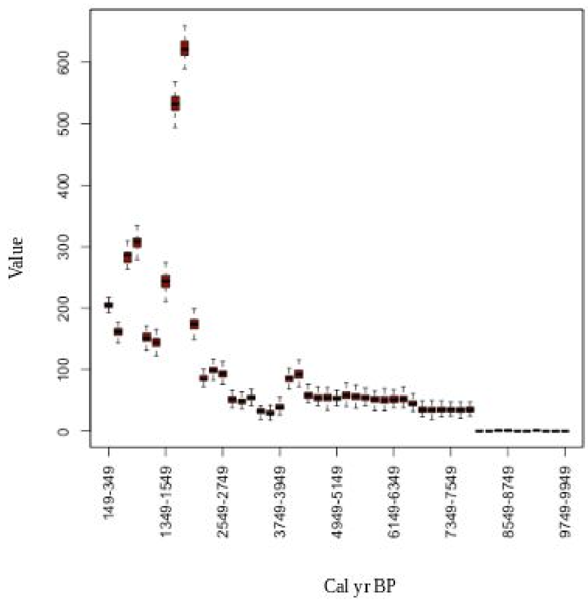


Figure Thirteen - ASC monte carlo results box plots

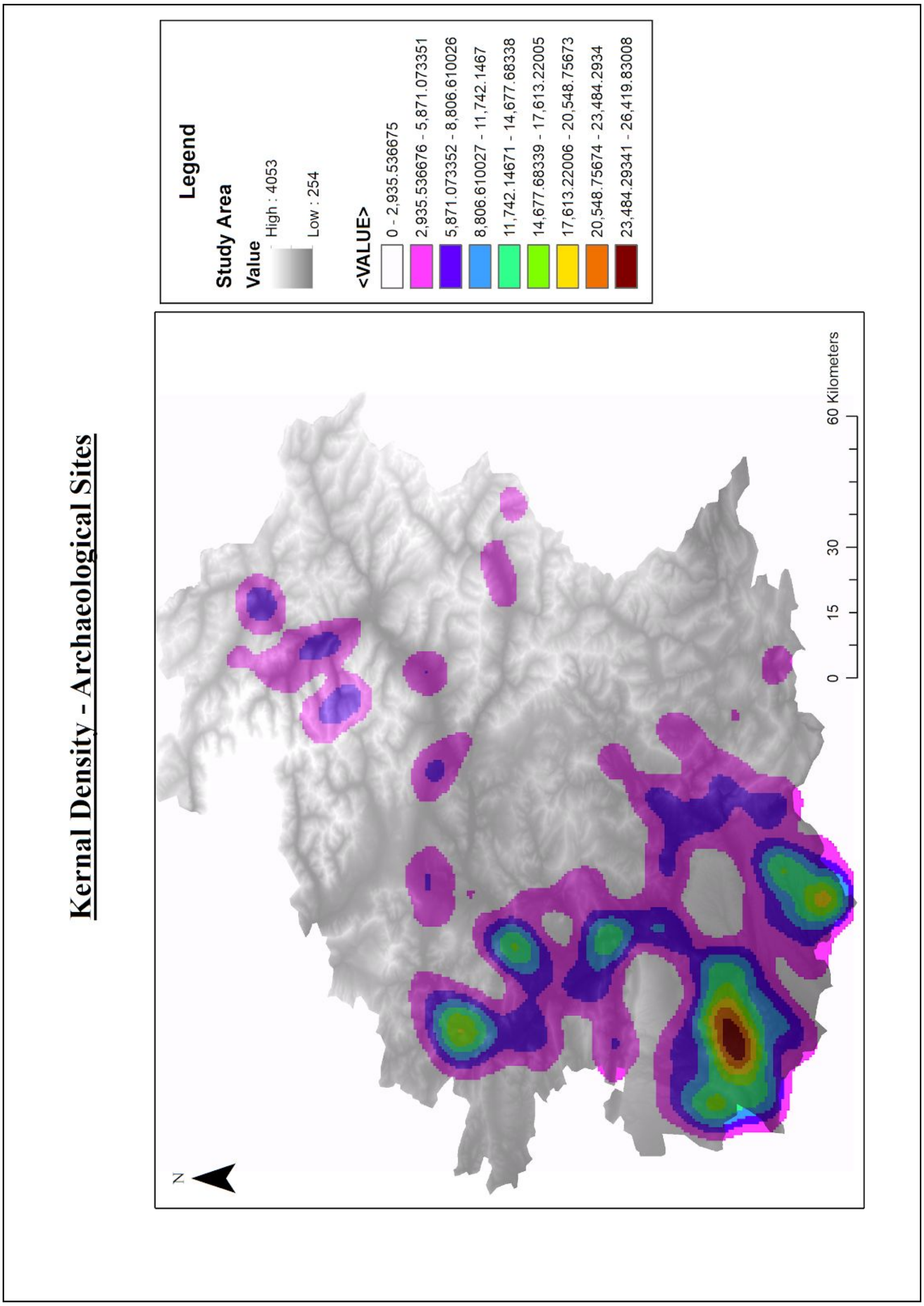


Figure Fourteen - Kernal Density map of the ASC sites against the monte carlo simulations that were run for this data, please see figures thirteen and fourteen, there seems to be a relatively wide confidence window during the Gallo-Roman period, suggesting that this spike is down to a bias in the data. Additionally, looking as the spatial density of the data, see figure fifteen, it is significantly biased towards activity in low lying areas, as a posed to the high altitude landscapes in the Ecrins

PBM Results

A visual inspection of the PBM results, please see figure sixteen, appear to highlight that there is a general trend throughout the Holocene towards a decrease in forest cover, and indeed a steady increase in open land cover categories, specifically in regards to arable/disturbed land. Indeed, there appears to be a steady decrease in forest cover throughout

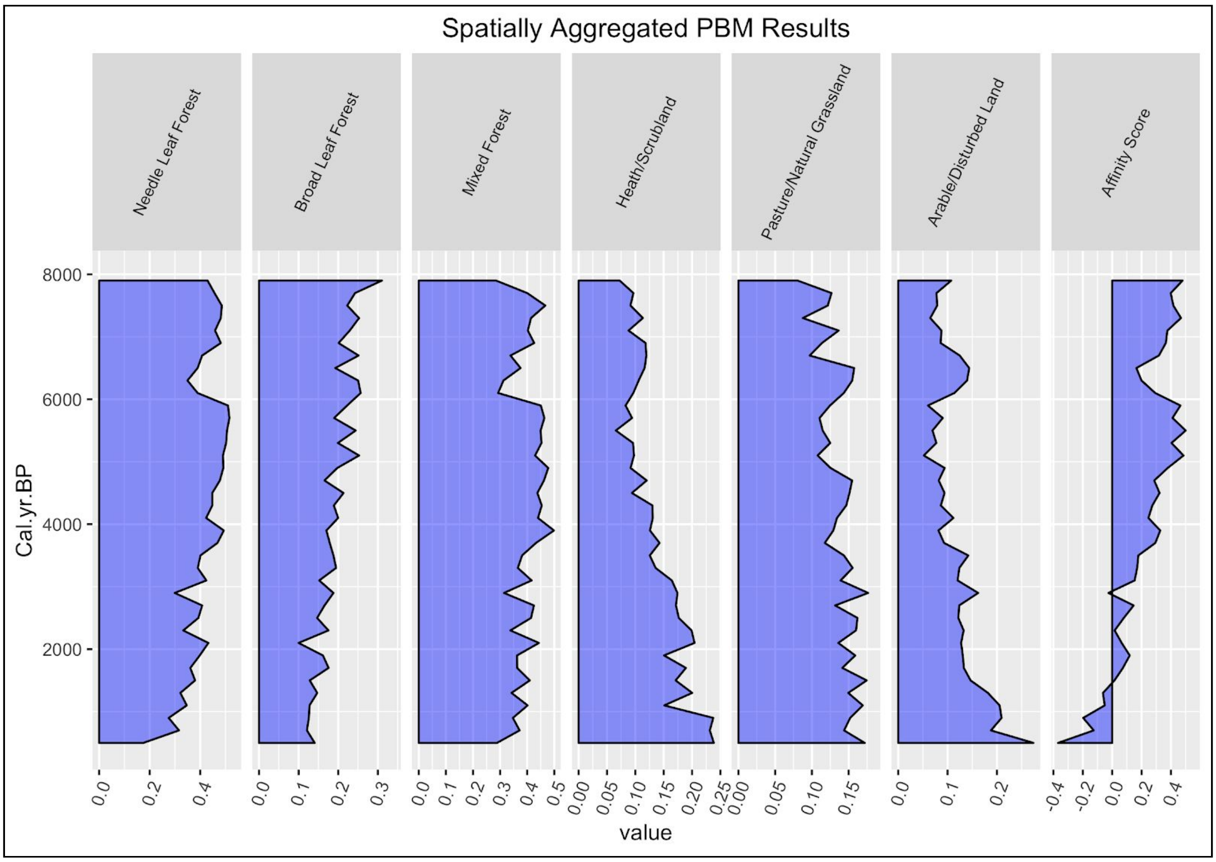


Figure Fifteen - Spatially aggregated PBM results the Neolithic into the Bronze Age, which is accompanied by a increase in needle leaf forest, as well as an increase in the affinity score, this is perhaps indicative of a drop off in human activity throughout the study during this period. The results seems to highlight that after this point there is a steady rate of deforestation, which is accelerated during the Medieval periods, which also see a dramatic increase in arable/disturbed land as well as a significantly decreasing affinity score, which may be suggestive of a marked increase in human activity during this period. However, these results must be read with a degree of caution, as it has been noted that it is in Alpine landscapes that the PBM approach has the lowest correspondence with real world land-cover.

Aggregated Results and Discussion

Overall Trends and the Ecrins National Park

Overall, the general trends highlighted from these results appear to correspond with the landscape scale interpretations from the Ecrins National Park. However, it must be reiterated that these are only first-order approximations, and that any interpretations for them beyond general trends cannot be considered valid. Moreover, although the methods used have been subject to empirical testing, they are cavetatted with the risk of confirmation bias (Crema et al. 2017, 3). Nevertheless, when the results are considered as an aggregated whole, see figure seventeen, there seems to be a good level of cross-correlation between the multiple proxies to infer that the trends themselves are very likely anthropic. Without jumping too far ahead to the discussion of the three periods that are specifically being tested, there is a correspondence within the data that suggests a growing population density having an increasingly significant impact on the on the vegetation in the study area, from predominantly forested to more open grasslands for pastoral activities. Indeed, thinking about the use of vertical space in

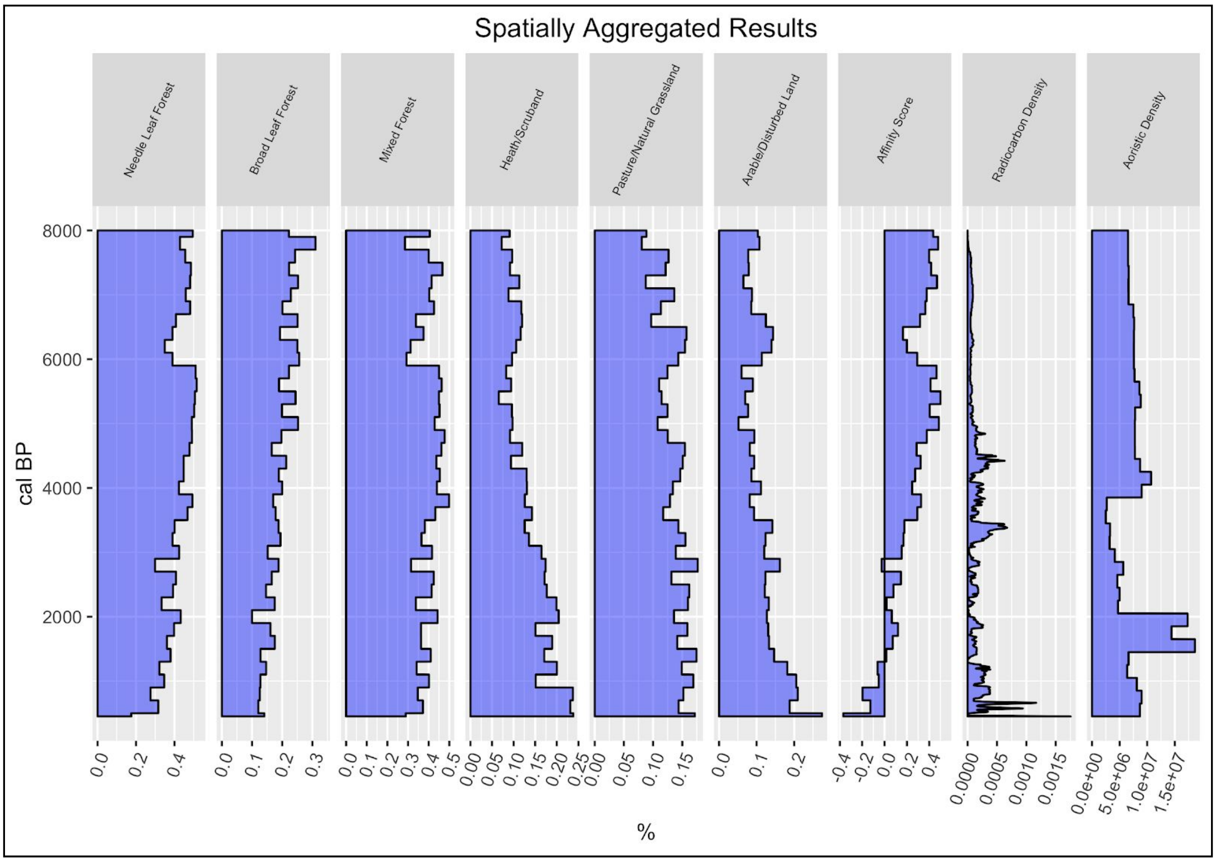


Figure Sixteen - Spatially aggregated results

mountainous landscapes (Walsh et al. 2014, 244–246), see figure eighteen, it appears that the trends seen at higher altitudes are also reflected in lower lying areas. Indeed, thinking critically about figure eighteen, when SPDs are generated for different vertical zones they are likely skewed do to the small sample size that is mostly restricted to the Ecrins, whereas the ASC results seem to indicate that there is a remarkable similarity between high and low altitudes, suggesting they were very much an integrated part of a much larger landscape. This is perhaps little surprise when put in perspective of the importance of transhumant pastoralism in the region (Walsh et al. 2014, 64).

