



**HAL**  
open science

# The Establishment of the Agricultural Landscape of Central Sicily Between the Middle Neolithic and the Beginning of the Iron Age

Claudia Speciale, Enrico Giannitrapani, Anna Maria Mercuri, Assunta Florenzano, Laura Sadori, Nathalie Combourieu-Nebout

► **To cite this version:**

Claudia Speciale, Enrico Giannitrapani, Anna Maria Mercuri, Assunta Florenzano, Laura Sadori, et al.. The Establishment of the Agricultural Landscape of Central Sicily Between the Middle Neolithic and the Beginning of the Iron Age. *Human Ecology*, In press, 10.1007/s10745-024-00496-3. hal-04625458

**HAL Id: hal-04625458**

**<https://hal.science/hal-04625458v1>**

Submitted on 26 Jun 2024

**HAL** is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.



# The Establishment of the Agricultural Landscape of Central Sicily Between the Middle Neolithic and the Beginning of the Iron Age

Claudia Speciale<sup>1,2,3</sup> · Enrico Giannitrapani<sup>4,5</sup> · Anna Maria Mercuri<sup>6</sup> · Assunta Florenzano<sup>6</sup> · Laura Sadori<sup>7</sup> · Nathalie Combourieu-Nebout<sup>8</sup>

Accepted: 19 April 2024  
© The Author(s) 2024

## Abstract

The possible co-variation of human occupation and vegetation from the Middle Neolithic to the beginning of the Iron Age (7.5–2.8 ka BP) in Central Sicily in the context of the central Mediterranean between Middle and Late Holocene are analysed in this paper to provide new insights on Sicilian prehistoric demography. The demographic and economic trends during these millennia were reconstructed using archaeological, Accelerator Mass Spectrometry <sup>14</sup>C dates, palynological, archaeobotanical, and zooarchaeological data from the northern, central, and southern sectors of Central Sicily through a diachronic comparison with variation in Arboreal Pollen, Anthropogenic Pollen Indicators, *Olea-Juglans-Castanea* pollen, microcharcoals, and *Sporormiella* from four pollen cores from sites in different ecosystems. A very significant spread of farming activities was found at the end of the Neolithic, together with an apparent demographic gap during the Middle Copper Age, and the emergence of agricultural landscapes at the end of the Copper Age associated with a striking increase in population. A combination of cultural and climatic changes during the late phase of the Bronze Age resulted in a subsequent overall decrease in population.

**Keywords** Prehistory · Paleodemography · Paleoenvironment · Pollen · Botany · Zooarchaeology · AMS · Neolithic · Bronze Age · Agricultural landscapes · Human impacts · Central Sicily · Mediterranean

## Introduction: Prehistoric Demography and Paleoenvironment of a Big Island

Due to their physical boundaries, islands evidence some ecosystems processes that are more difficult to isolate in continental areas (Kueffer et al., 2016; Whittaker et al., 2017). The central geographic location of Sicily and other Tyrrhenian islands in the Mediterranean Basin makes them a critical region for the study of Quaternary climates and environments (Lionello et al., 2006; Tinner et al., 2009; Guarino & Pasta, 2018) and as natural laboratories of plant evolution (Pasta & La Mantia, 2013; Thompson, 2020). The large islands have contributed to the conservation of middle Tertiary flora with a high degree of endemism (Magri et al., 2017), which in Sicily results also from its very complex geology and natural history (Quézel, 1995; Médail & Quézel, 1997) due to extremely varied lithographic and orographic features, hydrographic network, and morphogenetic processes (Catalano et al., 1996; Speranza et al., 2003).

Sicilian prehistory is an intriguing puzzle of several trajectories from the Eastern to the Western Mediterranean

---

✉ Claudia Speciale  
cspeciale@iphes.cat

<sup>1</sup> IPHES-CERCA, Catalan Institute of Human Palaeoecology and Social Evolution, Tarragona, Spain

<sup>2</sup> URV, Universitat Rovira i Virgili, Tarragona, Spain

<sup>3</sup> Department of Historical Studies, University of Gothenburg, Gothenburg, Sweden

<sup>4</sup> Arkeos, Servizi integrati per i Beni Culturali, Enna, Italy

<sup>5</sup> Dipartimento Culture e Società, University of Palermo, Palermo, Italy

<sup>6</sup> Department of Life Sciences, University of Modena and Reggio Emilia, Modena, Italy

<sup>7</sup> Dipartimento di Biologia Ambientale, Sapienza, Rome, Italy

<sup>8</sup> UMR 7194 CNRS/MNHN, Histoire Naturelle de l'Homme Préhistorique, Paris, France

and, at the same time, from Central Europe and the Italian peninsula to Northern Africa. Its importance in the Mediterranean Basin is due not just to its geographical location but also to its ecological diversity, cultural heritage, and historical significance (Romano et al., 2021). Understanding the dynamics and interactions of human communities within their environment has become one of the most significant improvements of recent archaeological studies in Sicily (Pasta & Speciale, 2021; Pasta et al., 2022). Nevertheless, there has not been a comprehensive study to evaluate Sicilian sub-regional human patterns, the use of abiotic (water, soil) and plant resources, and the main climatic trends between the Middle Holocene and the beginning of the Late Holocene.

In a broader archaeological framework, studies on prehistoric demographic trends have exponentially increased over the last 20 years (Shennan & Edinborough, 2007), creating what is termed the “boom-and-bust” theory in prehistoric demography, whose causes are not always easy to disentangle from climate and sociocultural changes (Shennan & Saer, 2021) and human conflicts (Kondor et al., 2022). A specific focus has been on the relationships among environmental trends (Capuzzo et al., 2018) and the correlation between the increase in human population and arboreal pollen percentages, notably tree crops (Bevan et al., 2019). Roberts et al. (2019; 11) note: “The results show that most Mediterranean regions experienced a series of population ‘cycles’ starting with the first appearance of Neolithic farming societies, but that demographic trends were region-specific rather than pan-Mediterranean.” The whole Mediterranean Basin as well as specific regions, have become the core area of demographic research based on large radiocarbon AMS datasets, their Summed Probability Distribution (SPD), and/or Kernel Density Estimation (KDE) models (e.g., Palmisano et al., 2021; Parkinson et al., 2021). Of course, SPD in demography should not be applied uncritically and should always be supported by the analysis of a very large dataset and, is ultimately mostly effective in evaluating multiregional trends (Crema, 2022). Using this framework for prehistoric Sicily is problematic because only a very small percentage of the many archaeological sites identified by surveys and/or archaeological excavations has been radiocarbon-dated (Giannitrapani, 2023). Thus, to preserve, evaluate, and exploit the considerable amount of archaeological data, any demographic estimate needs to rely on a network of relative chronology, whose precision can and must be profoundly enlarged. Even so, a picture of human occupation density based only on radiocarbon-dated sites could be severely misleading. We argue that discussion of not AMS-dated archaeological sites is necessary to gain further insight into demographic trends, revealing a crucial perspective on settlement spread and adding, when available, first-hand information on

interactions between landscape and human communities’ economic systems.

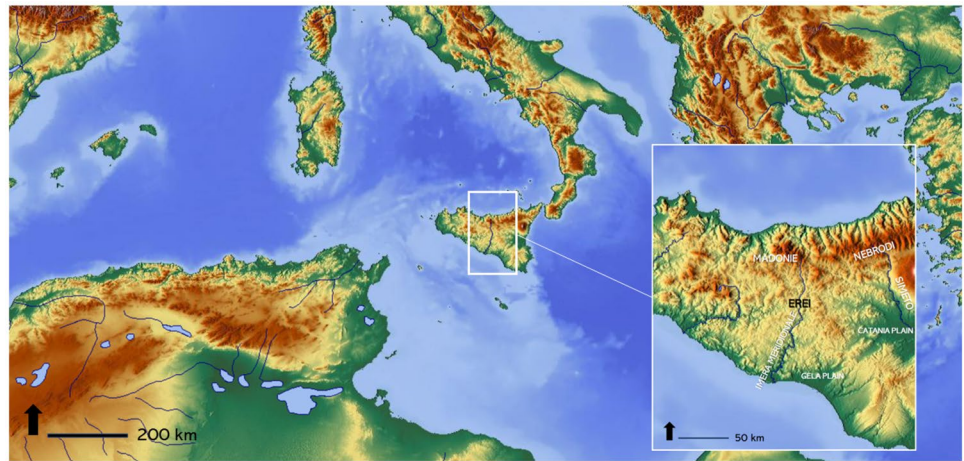
Paleodemography in Sicily and in some of its subregions has been approached by several authors, starting from the Paleolithic to the end of the Bronze Age. The island underwent a “late” process of human colonization, as an essential and recent line of research on the most ancient phases revealed (Lo Vetro & Martini, 2012; Di Maida et al., 2020; Romano et al., 2021). The human presence and its spread in some limited areas have been topics of several dedicated investigations from the Neolithic and/or Copper Age (CA) (Natali & Forgia, 2018; Giannitrapani & Ianni, 2020) to the Bronze Age (BA) (Bietti Sestieri, 2013; Pacciarelli et al., 2015; Battaglia et al., 2020; Martinelli, 2020; Speciale, 2021) to prehistoric diachronic occupation (Forgia et al., 2012; Cultrera, 2014; Giannitrapani, 2017), in some cases applying Bayesian methods (Alberti, 2013).

The literature on the occupation of the island before the historical Greek colonization (9.0–3.0 cal ka BP) (Tusa, 1999; Leighton, 1999; Albanese, 2003; Pasta et al., 2022) records intriguing oscillations, displacements, and occupation patterns that can be evaluated within the regional context but also into the broader Mediterranean context. Human genetic data are opening interpretations of prehistoric migrations that sometimes challenge previous archaeological assumptions about the timing and modes of population displacements among regions and can be crucial in the evaluation of demographic changes in Sicily (Sarno et al., 2017; Fernandes et al., 2020).

Human activity can be one of the main factors of landscape disturbance. Archaeobotanical research facilitates the identification of reciprocal influences of human and plant communities (Marignani et al., 2017; Mercuri & Florenzano, 2019; Michelangeli et al., 2022), notably on islands (Nogué et al., 2021), to improve our understanding of demographic patterns (Mercuri et al., 2019a). Although limited, archaeobotanical analyses for prehistoric Sicily provide insights into human communities’ economic and cultural strategies, including local woodland management practices and agricultural choices and techniques (e.g., Mercuri et al., 2020; Speciale et al., 2020). Ultimately, zooarchaeological analyses may contribute to reconstructing past human economies, evaluating landscape degradation, and improving our knowledge of past ecology (Steele, 2015).

Research on the Holocene on the island has also focused on the collection of datasets from the lacustrine sediments in Central Sicily (Sadori & Narcisi, 2001; Sadori et al., 2008, 2013, 2015; Zanchetta et al., 2007, 2022), southern coastal Sicily (Calò et al., 2012; Tinner et al., 2009; Noti et al., 2009; Magny et al., 2011), northern mountainous Sicily (Bisculm et al., 2012; Tinner et al., 2016) for the reconstruction of the paleoenvironment and human impacts on vegetation. Pollen and marine calcareous nannofossils extracted from marine

**Fig. 1** Position of Sicily within the Mediterranean Basin and main geographical areas cited in the text



sediment cores and stable isotopes of speleothems have served as proxies to quantify climate parameters and climate variability for the broader paleoclimatic picture (Incarbona et al., 2008, 2010; Frisia et al. 2006; Desprat et al., 2013).

We present an analysis of the variation in human occupation and vegetation in Central Sicily from the Middle Neolithic (MN) to the beginning of the Iron Age (7.5–2.8 cal ka BP).<sup>1</sup> We focus on three specific questions on establishing the agrarian landscape (i.e., the extensive reliance on crop resources) and detecting the human impacts: 1) Can we identify such human impacts in the Middle Neolithic period, or were the agrarian landscapes structured later? 2) Can we positively relate demographic oscillations during the Copper Age and Bronze Age to crucial climatic variations, such as increased aridity? and 3) did coastal and inland human communities adopt different settlement strategies?

## Geological, Geomorphological, and Vegetational Framework

Sicily (36°N to 38° N and from 12°E to 15° E.) is the largest island of the Mediterranean Basin, with an approximately triangular shape and a distance of ca. 250 km east to west and varying between 80 km (east) and 190 km (west) north to south. It is characterized by a Mediterranean climate, with average annual temperatures of 17–18 °C in the coastal areas, decreasing to 10 °C in the higher mountain areas (Viola et al., 2014). The island hosts about 3,200 native species, of which 10% are endemic (Brullo & Brullo, 2021), 23–25 vegetational bioclimatic assemblages (Bazan et al., 2015), and 250 biotopes and biotope complexes of fauna and vegetation (Piano Territoriale Paesistico Regionale

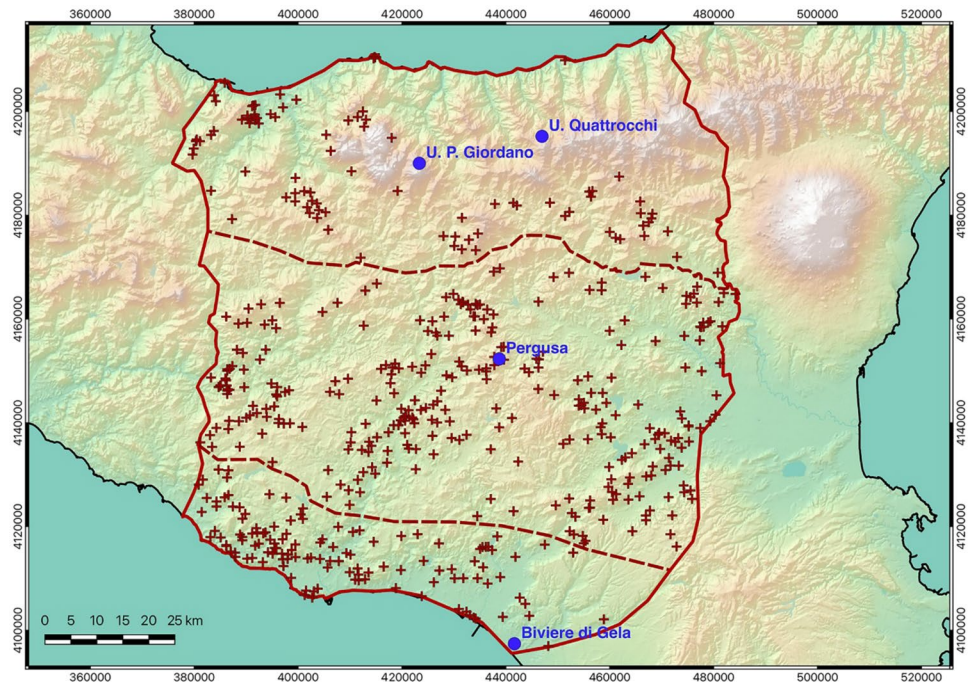
Sicilia, 1996). The study area is a longitudinal transect of ca. 9000 km<sup>2</sup> spanning the mountainous areas of Madonie and Nebrodi in the north to the hilly landscape of the Erei's uplands to the southern coastal Gela Plain (Figs. 1 and 2).

## Materials and Methods

To assess paleodemography, we used a main grid of AMS-dated sites. We evaluated the demographic spread in the study area based on the chronology of relative cultural elements (mostly pottery). We then compared the demographic data with the vegetational trends recorded on four lacustrine sites selected from those providing local and regional signals belonging to different phytoecological districts and with appropriate AMS dates correlated to the sedimentary sequence. When possible, we included the available data from wood charcoal remains, seeds, and faunal remains from the sites. We defined four chronological periods, divided according to major cultural changes: Phase A (Middle Neolithic, MN, 7.5–6.4 cal ka BP), Phase B (Late Neolithic - LN/Early and Middle Copper Age - ECA and MCA, corresponding for the discussion into B1 (6.4–5.3 cal ka BP, LN-ECA) and B2 (5.3–4.6 cal ka BP, MCA)), Phase C (Late Copper Age - LCA/Early Bronze Age - EBA, 4.6–3.6 cal ka BP), and Phase D (Middle Bronze Age - MBA/Late Bronze Age - LBA, 3.6–2.8 cal ka BP). We follow Leighton (1999) as well as Maniscalco (2007), Giannitrapani (2009), and Adamo and Gullì (2012), who argue that the Copper Age is divided into only two phases – Early and Late– as opposed to the traditional three sub-phases, and engage with Giannitrapani's (2020, 2023) proposal of the possible existence of a single phase bridging the Late Neolithic and the Early Copper Age in central Sicily. Similarly, Phase C combines the traditional Late Copper Age and Early Bronze Age (see also Procelli, 2001; Alberghina & Gullì, 2011; Giannitrapani & Ianni, 2011, 2020; Giannitrapani et al., 2023).

<sup>1</sup> We do not address the Early Neolithic here because of the lack of data on the research area.

