Research Article

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# Salt Production in Central Italy and Social Network Analysis Centrality Measures: An Exploratory Approach

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**Abstract:** In this work, we study salt-production settlement in central Italy with an exploratory application of centrality indexes, common in social network analysis: betweenness centrality, closeness centrality, and degree centrality. These methods are not new, but they have never been applied to this type of site and the results are innovative and illuminating. In fact, the closeness and degree centrality do not yield particularly interesting results. However, the betweenness centrality, which indicates the most commonly used routes in a given region, provide powerful insights. By indicating shifting most common routes through time, from the terrestrial and sea route along the coast in the Bronze and Iron Age, to the use of the Tiber River and Tiber valley as route, in the Orientalizing and Archaic Period, they allow us to advance hypotheses about the shift between two different productions. The briquetage salt production technique was used in the Bronze and Iron Age on the costal sites, which was also the most common route used in the region. While the proper marine production at the mouth of the Tiber, both on the Etruscan and Latin side, might develop during the Orientalizing and Archaic Age, together with an intensified use of the Via Salaria, running from the coast to the mountains of Latium, along the Tiber River. It would be interesting to confirm these hypotheses with further analyses and also targeted excavations.

**Keywords:** salt production, centrality indexes, fluvial and terrestrial routes, Central Italy, Pre-protohistory

## 1 Introduction

Since the first pioneering application of network principles to identify and analyse the "centrality" of a place and the dynamics of settlement and/or trade patterns such as e.g. the dynamic of hunter-gatherer populations in the Fjordland Archipelago (Mackie, 2001), or the brick trade in the Tiber valley during the Roman time (Graham, 2006), many advances have been made especially thanks to the application of different cost-allocation spatial models, gravity models, stochastic models, and more recent models that combine spatial and cultural variables (see e.g. contributions in recently edited volumes such as Brughmans, Collar, & Coward, 2016; Collar, Coward, Brughmans, & Mills, 2015; Dawson & Iacono, 2020; Donnellan, 2020; Felder & Evans, 2014; Knappett, 2013).

In this exploratory study, we partially go back one step and apply traditional social network centrality measures to fluvial and terrestrial transportation networks in central Italy with a focus on a particular type of site: "coastal sea-salt production" centres, about which many questions remain still unanswered (for another

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recent application of centrality measures see Roberts et al. (2023) and Santos (2022)). In particular, we want to explore the relation between salt sites and most used transportation routes to understand if there is any correlation between this production activity and transportation modes. We apply normalized degree centrality, betweenness centrality, and closeness centrality in combination with spatial data and visualization and obtain illuminating results that lead to relevant new hypotheses, which deserve further investigation with more sophisticated models and targeted excavations. After this work was submitted, a paper by Alessandri and other authors was published, which confirmed the use of the Piscina Torta site for salt production during the seventh to sixth century BC which coincide with the greater use of the way from and to the inland and the coast, identified by the modelling in this work (Alessandri et al., 2024).

In particular, the closeness centrality is probably the less interesting: all sites have more, or less, equal values, as it is probably foreseeable in a relatively small and compact region such as Latium and Etruria. The normalized degree centrality indicates some centres with a higher number of neighbours, which often seems to coincide with important centres also according to archaeological or historical evidence. However, the more interesting results come from the betweenness centrality.

The routes indicated by the centres with highest betweenness centrality are the potentially most used routes both fluvial and terrestrial. In addition, the analysis shows some different patterns in routes frequency of use in different time periods that potentially shed new light on the possible dating of the transition from briquetage to salt-production, because the latter implies the creation of salterns at the mouth of the river (Alessandri et al., 2024), and the change in route exploitation with a more frequent use of the famous salt road, later identified with the Salaria.