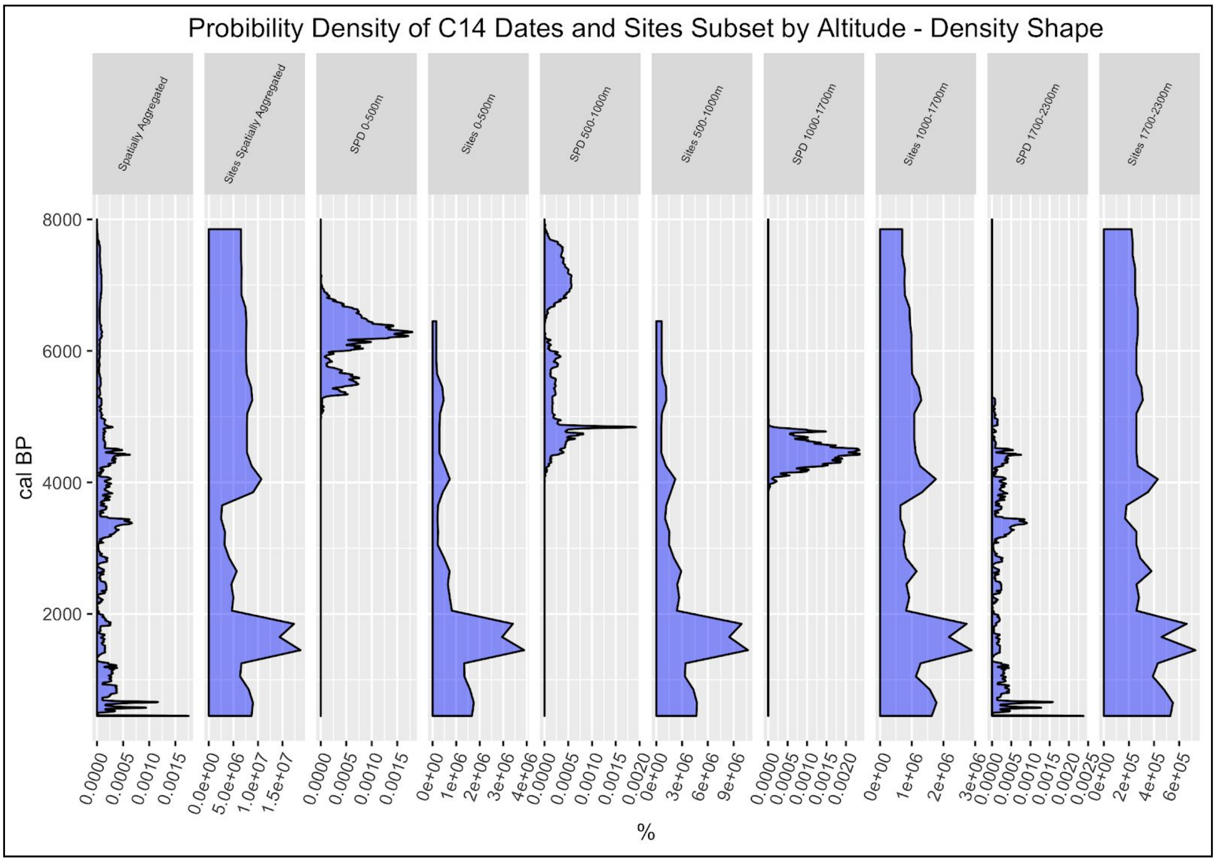


Figure Seventeen - SPD and ASC data subset by altitude

The Neolithic Transition, 4.2 ka Event, and the Little Ice Age

The following sections considers the previously discussed landscape-scale interpretation of the Neolithic transition, 4.2 ka event, and the little ice age against the result of the modelling, referring to figure seventeen.

Previous landscape-scale interpretations regarding the Neolithic transition in Ecrins National Park have highlighted the relatively modest impact this period (Walsh et al. 2014, 64), an interpretation that is echoed in the modelling results. Indeed, the evidence from the Ecrins National Park has very little in the way of archaeological evidence during this period, and changing human impacts on the environment are for the most part highlighted by episodes of burning that are been interpreted as the beginnings of landscape management, opening up areas for animals to graze (Walsh et al. 2014, 61). The result of the palaeodemograpahic proxies, SPD and ASC, appear to similarly highlight this trend across the study area, with a steady increase of population density through to the start of the Bronze Age. Additionally, this is correlated with the PBM results that highlight an overall decrease in forest cover.

With regards to the 4.2 ka event, it appears that in the Ecrins there was a negligible impact of the observable impact this had on human activities/behaviour in this area (Walsh et al. 2014, 61–65), whereas the results of the modelling appear to suggest at the very least that there was a very slight downturn in human activity across the study area. The landscape scale evidence very clearly highlights a boom of activity at high altitude in the Ecrins, with a large number of stone structures constructed, with palaeoecological evidence indicating a further opening of the landscape through the use of fire, which points towards an intensification of pastoral activity (Walsh et al. 2014, 61–64). Indeed, the SPD and ASC results both seem to indicate general increase of activity during the Bronze Age, with the PBM results also attesting to further opening of the landscape. However, there is a noticeable decline in both the SPD and ASC results around the 4200 BP mark, which although this is not confirmed in a deviation from the null model, the PBM results seem to suggest a period of reforestation, and as such a lull in human activity.

Finally, both the landscape scale interpretations, and the modelling results both appear to highlight that during the Medieval period, or moreover through the little ice age, the study area was at its busiest. In the Ecrins the little ice age seems to have no bearing on the exploitation of this high altitude landscape, where there is a boom in the number of stone structures found, as well as palaeoecological data highlighting an intensification of deforestation to support the large number of livestock being moved into the mountain in the summer months, and additionally the to support mining activity (Walsh et al. 2014, 60–71). The modelling results do not seem to contradict this interpretation, but rather support it. The SPD and ASC results seem to steadily increase through the Medieval periods, and the PBM results highlight greater deforestation across the study area, as well as a boom in the amount of arable/disturbed land there in in the study area, likely indicative of the increased presence of transhumant pastoralism.

The Efficacy of Formal Modelling to Integrate Data from different Scales

Therefore, in regards to the efficacy of this suite of formal models to integrate data from multiple scale, they are by themselves an inappropriate tool for the job. This is however not to take away from their utility, as they are first-order approximations by design. Nevertheless, this analysis has highlighted that when they are incorporated within a multiscalar framework, they can be utilized as an interesting tool to contextualise landscape-scale interpretations with their regional contexts, and thus help integrate data from multiple scales.

Chapter Four - Conclusion

To conclude, this dissertation set out to test the extent to which the application of formal modelling could elucidate our understanding of human behaviour/activities in the French Alps. Ultimately, due to the coarse-grained nature of the methodologies applied to the French Alps, SPD/ASC/PBM, it must be concluded that by themselves these models only offer a limited insight into the broad-scale trends of human behaviour/activities across the study area. However, in testing the efficacy of these methodologies as a means of helping to integrate data from multiple scales, they served as a interesting way of evaluating the validity of our landscape-scale interpretations against their regional context.

Relating this to the objectives set out in the introduction, due to the fact that the methodological approach taken was focused towards the assessment of human-environment interactions, objective one set out to think more broadly about how this topic is studied both within archaeology and its cognates. Indeed, this discussion, within section one of chapter one, set out a number of critical points that that were of significance when it can to the interpretation of the results of this dissertation, namely the complexity surrounding the integration of data from both the biophysical and social domains, and also the significant importance of scale in our analysis. This point was subsequently of great significance when it can to the interpretation of the results, as it informed a degree of methodological caution in regards to not mis-matching the scales of the methodologies used and that of the interpretations, while also highlighting the importance of a multiscalar approach to attain a more complex understanding of human behaviour/activities. Furthermore, objective two aimed to build on this discussion, by introducing key aspects of theory regarding the application of modelling, as well reviewing the methodologies used to provide robustness in the subsequent analysis. Moreover, the assessment of the contribution of modelling to our understanding of human-environment interactions served the purpose of highlighting the fact that models are not a panacea, but an analytical tool. In building up to objective three, testing the efficacy of a suite of formal models to integrate data from different scales, our current interpretations from the study area, specifically from the Ecrins National Park, were set out so they could be compared with the results of this dissertation. Furthermore, chapter two gave a detailed account of the methodological steps taken, ensuring a robust approach. Lastly, chapter three set out to answer object three, concluding that the suite of formal models applied to French Alps were a useful tool in integrating data from multiple different scale when used as a part of a multiscalar framework. Moreover, it was demonstrated that was a good level of cross-correlation between the landscape-scale interpretations of the Ecrins National Park, and the regional models employed here.

Suggestions for Further Work

Regarding suggestions for further work, there are two interesting avenues of research that may yield interesting results, the refinement of the PBM methodology, and the application of ABM. One of the limitations of the PBM as applied in dissertation was that the land cover classes used in this study were designed for the whole of Northern Europe, and it is within the Mediterranean basin and the Alpine arch that it has the lowest correspondence real world vegetation patterns (Woodbridge et al. 2014, 2018). As such, it would be interesting to follow in the stead of Lechterbeck et al (2014, 1297), in constructing land cover classes that are specific to the vegetation of the study area, much in the same way that biomes were constructed for the Eastern Mediterranean (Marinova et al. 2017, 490). Indeed, this highlight more nuanced interpretations of how human activity impacted the French Alps. Moreover, the application of ABM would be an interesting endeavour, as it may offer the opportunity to reach more fine-grain interpretations of human behaviour/activities, allowing us to experiment with why they spatial and temporal distribution of our data is the way it is.

Final Remarks

Therefore, the application of formal modelling the French Alps did to a limited extent elucidate our understanding of human behaviour/actives. Due to the coarse-grained nature of the methodology employed, the stand alone results offered only a first-order approximation of regional trends. However, when used within a multiscalar framework, these results were useful in contextualising landscape-scale interpretations with their wider context.

Bibliography

Aldred, O. (2017). Where to Go from Here: Movement and Finding the Path in the Landscape. *Landscapes*, 18 (1), Taylor & Francis., pp.88–92.

Ali, A. A. et al. (2005). Pinus cembra L.(arolla pine), a common tree in the inner French Alps since the early Holocene and above the present tree line: a synthesis based on charcoal data from soils and travertines. *Journal of biogeography*, 32 (9), Wiley Online Library., pp.1659–1669.

Allentoft, M. E. et al. (2015). Population genomics of Bronze Age Eurasia. *Nature*, 522 (7555), nature.com., pp.167–172.

Allué, E. et al. (2018). Montane pine forests in NE Iberia during MIS 3 and MIS 2. A study based on new anthracological evidence from Cova Gran (Santa Linya, Iberian Pre-Pyrenees). *Review of palaeobotany and palynology*, 258, Elsevier., pp.62–72.

Anon. (nd) DIVA-GIS webpage. Available at: http://www.diva-gis.org/gdata [accessed 22 June 2018].

Anon. (nd) USGS EarthExplorer webpage. Available at: https://earthexplorer.usgs.gov [accessed 22 June 2018].

Armit, I. et al. (2014). Rapid climate change did not cause population collapse at the end of the European Bronze Age. *Proceedings of the National Academy of Sciences of the United States of America*, 111 (48), National Acad Sciences., pp.17045–17049.

Armstrong, C. G. et al. (2017). Anthropological contributions to historical ecology: 50 questions, infinite prospects. *PloS one*, 12 (2), journals.plos.org., p.e0171883.

Arponen, V. P. J. and Ribeiro, A. (2018). Philosophy, archaeology and the Enlightenment heritage: Cartesian representationalism in applied contexts. *History of the human sciences*, 31 (3), SAGE Publications Ltd., pp.60–63.

Aston, M. (1997). *Interpreting the Landscape: Landscape Archaeology and Local History*. Psychology Press.

Axtell, R. L. et al. (2002). Population growth and collapse in a multiagent model of the Kayenta Anasazi in Long House Valley. *Proceedings of the National Academy of Sciences of the United States of America*, 99 Suppl 3, National Acad Sciences., pp.7275–7279.

Balée, W. (1998). Historical ecology: premises and postulates. *Advances in historical ecology*, Columbia University Press New York., pp.13–29.

Balée, W. (2006). The Research Program of Historical Ecology. *Annual review of anthropology*, 35 (1), annualreviews.org., pp.75–98.

Banks, W. E. (2017). The application of ecological niche modeling methods to archaeological data in order to examine culture-environment relationships and cultural trajectories. *Quaternaire. Revue de l'Association française pour l'étude du Quaternaire*, 28 (2), Association Française pour l'Étude du Quaternaire., pp.271–276.

Barnes, J. et al. (2013). Contribution of anthropology to the study of climate change. *Nature climate change*, 3, Nature Publishing Group, a division of Macmillan Publishers Limited. All Rights Reserved., p.541.

Barrett, B. J. (2018). Equifinality in empirical studies of cultural transmission. *Behavioural processes*, Elsevier. [Online]. Available at: doi:10.1016/j.beproc.2018.01.011.

Barrett, J. C. (2013). The Archaeology of Mind: its Not What You Think. *Cambridge Archaeological Journal*, 23 (1), Cambridge University Press., pp.1–17. [Accessed 9 November 2018].

Barrett, J. C. and Ko, I. (2009). A phenomenology of landscape: A crisis in British landscape archaeology? *Journal of Social Archaeology*, 9 (3), SAGE Publications., pp.275–294.

Barton, C. M. et al. (2012). Looking for the future in the past: Long-term change in socioecological systems. *Ecological modelling*, 241, Elsevier., pp.42–53.

Beiser, F. (2000). The Enlightenment and idealism. *The Cambridge companion to German idealism*, New York: Cambridge University Press., pp.18–36.

Bevan, A. (2015). The data deluge. *Antiquity*, 89 (348), Cambridge Univ Press., pp.1473–1484.

Bevan, A. et al. (2017). Holocene fluctuations in human population demonstrate repeated links to food production and climate. *Proceedings of the National Academy of Sciences of the United States of America*, 114 (49), National Acad Sciences., pp.E10524–E10531.

Bevan, A. and Conolly, J. (2006). Multiscalar Approaches to Settlement Pattern Analysis. In: Lock, G. and Molyneaux, B. L. (Eds). *Confronting Scale in Archaeology: Issues of Theory and Practice*. Boston, MA : Springer US. pp.217–234.

Bevan, A. and Lake, M. (2016). Intensities, interactions, and uncertainties: Some new approaches to archaeological distributions. In: *Computational approaches to archaeological spaces*. Routledge. pp.27–52.

Beven, K. (1996). 12 Equifinality and Uncertainty in Geomorphological Modelling. In: *The Scientific Nature of Geomorphology: Proceedings of the 27th Binghamton Symposium in Geomorphology, Held 27-29 September, 1996*. 27. 1996. John Wiley & Sons. p.289.