**Fig. 2** Map of Sicily with indication of the study area, the archaeological sites of all the phases (crosses) and the 4 pollen sites (circles)



## Archaeological Sites

Based on our research of the vast literature<sup>2</sup> on Sicily's prehistory, we include 524 archaeological sites (Fig. 2, Supplementary Materials: Table S1) divided according to their sector (northern, central, southern), indicating their phase(s) of occupation and the reliability of their chronological attribution (from 1 to 3). When a specific chronological span was not indicated in the original bibliographic source (i.e., only “prehistoric” or “Copper Age”), sites were not listed in the dataset. Beyond the issue of non-homogenous studies of the territory, where different archaeological investigations influenced the degree and significance of known archaeological remains, it is also essential to consider the change in coastlines during the Holocene that might have affected several kilometres of the southern sector (e.g., Pasta et al., 2022). Finally, it is noteworthy that the mountainous area of the northern sector currently has less archaeological data due to the scarcity of systematic investigations on the Nebrodi mountains. For the paleovegetational framework, in all sectors the archaeological sites are an average of between 30 and 50 km distant from the pollen sequence of reference, with the exception of the sites near Agrigento that are up to 70 km from the site of Biviere di Gela; nevertheless, the homogeneity of the coastal area and its vicinity between Gela and Agrigento allowed us to consider the sites at the

westernmost part of the sector as comparable with the Biviere di Gela sequence.

We gathered our data from the relevant archaeological sections of the PTP (Piano Territoriale Paesaggistico), the regional landscape catalogue produced by the Sicilian Regional Office for Cultural Heritage, integrated by the results of past and recent extensive survey projects (northern sector: Belvedere, 2002; Mannino, 2008; Forgia, 2019; central sector: La Rosa, 1997; Thompson, 1999; Agodi et al., 2000; Ianni, 2004; Procelli et al., 2007; Ayala & Fitzjohn, 2007; Giannitrapani, 2017; Brancato, 2020; southern sector: Castellana, 1982; Guzzone, 1994; La Torre & Toscano Raffa, 2016).

## AMS and Radiocarbon Dating

Despite a longstanding methodological resistance to the wide use of <sup>14</sup>C radiocarbon dating in defining the chronological framework of prehistoric Sicily, the situation has been changing rapidly, with many projects adopting multidisciplinary approaches. A recent survey conducted by the *Calib\_Sicily* project (Giannitrapani, 2023) listed 262 dates collected from 64 sites distributed throughout Sicily and its satellite islands (Fig. 3).

For the study area, we have a total of 108 AMS and radiocarbon dates obtained from 22 sites (4 for the northern sector, 10 for the central sector, 8 for the southern sector) (Supplementary Materials), covering the four sub-phases for which the start and end boundaries are defined by the Bayesian modelling of the relevant dates (Table 1). The Bayesian

<sup>2</sup> The data were gathered from the authors' private collections of papers, books, and documents from Regione Sicilia.

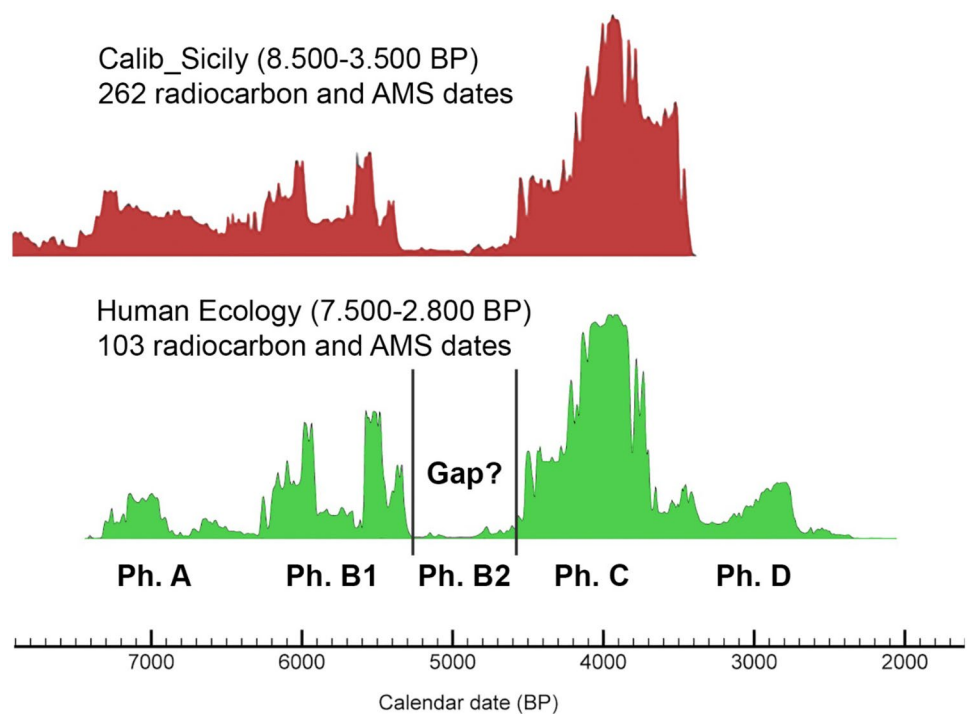
**Fig. 3** Distribution map of the sites with AMS and radiometric chronology selected in the study area



model presented here poses a series of methodological criticalities, mainly due to the limited dataset available (Table 1). However, we employed the model without referencing the statistical and analytical complex processes involved in such an analysis to provide a general chronological framework for the four sub-phases. The model evidences some gaps in the sequence. However, the gaps between Phases A and B (about 180 years) and between Phase C and D (about 50 years)

are false since in the general regional modelled framework, these overlap each other, thus suggesting a lack of sampling and dating for the study area. On the other hand, the gap between Phase B and C (about 850 years) is also clearly evidenced in the modelled dates for the Sicilian CA, as shown by the probability density curve that sums up all the dates available for the study area and confirmed by the modelled data for the entire region (Fig. 4).

**Fig. 4** Summed Probability Density curve for the AMS and radiocarbon dates from the study area (re-elaborated from Giannitrapani, 2023)



**Table 1** Bayesian modelled yrs BP boundaries for the four phases discussed in the text

	Phase A	Phase B	Phase C	Phase D
<b>Boundary Start</b>	7350–7190	6235–6105	4490–4425	3590–3290
<b>Boundary End</b>	6660–6420	5420–5305	3685–3640	2790–2610

## Archaeobotanical and Zooarchaeological Data

Archaeobotanical studies (plant macro- and micro-remains) from prehistoric contexts are scattered throughout the island. Some are more dispersed for the classical and medieval phases (Mercuri et al., 2015b, 2019b; Montecchi & Mercuri, 2018). Unfortunately, prehistoric analyses are centered on some "hotspots" such as North-Eastern Sicily for the BA, Western Sicily for the IA, and a reliable stratigraphic sequence from Mesolithic until LBA (Pasta & Speciale, 2021) (Fig. 5).

Only six sites in the study area have archaeobotanical analyses (Fig. 5; Table 2), covering from the MN to the LBA, but in very different ecological frameworks. Unfortunately, there is a big chronological gap between the early neolithization (Costantini & Costantini Biasini, 1997) and the widespread of domestic species during the CA (Speciale et al., 2020; Pasta & Speciale, 2021).

During the last 15 years, the use of stable isotopes allowed to increase the perspectives on local responses to environmental and climate changes. A series of AMS/IRMS analyses were conducted on plant remains from archaeological sites concomitant to carbon isotopic analyses,  $\delta^{13}\text{C}$  (Ferrio et al., 2003). The Aeolian islands archaeobotanical dataset has been enriched with a series of AMS/IRMS analyses

conducted on selected plant remains (Caracuta et al., 2012; Speciale et al., 2016). The most recent study of the isotope composition of seeds and wood charcoal remains from the site of Case Bastione gives a picture of the changes in aridity and manuring techniques (Speciale et al., 2020).

Sicily's zooarchaeological tradition is more consolidated, with a significant increase in studies since the 1990s. Data from Central Sicily are quite well represented, with 16 sites in total, six of which cover at least two chronological phases (Table 3); nevertheless, the applied sampling protocol is not always clearly reported, and data can be affected by different sampling methods adopted (see Prillo et al., *in press*).

## Paleoenvironmental and Paleoclimatic Data

The estimation of the vegetation composition during the four time periods was calculated taking into account the pollen records referring to key species available in the northern, central, and southern sectors of the study area. The selected sites provide well-dated pollen records covering the last 7000 years (Table 4) and all the archaeological sites compared are located in similar environments and no more than 50 km distant from the site (see above). The four pollen sequences are in very different environments, from the mountainous areas of Madonie and Nebrodi in the northern sector, to the continental climate of internal Sicily down to the sandy coast of the southern sector. The north-easternmost sequence is Urio Quattrocchi, a perennial pond in the supra-Mediterranean belt (1044 m a.s.l.); despite its geographical position in the Nebrodi Mts., we treated it as a marked but controversial local indicator of climatic changes, especially for

**Fig. 5** Sites with published archaeoenvironmental data: zooarchaeological data (blue dots), zooarchaeological and archaeobotanical data (blue dots with a red cross), stable Carbon isotope analyses (green squares)

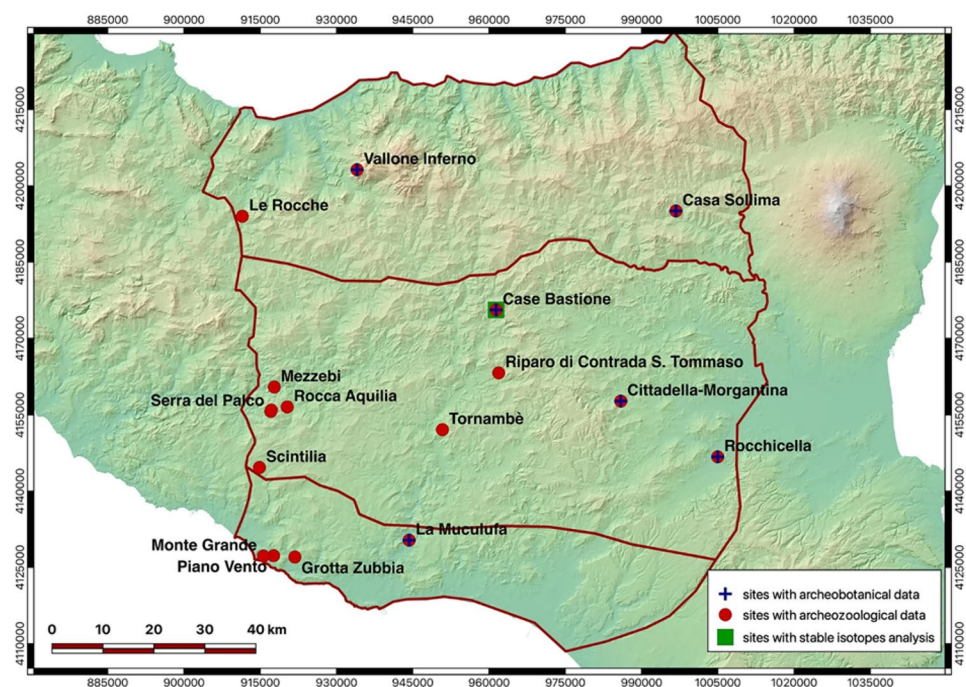


Table 2 List of the sites with archaeobotanical remains

Name Cultural Phase	Rocchicella		Rocchicella		C. Sollima		C. Bastione		V. Inferno		Rocchicella		Muculufa		Morgantina	
	A - MN	B - EC/MCA	B-C - MCA/LCA	B-C - MCA/LCA	B-C - MCA/LCA	B-C - MCA/LCA	C - LCA	C - LCA	C - EBA	C - EBA	C - EBA	C - EBA	C - EBA	C - EBA	D - LBA	D - LBA
<b>Arboreal plants</b>																
<i>Acer</i> sp.										x						
<i>Alnus</i> sp.							x									
<i>Carpinus</i> sp.							x									
<i>Erica arborea</i>							x			x						
<i>Ficus carica</i>						x										
<i>Fraxinus</i> sp.		x														
<i>Hedera helix</i>																
Fabaceae			x													
<i>Olea europaea</i>	x	x														
<i>Pistacia cf. terebinthus</i>							x									
<i>Populus/Salix</i>			x													
<i>Quercus</i> sp.	x															x
<i>Quercus type cerris</i>																
<i>Quercus type ilex</i>	x	x														
<i>Quercus type robur</i>	x	x														
<i>Rhamnus/Phillyrea</i>																
Rosaceae/Maloideae																
Rosaceae/Prunoideae																
<i>Ulmus</i> sp.																
<i>Pinus</i> sp.																
<i>Pinus type silvestris/nigra</i>																
<b>Seeds</b>																
Cereals undiff	x															
<i>Hordeum vulgare</i>																
<i>Triticum monococcum</i>																
<i>Triticum dicoccum</i>																
<i>Triticum cf. spelta</i>																
<i>Triticum aestivum (compactum)</i>																
<i>Triticum</i> sp.																
<i>Vicia faba</i>																
<i>Lens culinaris</i>																
<i>Pisum</i> sp.																
<i>Pisum cf. sativum</i>	x															
<i>Lathyrus</i> sp.																



Table 2 (continued)

Name	Rocchicella		Rocchicella		C. Sollima		C. Bastione		V. Inferno		Rocchicella		Muculufa		Morgantina	
	A - MN	B - ECA/MCA	B-C - MCA/LCA	B-C - MCA/LCA	B-C - MCA/LCA	C - LCA	C - LCA	C - EBA	C - EBA	C - EBA	C - EBA	C - EBA	C - EBA	C - EBA	D - LBA	D - LBA
Fabaceae > 0.5 cm						x										
<i>Vitis vinifera</i>				x										x		
cf. <i>Vitis vinifera</i>						x										
cf. <i>Ziziphus lotus</i>																
<i>Olea europaea</i>				x												
<i>Lithospermum</i> sp.																
<i>Prunus</i> sp.					x									x		
<i>Avena</i> sp.					x									x		
<i>Anthemis</i> sp.														x		
<i>Calendula</i> sp.														x		
<i>Sinapis</i> sp.														x		
Boraginaceae																
Brassicaceae																
Lamiaceae																
<i>Fumaria officinalis</i> -type																
<i>Quercus</i> sp.																
<i>Rubus</i> sp.																

**Table 3** List of the sites with archaeozoological remains; the percentages are calculated on the NISP based on the data available in the publications; site number are related to Table S1

ID	Site	Phase	Chronology	<i>Ovis/Capra</i>	<i>Sus s.</i>	<i>Bos t.</i>	Total Domestic	Wild ruminants	Birds	Carnivora	Other	Total Wild	Reference
389	Serra del Palco I	A	Middle Neolithic	46.75%	19.57%	20.19%	<b>86.51%</b>	N/A	N/A	N/A	N/A	<b>11.72%</b>	Wilkens (1997)
200	Rocchicella	A	Middle Neolithic	9.8%	3.3%	8.2%	<b>21.3%</b>	76.2%	0	0	2.5%	<b>78.7%</b>	Di Patti and Lupo (2008)
486	Fiaccati/Le Rocche	A	Middle Neolithic	47%	21%	19%	<b>86.7%</b>	2%	2%	5%	4%	<b>5.41%</b>	Ianni et al. (2022)
407	Rocca Aquilia	B C	Copper Age	71.55%	6.03%	17.67%	<b>92.25%</b>	N/A	N/A	N/A	N/A	<b>3.44%</b>	Wilkens (1997)
200	Rocchicella	B C	Copper Age	51.9%	8.0%	25.9%	<b>85.8%</b>	12.6%	0.3%	0	1.3%	<b>14.2%</b>	Di Patti and Lupo (2008)
367	Scintilia	B	Early Copper Age	69.53%	8.15%	22.32%	<b>100.00%</b>	0	0	0	0	<b>0.00%</b>	Di Rosa (2014)
130	Casa Sollima	B	Early Copper Age	62.7%	11.5%	16.1%	<b>90.3%</b>	1.1%	0	0	8.6	<b>9.7%</b>	Ashley et al. (2007)
10	Case Bastione	C	Late Copper Age	56.6%	17.5%	8.4%	<b>82.5%</b>	15.5%	0	1.7%	0.3%	<b>17.5%</b>	Giannitrapani et al. (2014)
55	Tomambè	C	Late Copper Age	76.0%	6.8%	14.6%	<b>97.4%</b>	1.8%	0	0.2%	0.6%	<b>2.6%</b>	Giannitrapani and Ianni (2022)
275	La Muculufa, village	C	Late Copper Age	63.2%	13.9%	19.1%	<b>96.3%</b>	3.7%	0	0	0	<b>3.7%</b>	Bartosiewicz (2012)
404	Mezzebi	C	Late Copper Age	46.18%	18.83%	32.73%	<b>97.74%</b>	N/A	N/A	N/A	N/A	<b>2.24%</b>	Wilkens (1997)
10	Case Bastione	C	Early Bronze Age	80.2%	22.1%	8%	<b>90.1%</b>	8.3%	0	1.5%	0	<b>9.9%</b>	Giannitrapani et al. (2014), Di Simone et al. (2019)
274	La Muculufa, sanctuary	C	Early Bronze Age	84.4%	9.5%	5.7%	<b>99.6%</b>	0.4%	0	0	0	<b>0.4%</b>	Bartosiewicz (2012)
367	Scintilia	C	Early Bronze Age	77.59%	3.45%	18.97%	<b>100.00%</b>	0	0	0	0	<b>0.00%</b>	Di Rosa (2014)
298	Monte Grande	C	Early Bronze Age	41.40%	22.10%	32.60%	<b>96.10%</b>	N/A	N/A	N/A	N/A	<b>3.90%</b>	Bedini (1998)
482	Vallone Inferno	C	Middle Neolithic/ Early Bronze Age	71.00%	12.00%	5.00%	<b>88.00%</b>	2.60%	-	1.20%	8.20%	<b>12.00%</b>	Di Simone et al. (2019), Forgia et al. (2023)
390	Serra del Palco II	C	Early Bronze Age	48.10%	10.12%	32.34%	<b>90.56%</b>	0	0	0	0	<b>0.00%</b>	Wilkens (1997)
39	Riparo San Tommaso	C	Early Bronze Age	17.95%	23.30%	7.90%	<b>49.20%</b>	36.3%	3.8%	1.85%	8.7%	<b>50.80%</b>	Mannino et al. (2010)
390	Serra del Palco II	D	Middle Bronze Age	50.22%	26.07%	21.31%	<b>97.90%</b>	N/A	N/A	N/A	N/A	<b>1.58%</b>	Wilkens (1997)
39	Riparo San Tommaso	D	Late Bronze Age	12.75%	17.08%	0.00%	<b>29.83%</b>	10.1%	4.40%	0	55.8%	<b>70.33%</b>	Mannino et al. (2010)
390	Serra del Palco II	D	Late Bronze Age	46.06%	13.48%	37.07%	<b>96.61%</b>	N/A	N/A	N/A	N/A	<b>2.80%</b>	Wilkens (1997)
200	Rocchicella	D	Late Bronze Age	20.3%	16.5%	40.5%	<b>77.2%</b>	20.3%	0	0	2.5	<b>22.8%</b>	Di Patti and Lupo (2008)
91	Morgantina	D	Late Bronze Age	34.62%	8.0%	41.7%	<b>84.3%</b>	15.7%	0	0	0	<b>15.7%</b>	Bartosiewicz (2012)