# 2 Data

## 2.1 Salt Production Sites in Central Italy Within the European Context

Prior to the invention and widespread adoption of refrigeration (Rees, 2014), which occurred at the turn of the nineteenth and twentieth centuries, there were only a few methods available for food preservation: drying, smoking, and salting. Among these methods, salting was the most effective and efficient. In this context, salt played a fundamental role in the socio-economic dynamics of ancient societies (Harding, 2021; Weller & Brigand, 2015). It is believed to have been a cornerstone of the early power structures in Rome (Giovannini, 1985) and certainly played a pivotal role in ancient Venice (Hocquet, 1973, 1979). However, due to the high solubility of sodium chloride (salt) in water, it has been quite challenging to trace its presence in ancient times, despite its vital importance. Nonetheless, in the latter part of the twentieth century, the significant integration of scientific approaches into archaeological research provided new tools for detecting salt production, both in terms of its manufacturing and consumption (Alessandri et al., 2019; Flad et al., 2005; Sandu, Weller, Stumbea, & Alexianu, 2012; Sordoillet, Weller, Rouge, Buatier, & Sizun, 2018; Vasilache, Kavruk, & Tencariu, 2020). In Europe, this development has recently sparked a renewed interest in the study of salt and its significance in ancient societies (Alessandri & Attema, 2022).

In general, there are three recognized phases that distinguish ancient salt production: concentration, crystallization, and conditioning. The initial phase, which leads to the formation of brine, involved the natural evaporation of saltwater, possibly enriched with sodium chloride (NaCl). Subsequent crystallization could occur in large artificial basins or by artificially heating the brine inside ceramic vessels placed in specially designed kilns. The former method is still in use in modern salterns. The latter, known as briquetage, based on current knowledge is the older method: the earliest evidence dates back to the Copper Age in Romania (Weller & Dumitroaia, 2005), but the technique quickly spread throughout Europe (Harding, 2013, 2021).

In the briquetage technique, once the salt had crystallized, it was necessary to break the container to extract the salt cake. Sites where briquetage was employed are typically characterized by extensive deposits of ashes and charcoal, the presence of kilns and pits, and, most importantly, large quantities of ceramic fragments attributed exclusively to so called *ollae* (in which the brine was placed for evaporation), usually in reddish hues. These features, found throughout Europe, were first highlighted along the Tyrrhenian coast of Italy by Pacciarelli at the end of the last century and linked to salt production (Pacciarelli, 1991, 2001). Following that, further investigations have led to the identification of similar sites, all located along the shoreline and often near ancient lagoons (Alessandri et al., 2019, with a list of Italian briquetage sites) (Figure 1).

The most recently identified site with these features, and the oldest in Tyrrhenian Italy (Middle Bronze Age), is Caprolace in the Pontine Plain (Alessandri et al., 2019). However, many aspects remain unresolved in the Italian context, and two, in particular, have been the subject of extensive research in recent years. The first concerns the ceramic forms associated with briquetage: while those found in the European context are mainly cylindrical or truncated-conical pots, the Italian ones exhibit a much broader variability, including closed forms (barrel or ovoid shapes) that are not well-suited for the evaporation process. This has led some authors to question the salt hypothesis and instead propose the processing of other edible products, such as fish (Belardelli, 2011, 2013; Di Fraia, 2023). The second issue pertains to the chronology and motivations underlying the transition from the briquetage production method to proper saltworks. In this study, we take a novel additional approach which is the combination of network indices with spatial data to provide novel insights and produce new hypotheses on the second issue: on the important moment of change from briquetage technique to proper saltern mode of production.

## 2.2 Regional Sites and Routes

For this work, settlements from *Latium vetus* and Southern Etruria from the Bronze Age to the end of the Archaic Period have been considered. These sites are very well known and documented thanks to a long tradition of studies that goes back to the first topographic studies conducted within the tradition of the aristocratic grand tours of Rome and the Roman countryside during the eighteenth century. British and German aristocrats, fascinated by the possibility of interacting and getting closer to ancient authors through the contemplation and study, were the first to produce catalogues and descriptions of the monuments and