Beven, K. (2006). A manifesto for the equifinality thesis. *Journal of Hydrology*, 320 (1), Elsevier., pp.18–36.

Biggs, M. (1999). Putting the State on the Map: Cartography, Territory, and European State

Formation. *Comparative studies in society and history*, 41 (2), Cambridge University Press., pp.374–405. [Accessed 9 April 2018].

Binford, L. R. (1962). Archaeology as Anthropology. *American antiquity*, 28 (2), Cambridge University Press., pp.217–225. [Accessed 9 November 2018].

Binford, L. R. (1980). Willow smoke and dogs' tails: hunter-gatherer settlement systems and archaeological site formation. *American antiquity*, 45 (1), Cambridge University Press., pp.4–20.

Biondi, F. (2014). Paleoecology grand challenge. *Frontiers in Ecology and Evolution*, 2, Frontiers. [Online]. Available at: doi:10.3389/fevo.2014.00050 [Accessed 27 April 2017].

Brisset, E. et al. (2013). Non-reversible geosystem destabilisation at 4200 cal. BP: Sedimentological, geochemical and botanical markers of soil erosion recorded in a Mediterranean alpine lake. *Holocene*, 23 (12), Sage Publications Sage UK: London, England., pp.1863–1874.

Brouwer Burg, M. (2017). It must be right, GIS told me so! Questioning the infallibility of GIS as a methodological tool. *Journal of archaeological science*, 84, Elsevier., pp.115–120.

Brown, W. A. (2015). Through a filter, darkly: population size estimation, systematic error, and random error in radiocarbon-supported demographic temporal frequency analysis. *Journal of archaeological science*, 53, Elsevier., pp.133–147.

Brück, J. (2005). Experiencing the past? The development of a phenomenological archaeology in British prehistory. *Archaeological Dialogues*, 12 (1), Cambridge University Press., pp.45–72. [Accessed 6 December 2018].

Buck, C. E. and Meson, B. (2015). On being a good Bayesian. *World archaeology*, 47 (4), Taylor & Francis., pp.567–584.

Bullot, N. J., Seeley, W. P. and Davies, S. (2017). Art and Science: A Philosophical Sketch of Their Historical Complexity and Codependence. *The Journal of Aesthetics and Art Criticism*, 75 (4), Wiley Online Library., pp.453–463.

Büntgen, U. et al. (2016). Cooling and societal change during the Late Antique Little Ice Age from 536 to around 660 AD. *Nature geoscience*, 9 (3), Nature Publishing Group., pp.231–236. [Accessed 19 July 2016].

Butzer, K. W. (1982). *Archaeology as Human Ecology: Method and Theory for a Contextual Approach*. Cambridge University Press.

Butzer, K. W. (2008). Challenges for a cross-disciplinary geoarchaeology: The intersection between environmental history and geomorphology. *Geomorphology* , 101 (1), Elsevier., pp.402–411.

Carrer, F. (2013). An ethnoarchaeological inductive model for predicting archaeological site location: A case-study of pastoral settlement patterns in the Val di Fiemme and Val di Sole (Trentino, Italian Alps). *Journal of Anthropological Archaeology*, 32 (1), pp.54–62.

Carrer, F. (2015). Herding Strategies, Dairy Economy and Seasonal Sites in the Southern Alps: Ethnoarchaeological Inferences and Archaeological Implications. *Journal of Mediterranean Archaeology*, 28 (1), equinoxpub.com., pp.3–22. [Accessed 1 December 2015].

Carrer, F. et al. (2016). Chemical Analysis of Pottery Demonstrates Prehistoric Origin for High-Altitude Alpine Dairying. *PloS one*, 11 (4), journals.plos.org., p.e0151442.

Carrer, F. and Angelucci, D. E. (2017). Continuity and discontinuity in the history of upland pastoral landscapes: the case study of Val Molinac and Val Poré (Val di Sole, Trentino, Eastern Italian Alps). *Landscape Research*, Routledge., pp.1–16.

Carrott, J. and Kenward, H. (2001). Species Associations Among Insect Remains from Urban Archaeological Deposits and their Significance in Reconstructing the Past Human Environment. *Journal of archaeological science*, 28 (8), Elsevier., pp.887–905.

Cartier, R. et al. (2015). 5000 years of lacustrine ecosystem changes from Lake Petit (Southern Alps, 2200 m asl): Regime shift and resilience of algal communities. *Holocene*, 25 (8), Sage Publications Sage UK: London, England., pp.1231–1245.

Cartier, R. et al. (2018). Multiproxy analyses of Lake Allos reveal synchronicity and divergence in geosystem dynamics during the Lateglacial/Holocene in the Alps. *Quaternary science reviews*, 186, Elsevier., pp.60–77.

Caseldine, C., Fyfe, R. and Hjelle, K. (2008). Pollen modelling, palaeoecology and archaeology: virtualisation and/or visualisation of the past? *Vegetation history and archaeobotany*, 17 (5), pp.543–549.

Castree, N. (2001). Socializing nature: Theory, practice, and politics. *Social nature: Theory, practice, and politics*, Blackwell Malden, MA., pp.1–21.

Castree, N. (2003). Environmental issues: relational ontologies and hybrid politics. *Progress in human geography*, 27 (2), SAGE Publications Ltd., pp.203–211.

Chilton, E. S. (2014). Plus ça change: From Postprocessualism to 'Big Data'. *Current Swedish Archaeology*, 22, scholarworks.umass.edu. [Online]. Available at: https://scholarworks.umass.edu/cgi/viewcontent.cgi?article=1344&context=anthro_faculty_pubs.

Chin, A. et al. (2016). An evolving Anthropocene for science and society. *Anthropocene*, 13, researchgate.net. [Online]. Available at: doi:10.1016/j.ancene.2016.05.002 [Accessed 8 December 2018].

Chliaoutakis, A. and Chalkiadakis, G. (2016). Agent-based modeling of ancient societies and their organization structure. *Autonomous agents and multi-agent systems*, 30 (6), Springer US., pp.1072–1116. [Accessed 7 September 2017].

Clarke, D. (1973). Archaeology: the loss of innocence. *Antiquity*, 47 (185), J. Bellows., p.6.

Clarke, D. L. (1972). *Models in Archaeology*. Routledge.

Clarke, D. L. (2014). *Analytical archaeology*. Routledge.

Cleary, M. C. and Smith, C. D. (1990). Transhumance reviewed: past and present practices in France and Italy. *Rivista di studi liguri*, (56), Istituto Internazionale di Studi Liguri., pp.21–38.

Collard, M. et al. (2010). Radiocarbon evidence indicates that migrants introduced farming to Britain. *Journal of archaeological science*, 37 (4), Elsevier., pp.866–870.

Collins, P. M., Davis, B. A. S. and Kaplan, J. O. (2012). The mid-Holocene vegetation of the Mediterranean region and southern Europe, and comparison with the present day. *Journal of biogeography*, 39 (10), Wiley Online Library., pp.1848–1861.

Conolly, J. and Lake, M. (2006). *Geographical information systems in archaeology*. Cambridge University Press.

Contreras, D. et al. (2018a). Reaching the human scale: A spatial and temporal downscaling approach to the archaeological implications of paleoclimate data. *Journal of archaeological science*, 93, Elsevier., pp.54–67.

Contreras, D. A. et al. (2018b). Regional paleoclimates and local consequences: Integrating GIS analysis of diachronic settlement patterns and process-based agroecosystem modeling of potential agricultural productivity in Provence (France). *PloS one*, 13 (12), Public Library of Science., p.e0207622.

Contreras, D. A. and Meadows, J. (2014). Summed radiocarbon calibrations as a population proxy: a critical evaluation using a realistic simulation approach. *Journal of archaeological science*, 52, Elsevier., pp.591–608.

Coombes, P. and Barber, K. (2005). Environmental determinism in Holocene research: causality or coincidence? *Area*, 37 (3), Blackwell Publishing, Ltd., pp.303–311.

Corlett, R. T. (2015). The Anthropocene concept in ecology and conservation. *Trends in ecology & evolution*, 30 (1), Elsevier., pp.36–41.

Court-Picon, M., Buttler, A. and de Beaulieu, J.-L. (2005). Modern pollen–vegetation relationships in the Champsaur valley (French Alps) and their potential in the interpretation of fossil pollen records of past cultural landscapes. *Review of palaeobotany and palynology*, 135 (1–2), pp.13–39.

Court-Picon, M., Buttler, A. and de Beaulieu, J.-L. (2006). Modern pollen/vegetation/land-use relationships in mountain environments: an example from the Champsaur valley (French Alps). *Vegetation history and archaeobotany*, 15 (3), Springer-Verlag., pp.151–168. [Accessed 25 November 2015].

Cowgill, G. L. (1967). Computer Applications in Archaeology. In: *Proceedings of the November 14-16, 1967, Fall Joint Computer Conference*. AFIPS '67 (Fall). 1967. New York, NY, USA : ACM. pp.331–337.

Crema, E. R. (2008). Aoristic approaches and voxel models for spatial analysis. In: *On the road to reconstructing the past. In Proceedings of the 36th annual conference on computer* *applications and quantitative methods in archaeology. Budapest: Archeolingua*. 2008. publikationen.uni-tuebingen.de. [Online]. Available at: https://publikationen.uni-tuebingen.de/xmlui/bitstream/handle/10900/60687/CD12_Crema_CAA2008.pdf?sequence=2.

Crema, E. R. (2012). Modelling Temporal Uncertainty in Archaeological Analysis. *Journal of Archaeological Method and Theory*, 19 (3), Springer., pp.440–461.

Crema, E. R. et al. (2016). Summed Probability Distribution of 14C Dates Suggests Regional Divergences in the Population Dynamics of the Jomon Period in Eastern Japan. *PloS one*, 11 (4), journals.plos.org., p.e0154809.

Crema, E. R. (2018). STATISTICAL INFERENCE AND ARCHAEOLOGICAL SIMULATIONS. *SAA Archaeological Record*, researchgate.net. [Online]. Available at: https://www.researchgate.net/profile/Enrico_Crema/publication/324757058_Statistical_Inference_and_Archaeological_Simulations/links/5ae0ad33a6fdcc91399eba29/Statistical-Inference-and-Archaeological-Simulations.pdf.

Crema, E. R., Bevan, A. and Lake, M. W. (2010). A probabilistic framework for assessing spatio-temporal point patterns in the archaeological record. *Journal of archaeological science*, 37 (5), Elsevier., pp.1118–1130.

Crema, E. R., Bevan, A. and Shennan, S. (2017). Spatio-temporal approaches to archaeological radiocarbon dates. *Journal of archaeological science*, 87 (Supplement C), pp.1–9.

Crema, E. R., Kandler, A. and Shennan, S. (2016). Revealing patterns of cultural transmission from frequency data: equilibrium and non-equilibrium assumptions. *Scientific reports*, 6, nature.com., p.39122.

Crist, E. (2004). Against the Social Construction of Nature and Wilderness. *Environmental ethics*, 26 (1), pdcnet.org., pp.5–24. [Accessed 6 November 2018].

Crumley, C. (2016). *Oxford Handbooks Online*. academia.edu. [Online]. Available at: http://www.academia.edu/download/41545744/New_Paths_into_the_Anthropocene--published.pdf.

Crutzen, P. J. (2006). The ‘Anthropocene’. In: Ehlers, E. and Krafft, T. (Eds). *Earth System Science in the Anthropocene*. Berlin, Heidelberg : Springer Berlin Heidelberg. pp.13–18.

Cumming, G., Cumming, D. H. M. and Redman, C. (2006). Scale mismatches in social-ecological systems: causes, consequences, and solutions. *Ecology and Society*, 11 (1), The Resilience Alliance. [Online]. Available at: http://www.ecologyandsociety.org/vol11/iss1/art14/main.html.

Cummings, V., Jones, A. and Watson, A. (2002). Divided Places: Phenomenology and Asymmetry in the Monuments of the Black Mountains, Southeast Wales. *Cambridge Archaeological Journal*, 12 (1), Cambridge University Press., pp.57–70. [Accessed 6 December 2018].

Davis, B. et al. (2013). The European modern pollen database (EMPD) project. *Vegetation history and archaeobotany*, Springer. [Online]. Available at: http://link.springer.com/article/10.1007/s00334-012-0388-5.

Dean, J. S. et al. (2000). Understanding Anasazi culture change through agent-based modeling. *Dynamics in human and primate societies: Agent-based modeling of social and spatial processes*, Oxford: Oxford University Press., pp.179–205.

Demeritt, D. (1996). Social Theory and the Reconstruction of Science and Geography. *Transactions of the Institute of British Geographers*, 21 (3), [Royal Geographical Society (with the Institute of British Geographers), Wiley]., pp.484–503.

Demeritt, D. (2001). Being constructive about nature. *Social nature: Theory, practice, and politics*, Blackwell Oxford., pp.22–40.

Demeritt, D. (2002). What is the 'social construction of nature'? A typology and sympathetic critique. *Progress in human geography*, 26 (6), Sage Publications Sage CA: Thousand Oaks, CA., pp.767–790.

Denevan, W. M. (2011). THE 'PRISTINE MYTH' REVISITED. *Geographical review*, 101 (4), Wiley Online Library., pp.576–591.

van Dommelen, P. (2014). Moving On: Archaeological Perspectives on Mobility and Migration. *World archaeology*, 46 (4), Routledge., pp.477–483.

Doran, J. (1970). Systems theory, computer simulations and archaeology. *World archaeology*, 1 (3), Routledge., pp.289–298.

Edinborough, K. et al. (2017). Radiocarbon test for demographic events in written and oral history. *Proceedings of the National Academy of Sciences of the United States of America*, 114 (47), National Acad Sciences., pp.12436–12441.

Edmonds, M. (2006). Who Said Romance Was Dead? *Journal of Material Culture*, 11 (1-2), SAGE Publications Ltd., pp.167–188.

Edney, M. H. (1996). Theory and the history of cartography. *Imago mundi*, 48 (1), Routledge., pp.185–191.

Edwards, K. J. et al. (2015). Moving forwards? Palynology and the human dimension. *Journal of archaeological science*, 56, Elsevier., pp.117–132.

Edwards, T. et al. (2017). Visualising scales of process: Multi-scalar geoarchaeological investigations of microstratigraphy and diagenesis at hominin bearing sites in South African karst. *Journal of archaeological science*, 83, Elsevier., pp.1–11.