**Table 4** List of the pollen sequences

Site	Coordinates	Elevation (m a.s.l.)	Bioclimate	Mean annual precipitation	Mean annual temperature	Chronology	Relevant data	References
Urio Quattrocchi	37.901, 14.395	1038	Oro-Mediterranean	990 mm	12.5 °C	10 cal ka - 0 BP	Pollen, microcharcoals, fungal spores ( <i>Sporormiella</i> )	Bisculm et al. (2012)
Urgo di Pietra Giordano	37.852, 14.127	1323	Oro-Mediterranean	870 mm	11.5 °C	6.6 cal ka - 0 BP	Pollen, microcharcoals, fungal spores ( <i>Sporormiella</i> )	Tinner et al. (2016)
Lago di Pergusa	37.514, 14.305	667	Meso-Mediterranean	600 mm	13.4 °C	6.8 cal ka - 0 BP	Pollen, microcharcoals	Sadori et al. (2013), Sadori and Narcisi (2001)
Biviere di Gela	37.017, 14.345	7	Thermo-Mediterranean	409 mm	18.5 °C	7.2 cal ka - 0 BP	Pollen, microcharcoals, fungal spores ( <i>Sporormiella</i> )	Noti et al. (2009)

some aridification trends during the Mid and Late Holocene (Bisculm et al., 2012). On the Madonie Massif, Urgo di Pietra Giordano (1323 m a.s.l.) (Tinner et al., 2016), a small mire with a chronology dating from 6.2 ka calBP, was considered. Lago di Pergusa, near Enna (667 m a.s.l.), includes two core sequences useful for the interpretation of the Mediterranean Holocene landscape. PG1 is a sequence with consistent results to this study (Sadori & Narcisi, 2001), and together with PG2 represents the main reference site for Central Sicily; not only pollen analyses, but also microcharcoals, stable isotopes of  $\delta^{18}\text{O}$  and oscillations in lake level were considered as palaeoenvironmental indicators (Sadori et al., 2013). The last sequence, Biviere di Gela, is situated on the Southern coast providing both local and regional data starting from about the 7.3 ka calBP (Noti et al., 2009).

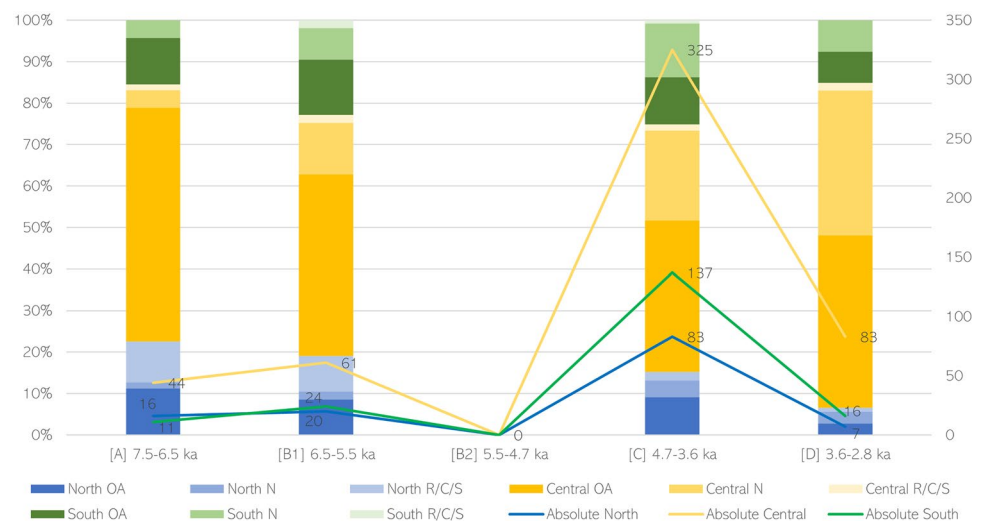
We collected pollen values of the four sequences as: API (Anthropogenic Pollen Indicators) (*Artemisia*, *Centaurea*, *Cichorieae*, *Plantago*, Cereals, *Urtica* and *Trifolium* type), following Mercuri et al. (2013a), AP – Arboreal Pollen and OJC – *Olea*,

*Juglans*, *Castanea* following Mercuri et al. (2013b). The raw pollen data were obtained using the Neotoma Paleocological Database, available by CC rights. When available, presence and density of microcharcoals and *Sporormiella* were used respectively to detect natural or anthropogenic fire activities, in some cases associated with lipid biomarkers (see Thienemann et al., 2017), and variation of husbandry practices (Etienne & Jouffroy-Bapicot, 2014). Further indicators of variations in lake levels of the Mediterranean area, like Lago Preola (Magny et al., 2011, 2013) and stable isotope curves of  $\delta^{18}\text{O}$  (Sadori et al., 2008; Zanchetta et al., 2007) were used as paleoclimatic indicators.

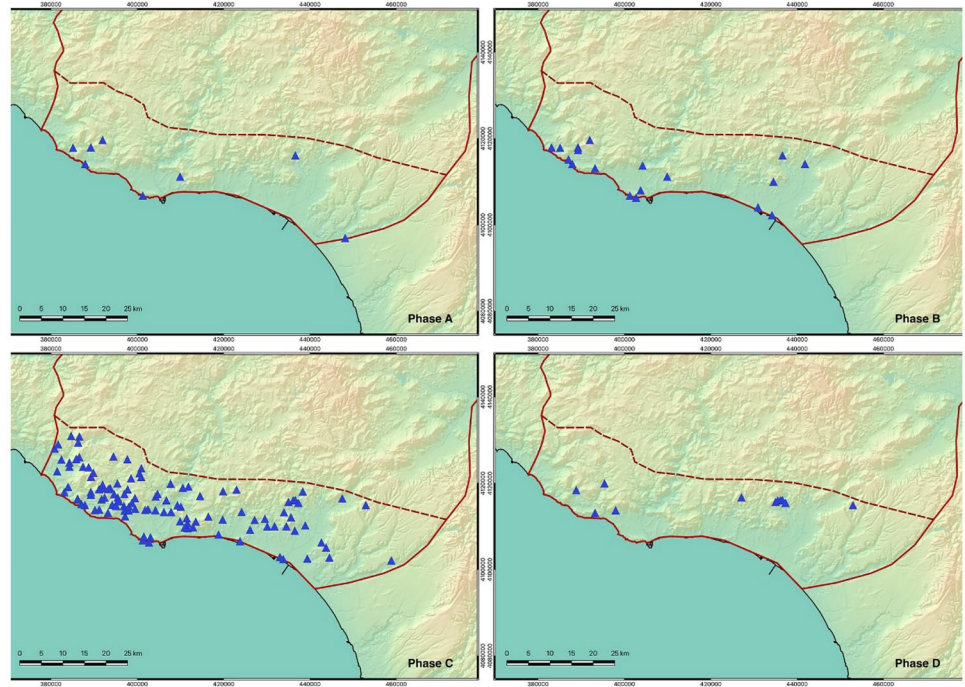
## Results

We considered a total of 524 sites, some of them with more than one chronological phase (Table S1, Fig. 6). The southern sector has an increasing relative contribution from the

**Fig. 6** Relative and absolute proportions of the sites per each phase; in the blue part of the columns, the relative contribution and blue line for the absolute contribution of the northern sector; in the yellow part of the columns, the relative contribution and yellow line for the absolute contribution of the Central Sector; in the green part of the columns, the relative contribution and green line for the absolute contribution of the Southern Sector. For the legend, please refer to Table S1 in ESM



**Fig. 7** Geographic distribution of the sites in the southern sector, in the four chronological phases selected in this study



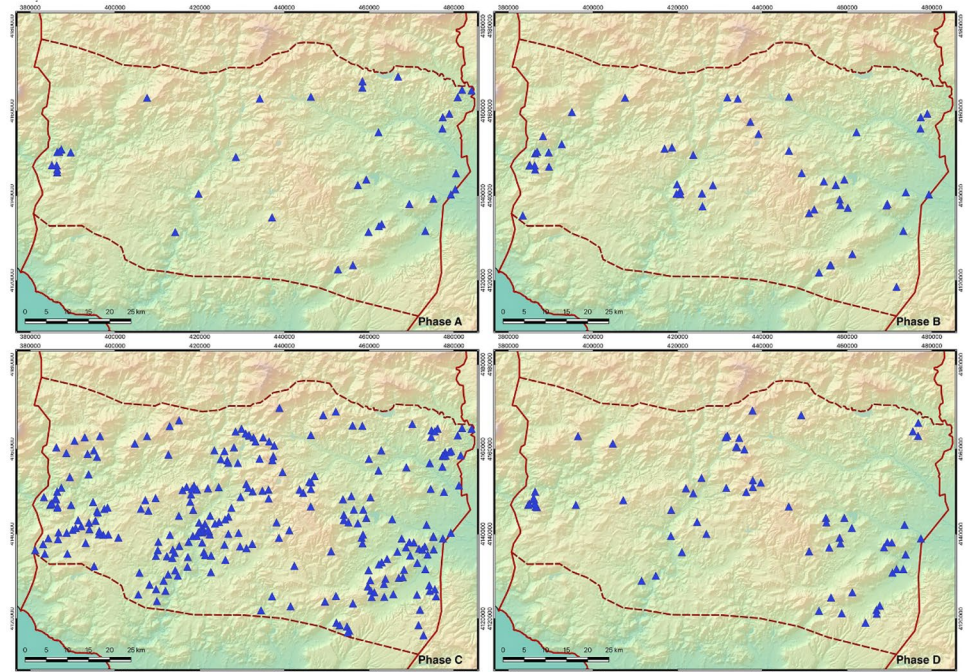
Neolithic to the Middle Bronze Age (phases A-C), with a decrease both in absolute and relative contribution in the last phase D. The central sector shows an inverted trend of decrease of relative proportion from phase A to phase C, despite its absolute proportion is significantly higher in phase C. The northern sector shows a relative contribution that is higher in the Middle Neolithic and that slightly

decreases until the end of the Bronze Age, with the highest absolute contribution in phase C, as the near sector (Fig. 6).

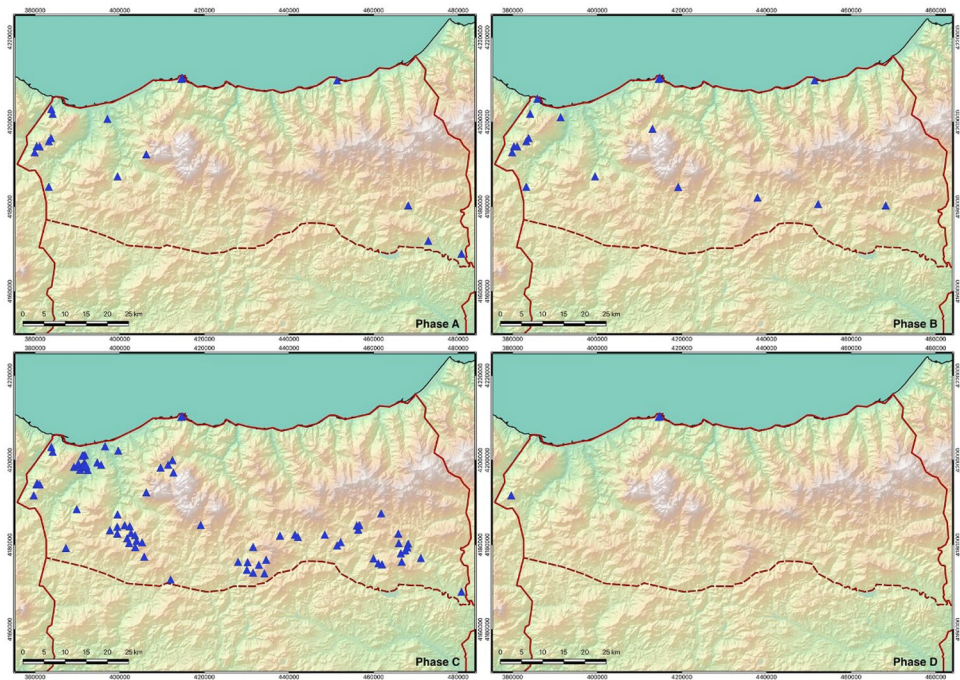
**Southern Sector**

The southernmost part of the study area is the hilly landscape of the coastal area of Agrigento and Caltanissetta

**Fig. 8** Geographic distribution of the sites in the central sector, in the four chronological phases selected in this study



**Fig. 9** Geographic distribution of the sites in the northern sector, in the four chronological phases selected in this study



provinces and hosts 153 archaeological sites (Fig. 7). The oldest phase registers 8 sites (five open-air sites and three open-air sites with necropolis); phase B1 has 18 sites (eight open-air sites, seven open-air sites with necropolis, two necropolis, one cave), while phase B2 has no archaeological sites definitively attributed. The area records the highest relative and absolute increase of the three sectors during phase C, with a presence of an absolute number of 113 both coastal and inland sites (three caves, one rock shelter, forty-seven necropolis, thirty-seven open-air settlements, and twenty-five open-air settlements with necropolises), mostly around the modern towns of Campobello di Mazara, Naro, Palma di Montechiaro, Licata, and Butera, along the river valleys of Naro, Palma, and southern part of Imera Meridionale. During phase D, the area is highly depopulated (11 sites, with eight necropolises with open-air sites and three open-air sites), with some remnants in the district of Butera.

In the site of La Muculufa, n. 274, archaeobotanical data revealed a spread consumption of domesticated cereals (*Hordeum vulgare*, *Triticum monococcum*, *Triticum dicoccon*, *Triticum aestivum*) and pulses (*Vicia faba*, *Pisum* sp.) during the EBA (phase C) in this area (Costantini, 1990). Faunal analyses are also available from the LCA/EBA phase of the site, showing a high percentage of domestic species (99.6%), similar to the ones from Monte Grande, n. 298 (96%) (Bedini, 1998).

### Central Sector

The central part of the study area includes 49 sites (forty-one open-air settlements, seven necropolises, and one rock

shelter dated to MN (phase A) located in the municipalities of Campofranco, Centuripe, Ramacca, and Mineo. Occupation slightly increases during phase B1, with the presence of 51 sites (thirty-two open-air settlements, two necropolises, fourteen open-air sites with necropolis, two caves) primarily concentrated in the municipalities of Mussomeli, Campofranco, Caltanissetta, Aidone, and Pietraperzia (Fig. 8); as for the other sectors, there are no sites unquestionably attributable to phase B2. The peak of the demographic spread of human communities in the central sector is during phase C, with 261 sites (three caves, three rock shelters, fifty-six necropolises, one hundred thirty-five open-air sites, sixty-three open-air sites, and necropolis, one open-air and ritual site, one ritual site), the highest presence since the Neolithic. Sites are mainly gathered along the river valleys, but the territory is densely occupied. During phase D, only a small part of the sites from phase C keeps being occupied (a total of 64 sites: one cave, one rock shelter, twenty-five open-air settlements, eighteen necropolises, nineteen open-air settlements and necropolis), so a huge decrease is registered.

The diachronic analysis of the exploitation of plant resources in Rocchicella, n. 200, shows that adopting the agrarian economy is established in the EBA, with the exploitation of olive trees since at least the CA (phases B-C) (Castiglioni, 2008). The almost exclusive presence of *Quercus pubescens* and the high presence of hygrophilous tree species in the macroremain record of Case Bastione, n. 10, underlines the presence of downy oak forests surrounding the prehistoric site and extensive cereal and legume croplands (phase C) (Speciale et al., 2020). Finally, data from

Morgantina, nn. 91–93, show the use of oaks in that area during the LBA (Ramsay, 2012).