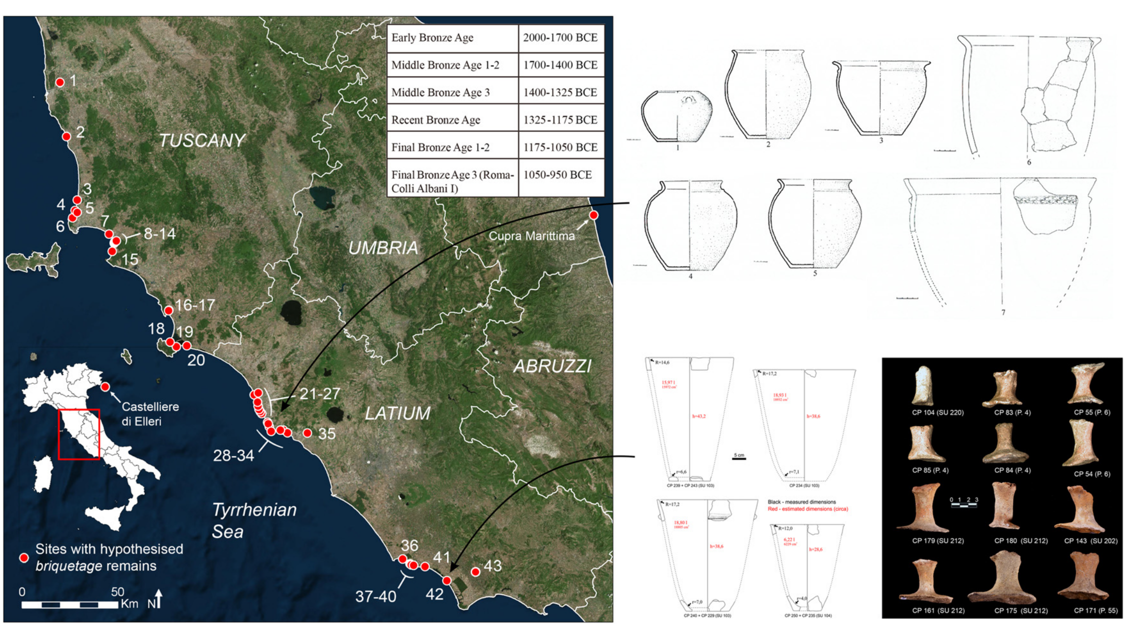


Figure 1: Sites along the Italian Tyrrhenian coast where briquetage salt-production has been hypothesized and a simplified chronological scheme for Central Italy Bronze Age (from Alessandri et al., 2019 and Belardelli, 2011).

environment of the so-called Campagna Romana including both the immediate surroundings of Rome and the southern Etruscan region, respectively, to the south and north of the Tiber river (Dennis, 1848; Gell, 1934; Nibby, 1837). Subsequently, this early activity of survey and documentation was continued by the Antiquarian tradition of the late nineteenth to early twentieth century (Lanciani, 1909; Nissen, 1883–1902; Solari, 1915–20) and the more recent landscape and topographic traditions before (*Carta Archaeologica del Territorio di Roma,* prepared in the 1920–1930 but only published in the 1960, Lugli, (1962)) and after World War II both by Italian (e.g.: Giuliani, 1966, 1970; Giuliani & Quilici, 1964) and other subsequent works of the Institute of Topography of the University of Rome La Sapienza and the volumes of the *Forma Italiae* published by them; or Quilici (1974) and other volumes of the *Latium vetus* series (see below) and international scholars.[1]

Finally, in the last few decades of the twentieth century many important research projects have been conducted by Italian and/or international teams with modern standards and up-to-date methodologies that have greatly improved the knowledge of the region not only at key excavated sites but also capillary in the territory around them. Among these works, the volumes of the Forma Italiae (Roman School of Topography), the volumes of the *Latium vetus* series (by Lorenzo and Stefania Quilici Gigli), and the work of John B. Ward-Perkins (1961, 1962) and Tim Potter (1979, 1985) in southern Etruria ought to be mentioned. In addition, an important survey of pre-and proto-historical sites in the territory of Rome was led by Anna Maria Bietti Sestieri (Bietti Sestieri & Sebastiani, 1986; Bietti Sestieri, 1989), while various survey projects and synthesis works have been conducted both in Latium and Etruria, by scholars of the Roman school of prehistory and protohistory, founded by Renato Peroni (e.g. di Gennaro, 1986; di Gennaro, 1988; Guidi, 1984, 1986a,b; di Gennaro & Peroni, 1986; and more recently Alessandri, 2007, 2013; Barbaro, 2010; Pacciarelli, 2001; Schiappelli, 2008). At the same time, the coastal area around the mouth of the Tiber was investigated by the Malafede survey Project (Arnoldus Huyzendveld, Gioia, Mineo, & Pascucci, 1995), while the Pontine Plain and the Nettuno area were intensively surveyed by teams led by Peter Attema from the University of Groningen.[2]