Erickson, C. L. (2008). Amazonia: The Historical Ecology of a Domesticated Landscape. In: Silverman, H. and Isbell, W. H. (Eds). *The Handbook of South American Archaeology*. New York, NY : Springer New York. pp.157–183.

Evans, J. G. and O'Connor, T. P. (1999). *Environmental archaeology: principles and* *methods*. Sutton Pub Limited.

Fitzhugh, B. et al. (2018). Human ecodynamics: A perspective for the study of long-term change in socioecological systems. *Journal of Archaeological Science: Reports*, Elsevier. [Online]. Available at: doi:10.1016/j.jasrep.2018.03.016.

Fleming, A. (2006). Post-processual landscape archaeology: a critique. *Cambridge Archaeological Journal*, 16 (03), Cambridge Univ Press., pp.267–280.

Folke, C. et al. (2002). Resilience and sustainable development: building adaptive capacity in a world of transformations. *Ambio*, 31 (5), BioOne., pp.437–440.

Fouinat, L. et al. (2018). Wet avalanches: long-term evolution in the Western Alps under climate and human forcing. *Climate of the Past*, 14 (9), search.ebscohost.com. [Online]. Available at: http://search.ebscohost.com/login.aspx?direct=true&profile=ehost&scope=site&authtype=crawler&jrnl=18149324&AN=132128520&h=j%2FdBYpiDjq7rmhKD7hFBGrMfGOUBzsa20s2aLLnJcGykHz9aKHsh7IJ4Mp5MbHgeSelZQVMLZK6Jdfd%2B2g%2F2cA%3D%3D&crl=c.

Freeman, J. et al. (2018). Culture Process and the Interpretation of Radiocarbon Data. *Radiocarbon*, 60 (2), Cambridge University Press., pp.453–467. [Accessed 13 September 2018].

Fyfe, R. M., Woodbridge, J. and Roberts, N. (2015). From forest to farmland: pollen-inferred land cover change across Europe using the pseudobiomization approach. *Global change biology*, 21 (3), Wiley Online Library., pp.1197–1212.

Fyfe, R., Roberts, N. and Woodbridge, J. (2010). A pollen-based pseudobiomisation approach to anthropogenic land-cover change. *Holocene*, 20 (7), SAGE Publications Ltd., pp.1165–1171.

Gaffney, V. and Van Leusen, M. (1995). Postscript-GIS, environmental determinism and archaeology: a parallel text. *Archaeology and geographical information systems: a European perspective*, pp.367–382.

Gamble, C. et al. (2005). The archaeological and genetic foundations of the European population during the Late Glacial: implications for ‘agricultural thinking’. *Cambridge Archaeological Journal*, 15 (2), Cambridge University Press., pp.193–223.

Giguet-Covex, C. et al. (2014). Long livestock farming history and human landscape shaping revealed by lake sediment DNA. *Nature communications*, 5, nature.com., p.3211.

Gizicki-Neundlinger, M. et al. (2017). *Land, food and labour in pre-industrial agro-ecosystems: a socio-ecological perspective on early 19th century seigneurial systems*. Sociedad Española de Historia Agraria (SEHA). [Online]. Available at: http://repositori.uji.es/xmlui/handle/10234/166639.

Graham, S. and Weingart, S. (2015). The Equifinality of Archaeological Networks: an Agent-Based Exploratory Lab Approach. *Journal of Archaeological Method and Theory*, 22

(1), Springer., pp.248–274.

Grande, S. M. A. (1999). Beyond the ecologically noble savage: Deconstructing the White man's Indian. *Environmental ethics*, 21 (3), pdcnet.org., pp.307–320.

Green, C. et al. (2017). Understanding the Spatial Patterning of English Archaeology: Modelling Mass Data, 1500 BC to AD 1086. *Archaeological Journal*, 174 (1), Routledge., pp.244–280.

Greenfield, H. J. (2010). The Secondary Products Revolution: the past, the present and the future. *World archaeology*, 42 (1), Taylor & Francis., pp.29–54.

Griffiths, S. (2017). We're All Cultural Historians Now: Revolutions In Understanding Archaeological Theory And Scientific Dating. *Radiocarbon*, 59 (5), Cambridge University Press., pp.1347–1357.

Grimm, V. and Railsback, S. F. (2005). *Individual-based modeling and ecology*. BioOne.

Gronenborn, D., Strien, H.-C. and Lemmen, C. (2017). Population dynamics, social resilience strategies, and Adaptive Cycles in early farming societies of SW Central Europe. *Quaternary international: the journal of the International Union for Quaternary Research*, 446, Elsevier., pp.54–65.

d'Alpoim Guedes, J. A. et al. (2016). Twenty-first century approaches to ancient problems: Climate and society. *Proceedings of the National Academy of Sciences*, 113 (51), National Acad Sciences., pp.14483–14491.

Haila, Y. (2000). Beyond the Nature-Culture Dualism. *Biology and Philosophy*, 15 (2), Springer., pp.155–175.

Harley, J. B. (1988). Silences and secrecy: The hidden agenda of cartography in early modern Europe. *Imago mundi*, 40 (1), Routledge., pp.57–76.

Harley, J. B. (1989). DECONSTRUCTING THE MAP. *Cartographica: The International Journal for Geographic Information and Geovisualization*, 26 (2), University of Toronto Press., pp.1–20.

Harris, O. J. T. (2017). Assemblages and Scale in Archaeology. *Cambridge Archaeological Journal*, 27 (1), Cambridge University Press., pp.127–139. [Accessed 14 December 2018].

Haughton, N. (2004). Perceptions of beauty in Renaissance art. *Journal of cosmetic dermatology*, 3 (4), Wiley Online Library., pp.229–233.

Head, L. and Regnell, J. (2012). *Nature, culture and time: contested landscapes among environmental managers in Skane, southern Sweden*. ro.uow.edu.au., p.221. [Accessed 31 May 2018].

Hendy, J. et al. (2018). Proteomic evidence of dietary sources in ancient dental calculus. *Proceedings. Biological sciences / The Royal Society*, 285 (1883), ncbi.nlm.nih.gov. [Online]. Available at: doi:10.1098/rspb.2018.0977.

Henton, E. et al. (2018). The Seasonal Mobility of Prehistoric Gazelle Herds in the Azraq Basin, Jordan: Modelling Alternative Strategies Using Stable Isotopes. *Environmental Archaeology*, 23 (2), Routledge., pp.187–199.

Hjelle, K. L. and Sugita, S. (2012). Estimating pollen productivity and relevant source area of pollen using lake sediments in Norway: How does lake size variation affect the estimates? *Holocene*, 22 (3), SAGE Publications Ltd., pp.313–324.

Hodder, I. (1991). Interpretive Archaeology and Its Role. *American antiquity*, 56 (1), Cambridge University Press., pp.7–18. [Accessed 9 July 2018].

Hodder, I. and Shanks, M. (2007). Processual, postprocessual and interpretive archaeologies. In: *Museums in the material world*. Routledge. pp.162–183.

Hofman, C. A. et al. (2015). Conservation archaeogenomics: ancient DNA and biodiversity in the Anthropocene. *Trends in ecology & evolution*, 30 (9), Elsevier., pp.540–549.

Hornborg, A. and Crumley, C. L. (2007). *The World System and the Earth System: GLOBAL SOCIOENVIRONMENTAL CHANGE AND SUSTAINABILITY SINCE THE NEOLITHIC*. Left Coast Press.

Howey, M. C. L. and Brouwer Burg, M. (2017). Assessing the state of archaeological GIS research: Unbinding analyses of past landscapes. *Journal of archaeological science*, 84 (Supplement C), Elsevier., pp.1–9.

Hughes, R. et al. (2018). Quantifying Land Use in Past Societies from Cultural Practice and Archaeological Data. *Land*, 7 (1), Multidisciplinary Digital Publishing Institute., p.9. [Accessed 30 December 2018].

Hulme, M. (2011). Reducing the Future to Climate: A Story of Climate Determinism and Reductionism. *Osiris*, 26 (1), [Saint Catherines Press, University of Chicago Press, History of Science Society]., pp.245–266.

Huvila, I. (2014). Be informed of your information. *Current Swedish Archaeology*, 22, arkeologiskasamfundet.se., pp.48–51.

Isendahl, C. (2016). Historical ecology coming of age. *Reviews in Anthropology*, 45 (3-4), Taylor & Francis., pp.127–147.

Izdebski, A. et al. (2016). Realising consilience: How better communication between archaeologists, historians and natural scientists can transform the study of past climate change in the Mediterranean. *Quaternary science reviews*, 136, pp.5–22.

Jackson, R. C., Dugmore, A. J. and Riede, F. (2018). Rediscovering lessons of adaptation from the past. *Global environmental change: human and policy dimensions*, 52, Elsevier., pp.58–65.

Jiménez Fernández-Palacios, B., Morabito, D. and Remondino, F. (2017). Access to complex reality-based 3D models using virtual reality solutions. *Journal of cultural heritage*, 23, Elsevier., pp.40–48.

Johnson, I. (2004). Aoristic analysis: seeds of a new approach to mapping archaeological distributions through time. *BAR INTERNATIONAL SERIES*, 1227, TEMPUS REPARATSM., pp.448–452.

Johnson, M. (2008). *Ideas of Landscape*. John Wiley & Sons.

Johnson, M. (2011). *Archaeological theory: an introduction*. John Wiley & Sons.

Johnson, M. H. (2015). The goals of archaeology, in theory: What are we trying to do? *Current Swedish Archaeology*, 23, Svenska Arkeologiska Samfundet, Goteborgs universitet., pp.61–65.

Jones, S. (2005). Transhumance Re-Examined. *The journal of the Royal Anthropological Institute*, 11 (2), [Wiley, Royal Anthropological Institute of Great Britain and Ireland]., pp.357–359.

Kaplan, J. O. et al. (2017). Constraining the Deforestation History of Europe: Evaluation of Historical Land Use Scenarios with Pollen-Based Land Cover Reconstructions. *Land*, 6 (4), Multidisciplinary Digital Publishing Institute., p.91. [Accessed 17 January 2018].

Keisler, H. J. and Chang, C.-C. (1990). *Model theory*. North-Holland Amsterdam.

Kenward, H. K. (1975a). Pitfalls in the environmental interpretation of insect death assemblages. *Journal of archaeological science*, 2 (2), Elsevier., pp.85–94.

Kenward, H. K. (1975b). The biological and archaeological implications of the beetle Aglenus brunneus (Gyllenhal) in ancient faunas. *Journal of archaeological science*, 2 (1), Elsevier., pp.63–69.

Kidner, D. W. (2000). Fabricating Nature: A Critique of the Social Construction of Nature. *Environmental ethics*, 22 (4), pdcnet.org., pp.339–357. [Accessed 6 November 2018].

Kintigh, K. W. et al. (2014). Grand challenges for archaeology. *Proceedings of the National Academy of Sciences of the United States of America*, 111 (3), National Acad Sciences., pp.879–880.

Kitchin, R. and Dodge, M. (2007). Rethinking maps. *Progress in human geography*, 31 (3), SAGE Publications Ltd., pp.331–344.

Kitchin, R., Gleeson, J. and Dodge, M. (2013). Unfolding mapping practices: a new epistemology for cartography. *Transactions of the Institute of British Geographers*, 38 (3), Wiley Online Library., pp.480–496.

Klein, J. (2002). *Social Constructivism and Environmental Problems-Epistemological challenges*. brage.bibsys.no. [Online]. Available at: https://brage.bibsys.no/xmlui/handle/11250/285770.

Kohler, T. A. et al. (2000). Be there then: A modeling approach to settlement determinants and spatial efficiency among late ancestral Pueblo populations of the Mesa Verde region, US Southwest. *Dynamics in human and primate societies: Agent-based modeling of social and* *spatial processes*, New York: Oxford Univ. Press., pp.145–178.

Kohler, T. A., Gumerman, G. J. and Reynolds, R. G. (2005). Simulating ancient societies. *Scientific American*, 293 (1), JSTOR., pp.76–82, 84.

Kohler, T. A. and van der Leeuw, S. E. (2007). *The Model-based Archaeology of Socionatural Systems*. School for Advanced Research Press.

Kohl, P. L. (1998). Nationalism and archaeology: on the constructions of nations and the reconstructions of the remote past. *Annual review of anthropology*, 27 (1), Annual Reviews 4139 El Camino Way, PO Box 10139, Palo Alto, CA 94303-0139, USA., pp.223–246.

Krishna, S. (1994). Cartographic Anxiety: Mapping the Body Politic in India. *Alternatives to laboratory animals: ATLA*, 19 (4), SAGE Publications Inc., pp.507–521.

Kristiansen, K. (2014). TOWARDS A NEW PARADIGM? *The Third Science Revolution and its Possible Consequences in Archaeology. I Current Swedish Archaeology*, 22, academia.edu., pp.11–34.

Kristiansen, K. (2017). The Nature of Archaeological Knowledge and Its Ontological Turns. *Norwegian Archaeological Review*, 50 (2), Routledge., pp.120–123.

Lake, M. W. (2013). Trends in Archaeological Simulation. *Journal of Archaeological Method and Theory*, 21 (2), Springer US., pp.258–287. [Accessed 15 July 2016].

Lake, M. W. (2015). Explaining the Past with ABM: On Modelling Philosophy. In: Wurzer, G., Kowarik, K. and Reschreiter, H. (Eds). *Agent-based Modeling and Simulation in Archaeology*. Advances in Geographic Information Science. Springer International Publishing. pp.3–35. [Accessed 18 July 2016].

Leary, J. (2014). *Past Mobilities: Archaeological Approaches to Movement and Mobility*. Ashgate Publishing, Ltd.

Leary, J. and Kador, T. (2016). *Moving on in Neolithic Studies: Understanding Mobile Lives*. Oxbow Books.

Lechterbeck, J. et al. (2014). Is Neolithic land use correlated with demography? An evaluation of pollen-derived land cover and radiocarbon-inferred demographic change from Central Europe. *Holocene*. [Online]. Available at: doi:10.1177/0959683614540952.

Leeuw, S. E. V. D. (2004). WHY MODEL? *Cybernetics and systems*, 35 (2-3), Taylor & Francis., pp.117–128.

van der Leeuw, S. and Redman, C. L. (2002). Placing Archaeology at the Center of Socio-Natural Studies. *American antiquity*, 67 (4), Society for American Archaeology., pp.597–605.

Lintusaari, J. et al. (2017). Fundamentals and Recent Developments in Approximate Bayesian Computation. *Systematic biology*, 66 (1), academic.oup.com., pp.e66–e82.

Liu, J. et al. (2007). Complexity of coupled human and natural systems. *Science*, 317 (5844), science.sciencemag.org., pp.1513–1516.