Serra del Palco I, n. 389, presents a high percentage of domestic animals (more than 85%) in the MN (Wilkins, 1997); this is in line with the Neolithic of Southern Italy, as a similar proportion was found in Fiaccati/Le Rocche, n. 46, during phase A (Iannì et al., 2022). The case of Rocchicella, n. 200, is very interesting for the exploitation of wild ruminants during the Neolithic phase (78.7%) (A), which decreases markedly during the CA (14.2%)(B1) and increases again at the end of BA (22%) (phase D). In Scintilia, n. 367, unexpectedly, both in phase B1 and C, only domestic animals are represented (*Ovis/Capra*, *Bos taurus* and *Sus scrofa*), maybe due to the limited number of samples (Di Rosa, 2014).

In Tornambè, n.55, the zooarchaeological analyses indicate a great importance of goats and sheep, followed by cattle and pigs, with a very low incidence of wild animals, possibly related to the sedentary nature of the community that occupied the village. At Case Bastione, n.10, the faunal assemblage shows some substantial differences: while the prevalence of goats and sheep in the faunal complex and the importance of pigs is here confirmed, the lesser importance of cattle is observed. The latter site may have been at the centre of routes connected with the seasonal transhumance practices adopted by shepherds in this internal part of the island, where, however, particular importance was also given to hunting, considering the high percentages of deer remains. The substantial differences in the faunal complex of the two sites also take on a value for the definition of the different environmental and landscape characteristics in which these settlements are located: Tornambè is situated in the meso-Mediterranean band, between 150 and 450 m above sea level, with more open vegetation than the forested supra-Mediterranean area, between 450 and 700 m, where Case Bastione is located, and consequently more sensitive to climatic variations such as those highlighted in the pollen sequence of Pergusa (Sadori et al., 2013).

## Northern Sector

During phase A (16 sites: seven open-air settlements, one open-air settlement with a necropolis, seven caves, one rock shelter), most areas located on the Madonie Mts. and near Termini Imerese (western part of the sector) register occupation, probably biased by the lack of extensive research in the Nebrodi area (Fig. 9). A slight increase occurs during phase B1 (19 sites: eight caves, two necropolis, and nine open-air settlements), a drop of sites is registered during phase B2 (0 sites) while during phase C, as in the other sectors, an increase on Madonie (municipalities of Caccamo and Gangi) and

southern slopes of Nebrodi Mts. is recorded (78 sites: ten caves, one rockshelter, eleven open air settlements with necropolis, thirteen necropolis, forty-three open air sites). Another significant drop is instead recorded for phase D (3 sites: two caves, one open-air site and necropolis).

Archaeobotanical data from Vallone Inferno, n. 482 (phase C), show the adoption of agricultural practices since the EBA on mountainous areas, with a high representation of naked wheat (*Triticum aestivum*). Probably due to the presence of several forested areas near the site, the percentage of wild fauna is high during phase C compared to the one of other sites (Forgia et al., 2012, 2023).

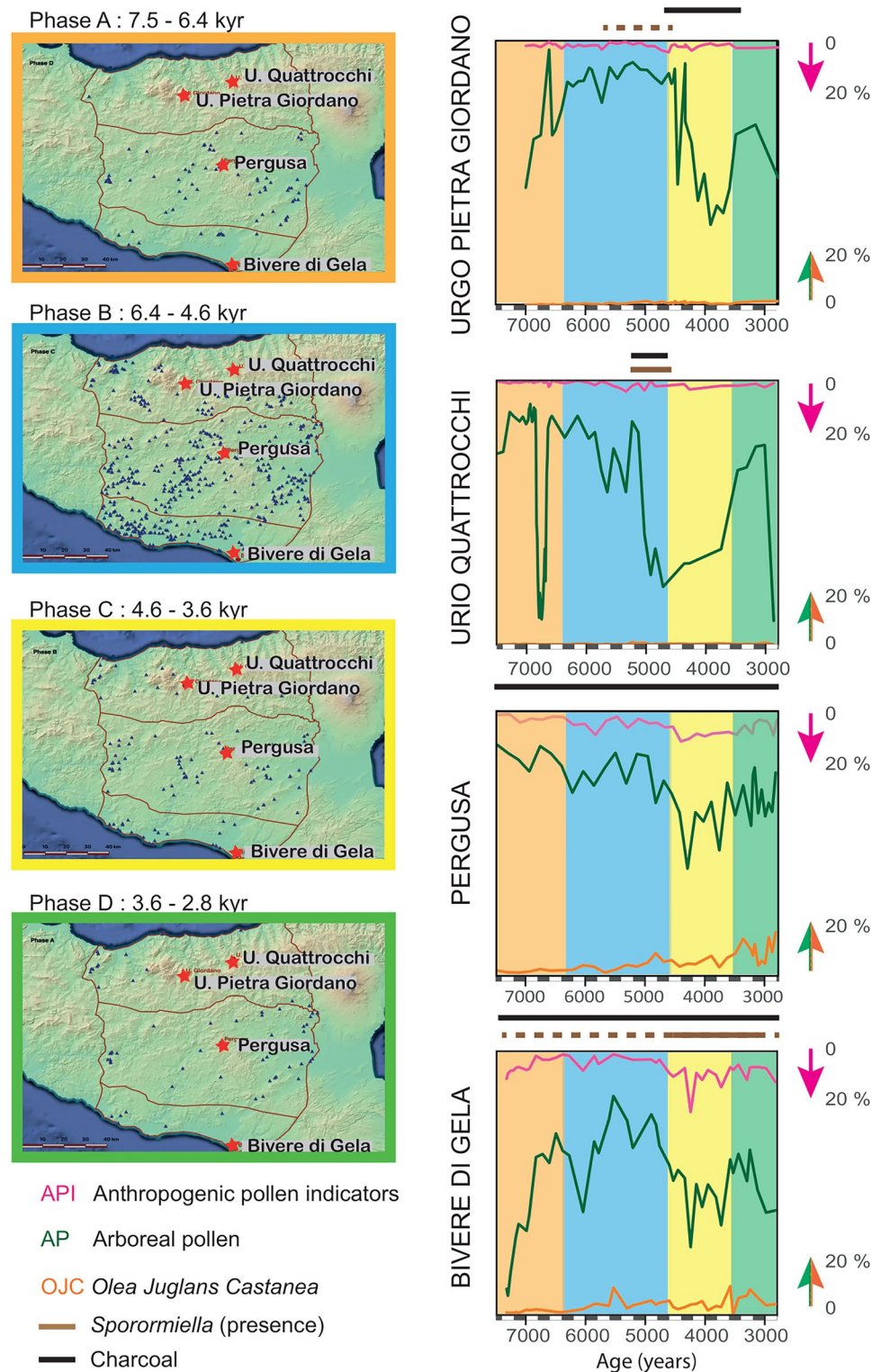
## Discussion

### Middle Neolithic (7.5–6.4 cal ka BP): The First Steps of the Farming Economy

The demographic and settlement patterns for this phase are still ambiguous in most of the three sectors, with little data for the northern sector. The central sector is populated primarily along the main eastern river valleys, possibly reflecting penetration routes from the Catania Plain, while in the southern sector, the few known Neolithic sites are concentrated along the coast, similarly to Eastern Sicily.

In general terms, the demographic trend for this period suggests a low-density occupation, followed by a slow increase of the occupied sites during the later phases, with a growth in cave sites and a decrease in open-air settlements. The relative contribution of the northern sector is nevertheless the highest of the whole chronological span (Fig. 6), and this could justify the unexpected drop of arboreal pollen, respectively at 6.8 and 6.6 cal ka BP in the natural sequence of U. P. Giordano (Fig. 11). At the same time, there is no apparent presence of indicators of pastoralism. Less clear is the interpretation for the sequence from the central part of the island from Pergusa. Here, the presence of API is relatively low, and no marked signal of agriculture or pastoralism is detected. In the southern sector, as in the whole sequence, the pollen sequence of Biviere Gela reveals an open environment, especially 7.4–7.0 cal ka BP, with a significant representation of API, mainly consisting of indicators of pastoral activities (Florenzano, 2019) (Fig. 10). These indicators decrease at the end of the phase. While not much can be said of crop cultivation from archaeobotanical remains, pollen sequences seem to point to a very low incidence of agricultural activities for these phases; the few data from faunal remains testify to the reliance on domestic species with

**Fig. 10** On the left, synthesis of the four phases with the archaeological sites and the position of the four pollen sequence; on the right, pink line = API, Anthropogenic Pollen Indicators (e.g. *Cerealia*-type, *Rumex*, *Plantago lanceolata*); green line = AP, Arboreal Pollen; red line = OJC, *Olea-Juglans-Castanea* sum; black line upon the graphics is the microcharcoals incidence when indicated in the publication, brown line is the *Sporormiella* incidence when indicated in the publication

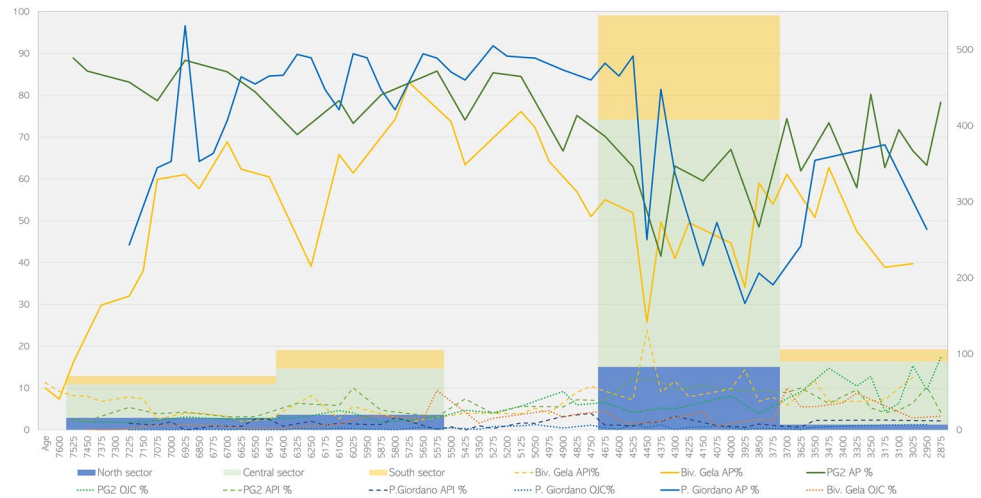


a still high percentage of wild species (Tables 2 and 3). Nevertheless, forest clearing during the Neolithic probably enhanced the effect of the natural trend of aridification that started earlier in Central Sicily and a little later in Northern Sicily (Frisia et al., 2006; Sadori et al., 2008; Sadori & Narcissi, 2001).

### Late Neolithic – Middle Copper Age (6.4–4.6 cal ka BP): The Beginning of the Economic Transition and the Demographic Gap

The demographic and cultural change from the Neolithic to the E-MCA is also a largely unclear phase. According

**Fig. 11** Synthesis of demographic (columns in the background) and pollen data (lines); in yellow, southern sector; in green, central sector; in blue, northern sector; solid lines indicate the AP%; dotted lines show OJC %; broken lines show API %



to the available AMS dates, the cultural differences evidenced in the current literature between LN and ECA are blurred, possibly reflecting geographical patterns more than cultural ones (particularly *Diana* and *San Cono-Piano Notaro* cultural assemblages). In Central-Eastern Sicily, the persistence of the Neolithic way of life has been recently suggested (Giannitrapani, 2020). The change in pottery production and in the funerary and settlement patterns of Western Sicily needs to be more evident here, also with influences from the Aeolian islands and the Italian peninsula. During subphase B1, the incidence of the occupation of the central sector starts to increase both relatively and absolutely (Fig. 6), starting a general trend of major occupation of the inner areas. According to the pollen data (Fig. 10), the presence of API strikingly increases in the central and southern sectors. At the same time, starting from 6.0 cal ka BP, corresponding to a general dry period in the Mediterranean (Mercuri et al., 2011; Sadori et al., 2011), the northern sector records a trend of decrease in AP, and a major incidence of API. These changes must be related to the spread of the *Diana* cultural phase and the increased involvement of Northern Sicily in the international trade network of obsidian at the end of the Neolithic. Right after 5.5 cal ka BP, central and especially northern sectors were probably relying on agropastoral activities, affecting the forest vegetation, despite the demographic pattern still to define more clearly for the Nebrodi Mts.; during this phase, a significant presence of indicators of pastoralism (*Sporormiella*) is registered in the two northern sequences. The vegetation framework in the coastal southern sector seems only partially affected after 5.5 cal ka BP, despite the slight increase in human occupation related to the ECA (Fig. 11). Archaeobotanical and zooarchaeological data are almost absent from the investigated area, except Rocchicella site, which shows the prevalence of domestic animals (mostly caprines and

cattle) and cultivation of wheat during these centuries; also, the exploitation of the oaks seems to decrease from the LN to the MCA phases, while the use of olive tree wood is registered, as in Casa Sollima (Tables 2 and 3). Data from the isotopic values of human bones in Scintilia (southern sector) confirm that their diet was prevalently based on agricultural products, something already detectable in the data from Piano Vento (Tykot et al., 2020).

The available AMS dates and the archaeological data suggest a possible demographic gap from 5.2 to 4.6 cal ka BP (phase B2)(MCA) (Giannitrapani, 2023); this finds a clear correlation in AP curves (both percentage and concentration) of Pergusa (AP dropped from 57% at ca. 5220 to 30% at 5080 cal BP to start recovering after 4800 with 49%) (Figs. 10 and 11) and corresponds to a period of general increased aridity in the Mediterranean, suggested also by drops in AP concentration in other sequences (Magny et al., 2013; Pérez-Obiol & Sadori, 2007); also in Urio Quattrocchi, right after 5.2 cal ka BP a sharp decrease in AP is detected, with a significant increase in microcharcoal concentration and *Sporormiella*. The negative deviation in demography, as already known in literature (Palmisano et al., 2021), follows a moment of increase between the end of the Neolithic and the beginning of the Copper Age all over the island (Parkinson et al., 2021). The explanation for this apparent gap is still unclear, although we argue a potential change of the economic system and a greater reliance on mobility and pastoral activities could have taken place, probably partially pushed by the increased aridity.

### Late Copper Age – Early Bronze Age (4.6–3.6 cal ka BP): After the Gap, the Demographic Explosion

A sharp economic, social, and cultural change took place, particularly in central Sicily, during the LCA, as suggested by an abrupt demographic rise of population. In



archaeological terms, this is pointed out by the appearance of substantial domestic architecture, complex funerary habits, and craft activities, supported by a primary economic system based on intensive agriculture and specialized pastoral activities. It is also possible that this demographic boom was supported by a more intensive exploitation of raw materials (sulphur, rock salt) available in the study area. Finally, the spread of metallurgical activities probably impacted the exploitation of wood resources (Giannitrapani & Ianni, 2020).

In terms of demography, the increase is quite marked in all three sectors, with an absolute increase higher for the central sector; the relative proportion of population from the central sector is nevertheless the same as in the previous phase (Fig. 6) while the EBA and Castelluccio cultural horizon mark everywhere the establishment of the agrarian landscape. API shows a slight decrease in the northern sector, a specific stability in the central one, and an increase in the southern one, while an opening in the landscape is registered in all the pollen records (Fig. 10). Differently from other Mediterranean regions (e.g., southern Greece (Weiberg et al., 2019); Central Italy (Stoddart et al., 2019)), the demographic increase develops along and through the 4.2 cal ka BP event (Bini et al., 2019). All the 3 sectors are involved in it, with a significant increase in the central sector (Fig. 11).

Regional climatic trends show that the island is only partially affected by this event: a gap in the Carburangeli sequence is due to the generally more arid conditions that had occurred since 6.0 ka BP (Zanchetta et al., 2022), while the persistence of *Fagus* in the northern Sicilian pollen sequences shows that humid conditions continued at higher elevations (Bisculm et al., 2012; Tinner et al., 2016). In fact, a rapid expansion of *Fagus* is known to have occurred since the early Holocene in southern and central Italy, and then its decrease just after around 5700 cal BP marked a trend towards increasing dryness (Magri et al., 2006; Mercuri et al., 2012).

Level in Lago Preola shows a quick decrease followed by an increase (Magny et al., 2011), and  $\delta^{18}\text{O}$  of the sediments (calcareous muds and freshwater shells) in Pergusa records a slight water level increase in the general trend of aridification (Zanchetta et al., 2007).  $\delta^{13}\text{C}$  values of archaeological seeds and wood charcoals from the Aeolian sequence show a discontinuous pattern of some drier conditions after the 4.2 cal ka BP that are nevertheless affecting the Capo Graziano economy (Speciale et al., 2016); other local responses, like the one from Case Bastione, show that slightly drier conditions corresponding to the 4.2 cal ka BP event, probably did not last very long and did not affect severely the local forest ecosystems or the agricultural activities (Speciale et al., 2020). Archaeobotanical and faunal remains show an established economy based on domestic species all over the island, with a possible preference for naked wheat

in Central Sicily (Speciale et al., 2020), in comparison with the higher presence of barley in other areas such as Aeolian islands (Speciale, 2021). Data concerning diet preferences inferred by stable isotope analysis of human bones show a very heterogeneous framework within the same communities (Varalli et al., 2022), nevertheless primarily based on agricultural products as shown also in a multiphase site as Grotta dell'Uzzo (Yu et al., 2022). Pastoral indicators like *Sporormiella* and API increase especially in the southern sector, but disappear in the northern sector, in favor of the sedentary socioeconomic system expected for this phase (Fig. 10). Reliance on hunting and wild animal species seems to be a feature of some specific sites. Carpological data from inner and southern Sicily (Case Bastione, Muculufa) indicate the spread of the most common crop species (glume and free-threshing wheats, barley, domestic pulses: *Hordeum vulgare*, *Triticum monococcum/dicoccum*, *T. cf. spelta*, *T. aestivum*, *Vicia* sp.) (Table 2) differently from mountainous areas like the Madonie mountains where it was probably not one of the main subsistence activities (Forgia et al., 2023). Forest clearance was enhanced by increasing grazing and burning disturbance as elsewhere in the Mediterranean (Vanni ere et al., 2011; Mercuri et al., 2019c; Pasta et al., 2022).