While a project directed by Helen Patterson and Christopher Smith with the collaboration of Helga di Giuseppe and Rob Witcher focused on an enhancement project of the original Tiber Valley Project of the British School of Rome,[3] the Sabine region, partially included in this work, has also been investigated by the Galantina project (Guidi, Gabrielli, & Santoro, 2003; Guidi, Rioda, & Santoro, 2008). Finally, the Suburbium Project led by Andrea Caradini and Paolo Carafa has conducted a systematic survey and documentation of both Rome (Carandini, 2012) and its territory, resulting in the Geographical Information System (GIS) available on-line for scholars and the public (http://www.archeositarproject.it/). This work is now continued and enhanced by the New *Latium vetus* project, directed by Paolo Carafa to produce a similar tool at the regional level in collaboration with Regione Lazio (Figure 2).

At the same time, in recent years, some synthetic works have been published, which have been points of reference for the present study. First, a project co-ordinated by Regione Lazio has revised all previous studies and produced the *Repertorio dei Siti Preistorici e Protostorici del Lazio*, a very special and useful tool to approach a great quantity of data with a synthetic but also a very detailed approach. For *Latium vetus*, we have used data already collected for the work *The Urbanization of Rome and Latium vetus from the Bronze Age to the Archaic Era* (Fulminante, 2014), also compared with the important works on the same region by Luca Alessandri (2007, 2013). For Etruria, the most important synthetic works for the Final Bronze Age are the works by Barbaro (2010), di Gennaro (1986, 1988), and di Gennaro and Peroni (1986); for the Mid Tiber valley, the work by Schiappelli (2008) is very useful; while Iaia and Mandolesi (2010) have produced a synthesis of the later Early Iron Age sites on the whole Etruria. Finally, for the later Etruscan phases, the work by Marco Rendeli on

**1** Obviously and mostly the famous John Bryan Ward-Perkins, director of the British School of Rome and of the important South Etruria Project. For a deep and detailed discussion of the work of this scholar, within the wider context of Landscape Archaeology, see Smith (2017) and Stoddart (2000).

**2** For some publications derived from the Pontine Region Project see for example Alessandri (2007, 2013), Attema (1990, 1993), Attema, Burgers, van Joolen, van Leusen, & Mater (2002), Attema, de Haas, & Tol (2010), Attema, van Leusen, Alessandri, & Anastasia (2007), and De Haas (2011).

**3** For results of this project see Cascino, Di Giuseppe, & Patterson (2012), Patterson, Di Giuseppe, & Witcher (2020), Patterson & Millett (1998), and Patterson et al. (2004).