Livingstone, D. N. (2012). Changing climate, human evolution, and the revival of environmental determinism. *Bulletin of the history of medicine*, 86 (4), JSTOR., pp.564–595.

Lock, G. R. (2003). *Using computers in archaeology: towards virtual pasts*. books.google.com. [Online]. Available at: https://books.google.co.uk/books?hl=en&lr=&id=6NYeSYNfeK0C&oi=fnd&pg=PR9&dq=using+computers+in+archaeology+Lock&ots=yv3aO2z3Ih&sig=sWFtTB2mzMaPXuntYTbMxA3c0rk.

Lucas, G. (2015). The mobility of theory. *Current Swedish Archaeology*, arkeologiskasamfundet.se. [Online]. Available at: http://www.arkeologiskasamfundet.se/csa/Dokument/Volumes/csa_vol_23_2015/csa_vol_23_2015_s13-32_lucas.pdf.

Luterbacher, J. et al. (2016). European summer temperatures since Roman times. *Environmental research letters: ERL [Web site]*, 11 (2), IOP Publishing., p.024001. [Accessed 8 December 2018].

Lycett, S. J. and Shennan, S. J. (2018). David Clarke's Analytical Archaeology at 50. *World archaeology*, Taylor & Francis., pp.1–11.

Lyman, R. L. (2004). The Concept of Equifinality in Taphonomy. *Journal of Taphonomy*, 2 (1), journaltaphonomy.com., pp.15–26.

Macal, C. M. (2016). Everything you need to know about agent-based modelling and simulation. *Journal of Simulation*, 10 (2), Palgrave Macmillan UK., pp.144–156. [Accessed 20 July 2016].

Madella, M. et al. (2014). Introduction to simulating the past. *Journal of Archaeological Method and Theory*, 21 (2), Springer Science & Business Media., p.251.

Magny, M. et al. (2009a). Possible complexity of the climatic event around 4300—3800 cal. BP in the central and western Mediterranean. *Holocene*, 19 (6), pp.823–833.

Magny, M. et al. (2009b). Quantitative reconstruction of climatic variations during the Bronze and early Iron ages based on pollen and lake-level data in the NW Alps, France. *Quaternary international: the journal of the International Union for Quaternary Research*, 200 (1–2), pp.102–110.

Malone, C. and Stoddart, S. (1998). Special section David Clarke's 'Archaeology: the loss of innocence'(1973) 25 years after. *Antiquity*, 72 (277), Cambridge University Press., pp.676–677.

Manning, K. et al. (2016). The cultural evolution of Neolithic Europe. EUROEVOL dataset 1: Sites, phases and radiocarbon data. *Journal of Open Archaeology Data*, 5, Ubiquity Press. [Online]. Available at: https://openarchaeologydata.metajnl.com/article/10.5334/joad.40/.

Markman, A. B. (2013). *Knowledge Representation*. Psychology Press.

Markman, A. B. and Dietrich, E. (2000/3). In Defense of Representation. *Cognitive psychology*, 40 (2), Elsevier., pp.138–171.

Markman, A. B. and Dietrich, E. (2000). Extending the classical view of representation. *Trends in cognitive sciences*, 4 (12), Elsevier., pp.470–475.

Marinova, E., Harrison, S.P., Bragg, F., Connor, S., De Laet, V., Leroy, S.A., Mudie, P., Atanassova, J., Bozilova, E., Caner, H. and Cordova, C., (2018). Pollen‐derived biomes in the Eastern Mediterranean–Black Sea–Caspian‐Corridor. *Journal of biogeography*, 45(2), pp.484-499.

Masson, S. (2007). Romanticism. In: *The Oxford Handbook of English Literature and Theology*. oxfordhandbooks.com.

Matthews, J. A. and Briffa, K. R. (2005). The 'Little Ice Age': re-evaluation of an evolving concept. *Geografiska Annaler: Series A, Physical Geography*, 87 (1), Taylor & Francis., pp.17–36.

McGlade, J. (1981). SYSTEMS AND SIMULACRA: MODELLING, SIMULATION AND ARCHAEOLOGICAL INTERPRETATION. *Simulation*, academia.edu., p.279.

McGlade, J. (1995). Archaeology and the ecodynamics of human-modified landscapes. *Antiquity*, 69 (262), Cambridge University Press., pp.113–132. [Accessed 9 July 2018].

McGlade, J. (2014). Simulation as Narrative: Contingency, Dialogics, and the Modeling Conundrum. *Journal of Archaeological Method and Theory*, 21 (2), Springer US., pp.288–305. [Accessed 6 October 2016].

McGregor, K. M. (2004). Huntington and Lovelock: Climatic Determinism in the 20th Century. *Physical Geography*, 25 (3), Taylor & Francis., pp.237–250.

Merchant, C. (2006). The Scientific Revolution and the Death of Nature. *Isis; an international review devoted to the history of science and its cultural influences*, 97 (3), journals.uchicago.edu., pp.513–533.

Meyer, W. J. and Crumley, C. L. (2011). Historical ecology: using what works to cross the divide. *Atlantic Europe in the First Millennium BC: Crossing the Divide*, 109, Oxford: Oxford University Press. [Online]. Available at: https://books.google.co.uk/books?hl=en&lr=&id=evyzbRSmLawC&oi=fnd&pg=PA109&dq=Historical+Ecology:+Using+what+Works+to+Cross+the+Divide&ots=FgstkHg84K&sig=WegLhhH3GgnZ8K8wTufkEFz-tFU.

Miras, Y. et al. (2010). Prehistoric impact on landscape and vegetation at high altitudes: An integrated palaeoecological and archaeological approach in the eastern Pyrenees (Perafita valley, Andorra). *Plant Biosystems - An International Journal Dealing with all Aspects of Plant Biology*, 144 (4), Taylor & Francis., pp.924–939.

Mokyr, J. (2015). Intellectuals and the rise of the modern economy. *Science*, 349 (6244), American Association for the Advancement of Science., pp.141–142. [Accessed 3 June 2018].

Moravia, S. (1980). The Enlightenment and the sciences of man. *History of science; an annual review of literature, research and teaching*, 18 (4), SAGE Publications Sage UK: London, England., pp.247–268.

Moulines, C. U. (2002). Introduction: Structuralism As A Program For Modelling Theoretical Science. *Synthese*, 130 (1), Kluwer Academic Publishers., pp.1–11. [Accessed 9 January 2017].

Muir, R. (1981). *Shell guide to reading the landscape*. Michael Joseph.

Murphy, C. and Fuller, D. Q. (2017). The Future is Long-term: past and current directions in environmental archaeology. *General Anthropology*, 24 (1), Wiley Online Library., pp.1–10.

Neocleous, M. (2003). Off the Map: On Violence and Cartography. *European Journal of Social Theory*, 6 (4), SAGE Publications Ltd., pp.409–425.

Novák, J. et al. (2018). History of the Litovelské Pomoraví woodland (NE Czech Republic): A comparison of archaeo-anthracological, pedoanthracological, and pollen data. *Quaternary international: the journal of the International Union for Quaternary Research*, 463, Elsevier., pp.352–362.

O'Leary, C. A. (2002). The Kurds of Iraq: recent history, future prospects. *Middle East Review of International Affairs*, 6 (4), rubincenter.org., pp.17–29.

Orton, D., Morris, J. and Pipe, A. (2017). Catch Per Unit Research Effort: Sampling Intensity, Chronological Uncertainty, and the Onset of Marine Fish Consumption in Historic London. *Open Quaternary*, 3 (1), Ubiquity Press., pp.1–20. [Accessed 29 September 2018].

Palmisano, A., Bevan, A. and Shennan, S. (2017). Comparing archaeological proxies for long-term population patterns: An example from central Italy. *Journal of archaeological science*, 87, Elsevier., pp.59–72.

Palmisano, A., Bevan, A. and Shennan, S. (2018). Regional Demographic Trends and Settlement Patterns in Central Italy: Archaeological Sites and Radiocarbon Dates. *Journal of Open Archaeology Data*, 6 (1), Ubiquity Press. [Online]. Available at: https://openarchaeologydata.metajnl.com/articles/10.5334/joad.43/print/.

Perry, G. et al. (2016). Experimental Simulation: Using Generative Modeling and Palaeoecological Data to Understand Human-Environment Interactions. *Front. Ecol. Evol. 4: 109. doi: 10. 3389/fevo*, journal-cdn.frontiersin.org. [Online]. Available at: http://journal-cdn.frontiersin.org/article/212042/files/provisional-pdf/versions/1/pdf.

Pettitt, P. and Zilhão, J. (2015). Problematizing Bayesian approaches to prehistoric chronologies. *World archaeology*, 47 (4), Routledge., pp.525–542.

Piiroinen, T. (2018). A meaning holistic (dis) solution of subject--object dualism--its implications for the human sciences. *History of the human sciences*, SAGE Publications Sage UK: London, England., p.0952695117752015.

Pollard, A. M. and Bray, P. (2007). A Bicycle Made for Two? The Integration of Scientific Techniques into Archaeological Interpretation. *Annual review of anthropology*, 36 (1), Annual Reviews., pp.245–259.

Ponel, P. et al. (2011). Holocene history of Lac des Lauzons (2180 m a.s.l.), reconstructed from multiproxy analyses of Coleoptera, plant macroremains and pollen (Hautes-Alpes, France). *Holocene*, 21 (4), pp.565–582.

Premo, L. S. (2006). Exploratory agent-based models: Towards an experimental ethnoarchaeology. *Digital discovery: exploring new frontiers in human heritage. CAA*, proceedings.caaconference.org., pp.29–36.

Preston, P. R. and Kador, T. (2018). Approaches to Interpreting Mesolithic Mobility and Settlement in Britain and Ireland. *Journal of World Prehistory*, 31 (3), Springer., pp.321–345.

Proctor, J. D. (1998). The Social Construction of Nature: Relativist Accusations, Pragmatist and Critical Realist Responses. *Annals of the Association of American Geographers. Association of American Geographers*, 88 (3), Routledge., pp.352–376.

Putzer, A. et al. (2016). The development of human activity in the high altitudes of the Schnals Valley (South Tyrol/Italy) from the Mesolithic to modern periods. *Journal of Archaeological Science: Reports*, 6, Elsevier., pp.136–147.

Py, V. et al. (2014). Interdisciplinary characterisation and environmental imprints of mining and forestry in the upper Durance valley (France) during the Holocene. *Quaternary international: the journal of the International Union for Quaternary Research*, 353 (0), Elsevier., pp.74–97.

Rae, G. (2014). Heidegger's influence on posthumanism: The destruction of metaphysics, technology and the overcoming of anthropocentrism. *History of the human sciences*, 27 (1), Sage Publications Sage UK: London, England., pp.51–69.

Ratcliffe, J. H. (2000). Aoristic analysis: the spatial interpretation of unspecific temporal events. *International journal of geographical information science: IJGIS*, 14 (7), Taylor & Francis., pp.669–679.

Raymond, H. (2007). The Ecologically Noble Savage Debate. *Annual review of anthropology*, 36 (1), Annual Reviews., pp.177–190.

Redman, C. L. (2005). Resilience Theory in Archaeology. *American anthropologist*, 107 (1), Blackwell Publishing Ltd., pp.70–77.

Reed, S. K. (2012). *Cognition: Theories and Applications*. Cengage Learning.

Rees, R. (1980). Historical Links between Cartography and Art. *Geographical review*, 70 (1), [American Geographical Society, Wiley]., pp.61–78.

Renfrew, C. and Bahn, P. G. (2007). *Archaeology essentials: Theories, methods, and practice*. Thames & Hudson.

Ribeiro, A. (2018). Death of the passive subject: Intentional action and narrative explanation in archaeological studies. *History of the human sciences*, 31 (3), SAGE Publications Ltd., pp.105–121.

Richer, S. and Gearey, B. (2017). From Rackham to REVEALS: Reflections on Palaeoecological Approaches to Woodland and Trees. *Environmental Archaeology*, Routledge., pp.1–12.

Rick, J. W. (1987). Dates as Data: An Examination of the Peruvian Preceramic Radiocarbon Record. *American antiquity*, 52 (1), Cambridge University Press., pp.55–73. [Accessed 4 March 2018].

Robbins Schug, G., Parnell, E. K. and Harrod, R. P. (2019). Changing the Climate: Bioarchaeology Responds to Deterministic Thinking About Human-Environmental Interactions in the Past. In: Buikstra, J. E. (Ed). *Bioarchaeologists Speak Out: Deep Time Perspectives on Contemporary Issues*. Cham : Springer International Publishing. pp.133–159.

Roberts, N. et al. (2018). Europe's lost forests: a pollen-based synthesis for the last 11,000 years. *Scientific reports*, 8 (1), nature.com., p.716.

Robinson, D. T. et al. (2018). Modelling feedbacks between human and natural processes in the land system. *Earth System Dynamics (Online)*, 9 (2), Lawrence Berkeley National Lab.(LBNL), Berkeley, CA (United States). [Online]. Available at: https://www.osti.gov/biblio/1476517.

Roffet-Salque, M. et al. (2017). From the inside out: Upscaling organic residue analyses of archaeological ceramics. *Journal of Archaeological Science: Reports*, 16, Elsevier., pp.627–640.

Rohling, E. J. (2016/9). Of lakes and fields: A framework for reconciling palaeoclimatic drought inferences with archaeological impacts. *Journal of archaeological science*, 73, Elsevier., pp.17–24.

Schimel, D. et al. (2015). Analysis, Integration and Modeling of the Earth System (AIMES): Advancing the post-disciplinary understanding of coupled human–environment dynamics in the Anthropocene. *Anthropocene*, 12, Elsevier., pp.99–106.

Schmidt, A. (2004). Remote sensing and geophysical prospection. *Internet Archaeology*, 15 (9), researchgate.net. [Online]. Available at: https://www.researchgate.net/profile/Armin_Schmidt/publication/38141610_Remote_Sensing_and_Geophysical_Prospection/links/555b312208ae980ca61301fd.pdf.

Scollar, I. et al. (1999). 25 years of Computer Applications in Archaeology. In: *Archaeology in the Age of the Internet, Computer Applications and Quantitative Methods in Archaeology 1997*. BAR International Series 750, Oxford. pp.5–10.

Shahack-Gross, R. (2017/3). Archaeological formation theory and geoarchaeology: State-of-the-art in 2016. *Journal of archaeological science*, 79, Elsevier., pp.36–43.

Shanks, M. and Tilley, C. (1989). Questions rather than answers: Reply to comments on archaeology into the 1990s. *Norwegian Archaeological Review*, 22 (1), Routledge., pp.42–54.