### **Middle Bronze Age-Late Bronze Age (3.6–2.8 cal ka BP): The Human Demographic Drop**

The selected time window ends at about 2.8 ka cal. BP, i.e., at the end of the LBA with the arrival of Greek colonists. This phase is characterized by the setup of an extended network with the Mycenaean societies, a larger use of metals and the transformation of settlements that reduce their number but generally increase their size and complexity (Knapp & van Dommelen, 2014). A general demographic drop is recorded in Central Sicily after 3.6 cal ka BP, with a relative proportion for the central sector significant compared to the coastal areas of the study region (Fig. 6). Local environmental conditions in Aeolian Islands show a short trend towards moister conditions (Speciale et al., 2016); the same positive moisture trend is registered in Carburangeli cave at the beginning of the MBA (Frisia et al., 2006), as well as at Lago Preola and Lago di Pergusa (Curry et al., 2016). All the four sequences show an increase in the AP since around 3.6 ka BP and a decrease of AP at 3.2 cal ka BP or right after; this probably corresponds to a peak in aridity soon before the prolonged increase of wetness lasting until 2.8 cal ka BP in the PG2 isotope record of Pergusa, that matches an increase in wood cover (Zanchetta et al., 2022). API is almost absent in the pollen sequences of the northern sector. In contrast, human imprint on the central and southern sector is more evident, together with some recovery of woodlands, primarily oaks (Fig. 10). Some of

the AMS-based demographic analyses show short positive deviations (Palmisano et al., 2021), while others record a slower and continuous decrease (Parkinson et al., 2021). The combination of natural and anthropogenic factors seems to have marked quite irreversibly the central sector, probably starting those profound processes of environmental disturbance of inner and Southern Sicily until today (Henne et al., 2015). Data on the economic subsistence systems are quite poorly represented for this phase, despite the fact that the available faunal remains show similar percentages as the one of phase C. Still unclear is the exploitation of fruit tree species, probably not significant in Sicily in this phase compared to other parts of Southern Italy, with the exception of figs. Nevertheless, interestingly, in Pergusa there is an increase in OJC-*Olea*, *Juglans* and *Castanea* cultivation that clearly indicates the establishment of an agricultural and arboricultural landscape and an exploitation of woodland since around 3.2 cal ka BP, mainly olive trees. Wild olive (*Olea europaea* var. *sylvestris*) is autochthonous in Sicily, it requires a Mediterranean climate characterized by summer aridity and is typical of the coastal zone in Sicily and of the warmest areas of Mediterranean (Langgut et al., 2019). The cultivated olive tree (*O. europaea*) is now found in the whole area colonized by the evergreen oak forests. In this perspective, more than 20% of olive pollen at Pergusa can hardly be interpreted as “natural” as discussed in Sadori et al. (2013), also considering the modern pollen production in olive groves (meanly 13%, Florenzano et al., 2017). Such high values are in fact found only in coastal pollen records of Sicily, where wild olives are widespread (Tinner et al., 2009; Calò et al., 2012). Even if we lean towards an explanation of cultivation for olives, we must also consider that the climate at that time would have been arid and warm enough to allow the growing of olive groves outside their natural distribution area.

Disentangling human and natural factors in the human decrease during these phases is extremely difficult. Beyond the climatic constraints and the potential overexploitation of some areas (Molloy, 2022), the significant increase in Mediterranean conflicts could have played an essential role in establishing the demographic pattern at the end of the BA (Fernandes et al., 2020).

## Conclusions

Our research covers the most recent data on the demography of late prehistoric Sicily, which we interpret from a diachronic perspective, aiming to reconstruct the changes in landscape of Central Sicily and comparing demographic with archaeobotanical and archaeozoological datasets and pollen sequences. Thanks to the density and accuracy of

paleoenvironmental analyses, Sicily stands out in the wider framework of Central Mediterranean Holocene climate reconstruction. But even with detailed paleoclimatic datasets, the “worse” or “better” climatic conditions, mostly defined on “dry” or “moist” conditions, cannot always be positively correlated with demographic trends. Rather, specifically in a region such Sicily, prehistoric demography and climate amelioration apparently show an opposite trend during many phases. The phase post-4.2 ka BP event is one of the most significant in this sense, as increase of population occurred during increasing dryness, and only cultural interpretation and economic adaptation can help to find some answers.

Despite not being analytically presented, Early Neolithic data in Sicily record the introduction of domesticated plants at least around 9.0 ka cal BP, as testified by the archaeobotanical dataset of Grotta dell’Uzzo (Costantini & Costantini Biasini, 1997), but less clear for the rest of the region (Speciale, 2023). During Middle Neolithic (7.5–6.4 cal ka BP), Sicily has a low-density demography, even if mountainous areas (Madonie massif and Nebrodi Mts.) are quite well represented; as shown by the pollen sequences, the whole island experiences some human impact due to the spread of the Neolithic economy and the exploitation of part of the central and northern areas for pastoral activities. An opening of the landscape is registered especially in the northern sector. Nevertheless, analyzing the API, the incidence of the agricultural activities still seems quite low. In the southern sector, the indicators of pastoralism are higher than in the other sectors.

Between the end of the Neolithic and the beginning of the Copper Age (6.4–5.2 cal ka BP), there is a slight increase in demography in all the sectors. API is more detectable in all the sequences and the indicators point to a diffused agro-pastoral economy. The few archaeobotanical and zooarchaeological data, together with the isotopes of human diet, support this increase in the reliance on domestic species. The demographic drop right after, during the so-called Middle Copper Age (5.2–4.6 cal ka BP), could be the result of a combination of environmental and anthropogenic factors and a partial switch to a less permanent settlement system. As a matter of fact, the lowest tree cover percentage recorded at Pergusa and Urgo di Pietra Giordano in the considered period (7.0–2.8 cal ka BP) is found in the correspondence of the start of the demographic gap evidenced by Giannitrapani (2023); so, in this case, a phase of potential increased aridity is correlated to a decrease in human demography, despite the API had an increase in all the sequences. Probably, the anthropogenic pollen indicators mark pastoral activity as the most common land-use, which greatly favoured synanthropic plants.

It is only in the following phases, at the end of the Copper Age (4.6–4.2 cal ka BP), that human impacts become

evident and relevant. The demographic boom after the Late Copper Age in Sicily seems strictly dependent on regional conditions that allowed human communities to populate notably the inner areas and establish a capillary spread all over the island, more intensely than in other regions of Central Mediterranean. Perhaps the Sicilian environment was less affected by the 4.2 ka BP event, rather by the general aridification trend that had started, according to some authors, at the beginning of the Neolithic (Sadori & Narcisi, 2001). The striking demographic increase between the Late Copper Age and Early Bronze Age (4.6–3.6 cal ka BP) is characterized by the first establishment of a structured agricultural landscape. This is quite clear from API evidence of Biviere Gela and Pergusa, while in the northern sector API does not account for significant changes. Archaeobotanical and zooarchaeological data point to the establishment of a structured agropastoral economy, that persists in the following phase.

The demographic increase of this last phase is followed by a decrease during the Middle Bronze Age (3.6–3.3 cal ka BP), probably enhanced by a change in the settlement system, as known also in other regions of the Italian peninsula. This demographic decrease seems counterintuitive in view of the conditions of increased humidity indicated in palaeoclimatic data; also, a significant recovery of the wood cover is detectable in all the sequences, possibly also as result of the lowered human presence. Between the end of the Middle Bronze Age and the Late Bronze Age (ca. 3.3–2.8 cal ka BP) the decrease in demography becomes more evident. The causes are probably, once again, a synergy of natural and human dynamics, following what has been defined as climatic crisis of 3.2 cal ka BP event (Molloy, 2022; Zanchetta et al., 2022). The depopulation of this central sector of the island, despite the slight increase in humidity at the beginning of the Late Bronze Age, is probably due to changes in the local economic and cultural assets, which at the present state of our investigation cannot be linked just to the over-exploitation of local natural resources. The central sector is the only one characterized by a significant presence of API and OJC, recording a clear structuring of an agricultural and arboricultural landscape with olive tree exploitation, which is almost nonexistent in the southern sector. In sum, despite the early arrival of domestic species on the island, the spread and adoption of an intensive agricultural system seems to have occurred only during the Late Copper Age.

**Supplementary Information** The online version contains supplementary material available at <https://doi.org/10.1007/s10745-024-00496-3>.

**Author Contributions** C.S. and E.G. wrote the main manuscript text; A.M., A.F., L.S. and N.C. integrated the paleoenvironmental data and their discussion; C. S. prepared Tables 3–5 and Figs. 1, 5, 6, 11; E.G. prepared Tables 1 and 2 and Figs. 2–4, 7–9; N.C. prepared Fig. 10. All authors reviewed the manuscript.

**Funding** Open Access funding provided thanks to the CRUE-CSIC agreement with Springer Nature. Postdoctoral contract to CS for the project “SILVA – Sicilian small IsLands Vegetation under the effect of the human Arrival” is part of the European Union’s Horizon 2020 research and innovation programme MSCA-COFUND R2STAIR (GA 101034349). Her research is also supported by the Spanish Ministry of Science and Innovation through the “María de Maeztu” excellence accreditation (CEX2019-000945-M) and CERCA, Centres de Recerca de Catalunya. NCN received financial support from CNRS (INSU Mistral -PaleoMex and BioDivMex projects). Open Access funding provided thanks to the URV agreement with Springer Nature.

**Availability of Data and Materials** All the tables are accessible as Supplementary Materials, beyond the S1, the tables 1, 2, 3 and 4 as raw.csv.

## Declarations

**Conflict of Interest** The authors declare no conflict of interests.

**Open Access** This article is licensed under a Creative Commons Attribution 4.0 International License, which permits use, sharing, adaptation, distribution and reproduction in any medium or format, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons licence, and indicate if changes were made. The images or other third party material in this article are included in the article’s Creative Commons licence, unless indicated otherwise in a credit line to the material. If material is not included in the article’s Creative Commons licence and your intended use is not permitted by statutory regulation or exceeds the permitted use, you will need to obtain permission directly from the copyright holder. To view a copy of this licence, visit <http://creativecommons.org/licenses/by/4.0/>.

## References

- AA.VV. (Ed.). (2000). *Da Malpasso a Calcarella*. Itinerario archeologico di Calascibetta. Enna.
- AA.VV. (Ed.). (2002). *Villarosa*. Itinerario archeologico del territorio. Enna.
- Adamesteanu, D. (1958). Butera: Piano della Fiera, Consi e Fontana Calda. *Monumenti Antichi*. Roma: Bretschneider.
- Adamo, O., & Gulli, D. (2012). La ceramica Serraferlicchio da Serraferlicchio. In AA.VV. (Ed.), *Dai Ciclopi agli Ecasti. Società e Territorio nella Sicilia Preistorica e Protostorica, Atti della 41a Riunione Scientifica* (pp. 601–609). Istituto Italiano di Preistoria e Protostoria.
- Agodi, S., Gueli, A. M., Mege, D., Mazzoleni, P., Pezzino, A., Procelli, E., Sapuppo, L., & Troja, S. O. (2000). Il villaggio dell’Antico Bronzo di c.da Torricella: un progetto per lo studio e la datazione dei materiali. *Bollettino dell’Accademia Gioenia di Scienze Naturali in Catania*, 33(357), 17–30.
- Albanese, R. M. (2003). *Sicani, Siculi, Elimi: forme di identità, modi di contatto e processi di trasformazione*. Milano: Longanesi.
- Albanese Procelli, R. M. (1982). Calascibetta. La necropoli di Cozzo S. Giuseppe in Contrada Realmese. *Notizie degli Scavi*, XXXVI, 425–632.
- Albanese Procelli, R. M. (1988–89). Calascibetta. Le necropoli di Malpasso, Calcarella e Valle del Coniglio. *Notizie degli Scavi XLII–XLIII*:161–225.
- Alberghina, F., & Gulli, D. (2011). L’età del rame finale in Sicilia: considerazioni per una facies unitaria di Malpasso-Sant’Ippolito. In AA.VV. (Ed.), *L’età del Rame in Italia. Atti della 43a Riunione Scientifica* (pp. 129–134). Istituto Italiano di Preistoria e Protostoria.

- Alberti, G. (2013). A Bayesian 14C chronology of Early and Middle Bronze Age in Sicily. Towards an independent absolute dating. *Journal of Archaeological Science*, 40(5), 2502–2514. <https://doi.org/10.1016/j.jas.2012.08.014>
- Amenta, C. (1997). L'insediamento preistorico di Pizzo Tre Fontane nel territorio di Mussomeli. *Sicilia Archeologica*, 93–95, 59–86.
- Arcidiacono, M., Baldini, L. R., Longo, U., & e Recami, E. (1976). Nuove notizie sulla preistoria della Sicilia orientale. *Natura*, 67(3–4), 175–184.
- Arena, A. E. L., Giannitrapani, E., Guzzardi, L., & Ianni, F. (2021). L'insediamento di Contrada Marcato (Valguarnera Caropepe – EN) nel contesto del Bronzo antico della Sicilia centrale. *Archivio Storico Della Sicilia Centro-Meridionale*, 13, 137–151.
- Ashley, S., Bending, J., Cook, G., Coorado, A., Malone, C., Pettitt, P., Puglisi, D., Redhouse, D., & Stoddart, S. (2007). The resources of an upland community in the fourth millennium BC. In M. Fitzjohn (Ed.), *Uplands of Ancient Sicily and Calabria* (pp. 59–81). Accordia Research Centre: London.
- Ayala, G., & Fitzjohn, M. (2007). To be seen or not to be: interpretations of survey data and questions of archaeological visibility in upland Sicily. *Uplands of Ancient Sicily and Calabria. The archaeology of landscape revisited* (Vol. 13, pp. 99–113). London: Accordia Specialist Studies on Italy.
- Barberi, A. M., & Ianni, F. (2012). Enna Un parco eolico nel territorio di Villarosa (EN), in *Studi, ricerche, restauri per la tutela del patrimonio culturale ennese. I Quaderni Del Patrimonio Culturale Ennese*, 1, 251–254.
- Bartosiewicz, L. (2012). Faunal remains. In R. Leighton (Ed.), *Pre-historic houses at Morgantina Excavation on the Cittadella of Morgantina in Sicily 1989–2004* (pp. 154–172). London
- Battaglia, G., Micciché, R. M., Forgia, V., Mannino, M. A., Scopelliti, M. G., Sineo, L., & Valenti, P. (2020). New perspectives on the human occupation of the Gulf of Palermo during the Metal Ages: The funerary cave of Zubbio di Cozzo San Pietro (Bagheria) and the necropolis of Viale Venere (Mondello, Palermo). *Journal of Archaeological Science: Reports*, 31, 102276. <https://doi.org/10.1016/j.jasrep.2020.102276>
- Bazan, G., Marino, P., Guarino, R., Domina, G., & Schicchi, R. (2015). Bioclimatology and vegetation series in Sicily: A geostatistical approach. *Annales Botanici Fennici*, 52(1–2), 1–18. <https://doi.org/10.5735/085.052.0202>
- Bedini, E. (1998). I reperti faunistici del deposito votivo del Bronzo Antico di Monte Grande. In G. Castellana (Ed.), *Il santuario castellucciano di Monte Grande e l'approvvigionamento dello zolfo nel Mediterraneo dell'età del bronzo*. Agrigento.
- Bella, E. (1996). Il villaggio castellucciano della Contrada del Conte Bosco (Ravanusa). *Sicilia Archeologica*, 90–91–92, 133–152.
- Belvedere, O. (2002). L'evoluzione storica del territorio imerese dalla fondazione della colonia al periodo tardo-antico. *Himera III*, 2, 377–397.
- Bernabò Brea, L. (1958). *La Sicilia prima dei Greci*. Il Saggiatore: Milano.
- Bevan, A., Palmisano, A., Woodbridge, J., Fyfe, R., Roberts, C. N., & Shennan, S. (2019). The changing face of the Mediterranean-Land cover, demography and environmental change: Introduction and overview. *The Holocene*, 29(5), 703–707. <https://doi.org/10.1177/0959683619826688>
- Bietti Sestieri, A. M. (2013). The Bronze Age in Sicily. In A. Harding & H. Fokkens (Eds.), *The Oxford Handbook of the European Bronze Age* (pp. 653–667). Oxford University Press.
- Bileddo M. 2003–2004, Carta archeologica della valle del torrente Salito (Sclafani Bagni), F 259 I SE (Scillato), F 259 II NE (Caltavuturo), Unpublished PhD thesis. Università degli Studi di Palermo, Facoltà di Lettere e Filosofia.
- Bini, M., Zanchetta, G., Perçoiu, A., Cartier, R., Català, A., et al. (2019). The 4.2 ka BP Event in the Mediterranean region: An overview. *Climate of the Past*, 15, 555–577.
- Biondi, G. (2002). Per una carta archeologica del territorio di Centuripe. In G. Rizza (Ed.), *Scavi e ricerche a Centuripe* (pp. 41–81). CNR-IBAM: Catania.
- Bisculm, M., Colombaroli, D., Vescovi, E., van Leeuwen, J. F. N., Henne, P. D., Rothen, J., Procacci, G., Pasta, S., La Mantia, T., & Tinner, W. (2012). Holocene vegetation and fire dynamics in the supra-mediterranean belt of the Nebrodi Mountains (Sicily, Italy). *Journal of Quaternary Science*, 27(7), 687–698. <https://doi.org/10.1002/jqs.2551>
- Bonanno, C. (2000). Nuovi ritrovamenti di età preistorica nella costa settentrionale messinese. *Sicilia Archeologica*, 98, 75–86.
- Bovio Marconi, J. (1979). *La Grotta del Vecchiuzzo*. Giorgio Bretschneider: Roma.
- Branco, R. (2020). *Topografia della piana di Catania. Archeologia, viabilità e sistemi insediativi*. Edizioni Quasar: Roma.
- Brullo, C., & Brullo, S. (2021). *Flora endemica illustrata della Sicilia* (p. 427). Reggio Calabria: Laruffa Editore.
- Buscemi Felici, G. (2004). Ricognizioni sulla “Montagna” di Nissoria (Enna). Materiali per una carta archeologica. *Orizzonti*, V, 175–188.
- Calò, C., Henne, P. D., Curry, B., Magny, M., Vescovi, E., La Mantia, T., Pasta, S., Vannièrè, B., & Tinner, W. (2012). Spatio-temporal patterns of Holocene environmental change in southern Sicily. *Palaeogeography, Palaeoclimatology, Palaeoecology*, 323, 110–122. <https://doi.org/10.1016/j.palaeo.2012.01.038>
- Calderone, A., Caccamo, Caltabiano M., De Miro, E., Denti, A., & Siracusano, A. (1996). *Monte Saraceno di Ravanusa*. Messina, Sikanìa: Un Ventennio di ricerche e studi.
- Capuzzo, G., Zanon, M., Dal Corso, M., Kirleis, W., & Barceló, J. A. (2018). Highly diverse Bronze Age population dynamics in Central-Southern Europe and their response to regional climatic patterns. *PLoS ONE*, 13(8), e0200709. <https://doi.org/10.1371/journal.pone.0200709>
- Caracuta, V., Fiorentino, G., & Martinelli, M. (2012). Plant Remains and AMS: Dating Climate Change in the Aeolian Islands (Northeastern Sicily) During the 2nd Millennium BC. *Radiocarbon*, 54(3–4), 689–700. <https://doi.org/10.1017/S003382220047354>
- Castellana, G. (1982). Nuove ricognizioni nel territorio di Palma di Montechiaro (Agrigento). *Sicilia Archeologica*, 49–50, 81–102.
- Castellana, G. (1997). *La grotta Ticchiara e il castelluciano agrigentino*. Palermo: Museo Archeologico Regionale di Agrigento.
- Castiglioni, E. (2008). I resti botanici. In L. Maniscalco (Ed.), *Il Santuario dei Palici. Un centro di culto nella valle del Margi* (pp. 365–386). Palermo.
- Catalano, R., Di Stefano, P., Sulli, A., & Vitale, F. P. (1996). Paleogeography and structure of the central Mediterranean: Sicily and its offshore area. *Tectonophysics*, 260(4), 291–323. [https://doi.org/10.1016/0040-1951\(95\)00196-4](https://doi.org/10.1016/0040-1951(95)00196-4)
- Contino, I., & Buscemi, F. (2012). *L'insediamento rupestre di Monte S. Antonio a Regalbuto*. Caltanissetta, Paruzzo Editore.
- Costantini, L. (1990). La Muculufa, the Early Bronze Age Sanctuary: The Early Bronze Age Village (excavation of 1982 and 1983). VIII. Report of Vegetal Remains Collected in Castellucian Strata of the Village in 1988. *Revue Des Archéologues Et Historiens D'art De Louvain*, 23, 66–67.
- Costantini, L., & Costantini, Biasini L. (1997). La domesticazione vegetale. Piante spontanee e piante coltivate. In S. Tusa (Ed.), *Prima Sicilia Alle origini della società siciliana 1* (pp. 253–257). Palermo.
- Crema, E. R. (2022). Statistical inference of prehistoric demography from frequency distributions of radiocarbon dates: A review and a guide for the perplexed. *Journal of Archaeological Method and Theory*, 29, 1387–1418. <https://doi.org/10.1007/s10816-022-09559-5>

- Cucco, R. M. (2007). Montemaggiore Belsito. In S. Vassallo (Ed.), *Archeologia nelle vallate del Fiume Torto e del San Leonardo* (pp. 92–98). Palermo.
- Cucco, R. M., & Vassallo, S. (2007). Sciara. In S. Vassallo (Ed.), *Archeologia nelle vallate del Fiume Torto e del San Leonardo* (pp. 103–116). Palermo.
- Cultrera, D. (2014). Strategie insediative nella Sicilia sud-orientale: Le grotte dei Monti Iblei nella preistoria. In D. Gulli (Ed.), *From Cave to Dolmen: Ritual and symbolic aspects in the pre-history between Sciacca* (pp. 195–220). Archaeopress.
- Curry, B., Henne, P. D., Mesquita-Joanes, F., Marrone, F., Pieri, V., La Mantia, T., Calò, C., & Tinner, W. (2016). Holocene paleoclimate inferred from salinity histories of adjacent lakes in southwestern Sicily (Italy). *Quaternary Science Reviews*, 150, 67–83. <https://doi.org/10.1016/j.quascirev.2016.08.013>
- De Miro, E. (1961). Ricerche preistoriche a nord dell'abitato di Palma di Montechiaro. *Rivista Scienze Preistoriche*, XVI, 15–54.
- Desprat, S., Combourieu-Nebout, N., Essallami, L., Sicre, M.-A., Dormoy, I., Peyron, O., Siani, G., Roumazeilles, V. B., & Turon, J.-L. (2013). Deglacial and Holocene vegetation and climatic changes in the southern Central Mediterranean from a direct land–sea correlation. *Climate of the Past*, 9(2), 767–787. <https://doi.org/10.5194/cp-9-767-2013>
- Di Maida, G. (2020). The earliest human occupation of Sicily: A review. *The Journal of Island and Coastal Archaeology*. <https://doi.org/10.1080/15564894.2020.1803460>
- Di Patti, C., & Lupo, F. (2008). La fauna: indagine archeozoologica. In L. Maniscalco (Ed.), *Il santuario dei Palici Un centro di culto nella valle del Margi* (pp. 387–400). Palermo.
- Di Rosa, M. (2014). I resti faunistici eneolitici e del Bronzo iniziale nell'insediamento di Scintilia (Favara) in provincia di Agrigento. Analisi preliminare. In G. Gulli (Ed.), *Storie sepolte: riti, culti e vita quotidiana all'alba del IV millennio a.C. La necropoli dell'età del Rame di contrada Scintilia di Favara* (pp. 81–85). Palermo.
- Di Simone, G., Thun, Hohenstein U., Petruso, D., Forgia, V., Giannitrapani, E., Iannì, F., & Martín, Rodríguez P. (2019). Gestione e sfruttamento delle risorse faunistiche nei siti di Vallone Inferno (Palermo) e Case Bastione (Enna). *Atti dell'8° Convegno Nazionale di Archeozoologia*, 1, 71–78.
- Di Stefano, G. (1984). *Piccola guida delle stazioni preistoriche degli Iblei*. Libreria Dante: Ragusa.
- Draïà, E. (2018). Le tombe a grotticella artificiale del territorio di Valguarnera: nuovi dati. In E. Herring & E. O'Donoghue (Eds.), *The archaeology of death. Proceedings of the 7th Conference of Italian Archaeology* (pp. 354–364). Oxford: Archaeopress.
- Draïà, E. (2020). Un centro indigeno-ellenizzato nella Sicilia centro-orientale: Rossomanno. In L. M. Calò, G. M. Gerogiannis, & M. Kopsacheili (Eds.), *Fortificazioni e società nel Mediterraneo occidentale. Sicilia e Italia* (pp. 71–86). Edizioni Quasar: Roma.
- Etienne, D., & Jouffroy-Bapicot, I. (2014). Optimal counting limit for fungal spore abundance estimation using *Sporormiella* as a case study. *Vegetation History and Archaeobotany*, 23, 743–749. <https://doi.org/10.1007/s00334-014-0439-1>
- Fernandes, D. M., Mittnik, A., Olalde, I., Lazaridis, I., Cheronet, O., Rohland, N., Mallick, S., et al. (2020). The spread of steppe and Iranian-related ancestry in the islands of the western Mediterranean. *Nature Ecology & Evolution*, 4(3), 334–345. <https://doi.org/10.1038/s41559-020-1102-0>
- Ferrio, J. P., Voltas, J., & Araus, J. L. (2003). Use of carbon isotope composition in monitoring environmental changes. *Management of Environmental Quality*, 14(1), 82–98. <https://doi.org/10.1108/14777830310460405>
- Fiorani, D. (2004–2005). *Prospezione archeologica della valle del torrente Caltavuturo* (IGM F 259 I SE, Scillato, F 259 II NE, Caltavuturo), Unpublished PhD Dissertation. Università degli Studi di Palermo, Facoltà di Lettere e Filosofia.
- Fiorentini, G. (1980–81). Ricerche archeologiche nella Sicilia centro-meridionale. *Kokalos XXVI-XXVII*, 2.1, 581–599.
- Florenzano, A. (2019). The History of Pastoral Activities in S Italy Inferred from Palynology: A Long-Term Perspective to Support Biodiversity Awareness. *Sustainability*, 11(2), 404. <https://doi.org/10.3390/su11020404>
- Florenzano, A., Mercuri, A. M., Rinaldi, R., Rattighieri, E., Fornaciari, R., Messori, R., & Arru, L. (2017). The representativeness of Olea pollen from olive groves and the Late Holocene landscape reconstruction in central Mediterranean. *Frontiers in Earth Science*, 5, 85.
- Forgia, V. (2019). *Archaeology of Uplands on a Mediterranean Island: The Madonie Mountain Range In Sicily*. Università di Palermo-Springer.
- Forgia, V., Ollé, A., & Vergès, J. M. (2012). Paesaggi montani e popolamento antico in Sicilia: Una proposta metodologica. *Agri Centuriati: An International Journal of Landscape Archaeology*, 9, 43–60.
- Forgia, V., Ollé, A., & Vergès Bosch, J. M. (2023). *Il riparo di Vallone Inferno (Madonie, Sicilia)*. BAR Publishing.
- Frasca, M., Palermo, D., & Procelli, E. (1975). Ramacca (Catania). Saggi di scavo nel villaggio preistorico di contrada Torricella. *Notizie degli Scavi*, 8, 29, 557–585.
- Frisia, S., Borsato, A., Mangini, A., Spötl, C., Madonia, G., & Sauro, U. (2006). Holocene climate variability in Sicily from a discontinuous stalagmite record and the Mesolithic to Neolithic transition. *Quaternary Research*, 66(3), 388–400. <https://doi.org/10.1016/j.yqres.2006.05.003>
- Giannitrapani, E. (2009). Nuove considerazioni sulla presenza in Sicilia del Bicchiere Campaniforme. *Rivista di Scienze Preistoriche*, LXIX, 219–242.
- Giannitrapani, E. (2014). The social significance of caves and rock-shelters in the prehistory of the Erei (Central Sicily): archaeological investigations at the Riparo 1 di Contrada San Tommaso near Enna. In D. Gulli (Ed.), *From Cave to Dolmen. Ritual and Symbolic Aspects in the Prehistory between Sciacca, Sicily and the Central Mediterranean* (pp. 91–103). Oxford, Archaeopress.
- Giannitrapani, E. (2017). Paesaggi e dinamiche del popolamento di età preistorica nella Sicilia centrale. *Mappa Data Book*, 2, 43–64.
- Giannitrapani, E. (2018). Le case dei vivi e le case dei morti. Architettura domestica e funeraria nella Sicilia centrale tra il IV e il II millennio a.C. *Rivista di Scienze Preistoriche*, LXVIII, 191–228.
- Giannitrapani, E. (2020). Continuity or change? Alcune considerazioni sul passaggio dal Neolitico al Rame Iniziale nella Sicilia centrale. In O. Palio, S. Todaro, & M. Turco (Eds.), *Vivere all'ombra del Vulcano. L'insediamento di Valcorrente di Belpasso nel contesto degli studi sulla preistoria siciliana tra il IV e la prima metà del II millennio a.C. Studi in memoria di Enrico Procelli (Catania 19 ottobre 2016)* (pp. 139–176). Roma: Edizioni Quasar.
- Giannitrapani, E. (2023). Calib\_Sicily: a new radiocarbon dataset for prehistoric Sicily. Spatiotemporal dynamics from ca. 6.500 to 1.500 cal. BC. *Archeologica Data*, 3, 153–166. <https://doi.org/10.13131/unipi/9jff-np71>
- Giannitrapani, E., & Ianni, F. (2011). La tarda età del Rame nella Sicilia centrale. In AA.VV. (Ed.), *L'età del Rame in Italia. Atti della 43a Riunione Scientifica* (pp. 271–278). Istituto Italiano di Preistoria e Protostoria.
- Giannitrapani, E., & Ianni, F. (2020). Demographic dynamics, paleoenvironmental changes and social complexity in the late prehistory of central Sicily. In T. Lachenal, R. Roure, & O. Lemerrier (Eds.), *Demography and Migration Population trajectories from the Neolithic to the Iron Age: Proceedings of the XVIII UISPP*