Shanks, M., Tilley, C. Y. and Others. (1987). *Social theory and archaeology*. Polity Press

Cambridge.

Shannon, R. E. (1998). Introduction to the Art and Science of Simulation. In: *Proceedings of the 30th Conference on Winter Simulation*. WSC '98. 1998. Los Alamitos, CA, USA : IEEE Computer Society Press. pp.7–14.

Shennan, S. (2000). Population, Culture History, and the Dynamics of Culture Change. *Current anthropology*, 41 (5), journals.uchicago.edu., pp.811–835.

Shennan, S. et al. (2013). Regional population collapse followed initial agriculture booms in mid-Holocene Europe. *Nature communications*, 4, p.2486.

Shennan, S. and Edinborough, K. (2007). Prehistoric population history: from the Late Glacial to the Late Neolithic in Central and Northern Europe. *Journal of archaeological science*, 34 (8), Elsevier., pp.1339–1345.

Sjögren, K.-G., Price, T. D. and Kristiansen, K. (2016). Diet and Mobility in the Corded Ware of Central Europe. *PloS one*, 11 (5), journals.plos.org., p.e0155083.

Slaymaker, O. (2017). Physical geographers' understanding of the real world. *The Canadian Geographer/Le Géographe canadien*, 61 (1), Wiley Online Library., pp.64–72.

Smith, M. (2016). The use of summed-probability plots of radiocarbon data in archaeology. *Archaeology in Oceania*, 51 (3), Wiley Online Library., pp.214–215.

Smith, M. E. et al. (2012). Archaeology as a social science. *Proceedings of the National Academy of Sciences of the United States of America*, 109 (20), National Acad Sciences., pp.7617–7621.

Smith, P. H. (2009). Science on the move: recent trends in the history of Early Modern science. *Renaissance quarterly*, 62 (2), journals.uchicago.edu., pp.345–375.

Snow, C. P. (2012). *The Two Cultures*. Cambridge University Press.

Spackman, J. S. and Yanchar, S. C. (2014). Embodied Cognition, Representationalism, and Mechanism: A Review and Analysis. *Journal for the theory of social behaviour*, 44 (1), Wiley Online Library., pp.46–79.

Stedman, R. C. (2003). Is It Really Just a Social Construction?: The Contribution of the Physical Environment to Sense of Place. *Society & natural resources*, 16 (8), Routledge., pp.671–685.

Stedman, R. C. (2016). Subjectivity and social-ecological systems: a rigidity trap (and sense of place as a way out). *Sustainability Science*, 11 (6), Springer Japan., pp.891–901. [Accessed 22 April 2018].

Stork, D. G. (2004). Optics and realism in Renaissance art. *Scientific American*, 291 (6), JSTOR., pp.76–83.

Sugita, S. et al. (2010). Testing the Landscape Reconstruction Algorithm for spatially explicit reconstruction of vegetation in northern Michigan and Wisconsin. *Quaternary Research*, 74

(2), Cambridge University Press., pp.289–300. [Accessed 30 December 2018].

Surovell, T. A. et al. (2009). Correcting temporal frequency distributions for taphonomic bias. *Journal of archaeological science*, 36 (8), Elsevier., pp.1715–1724.

Sutton, M. Q. and Anderson, E. N. (2013). *Introduction to Cultural Ecology*. Rowman & Littlefield.

Szabó, P. (2015). Historical ecology: past, present and future. *Biological reviews of the Cambridge Philosophical Society*, 90 (4), Wiley Online Library., pp.997–1014.

Talon, B. (2010). Reconstruction of Holocene high-altitude vegetation cover in the French southern Alps: evidence from soil charcoal. *Holocene*, 20 (1), pp.35–44.

Tebeaux, E. (2018). *The emergence of a tradition: Technical writing in the English Renaissance, 1475-1640*. Routledge.

Tilley, C. (1998). Archaeology: the loss of isolation. *Antiquity*, 72 (277), Cambridge University Press., pp.691–693. [Accessed 11 November 2018].

Tilley, C. Y. (1994). *A phenomenology of landscape: places, paths, and monuments*. Berg Oxford.

Timpson, A. et al. (2014). Reconstructing regional population fluctuations in the European Neolithic using radiocarbon dates: a new case-study using an improved method. *Journal of archaeological science*, 52, pp.549–557.

Timpson, A., Manning, K. and Shennan, S. (2015). Inferential mistakes in population proxies: A response to Torfing's 'Neolithic population and summed probability distribution of 14C-dates'. *Journal of archaeological science*, 63, Elsevier., pp.199–202.

Torfing, T. (2015a). Layers of assumptions: A reply to Timpson, Manning, and Shennan. *Journal of archaeological science*, 63, Elsevier., pp.203–205.

Torfing, T. (2015b). Neolithic population and summed probability distribution of 14C-dates. *Journal of archaeological science*, 63, Elsevier., pp.193–198.

Torrence, R., Martinón-Torres, M. and Rehren, T. (2015/4). Forty years and still growing: Journal of Archaeological Science looks to the future. *Journal of archaeological science*, 56, Elsevier., pp.1–8.

Touflan, P., Talon, B. and Walsh, K. (2010). Soil charcoal analysis: a reliable tool for spatially precise studies of past forest dynamics: a case study in the French southern Alps. *Holocene*, SAGE PublicationsSage UK: London, England. [Online]. Available at: doi:10.1177/0959683609348900 [Accessed 6 February 2017].

Trigger, B. G. (1998). 'The loss of innocence'in historical perspective. *Antiquity*, 72 (277), Cambridge University Press., pp.694–698.

Tringham, R. (2018). A Plea for a Richer, Fuller and More Complex Future Archaeology.

Norwegian Archaeological Review, Routledge., pp.1–7.

Trondman, A.-K. et al. (2015). Pollen-based quantitative reconstructions of Holocene regional vegetation cover (plant-functional types and land-cover types) in Europe suitable for climate modelling. *Global change biology*, 21 (2), Wiley Online Library., pp.676–697.

Turnbull, D. (1996). Cartography and science in early modern Europe: Mapping the construction of knowledge spaces. *Imago mundi*, 48 (1), Routledge., pp.5–24.

Uggla, Y. (2010). What is this thing called'natural'? The nature-culture divide in climate change and biodiversity policy. *Journal of Political Ecology*, 17 (1), journals.uair.arizona.edu., pp.79–91.

Vaught, R. L. (1986). Alfred Tarski's work in model theory. *Journal of Symbolic Logic*, Cambridge Univ Press. [Online]. Available at: http://journals.cambridge.org/abstract_S0022481200030358.

Veeramah, K. R. (2018). The importance of fine-scale studies for integrating paleogenomics and archaeology. *Current opinion in genetics & development*, 53, Elsevier., pp.83–89.

Verburg, P. H. et al. (2016/7). Methods and approaches to modelling the Anthropocene. *Global environmental change: human and policy dimensions*, 39, pp.328–340.

Vining, J., Merrick, M. S. and Price, E. A. (2008). The Distinction between Humans and Nature: Human Perceptions of Connectedness to Nature and Elements of the Natural and Unnatural. *Human Ecology Review*, 15 (1), Society for Human Ecology., pp.1–11.

Walsh, K. (1999). Mediterranean landscape archaeology and environmental reconstruction. *Environmental reconstruction in Mediterranean landscape archaeology*, books.google.com., pp.1–8.

Walsh, K. (2008). Mediterranean Landscape Archaeology: Marginality and the Culture--Nature 'Divide'. *Landscape Research*, 33 (5), Taylor & Francis., pp.547–564.

Walsh, K. (2013). *The archaeology of Mediterranean landscapes: human-environment interaction from the Neolithic to the Roman period*. Cambridge University Press.

Walsh, K. et al. (2014). A historical ecology of the Ecrins (Southern French Alps): Archaeology and palaeoecology of the Mesolithic to the Medieval period. *Quaternary international: the journal of the International Union for Quaternary Research*, 353 (0), Elsevier., pp.52–73.

Walsh, K. et al. (2016). Interpreting the Rock Paintings of Abri Faravel: laser and white-light scanning at 2,133 m in the southern French Alps. *Internet Archaeology*, 42, halshs.archives-ouvertes.fr. [Online]. Available at: https://halshs.archives-ouvertes.fr/halshs-01478757/.

Walsh, K., Brown, T. and de Haas, T. (2017). Introduction—Human-environment interfaces: Assessing the use of palaeoenvironmental information in Mediterranean landscape archaeology. *Journal of Archaeological Science: Reports*, Elsevier. [Online]. Available at:

http://www.sciencedirect.com/science/article/pii/S2352409X17301712.

Walsh, K. and Mocci, F. (2011). Mobility in the Mountains: Late Third and Second Millennia Alpine Societies' Engagements with the High-Altitude Zones in the Southern French Alps. *European Journal of Archaeology*, 14 (1-2), maneyonline.com., pp.88–115.

Walsh, K., Mocci, F. and Palet-Martinez, J. (2007). Nine thousand years of human/landscape dynamics in a high altitude zone in the southern French Alps (Parc National des Ecrins, Hautes-Alpes). *Preistoria alpina*, 42, muse.it., pp.9–22.

Walsh, K., Richer, S. and de Beaulieu, J.-L. (2006). Attitudes to altitude: changing meanings and perceptions within a 'marginal'Alpine landscape--the integration of palaeoecological and archaeological data in a high-altitude landscape in the French Alps. *World archaeology*, 38 (3), Taylor & Francis., pp.436–454.

Weninger, B. et al. (2015). Quantum theory of radiocarbon calibration. *World archaeology*, 47 (4), Routledge., pp.543–566.

Whitley, T. G. (2017). Geospatial analysis as experimental archaeology. *Journal of archaeological science*, 84, Elsevier., pp.103–114.

Williams, M. (2000). Dark ages and dark areas: global deforestation in the deep past. *Journal of historical geography*, 26 (1), Elsevier., pp.28–46.

Withers, C. (1995). Geography, Natural History and the Eighteenth-Century Enlightenment: Putting the World in Place. *History workshop journal: HWJ*, (39), Oxford University Press., pp.136–163.

Wolloch, N. (2016). *History and nature in the enlightenment: Praise of the mastery of nature in eighteenth-century historical literature*. Routledge.

Woodbridge, J. et al. (2014). The impact of the Neolithic agricultural transition in Britain: a comparison of pollen-based land-cover and archaeological 14C date-inferred population change. *Journal of archaeological science*, 51, Elsevier., pp.216–224.

Woodbridge, J., Fyfe, R. M. and Roberts, N. (2014). A comparison of remotely sensed and pollen-based approaches to mapping Europe's land cover. *Journal of biogeography*, 41 (11), Wiley Online Library., pp.2080–2092.

Woodgate, G. and Redclift, M. (1998). From a 'sociology of nature'to environmental sociology: beyond social construction. *Environmental values*, 7 (1), White Horse Press., pp.3–24.

Wylie, A. (1992). On Scepticism, Philosophy, and Archaeological Science. *Current anthropology*, 33 (2), journals.uchicago.edu., pp.209–214.

Zanchetta, G. et al. (2016). The so-called '4.2 event' in the central Mediterranean and its climatic teleconnections. *Alpine and Mediterranean quaternary*, 29 (1), researchgate.net., pp.5–17.

Zanon, M. et al. (2018). European Forest Cover During the Past 12,000 Years: A

Palynological Reconstruction Based on Modern Analogs and Remote Sensing. *Frontiers in plant science*, 9, frontiersin.org., p.253.

Appendix

1) R script for SPDs

```
library(rcarbon)

Radiocarbon_MA <-
read.csv("/Users/Robert/Dropbox/MA/Master_File/Data/SPD_data/Radiocarbon_Dates_Mast
er.csv")

RD <- calibrate(Radiocarbon_MA$BP, errors = Radiocarbon_MA$Error, ids =
Radiocarbon_MA$DateID)

RD_false <- calibrate(Radiocarbon_MA$BP, errors = Radiocarbon_MA$Error, ids =
Radiocarbon_MA$DateID, normalised = FALSE)

summary(RD)
summary(RD_false)
```

```
binsense(RD, Radiocarbon_MA, seq(50, 200), timeRange = c(8000, 450), sitecol = "DateID",
agecol = "BP" )
binsense(RD_false, Radiocarbon_MA, seq(50, 200), timeRange = c(8000, 450), sitecol =
"DateID", agecol = "BP" )

SPD_bin <- binPrep(Radiocarbon_MA$DateID, Radiocarbon_MA$BP, h = 200)
SPD_bin_False <- binPrep(Radiocarbon_MA$DateID, Radiocarbon_MA$BP, h = 200)



RD_spd <- spd(RD, bins = SPD_bin, timeRange = c(8000, 450))
RD_spd_False <- spd(RD_false, bins = SPD_bin_False, timeRange = c(8000, 450),
datenormalised = TRUE, spdnormalised = TRUE)

write.csv(RD_spd, "SPD.csv")
write.csv(RD_spd_False, "SPD_FAlSE.csv")

plot(RD_spd)

png("~/Desktop/SPD.png")
plot(RD_spd_False)
dev.off()
```

```
plot(RD_spd, runm=200,add=TRUE,type="simple",col="indianred",lwd=2,lty=2)

SPD_Exp <- modelTest(RD_false, Radiocarbon_MA$Error, nsim = 100, timeRange =
c(8000, 450), model = "exponential", runm = 200, datenormalised=TRUE)

SPD_Lin <- modelTest(RD, Radiocarbon_MA$Error, nsim = 100, timeRange = c(8000,
450), model = "linear", runm = 200)
SPD_Uni <-modelTest(RD, Radiocarbon_MA$Error, nsim = 100, timeRange = c(8000, 450),
model = "uniform", runm = 200)

png("~/Desktop/SPD_Exp.png")
plot(SPD_Exp)
dev.off()

plot(SPD_Lin)
plot(SPD_Uni)

C14_0_500 <-
read.csv("/Users/Robert/Dropbox/MA/Master_File/Data/Final_data/0-500/C14_0_500.csv")
C14_500_1000 <-
read.csv("/Users/Robert/Dropbox/MA/Master_File/Data/Final_data/500-1000/C14_500_100
0.csv")
```

```
C14_1000_1700 <-
read.csv("/Users/Robert/Dropbox/MA/Master_File/Data/Final_data/1000-1700/C14_1000_1
700.csv")
C14_1700_2300 <-
read.csv("/Users/Robert/Dropbox/MA/Master_File/Data/Final_data/1700-2300/C14_1700_2
300.csv")
C14_2300_4000 <-
read.csv("/Users/Robert/Dropbox/MA/Master_File/Data/Final_data/2300-4000/C14_2300_4
000.csv")

C14_0_500_Norm <- calibrate(C14_0_500$BP, errors = C14_0_500$Error, ids =
C14_0_500$DateID, normalised = FALSE)
C14_500_1000_Norm <- calibrate(C14_500_1000$BP, errors = C14_500_1000$Error, ids =
C14_500_1000$DateID, normalised = FALSE)
C14_1000_1700_Norm <- calibrate(C14_1000_1700$BP, errors = C14_1000_1700$Error,
ids = C14_1000_1700$DateID, normalised = FALSE)
C14_1700_2300_Norm <- calibrate(C14_1700_2300$BP, errors = C14_1700_2300$Error,
ids = C14_1700_2300$DateID, normalised = FALSE)
C14_2300_4000_Norm <- calibrate(C14_2300_4000$BP, errors = C14_2300_4000$Error,
ids = C14_2300_4000$DateID, normalised = FALSE)


C14_0_500_bin <- binPrep(C14_0_500$DateID, C14_0_500$BP, h = 200)
C14_500_1000_bin  <- binPrep(C14_500_1000$DateID, C14_500_1000$BP, h = 200)
```

```
C14_1000_1700_bin <- binPrep(C14_1000_1700$DateID, C14_1000_1700$BP, h = 200)
C14_1700_2300_bin <- binPrep(C14_1700_2300$DateID, C14_1700_2300$BP, h = 200)
C14_2300_4000_bin <- binPrep(C14_2300_4000$DateID, C14_2300_4000$BP, h = 200)

C14_0_500_SPD <- spd(C14_0_500_Norm, bins = C14_0_500_bin, timeRange = c(8000,
450), datenormalised = TRUE, spdnormalised = TRUE)
C14_500_1000_SPD <- spd(C14_500_1000_Norm, bins = C14_500_1000_bin, timeRange =
c(8000, 450), datenormalised = TRUE, spdnormalised = TRUE)
C14_1000_1700_SPD <- spd(C14_1000_1700_Norm, bins = C14_1000_1700_bin,
timeRange = c(8000, 450), datenormalised = TRUE, spdnormalised = TRUE)
C14_1700_2300_SPD <- spd(C14_1700_2300_Norm, bins = C14_1700_2300_bin,
timeRange = c(8000, 450), datenormalised = TRUE, spdnormalised = TRUE)
C14_2300_4000_SPD <- spd(C14_2300_4000_Norm, bins = C14_2300_4000_bin,
timeRange = c(8000, 450), datenormalised = TRUE, spdnormalised = TRUE)

write.csv(C14_0_500_SPD, "C14_0_500_SPD.csv")
write.csv(C14_500_1000_SPD, "C14_500_1000_SPD.csv")
write.csv(C14_1000_1700_SPD, "C14_1000_1700_SPD.csv")
write.csv(C14_1700_2300_SPD, "C14_1700_2300_SPD.csv")
write.csv(C14_2300_4000_SPD, "C14_2300_4000_SPD")

plot(C14_0_500_SPD)
plot(C14_500_1000_SPD)
plot(C14_1000_1700_SPD)
```

```
plot(C14_1700_2300_SPD)

plot(C14_2300_4000_SPD)


Ecrins_C14 <-
read.csv("/Users/Robert/Dropbox/MA/Master_File/Data/Ecrins/C14_Ecrins.csv")


Ecrins_C14_Norm <- calibrate(Ecrins_C14$BP, errors = Ecrins_C14$Error, ids =
Ecrins_C14$DateID, normalised = FALSE)


Ecrins_C14_bin <- binPrep(Ecrins_C14$DateID, Ecrins_C14$BP, h = 200)


Ecrins_C14_SPD <- spd(Ecrins_C14_Norm, bins = Ecrins_C14_bin, timeRange = c(8000,
450), datenormalised = TRUE, spdnormalised = TRUE)


write.csv(Ecrins_C14_SPD, "Ecrins_C14_SPD.csv")
```

2) R script for ACS

```
library(archSeries)

Sites_Data_BP <-
read.csv("/Users/Robert/Dropbox/MA/Master_File/Data/Sites_Data/Sites_Data_Master_Fina
l_BPONLY.csv")
View(Sites_Data_BP)

Aorist_BP <- aorist(Sites_Data_BP, 10000, 450, end.date = NULL, bin.width = 200)
View(Aorist_BP)

png("~/Desktop/Aoristic_Plot.png")
Aoristic_Plot <- aorist.plot(Aorist_BP, col="grey60",lab.sp = 6 ,ylab="Total probability
density")
dev.off()

ggplot(Aorist_BP, aes(x = Aorist_BP$bin))
```

```
write.csv(Aorist_BP, file =
"/Users/Robert/Dropbox/MA/Master_File/Data/Sites_Data/Aorsit_Results.csv")

Simulate_Sites_BP <- date.simulate(Sites_Data_BP, bin.width = 200)

png("~/Desktop/Aoristic_Box.png")
box.chron(Simulate_Sites_BP, lab.sp = 6)
dev.off()

png("~/Desktop/Aoristic_Line.png")
lines.chron(Simulate_Sites_BP, lab.sp = 6)
dev.off()

Sites_Data_BP_0_500 <-
read.csv("/Users/Robert/Dropbox/MA/Master_File/Data/Final_data/0-500/Sites_0_500.csv")
Sites_Data_BP_500_1000 <- read.csv(
"/Users/Robert/Dropbox/MA/Master_File/Data/Final_data/500-1000/Sites_500_1000.csv")
```

```
Sites_Data_BP_1000_1700 <-
read.csv("/Users/Robert/Dropbox/MA/Master_File/Data/Final_data/1000-1700/Sites_1000_1
700.csv")
Sites_Data_BP_1700_2300 <-
read.csv("/Users/Robert/Dropbox/MA/Master_File/Data/Final_data/1700-2300/Sites_1700_2
300.csv")
Sites_Data_BP_2300_4000 <-
read.csv("/Users/Robert/Dropbox/MA/Master_File/Data/Final_data/2300-4000/Sites_2300_4
000.csv")

Sites_Data_BP_0_500_aorist <- aorist(Sites_Data_BP_0_500, 10000, 450, end.date = NULL,
bin.width = 200)
Sites_Data_BP_500_1000_aorist <- aorist(Sites_Data_BP_500_1000, 10000, 450, end.date =
NULL, bin.width = 200)
Sites_Data_BP_1000_1700_aorist <- aorist(Sites_Data_BP_1000_1700, 10000, 450,
end.date = NULL, bin.width = 200)
Sites_Data_BP_1700_2300_aorist <- aorist(Sites_Data_BP_1700_2300, 10000, 450,
end.date = NULL, bin.width = 200)
Sites_Data_BP_2300_4000_aorist <- aorist(Sites_Data_BP_2300_4000, 10000, 450,
end.date = NULL, bin.width = 200)

write.csv(Sites_Data_BP_0_500_aorist, "Sites_Data_BP_0_500_aorist.csv")
write.csv(Sites_Data_BP_500_1000_aorist, "Sites_Data_BP_500_1000_aorist.csv")
write.csv(Sites_Data_BP_1000_1700_aorist, "Sites_Data_BP_1000_1700_aorist.csv")
```

```
write.csv(Sites_Data_BP_1700_2300_aorist, "Sites_Data_BP_1700_2300_aorist.csv")
write.csv(Sites_Data_BP_2300_4000_aorist, "Sites_Data_BP_2300_4000_aorist.csv")

aorist.plot(Sites_Data_BP_0_500_aorist, col="grey60",lab.sp = 6 ,ylab="Total probability density")
aorist.plot(Sites_Data_BP_500_1000_aorist, col="grey60",lab.sp = 6 ,ylab="Total probability density")
aorist.plot(Sites_Data_BP_1000_1700_aorist, col="grey60",lab.sp = 6 ,ylab="Total probability density")
aorist.plot(Sites_Data_BP_1700_2300_aorist, col="grey60",lab.sp = 6 ,ylab="Total probability density")
aorist.plot(Sites_Data_BP_2300_4000_aorist, col="grey60",lab.sp = 6 ,ylab="Total probability density")


Sites_Ecrins <-
read.csv("/Users/Robert/Dropbox/MA/Master_File/Data/Ecrins/Sites_Ecrins.csv")
Sites_Non_Ecrins <-
read.csv("/Users/Robert/Dropbox/MA/Master_File/Data/Ecrins/Not_Ecrins_Sites.csv")

Sites_Ecrins_aorist <- aorist(Sites_Ecrins, 10000, 450, end.date = NULL, bin.width = 200)
Sites_Non_Ecrins_aorist <- aorist(Sites_Non_Ecrins, 10000, 450, end.date = NULL, bin.width = 200)
```

```
write.csv(Sites_Ecrins_aorist, "Sites_Ecrins_aorist.csv")
write.csv(Sites_Non_Ecrins_aorist, "Sites_Non_Ecrins_aorist.csv")


aorist.plot(Sites_Ecrins_aorist, col="grey60",lab.sp = 6 ,ylab="Total probability density")
aorist.plot(Sites_Non_Ecrins_aorist, col="grey60",lab.sp = 6 ,ylab="Total probability
density")
```

3) R script for data management for PBM

```
library("dplyr", lib.loc="~/R/win-library/3.4")
library(xlsx)
library(scales)
library(writexl)


setwd("C:/Users/Patrick/Dropbox/MA/R/MA_1")
PBM_Pollen_Study_Area <-
read.csv("C:/Users/Patrick/Dropbox/MA/R/MA_1/PBM_Pollen_Study_Area.csv")

View(PBM_Pollen_Study_Area)


Pollen_Data <- PBM_Pollen_Study_Area
P_D = Pollen_Data
```

P_D_Needle_leaf_forest <- P_D %>% select(Site.code, Cal.yr.BP, Abies, Cupressaceae, Larix, Picea, Pinaceae, Taxus)

P_D_Broad_leaf_forest <- P_D %>% select(Site.code, Cal.yr.BP, Acer, Aesculus, Alnus, Arceuthobium, Betula, Buxus, Carpinus, Castanea, Celtis, Cercis.siliquastrum, Corylus, Crataegus, Daphne, Quercus.deciduous, Fagus, Frangula, Fraxinus, Hedera, Ilex, Juglandinae, Liquidambar, Lonicera, Myrica, Myrtaceae, Oleaceae, Parrotia, Platanus, Populus, Prunus, Rosaceae, Rhamnaceae, Robinia, Robinia, Salix, Sambucus.nigra, Sorbus, Tilia, Ulmaceae, Viscum, Vitaceae)

P_D_Heath_scrubland <- P_D %>% select(Site.code, Cal.yr.BP, Aellenia, Alkanna, Anagallis, Arctostaphylos, Argania.spinosa, Asphodelus, Astragalus, Ballota, Beta, Calluna, Carex, Casuarina, Centaurea.sclerophyllus, Ceratonia, Chamaerops, Cistaceae, Citrus, Convolvulaceae, Coriaria, Cyperaceae, Cytisus, Echium, Empetrum, Ephedra, Genista, Hippophae, Hypericum, Juniperus, Lotus, Melampyrum, Narthecium, Parnassia, Phlomis, Pistacia, Polygonum.heath, Quercus.evergreen, Rhynchospora, Rosmarinus, Rutaceae, Scheuchzeria, Tamarix, Ulex)

P_D_Pastures_natural_grassland <- P_D %>% select(Site.code, Cal.yr.BP, Anemone, Anthyllis, Apiaceae, Asperula, Asteraceae.subfam..Lactucoides, Bunium, Bupleurum, Caltha, Campanulaceae, Centaurea.grassland, Dipsacaceae, Epilobium, Filipendula, Galium, Gentianaceae, Geum, Knautia, Paliurus.spina.christi, Papaveraceae, Plantago.alpina, Plantago.coronopus, Plantago.lanceolata, Plantago.tenuiflora, Poaceae, Polygala, Potentilla, Ranunculaceae, Rhinanthus, Rumex.acetosa, Rumex.acetosella, Sanguisorba, Senecio, Stachys, Succisa, Thalictrum, Trifolium, Urticaceae, Valerianaceae.grassland, Veronica, Viciaceae)

```
P_D_Arable_disturbed_land <- P_D %>% select(Site.code, Cal.yr.BP, Allium, Anagallis,
Anchusa, Arctium, Artemisia, Asparagaceae, Asteraceae.subfam..Asteroideae, Brassicaceae,
Cannabaceae, Carduus, Caryophyllaceae, Centaurea.arable, Centaurea.undifferentiated,
Cerealia, Chenopodiaceae, Cirsium, Cucurbitaceae, Fagopyrum, Galeopsis, Humulus,
Hypericum, Lamiaceae, Lathyrus, Leguminosae, Linaceae, Noaea, Ononis, Plantaginaceae,
Plantago.albicans, Plantago.atrata, Plantago.major, Plantago.maritima, Plantago.media,
Plantago.montana, Plantago.ovata, Plantago.psyllium, Polygonaceae.arable, Rheum, Ribes,
Rumex.type, Scorzonera, Silenaceae, Solanaceae, Valerianaceae.arable, Zea)


#The next step is to write the LCCs into excel spreadsheets
write.xlsx(P_D_Needle_leaf_forest, file = "P_D_Needle_leaf_forest.xlsx",
	sheetName = "P_D_Needle_leaf_forest", append = FALSE)
write.xlsx(P_D_Broad_leaf_forest, file = "P_D_Broad_leaf_forest.xlsx",
	sheetName = "P_D_Broad_leaf_forest", append = FALSE)
write.xlsx(P_D_Heath_scrubland, file = "P_D_Heath_scrubland.xlsx",
	sheetName = "P_D_Heath_scrubland", append = FALSE)
write.xlsx(P_D_Pastures_natural_grassland, file = "P_D_Pastures_natural_grassland.xlsx",
	sheetName = "P_D_Pastures_natural_grassland", append = FALSE)
write.xlsx(P_D_Arable_disturbed_land, file = "P_D_Arable_disturbed_land.xlsx",
	sheetName = "P_D_Arable_disturbed_land", append = FALSE)
```

```
PBM_W <-
read.csv("/Users/Robert/Dropbox/MA/Master_File/Data/PBM_Data/LCCs/PBM_Weighted_
Numeric.csv")

PBM_rescale <- rescale(PBM_W$Weighted_Score, to = c(0, 100))

View(PBM_rescale)


PBM_W$X.1 <- NULL
PBM_W$X.2 <- NULL


PBM_W$Rescaled <- c("")
PBM_W$Rescale <- PBM_rescale


SJSL972 <- subset(PBM_W, Site.code == "SJSL972")
SJSLS <- subset(PBM_W, Site.code == "SJSLS")
ALLOS <- subset(PBM_W, Site.code == "ALLOS")
VALPROV2 <- subset(PBM_W, Site.code == "VALPROV2")
CORREO <- subset(PBM_W, Site.code == "CORREO")
CRISTOL <- subset(PBM_W, Site.code == "CRISTOL")
FANGEAS <- subset(PBM_W, Site.code == "FANGEAS")
```

```
MIROIR <- subset(PBM_W, Site.code == "MIROIR")

PELL79C2 <- subset(PBM_W, Site.code == "PELL79C2")

PLAINEP <- subset(PBM_W, Site.code == "PLAINEP")

PREROND <- subset(PBM_W, Site.code == "PREROND")


library(writexl)


write_xlsx(SJSL972, path = "/Users/Robert/Dropbox/MA/R/MA_1/SJSL972.xlsx")

write_xlsx(SJSLS, path = "/Users/Robert/Dropbox/MA/R/MA_1/SJSLS.xlsx")

write_xlsx(ALLOS, path = "/Users/Robert/Dropbox/MA/R/MA_1/ALLOS.xlsx")

write_xlsx(VALPROV2, path = "/Users/Robert/Dropbox/MA/R/MA_1/VALPROV2.xlsx")

write_xlsx(CORREO, path = "/Users/Robert/Dropbox/MA/R/MA_1/CORREO.xlsx")

write_xlsx(CRISTOL, path = "/Users/Robert/Dropbox/MA/R/MA_1/CRISTOL.xlsx")

write_xlsx(FANGEAS, path = "/Users/Robert/Dropbox/MA/R/MA_1/FANGEAS.xlsx")

write_xlsx(MIROIR, path = "/Users/Robert/Dropbox/MA/R/MA_1/MIROIR.xlsx")

write_xlsx(PELL79C2, path = "/Users/Robert/Dropbox/MA/R/MA_1/PELL79C2.xlsx")

write_xlsx(PLAINEP, path = "/Users/Robert/Dropbox/MA/R/MA_1/PLAINEP.xlsx")

write_xlsx(PREROND, path = "/Users/Robert/Dropbox/MA/R/MA_1/PREROND.xlsx")
```