- World Congress, Volume 5: Sessions XXXII-2 and XXXIV-8 (pp. 39–58). Oxford: Archaeopress Publishing Ltd.
- Giannitrapani, E., & Ianni, F. (2022). L'insediamento pre-protostorico di Tornambè (Pietraperzia, Enna) nella valle dell'Imera Meridionale. *Sicilia Archeologica*, 113, 99–129. <https://doi.org/10.48255/2283.3307.SICA.113.2022.05>
- Giannitrapani, E., & Pluciennik, M. (1998). La seconda campagna di ricognizione (settembre 1997) del progetto "Archeologia nella Valle del Torricoda." *Sicilia Archeologica*, 96, 59–69.
- Giannitrapani, E., & Pluciennik, M. (2001). Rock-shelter research in central Sicily. *Antiquity*, 75(287), 13–14.
- Giannitrapani, E., Ianni, F., Chilardi, S., & Anguilano, L. (2014). Case Bastione: a prehistoric settlement in the Erei uplands (central Sicily). *Origini XXXVI*, 12, 181–212.
- Giannitrapani, E., Ianni, F., & Valbruzzi, F. (2023). Dinamiche sociali, modelli insediativi e lo sviluppo del sistema proto-urbano nella Sicilia centrale: Nuovi dati per la definizione delle fasi protostoriche e di età arcaica nella media valle del Salso/Imera meridionale. *Studi di Protostoria in memoria di Renato Peroni, Universitätsforschungen zur prähistorischen Archäologie* (Vol. 394, pp. 161–196). Verlag Dr. Rudolf Habelt GmbH.
- Guarino, R., & Pasta, S. (2018). Sicily: The island that didn't know to be an archipelago. *Berichte Der Reinhold Tüxen Gesellschaft*, 30, 133–148.
- Gulli, D. (2014). *Storie sepolte. Riti, culti e vita quotidiana all'alba del IV millennio a.C. La necropoli di contrada Scintilia di favara*. Palermo: Agrigento.
- Guzzardi, L. (2009). Attività della Sezione archeologica della Soprintendenza di Enna negli anni 1997–2001. *Kokalos*, XLVII–XLVIII, 561–598.
- Guzzone, C. (1998). Il territorio dall'età preistorica all'età ellenistica. In R. Panvini (Ed.), *Gela* (pp. 193–195). Il Museo Archeologico.
- Guzzone, C. (1994). La ceramica del villaggio di Serra del Palco ed il territorio di Milena in età Neolitica. In S. Tusa (Ed.), *La preistoria del basso Belice e della Sicilia meridionale nel quadro della preistoria siciliana e mediterranea* (pp. 305–321). Società Siciliana per la Storia Patria: Palermo.
- Henne, P. D., Elkin, C., Franke, J., Colombaroli, D., Calò, C., La Mantia, T., Pasta, S., Conedera, M., Dermody, O., & Tinner, W. (2015). Reviving extinct Mediterranean forest communities may improve ecosystem potential in a warmer future. *Frontiers in Ecology and the Environment*, 13(7), 356–362. <https://doi.org/10.1890/150027>
- Ianni, F. (2004). *Il Castellucciano nel bacino centro-occidentale del fiume Salso*. Peruzzo Editore: Caltanissetta.
- Ianni, F. (2012). L'Eneolitico nella media valle del Salso. In AA.VV. (Ed.), *Dai Ciclopi agli Ecasti. Società e Territorio nella Sicilia Preistorica e Protostorica. Atti della 41a Riunione Scientifica* (pp. 1141–1143). Istituto Italiano di Preistoria e Protostoria.
- Ianni, F. (2016). L'età del Rame nelle Sicilia centro-meridionale: Nuovi dati dalla valle del Salso. *Rivista Di Scienze Preistoriche*, 66, 61–76.
- Ianni, F., Micciché, R. M., Manzella, G., & Vassallo, S. (2022). Il Neolitico medio nel Palermitano e il sito di Castellaccio di Fiaccati/le Rocche (Roccapalumba). *Notiziario Archeologico Soprintendenza Palermo*, 59, 1–76.
- Incarbona, A., Di Stefano, E., Patti, B., Pelosi, N., Bonomo, S., Mazzola, S., Sprovieri, R., Tranchida, G., Zgozi, S., & Bonanno, A. (2008). Holocene millennial-scale productivity variations in the Sicily Channel (Mediterranean Sea). *Paleoceanography*, 23, 3. <https://doi.org/10.1029/2007PA001581>
- Incarbona, A., Zarccone, G., Agate, M., Bonomo, S., Stefano, E., Masini, F., Russo, F., & Sineo, L. (2010). A multidisciplinary approach to reveal the Sicily Climate and Environment over the last 20 000 years. *Open Geosciences*, 2(2), 71–82. <https://doi.org/10.2478/v10085-010-0005-8>
- Knapp, A. B., & van Dommelen, P. (Eds.). (2014). *The Cambridge Pre-history of the Bronze and Iron Age Mediterranean*. Cambridge University Press.
- Kondor, D., Bennett, J. S., Gronenborn, D., Antunes, N., Hoyer, D., & Turchin, P. (2022). Explaining Population Booms and Busts in Mid-holocene Europe. *SocArXiv*. <https://doi.org/10.31235/osf.io/c32up>
- Kueffer, C., Drake, D., & Fernández-Palacios, J. M. (2016). Island biology. *Oxford Bibliographies, OUP, Oxford*. <https://doi.org/10.1093/OBO/9780199830060-0149>
- La Rosa, V. (1994). Le nuove indagini nella media valle del Platani. In S. Tusa (Ed.), *La preistoria del basso Belice e della Sicilia meridionale nel quadro della preistoria siciliana e mediterranea* (pp. 287–304). Società Siciliana per la Storia Patria: Palermo.
- La Rosa, V. (Ed.). (1997). *Dalle Capanne alle Robbe. La storia lunga di Milocca-Milena*. Pro Loco.
- La Torre, G. F., & Toscano Raffa, A. (2016). Archeologia dei paesaggi: Il territorio di Licata (AG) e la bassa valle dell'Himera meridionale. *LAC2014 Proceedings*. DOI. <https://doi.org/10.5463/lac.2014.40>
- Langgut, D., Cheddadi, R., Carrión, J. S., Cavanagh, M., Colombaroli, D., Eastwood, W. J., Greenberg, R., Litt, T., Mercuri, A. M., Miebach, A., Roberts, C. N., Woldring, H., & Woodbridge, J. (2019). The origin and spread of olive cultivation in the Mediterranean Basin: The fossil pollen evidence. *The Holocene*, 29, 902–922.
- Lauro, D. (2007). Caccamo. In S. Vassallo (Ed.), *Archeologia nelle vallate del Fiume Torto e del San Leonardo* (pp. 26–35). Palermo.
- Leighton, R. (1993). *The protohistoric settlement on the Cittadella, Morgantina Studies* (Vol. IV). Princeton.
- Leighton, R. (1999). *Sicily before history: An archaeological survey from the Palaeolithic to the Iron Age*. Cornell University Press.
- Leighton, R. (2012). *Prehistoric Houses at Morgantina. Excavations on the Cittadella of Morgantina in Sicily 1989–1994*. London: Accordia Research Institute.
- Li Gotti, A. (1956). Barrafranca (Enna). Rinvenimenti archeologici nel territorio. *Notizie Degli Scavi x, Serie VIII, 1–2*, 190–202.
- Li Gotti, A. (1959). Barrafranca. Rinvenimenti nel territorio. *Notizie Degli Scavi XIII, Serie VIII, 1–2*, 357–365.
- Lionello, P., Malanotte-Rizzoli, P., Boscolo, R., Alpert, P., Artale, V., Li, L., Luterbacher, J., May, W., Trigo, R., Tsimplis, M., Ulbrich, U., & Xoplaki, E. (2006). The Mediterranean climate: an overview of the main characteristics and issues. *Developments in Earth and Environmental Sciences*, 4, 1–26. [https://doi.org/10.1016/S1571-9197\(06\)80003-0](https://doi.org/10.1016/S1571-9197(06)80003-0)
- Lo Vetro, D., & Martini, F. (2012). Il Paleolitico e il Mesolitico in Sicilia. In AA.VV. (Ed.), *Dai Ciclopi agli Ecasti. Società e Territorio nella Sicilia Preistorica e Protostorica. Atti della 41a Riunione Scientifica* (pp. 19–47). Istituto Italiano di Preistoria e Protostoria.
- Magny, M., Vannièr, B., Calò, C., Millet, L., Leroux, A., Peyron, O., Zanchetta, G., La Mantia, T., & Tinner, W. (2011). Holocene hydrological changes in south-western Mediterranean as recorded by lake-level fluctuations at Lago Preola, a coastal lake in southern Sicily. *Italy. Quaternary Science Reviews*, 30(19–20), 2459–2475. <https://doi.org/10.1016/j.quascirev.2011.05.018>
- Magny, M., Combouieu-Nebout, N., De Beaulieu, J. L., Bout-Roumazielles, V., Colombaroli, D., Desprat, S., & Wirth, S. (2013). North–south palaeohydrological contrasts in the central Mediterranean during the Holocene: Tentative synthesis and working hypotheses. *Climate of the Past*, 9(5), 2043–2071.
- Magri, D., Vendramin, G. G., Comps, B., Dupanloup, I., Geburek, T., Gömöry, D., Latałowa, M., Litt, T., Paule, L., Roure, J. M., Tantau, I., Van Der Knaap, W. O., Petit, R. J., & De Beaulieu, J.-L. (2006). A new scenario for the Quaternary history of European beech populations: Palaeobotanical evidence and genetic

- consequences. *New Phytologist*, 171, 199–221. <https://doi.org/10.1111/j.1469-8137.2006.01740.x>
- Magri, D., Di Rita, F., Aranbarri, J., Fletcher, W., & González-Sampériz, P. (2017). Quaternary disappearance of tree taxa from Southern Europe: Timing and trends. *Quaternary Science Reviews*, 163, 23–55. <https://doi.org/10.1016/j.quascirev.2017.02.014>
- Magro, M. T., Galassi, F. M., Platania, E., Sferazza, P., Vacirca, I., & Varotto, E. (2021). Analisi multidisciplinari dei ritrovamenti di età neolitica di contrada Molona di Caltagirone (Catania, Sicilia): nuovi risultati e considerazioni. In P. Militello, F. Nicoletti, & R. Panvini (Eds.), *La Sicilia preistorica. Dinamiche interne e relazioni esterne (Catania-Siracusa 7–9 ottobre 2021)* (pp. 153–162). Palermo-Catania: Assessorato dei Beni Culturali e dell'Identità Siciliana-Università degli Studi di Catania.
- Malone, C., Ayala, G., Fitzjohn, M., & Stoddart, S. (2003). Under the Volcano. *Accordia Research Papers*, 9, 7–21.
- Maniscalco, L. (2007). Considerazioni sull'età del Rame nella media valle del Platani (Sicilia). *Rivista Di Scienze Preistoriche*, 57, 167–184.
- Maniscalco, L. (2008). *Il santuario dei Palici. Un centro di culto nella Valle del Margi*. Soprintendenza BB.CC.AA. di Catania.
- Maniscalco, L. (2009). Il Neolitico nella valle del Simeto. In G. Lamagna (Ed.), *Tra Etna e Simeto* (pp. 27–48). Palermo.
- Mannino, G. (2008). *Guida alla preistoria del Palermitano*. Palermo, Istituto Siciliano Studi Politici ed Economici.
- Mannino, M. A., Pluciennik, M., & Giannitrapani, E. (2010). Risultati preliminari dello studio archeozoologico dei reperti osteologici dal Riparo San Tommaso (Enna). In A. Tagliacozzo, I. Fiore, S. Marconi, & U. Tecchiati (Eds.), *Atti del 5° Convegno Nazionale di Archeozoologia* (pp. 165–167). Osiride.
- Marignani, M., Chiarucci, A., Sadori, L., & Mercuri, A. M. (2017). Natural and human impact in Mediterranean landscapes: An intriguing puzzle or only a question of time? *Plant Biosystems-an International Journal Dealing with All Aspects of Plant Biology*, 151(5), 900–905. <https://doi.org/10.1080/11263504.2016.1244121>
- Martinelli, M. C. (2020). *Isole vicine. L'arcipelago delle isole Eolie e le comunità umane nella preistoria mediterranea*. Ragusa: Edizioni di storia e studi sociali.
- Maurici, F., Nicoletti, F., & Tusa, S. (1995). L'insediamento archeologico di Cozzo Rocca (Caltanissetta). *Sicilia Archeologica*, XXVIII, 39–56.
- Médail, F., & Quézel, P. (1997). Hot-spots analysis for conservation of plant biodiversity in the Mediterranean Basin. *Annals of the Missouri Botanical Garden*. <https://doi.org/10.2307/2399957>
- Mercuri, A. M., & Florenzano, A. (2019). The Long-Term Perspective of Human Impact on Landscape for Environmental Change (LoTEC) and Sustainability: From Botany to the Interdisciplinary Approach. *Sustainability*, 11, 413. <https://doi.org/10.3390/su11020413>
- Mercuri, A. M., Sadori, L., & Uzquiano, O. P. (2011). Mediterranean and north-African cultural adaptations to mid-Holocene environmental and climatic change. *Holocene*, 21, 189–206. <https://doi.org/10.1177/0959683610377532>
- Mercuri, A. M., Mazzanti, M. B., Torri, P., Vigliotti, L., Bosi, G., Florenzano, A., Olmi, L., & Massamba, N. I. (2012). A marine/terrestrial integration for mid-late Holocene vegetation history and the development of the cultural landscape in the Po valley as a result of human impact and climate change. *Vegetation History and Archaeobotany*, 21, 353–372. <https://doi.org/10.1007/s00334-012-0352-4>
- Mercuri, A. M., Mazzanti, M., Florenzano, A., Montecchi, M. C., Rattighieri, E., & Torri, P. (2013a). Anthropogenic Pollen Indicators (API) from archaeological sites as local evidence of human-induced environments in the Italian peninsula. *Annali di Botanica*, 3, 143–153.
- Mercuri, A. M., Mazzanti, M. B., Florenzano, A., Montecchi, M. C., & Rattighieri, E. (2013b). Olea, Juglans and Castanea: The OJC group as pollen evidence of the development of human-induced environments in the Italian peninsula. *Quaternary International*, 303, 24–42.
- Mercuri, A. M., Marignani, M., & Sadori, L. (2015a). Palaeoecology and long-term human impact in plant biology. *Plant Biosystems-an International Journal Dealing with All Aspects of Plant Biology*, 149(1), 136–143. <https://doi.org/10.1080/11263504.2014.998309>
- Mercuri, A. M., Allevato, E., Arobba, D., Bandini, M. M., Bosi, G., Caramiello, R., Castiglioni, E., et al. (2015b). Pollen and macroremains from Holocene archaeological sites: A dataset for the understanding of the bio-cultural diversity of the Italian landscape. *Review of Palaeobotany and Palynology*, 218, 250–266. <https://doi.org/10.1016/j.revpalbo.2014.05.010>
- Mercuri, A. M., Florenzano, A., Burjachs, F., Giardini, M., Kouli, K., Masi, A., Picornell-Gelabert, L., et al. (2019a). From influence to impact: The multifunctional land use in Mediterranean prehistory emerging from palynology of archaeological sites (8.0–2.8 ka BP). *The Holocene* 29, 5, 830–846. <https://doi.org/10.1177/0959683619826631>
- Mercuri, A. M., Montecchi, M. C., Florenzano, A., Rattighieri, E., Torri, P., Dallai, D., & Vaccaro, E. (2019b). The Late Antique plant landscape in Sicily: Pollen from the agro-pastoral villa del Casale - Philosophiana system. *Quaternary International*, 499, 24–34. <https://doi.org/10.1016/j.quaint.2017.09.036>
- Mercuri, A. M., Florenzano, A., Terenziani, R., Furia, E., Dallai, D., & Torri, P. (2019c). Middle- to late-Holocene fire history and the impact on Mediterranean pine and oak forests according to the core RF93–30, central Adriatic Sea. *The Holocene*. <https://doi.org/10.1177/0959683619846982>
- Mercuri, A. M., Cannavò, V., Clò, E., Di Renzoni, A., Florenzano, A., Rattighieri, E., Yoon, D., & Levi, S. T. (2020). Palynology of San Vincenzo-Stromboli: Interdisciplinary perspective for the diachronic palaeoenvironmental reconstruction of an island of Sicily. *Journal of Archaeological Science: Reports*, 30, 102235. <https://doi.org/10.1016/j.jasrep.2020.102235>
- Messina, F., Frasca, M., Palermo, D., & Procelli, E. (1975). Ramacca. *Saggi Di Scavo Nel Villaggio Di Contrada Torricella*, in *Notizie Degli Scavi*, 29, 565–574.
- Michelangeli, F., Di Rita, F., Celant, A., Tisnérat-Laborde, N., Lirer, F., & Magri, D. (2022). Three Millennia of Vegetation, Land-Use, and Climate Change in SE Sicily. *Forests*, 13(1), 102. <https://doi.org/10.3390/f13010102>
- Molloy, B. (2022). Was There a 3.2 ka Crisis in Europe? A Critical Comparison of Climatic, Environmental, and Archaeological Evidence for Radical Change during the Bronze Age-Iron Age Transition. *Journal of Archaeological Research*. <https://doi.org/10.1007/s10814-022-09176-6>
- Montagna, S. (2010). *Montedoro. Paese. Museo. Un percorso open air per le identità delle zolfare*. Unpublished Master thesis. Politecnico di Milano.
- Montecchi, M. C., & Mercuri, A. M. (2018). When palynology meets classical archaeology: The Roman and medieval landscapes at the Villa del Casale di Piazza Armerina, UNESCO site in Sicily. *Archaeological and Anthropological Sciences*, 10, 743–757. <https://doi.org/10.1007/s12520-016-0442-9>
- Natali, E., & Forgia, V. (2018). The beginning of the Neolithic in Southern Italy and Sicily. *Quaternary International*, 470, 253–269. <https://doi.org/10.1016/j.quaint.2017.07.004>
- Nicoletti, F. (1994). Considerazioni sulle origini e il consolidarsi del popolamento umano nel calatino. *Bollettino Della Società Calatina Di Storia Patria e Cultura*, 3, 163–194.
- Nicoletti, F. (2000). Indagini sull'organizzazione del territorio nella facies di Castelluccio. *Il Caso Dei Monti Algar, Sicilia Archeologica*, 98, 106–127.

- Nicoletti, F., & Panvini, R. (2015). Due insediamenti del bronzo antico nella valle del Platani (Caltanissetta): Corvo e Valle Oscura. In R. Panvini & M. Congiu (Eds.), *Indigeni e Greci tra le Valli dell'Himera e dell'Halykos* (pp. 119–149). Caltanissetta, paruzzo Editore.
- Nicoletti, F., & Panvini, R. (2019). Dessucri. L'abitato protostorico di Monte Maio (Scavi 1993–2001). In M. Blancato, P. Militello, D. Palermo, & R. Panvini (Eds.), *Pantalica e la Sicilia nelle età di Pantalica* (pp. 297–322). Aldo Ausilio Editore: Padova.
- Nogué, S., Santos, A. M. C., Birks, H. J. B., Björck, S., Castilla-Beltrán, A., Connor, S., De Boer, E. J., et al. (2021). The human dimension of biodiversity changes on islands. *Science*, 372(6541), 488–491. <https://doi.org/10.1126/science.abd6706>
- Noti, R., van Leeuwen, J. F. N., Colombaroli, D., Vescovi, E., Pasta, S., La Mantia, T., & Tinner, W. (2009). Mid-and late-Holocene vegetation and fire history at Biviere di Gela, a coastal lake in southern Sicily, Italy. *Vegetation History and Archaeobotany*, 18(5), 371–387. <https://doi.org/10.1007/s00334-009-0211-0>
- Pacciarelli, M., Scarano, T., & Crispino, A. (2015). The transition between the Copper and Bronze Ages in southern Italy and Sicily. In H. Meller, H. W. Arz, R. Jung, & R. Risch (Eds.), *2200 BC: A climatic breakdown as a cause for the collapse of the Old World* (pp. 253–282). Landesamt für Denkmalpflege und Archäologie Sachsen-Anhalt.
- Palio, O. (1994). La stazione di Serra del palco e le fasi finali del bronzo antico nel territorio di Milena. In S. Tusa (Ed.), *La preistoria del basso Belice e della Sicilia meridionale nel quadro della preistoria siciliana e mediterranea* (pp. 357–364). Società Siciliana per la Storia Patria: Palermo.
- Palio, O., & Turco, M. (2018). La Grotta 3 di località Marineo (Licodia Eubea, Catania). Scavi 2017. *Cronache Di Archeologia*, 37, 41–60.
- Palmisano, A., Bevan, A., Kabelinnde, A., Roberts, N., & Shennan, S. (2021). Long-term demographic trends in prehistoric Italy: Climate impacts and regionalised socio-ecological trajectories. *Journal of World Prehistory*, 34(3), 381–432. <https://doi.org/10.1007/s10963-021-09159-3>
- Panvini, R. (2006). *Caltanissetta, il Museo archeologico: catalogo*. Palermo.
- Panvini, R. (2014). Forme di popolamento nella Sicilia centro-meridionale durante l'Eneolitico. In D. Gulli (Ed.), *From Cave to Dolmen Ritual and Symbolic Aspects in the Prehistory between Sciacca, Sicily and the Central Mediterranean* (pp. 81–90). Archaeopress: Oxford.
- Panvini, R., Guzzone, C., & Congiu, M. (Eds.). (2008). *Sabucina*. Cinquant'anni di studi e ricerche archeologiche. Roma: Arbor Sapientia.
- Panvini, R., Guzzone, C., & Palermo, D. (Eds.). (2009). *Polizzello. Lo scavo del 2004 nell'area del santuario arcaico dell'acropoli*. Arbor Sapientia: Roma.
- Parkinson, E. W., McLaughlin, T. R., Esposito, C., Stoddart, S., & Malone, C. (2021). Radiocarbon dated trends and central Mediterranean prehistory. *Journal of World Prehistory*, 34(3), 317–379. <https://doi.org/10.1007/s10963-021-09158-4>
- Pasta, S., Di Maggio, C., Di Pasquale, G., D'amore, G., Forgia, V., Incarbona, A., Madonia, G., Morales-Molino, C., Rotolo, S. G., Sineo, L., Speciale, C., Sulli, A., Tinner, W., & Vacchi, M. (2022). The impact of climate, resource availability, natural disturbances and human subsistence strategies on the Sicilian landscape dynamics during Holocene. In G. Polizzi, V. Olivier, & S. Bouffier (Eds.), *From Hydrology to Hydroarchaeology in the Ancient Mediterranean: An Interdisciplinary Approach*. Archaeopress.
- Pasta, S., & La Mantia, T. (2013). Plant species richness, biogeographic and conservation interest of the vascular flora of the satellite islands of Sicily: patterns, driving forces and threats. In E. Cardona Pons, I. Estaun Clariso, M. Comas Casademont, & P. Fraga i Arguimbau (Eds.), *Proceedings and abstracts of the 2nd Botanical Conference in Menorca Islands and plants: preservation and understanding of flora on Mediterranean Islands* (pp. 201–240). Institut Menorquí d'Estudis.
- Pasta, S., & Speciale, C. (2021). Comunità umane e piante in Sicilia: una lunga (pre)istoria. In P. Militello, F. Nicoletti, & R. Panvini (Eds.), *La Sicilia Preistorica* (pp. 31–42). Dinamiche interne e relazioni esterne, Atti del Convegno Internazionale, Palermo: Regione Siciliana, Assessorato dei Beni Culturali e dell'Identità Siciliana. Springer.
- Pérez-Obiol, R., & Sadori, L. (2007). Similarities and dissimilarities, synchronisms and diachronisms in the Holocene vegetation history of the Balearic Islands and Sicily. *Vegetation History and Archaeobotany*, 16, 259–265.
- Prillo, V. G., Speciale, C., & Miccichè, R. (in press). Insularity and singularity: exploitation of animal resources in Sicilian insular and inland territories during Prehistoric times. In *Proceedings of the 9th Postgraduate ZooArchaeology Forum (PZAF)* (pp. 27–29). BAR series.
- Privitera, F. (1994). La stazione di Mezzebi nel contesto del bronzo antico del territorio di Milena. In S. Tusa (Ed.), *La preistoria del basso Belice e della Sicilia meridionale nel quadro della preistoria siciliana e mediterranea* (pp. 339–356). Società Siciliana per la Storia Patria: Palermo.
- Procelli, E. (2001). Continuità e cesura tra Tardo Rame e Antico Bronzo in Sicilia. *Qualche Riflessione*, in *Studi Di Preistoria*, 2001, 157–173.
- Procelli, R. A., Alberghina, F., Brancato, M., Procelli, E., & Sirena, G. (2007). The project and the first results of the Gornalunga and Margi Valleys Survey. *Uplands of Ancient Sicily and Calabria. The archaeology of landscape revisited* (Vol. 13, pp. 35–48). London: Accordia Specialist Studies on Italy.
- Puglisi, V. (2018). Il sito dell'Antico Bronzo di Contrada Calderone di Raddusa (CT): Considerazioni tipologiche e stilistiche sui materiali ceramici a decorazione dipinta. *Cronache Di Archeologia*, 37, 335–343.
- PTP Agrigento. (2021). *Piano Territoriale Paesaggistico della Provincia di Agrigento*. Regione Sicilia.
- PTP Caltanissetta. (2015). *Piano Territoriale Paesaggistico della Provincia di Caltanissetta*. Regione Sicilia.
- PTPR. (1996). *Linee Guida del Piano Territoriale Paesaggistico Regionale*. Ambientali e della Pubblica Istruzione, Palermo: Regione Siciliana Assessorato dei Beni Culturali.
- Quézel, P. (1995). La flore du bassin méditerranéen: Origine, mise en place, endémisme. *Ecologia Mediterranea*, 21(1), 19–39.
- Ramsay, S. (2012). Charcoal remains. In R. Leighton (Ed.), *Prehistoric Houses at Morgantina. Excavations on the Cittadella of Morgantina in Sicily* (pp. 1989–2004). Ithaca (NY): Cornell University Press.
- Romano, V., Catalano, G., Bazan, G., Cali, F., & Sineo, L. (2021). Archaeogenetics and Landscape Dynamics in Sicily during the Holocene: A Review. *Sustainability*, 13(17), 9469. <https://doi.org/10.3390/su13179469>
- Roberts, C. N., Woodbridge, J., Palmisano, A., Bevan, A., Fyfe, R., & Shennan, S. (2019). Mediterranean landscape change during the Holocene: Synthesis, comparison and regional trends in population, land cover and climate. *The Holocene*, 29(5), 923–937.
- Sadori, L., & Narcisi, B. (2001). The Postglacial record of environmental history from Lago di Pergusa. *Sicily. the Holocene*, 11(6), 655–671. <https://doi.org/10.1191/09596830195681>
- Sadori, L., Zanchetta, G., & Giardini, M. (2008). Last Glacial to Holocene palaeoenvironmental evolution at Lago di Pergusa (Sicily, Southern Italy) as inferred by pollen, microcharcoal, and stable isotopes. *Quaternary International*, 181(1), 4–14. <https://doi.org/10.1016/j.quaint.2007.02.024>
- Sadori, L., Jahns, S., & Peyron, O. (2011). Mid-Holocene vegetation history of the central Mediterranean. *The Holocene*, 21, 117–129.
- Sadori, L., Ortu, E., Peyron, O., Zanchetta, G., Vannièrè, B., Desmet, M., & Magny, M. (2013). The last 7 millennia of vegetation and climate changes at Lago di Pergusa (central Sicily, Italy). *Climate of the Past* 9, 4, 1969–1984. <https://doi.org/10.5194/cp-9-1969-2013>
- Sadori, L., Masi, A., & Ricotta, C. (2015). Climate-driven past fires in central Sicily. *Plant Biosystems-an International Journal*



- Dealing with All Aspects of Plant Biology*, 149(1), 166–173. <https://doi.org/10.1080/11263504.2014.992996>
- Sammito, A. M. (2002). Testimonianze di età neolitica nel Museo di Modica. *Rivista di Scienze Preistoriche*, LII, 345–366.
- Sarno, S., Boattini, A., Pagani, L., Sazzini, M., De Fanti, S., Quagliariello, A., Gneccchi, R. G., A., et al. (2017). Ancient and recent admixture layers in Sicily and Southern Italy trace multiple migration routes along the Mediterranean. *Scientific Reports*, 7(1), 1–12. <https://doi.org/10.1038/s41598-017-01802-4>
- Scibona, G. (1987). sv. Cerami. In G. Nenci & G. Vallet (Eds.), *Bibliografia Topografica della Colonizzazione Greca in Italia e nelle Isole Tirreniche* (pp. 244–245). Scuola Normale Superiore-École Française de Rome: Pisa-Roma.
- Scibona, G. (1993). sv. Nicosia. In G. Nenci e G. Vallet, (Ed.), *Bibliografia Topografica della Colonizzazione Greca in Italia e nelle Isole Tirreniche* (pp. 332–335). Scuola Normale Superiore-École Française de Rome: Pisa-Roma.
- Shennan, S., & Edinborough, K. (2007). Prehistoric population history: From the Late Glacial to the Late Neolithic in central and northern Europe. *Journal of Archaeological Science*, 34, 1339–1345. <https://doi.org/10.1016/j.jas.2006.10.031>
- Shennan, S., & Sear, R. (2021). Archaeology, demography and life history theory together can help us explain past and present population patterns. *Philosophical Transactions of the Royal Society B*, 376(1816), 20190711. <https://doi.org/10.1098/rstb.2019.0711>
- Sjöqvist, E. (1962). Excavations at Morgantina (Serra Orlando), 1961. Preliminary report VI. *American Journal of Archaeology*, 66(2), 135–143.
- Sjöqvist, E. (1964). Excavations at Morgantina (Serra Orlando), 1963. Preliminary report VIII. *American Journal of Archaeology*, 68(2), 137–147.
- Speciale, C. (2021). *Human-Environment Dynamics in the Aeolian Islands during the Bronze Age: A paleodemographic model*. BAR series.
- Speciale, C. (2023). Sicily and the process of Neolithisation: A review of the archaeobotanical data. *Vegetation History and Archaeobotany*. <https://doi.org/10.1007/s00334-023-00963-9>
- Speciale, C., D'Oronzo, C., Stellati, A., & Fiorentino, G. (2016). *Ubi Minor... deinde summa?*: Archaeobotanical data from the prehistoric village of Filo Braccio (Filicudi, Aeolian Archipelago): Spatial analysis, crop production and paleoclimate reconstruction. *Scienze Dell'antichità*, 22(2), 281–296.
- Speciale, C., Bentaleb, I., Combourieu-Nebout, N., Di Sansebastiano, G. P., Ianni, F., Fourel, F., & Giannitrapani, E. (2020). The case study of Case Bastione: First analyses of 3rd millennium cal BC paleoenvironmental and subsistence systems in central Sicily. *Journal of Archaeological Science: Reports*, 31, 102332. <https://doi.org/10.1016/j.jasrep.2020.102332>
- Speranza, F., Maniscalco, R., & Grasso, M. (2003). Pattern of orogenic rotations in central-eastern Sicily: Implications for the timing of spreading in the Tyrrhenian Sea. *Journal of the Geological Society*, 160(2), 183–195. <https://doi.org/10.1144/0016-764902-043>
- Steele, T. E. (2015). The contributions of animal bones from archaeological sites: The past and future of zooarchaeology. *Journal of Archaeological Science*, 56, 168–176.
- Stillwell, R. (1959). Excavations at Serra Orlando (1958) Preliminary report III. *American Journal of Archaeology*, 63(2), 167–173.
- Stoddart, S., Woodbridge, J., Palmisano, A., Mercuri, A. M., Mensing, S. A., Colombaroli, D., & Roberts, C. N. (2019). Tyrrhenian central Italy: Holocene population and landscape ecology. *The Holocene*, 29(5), 761–775.
- Tanasi, D. (2008). *La necropoli protostorica della Montagna di Caltagirone*. Polimetrica: Milano.
- Thienemann, M., Masi, A., Kusch, S., et al. (2017). Organic geochemical and palynological evidence for Holocene natural and anthropogenic environmental change at Lake Dojran (Macedonia/Greece). *The Holocene*, 27(8), 1103–1114. <https://doi.org/10.1177/0959683616683261>
- Thompson, S. M. (1999). *A Central Sicilian Landscape: Settlement and Society in the Territory of Ancient Morgantina* (5000 BC - AD 50). Unpublished PhD dissertation: University of Virginia (Charlottesville).
- Thompson, J. D. (2020). *Plant Evolution in the Mediterranean. Insights for conservation* (2nd ed., p. 439). Oxford.
- Tiné, V. (2014). The stratigraphic sequence of the Grotta del Kronio and the neolithization of Sicily and Calabria A brief chronological summary. In D. Gullì (Ed.), *From Cave to Dolmen. Sicily and the central Mediterranean: Ritual and symbolic aspects in the prehistory between Sciacca, Sicily and the central Mediterranean* (pp. 43–49). Archaeopress.
- Tinner, W., van Leeuwen, J. F. N., Colombaroli, D., Vescovi, E., van der Knaap, W. O., Henne, P. D., Pasta, S., D'Angelo, A., & La Mantia, T. (2009). Holocene environmental and climatic changes at Gorgo Basso, a coastal lake in southern Sicily. *Italy. Quaternary Science Reviews*, 28(15–16), 1498–1510. <https://doi.org/10.1016/j.quascirev.2009.02.001>
- Tinner, W., Vescovi, E., van Leeuwen, J. F. N., Colombaroli, D., Henne, P. H., Kaltenrieder, P., Morales-Molin, C., et al. (2016). Holocene vegetation and fire history of the mountains of Northern Sicily (Italy). *Vegetation History and Archaeobotany*, 25(5), 499–519. <https://doi.org/10.1007/s00334-016-0569-8>
- Tusa, S. (1999). *La Sicilia nella preistoria*. Palermo: Sellerio.
- Tykot, R. H., Vianello, A., & Gullì, D. (2020). Osservazioni sull'alimentazione della comunità preistorica di contrada Scintilia di Favara (AG) sulla base di analisi isotopiche. In I. Damiani, A. Cazzella, & V. Copat (Eds.), *Preistoria del cibo. L'alimentazione nella preistoria e nella protostoria* (pp. 65–74). Firenze, IIPP, Studi di Preistoria e Protostoria 6.
- Vannière, B., Power, M. J., Roberts, N., Tinner, W., Carrión, J., Magny, M., Bartlein, P., et al. (2011). Circum-Mediterranean fire activity and climate changes during the mid-Holocene environmental transition (8500–2500 cal. BP). *The Holocene*, 21(1), 53–73. <https://doi.org/10.1177/0959683610384164>
- Varalli, A., Moggi-Cecchi, J., & Goude, G. (2022). A multi-proxy bioarchaeological approach reveals new trends in Bronze Age diet in Italy. *Scientific Reports*, 12(1), 1–20. <https://doi.org/10.1038/s41598-022-15581-0>
- Viola, F., Liuzzo, L., Noto, L. V., Lo, C. F., & La Loggia, G. (2014). Spatial distribution of temperature trends in Sicily. *International Journal of Climatology*, 34(1), 1–17. <https://doi.org/10.1002/joc.3657>
- Weiberg, E., Bevan, A., Kouli, K., Katsianis, M., Woodbridge, J., Bonnier, A., Engel, M., Finné, M., Fyfe, R., Maniatis, Y., Palmisano, A., Panajiotidis, S., Roberts, C. N., & Shennan, S. (2019). Long-term trends of land use and demography in Greece: A comparative study. *The Holocene*, 29(5), 742–760. <https://doi.org/10.1177/0959683619826641>
- Whittaker, R. J., Fernández-Palacios, J. M., Matthews, T. J., Borregaard, M. K., & Triantis, K. A. (2017). Island biogeography: Taking the long view of nature's laboratories. *Science*, 357(6354), eaam8326. <https://doi.org/10.1126/science.aam8326>
- Wilkens, B. (1997). Resti faunistici provenienti da alcuni siti dell'area di Milena. In V. La Rosa (Ed.), *Dalle Capanne alle Robbe* (pp. 127–134). Milena: La storia lunga di Milena-Milocca. Pro Loco Milena.
- Yu, H., van de Loosdrecht, M. S., Mannino, M. A., Talamo, S., Rohrlach, A. B., Childebayeva, A., Villalba-Mouco, V., Aron, F., Brandt, G., Burri, M., & Freund, C. (2022). Genomic and dietary discontinuities during the Mesolithic and Neolithic in Sicily. *Science*, 25(5), 104244.
- Zanchetta, G., Borghini, A., Fallick, A. E., Bonadonna, F. P., & Leone, G. (2007). Late Quaternary palaeohydrology of Lake Pergusa (Sicily, southern Italy) as inferred by stable isotopes of lacustrine carbonates. *Journal of Paleolimnology*, 38(2), 227–239. <https://doi.org/10.1007/s10933-006-9070-1>
- Zanchetta, G., Baneschi, I., Magny, M., Sadori, L., Termine, R., Bini, M., Vannière, B., Desmet, M., Natali, S., Luppichini, M., &

Pasquetti, F. (2022). Insight into summer drought in southern Italy: Palaeohydrological evolution of Lake Pergusa (Sicily) in the last 6700 years. *Journal of Quaternary Science*, 37(7), 1280–1293. <https://doi.org/10.1002/jqs.3435>

**Publisher's Note** Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.