4) Table of PBM sites

FID	Site_name	Site_Code	Latitude	Longitude
0	Lac Saint Léger	SJSL972	44.42	6.336389
1	Lac Saint Léger	SJSLS	44.42	6.336389
2	Plan du Laus	ALLOS	44.241667	6.702222
3	Vallon de Provence	VALPROV2	44.391111	6.404167
4	Correo	CORREO	44.508333	5.983056
5	Cristol Lake	CRISTOL	44.9975	6.633333
6	Fangeas	FANGEAS	44.716111	6.449444
7	Lac Miroir	MIROIR	44.635278	6.793889
8	Pelléautier	PELL79C2	44.522222	6.183333
9	Plaine Alpe	PLAINEP	44.963889	6.594167
10	Pré Rond	PREROND	44.918889	6.594167

6) Table of C14 dates used:

Date ID	LablD	BP	Error	SiteName	Longitude	Latitude	Source

68	266	795 0	150	Saint Mitre:abri 3	5.66	43.88	Manning, K.; Timpson, A.; Colledge, S.; Crema, E.; Shennan, S. (2015), The Cultural Evolution of Neolithic Europe. EUROEVOL Dataset.
70	263	640 0	130	Saint Mitre:abri 3	5.66	43.88	Manning, K.; Timpson, A.; Colledge, S.; Crema, E.; Shennan, S. (2015), The Cultural Evolution of Neolithic Europe. EUROEVOL Dataset.
71	264	670 0	130	Saint Mitre:abri 3	5.66	43.88	Manning, K.; Timpson, A.; Colledge, S.; Crema, E.; Shennan, S. (2015), The Cultural Evolution of Neolithic Europe. EUROEVOL Dataset.
72	203	515 0	100	Saint Mitre:abri 3	5.66	43.88	Manning, K.; Timpson, A.; Colledge, S.; Crema, E.; Shennan, S. (2015), The Cultural Evolution of Neolithic Europe. EUROEVOL Dataset.
73	265	610 0	150	Saint Mitre:abri 3	5.66	43.88	Manning, K.; Timpson, A.; Colledge, S.; Crema, E.; Shennan, S. (2015), The Cultural Evolution of Neolithic Europe. EUROEVOL Dataset.
74	201	435 0	150	Saint Mitre:abri 3	5.66	43.88	Manning, K.; Timpson, A.; Colledge, S.; Crema, E.; Shennan, S. (2015), The Cultural Evolution of Neolithic Europe. EUROEVOL Dataset.
66	152 4	894 5	50	Saint Antoine	5.95	44.4333	Manning, K.; Timpson, A.; Colledge, S.; Crema, E.; Shennan, S. (2015), The Cultural Evolution of Neolithic Europe. EUROEVOL Dataset.
69	152 3	891 0	50	Saint Antoine	5.95	44.4333	Manning, K.; Timpson, A.; Colledge, S.; Crema, E.;

							Shennan, S. (2015), The Cultural Evolution of Neolithic Europe. EUROEVOL Dataset.
75	408	6170	150	Saint Antoine	5.95	44.4333	Manning, K.; Timpson, A.; Colledge, S.; Crema, E.; Shennan, S. (2015), The Cultural Evolution of Neolithic Europe. EUROEVOL Dataset.
67	2454	4260	45	LES GRANGES	5.953	44.139	Manning, K.; Timpson, A.; Colledge, S.; Crema, E.; Shennan, S. (2015), The Cultural Evolution of Neolithic Europe. EUROEVOL Dataset.
65	8479	5450	100	FRIGOURAS	5.96	44.13	Manning, K.; Timpson, A.; Colledge, S.; Crema, E.; Shennan, S. (2015), The Cultural Evolution of Neolithic Europe. EUROEVOL Dataset.
62	867	4740	140	Montpezat grotte Muree	6.09	43.78	Manning, K.; Timpson, A.; Colledge, S.; Crema, E.; Shennan, S. (2015), The Cultural Evolution of Neolithic Europe. EUROEVOL Dataset.
63	11613	4069	118	Montpezat grotte Muree	6.09	43.78	Manning, K.; Timpson, A.; Colledge, S.; Crema, E.; Shennan, S. (2015), The Cultural Evolution of Neolithic Europe. EUROEVOL Dataset.
59	-112	4825	130	Grotte de l'Eglise	6.15	43.75	Manning, K.; Timpson, A.; Colledge, S.; Crema, E.; Shennan, S. (2015), The Cultural Evolution of Neolithic Europe. EUROEVOL Dataset.
60	1333	5500	140	Grotte de l'Eglise	6.15	43.75	Manning, K.; Timpson, A.; Colledge, S.; Crema, E.; Shennan, S. (2015), The Cultural Evolution of

							Neolithic Europe. EUROEVOL Dataset.
61	1334	5760	140	Grotte de l'Eglise	6.15	43.75	Manning, K.; Timpson, A.; Colledge, S.; Crema, E.; Shennan, S. (2015), The Cultural Evolution of Neolithic Europe. EUROEVOL Dataset.
76	704	4100	140	Sainte-Croix-du-Verdon, abri du Capitaine	6.15	43.76	Manning, K.; Timpson, A.; Colledge, S.; Crema, E.; Shennan, S. (2015), The Cultural Evolution of Neolithic Europe. EUROEVOL Dataset.
77	1111	6050	150	Sainte-Croix-du-Verdon, abri du Capitaine	6.15	43.76	Manning, K.; Timpson, A.; Colledge, S.; Crema, E.; Shennan, S. (2015), The Cultural Evolution of Neolithic Europe. EUROEVOL Dataset.
15	Pa 2208	240	30	Col du Palastre	6.206051	44.697516	Walsh (2014)
16	Pa 2239	1915	80	Col du Palastre	6.206051	44.697516	Walsh (2014)
64	8930	7760	80	RAVIN DE MOURESSE BOLINE	6.23	43.89	Manning, K.; Timpson, A.; Colledge, S.; Crema, E.; Shennan, S. (2015), The Cultural Evolution of Neolithic Europe. EUROEVOL Dataset.
5	Pa 2138	1550	40	Cheval de Bois	6.341443	44.753533	Walsh (2014)
45	Poz-32463	3125	35	Serre de l'Homme X	6.391469	44.773193	Walsh (2014)
46	Poz-32	2435	35	Serre de l'Homme	6.391469	44.773193	Walsh (2014)

	465			X			
47	Poz -32 466	2395	35	Serre de l'Homme X	6.391469	44.773193	Walsh (2014)
48	Poz -32 467	3075	30	Serre de l'Homme X	6.391469	44.773193	Walsh (2014)
49	Poz -32 469	4105	35	Serre de l'Homme XI CPA	6.392509	44.772552	Walsh (2014)
50	Pa 2463	3375	30	Serre de l'Homme XIa	6.392509	44.772552	Walsh (2014)
51	Pa 2462	3895	35	Serre de l'Homme XIa	6.392509	44.772552	Walsh (2014)
52	Poz -32 472	4475	35	Serre de l'Homme XIa	6.392509	44.772552	Walsh (2014)
53	Poz -32 470	3175	30	Serre de l'Homme XIa	6.392509	44.772552	Walsh (2014)
54	Poz -32 471	3140	30	Serre de l'Homme XIa	6.392509	44.772552	Walsh (2014)
55	Poz -32 473	4365	35	Serre de l'Homme XIX	6.393592	44.772858	Walsh (2014)
28	Pa 2461	2275	40	Grand Founze IA	6.440189	44.807253	Walsh (2014)
29	Pa 2460	1095	30	Grand Founze IB	6.440189	44.807253	Walsh (2014)

30	Poz -22 633	274 5	30	Grand Founze IC	6.440189	44.807253	Walsh (2014)
1	Poz -43 854	172 5	30	Abri Faravel	6.44446	44.708476	Walsh (2014)
2	Poz -45 433	124 5	30	Abri Faravel	6.44446	44.708476	Walsh (2014)
3	Poz -43 853	353 0	35	Abri Faravel	6.44446	44.708476	Walsh (2014)
4	Poz -45 434	940	30	Abri Faravel	6.44446	44.708476	Walsh (2014)
58	302 3	398 0	120	Demando lx Dolmen de Vieilleville	6.5794	43.8696	Manning, K.; Timpson, A.; Colledge, S.; Crema, E.; Shennan, S. (2015), The Cultural Evolution of Neolithic Europe. EUROEVOL Dataset.
6	Pa 214 2	895	35	Cheval de Bois II	6.33594881 3	44.75310581	Walsh (2014)
7	Poz -56 03	322 0	35	Chichin IIa	6.40544482 9	44.74219922	Walsh (2014)
8	Poz -54 99	685	35	Chichin IIb	6.40544482 9	44.74219922	Walsh (2014)
9	Poz -54 98	384 5	35	Chichin IIIa	6.39049108 3	44.74277935	Walsh (2014)
10	Poz -55 00	397 0	35	Chichin IIIb	6.39049108 3	44.74277935	Walsh (2014)

11	Pa 2240	1620	55	Clot Lamiande	6.240608121	44.70744755	Walsh (2014)
12	Pa 2207	1230	30	Clot Lamiande	6.240608121	44.70744755	Walsh (2014)
13	Pa 2205	960	35	Clot Lamiande	6.240608121	44.70744755	Walsh (2014)
14	Pa 2206	1145	50	Clot Lamiande II	6.235916945	44.70814674	Walsh (2014)
17	Pa 2236	2770	95	Col du Palastre II	6.207092424	44.69731504	Walsh (2014)
18	Pa 2234	195	30	Fangeas VI	6.448153183	44.71589819	Walsh (2014)
19	Pa 2235	1180	80	Fangeas VIIa	6.448567925	44.71532476	Walsh (2014)
20	Pa 1800	500	40	Fangeas VIIb	6.448567925	44.71532476	Walsh (2014)
21	Pa 1728	857	40	Faravel VIIIb	6.449777397	44.71743517	Walsh (2014)
22	Pa 1841	3665	40	Faravel VIIId	6.449777397	44.71743517	Walsh (2014)
23		680	30	Faravel XIIa	6.446657395	44.71799686	Walsh (2014)
24	Pa 184	650	40	Faravel XIIb	6.446657395	44.71799686	Walsh (2014)

	3						
25	Pa 2113	2460	50	Faravel XIIIb	6.447199525	44.71671608	Walsh (2014)
26	Pa 2097	1985	50	Faravel XIV	6.446960004	44.71690482	Walsh (2014)
27	Pa 2209	3670	45	Faravel XIX	6.446979108	44.71357025	Walsh (2014)
31	Pa 2296 + 2309	660	50	Jas des Provençaux	6.20536834	44.71140032	Walsh (2014)
32	Pa 2303	700	50	Jas des Provençaux	6.20536834	44.71140032	Walsh (2014)
33	Pa 2238	955	70	Jas du Cros	6.209850741	44.71997092	Walsh (2014)
34	Pa 1971	3180	60	Lac des Lauzons II	6.278436742	44.77688625	Walsh (2014)
35	Pa 1973	3470	100	Lac des Lauzons II	6.278436742	44.77688625	Walsh (2014)
36	Poz 13919	3965	35	Serre de l'Homme IIb	6.399292446	44.77693366	Walsh (2014)
37	Poz 14893	3960	35	Serre de l'Homme IIb	6.399292446	44.77693366	Walsh (2014)
38	Pa 2364	3665	45	Serre de l'Homme IIc	6.399292446	44.77693366	Walsh (2014)

39	Pa 2363	3890	30	Serre de l'Homme IIc	6.399292446	44.77693366	Walsh (2014)
40	Poz-32481	3210	35	Serre de l'Homme SPA	6.399292446	44.77693366	Walsh (2014)
41	Lyon-8553	2990	30	Serre de l'Homme SPA	6.399292446	44.77693366	Walsh (2014)
42	Lyon-8554	3030	30	Serre de l'Homme SPA	6.399292446	44.77693366	Walsh (2014)
43	Lyon-8555	3055	30	Serre de l'Homme SPA	6.399292446	44.77693366	Walsh (2014)
44	Lyon-8556	3535	30	Serre de l'Homme SPA	6.399292446	44.77693366	Walsh (2014)
56	Pa 2304	1900	30	Vallon de la Vallette	6.318081935	44.77394996	Walsh (2014)
57	Pa 2299	1210	60	Vallon de la Vallette	6.318081935	44.77394996	Walsh (2014)