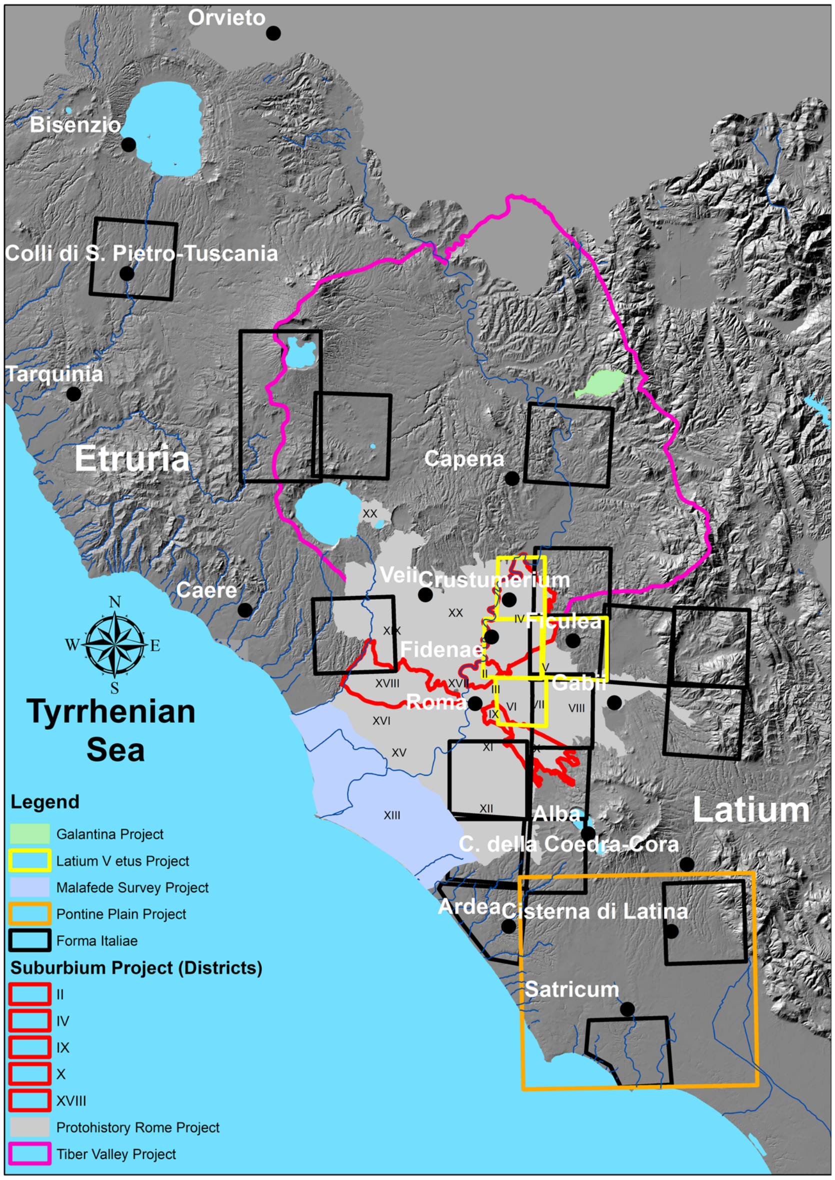


**Figure 2:** Survey Project conducted in central Italy with modern fieldwork methodologies and recording standards (from Fulminante, 2023).

the territorial organization of southern Etruria in the Orientalizing and Archaic Period (Rendeli, 1993) has been important. All these works have been up-dated based on the review of Studi Etruschi and major Italian and international journals, proceedings of specialistic conferences (e.g. the Proceedings of the biannual conference *Preistoria and Protostoria in Etruria* or International Conference on Italian Archaeology) and exhibition catalogues (e.g. Della Fina & Pellegrini, 2013).

These settlements are primarily known from either excavation or by survey. However, geophysical prospection has been used in recent years (teams led by the British School at Rome, the University of Siena and the Groningen Institute of Archaeology) (e.g. for salt production sites, see Sevink et al., 2021), which provide new data especially on the built environment and the organization of the space within the nucleated settlements and opens new perspective for multi-scalar analyses. To build the database of sites with their extensions and geographical location, some assumptions have been made following a long tradition of study present in central Italy. According to these assumptions, settlements are hypothesized in the case of coherent oro-graphical units even if only few sherds are available from the survey and/or excavation. This normally applies mainly to

Bronze Age and Early Iron Age sites, for which the evidence is scarcer. In addition, some other sites identified because of literary sources but for which archaeological evidence was not available have also been included. This second assumption mainly applies to the Latin region rather than the Etruscan one, for which literary sources are less abundant.

We have considered the maximum period in which the settlements co-existed without major changes and obtained six time slices:
- Final Bronze Age 3 (FBA3): 1050/1025–950/925 BC
- Early Iron Age 1 Early (EIA1E): 950/925–900 BC
- Early Iron Age 1 Late (EIA1L): 900–850/825 BC
- Early Iron Age 2 (EIA2): 850/825–730/720 BC
- Orientalizing Age (OA): 730/720–580 BC
- Archaic Period (AP): 580–500 BC

Both terrestrial and fluvial communications have been considered in this study. To construct the terrestrial and the fluvial route networks, a bidirectional link has been established between two settlements directly adjacent on a terrestrial or a fluvial route without any settlement in between. The fluvial routes have been based on digital data of modern rivers provided by Regione Lazio and published on the website of Ministero dell'Ambiente (http://www.pcn.minambiente.it/viewer/). While some studies are available on the changes in the Tiber River route through time,[4] to our knowledge, there are no studies available at the regional level. To eliminate recent channels and irrigation works and to obtain the network most likely to have been present in antiquity, the modern rivers have been selected with a query performed in GIS about the superimposition of modern rivers to alluvial deposit, because these are the most likely channel that were probably present also in antiquity.

The terrestrial communication and transportation routes have been reconstructed from hypotheses advanced by various scholars. For *Latium vetus*, the reconstruction by Lorenzo and Stefania Quilici Gigli (in Colonna, 1976) elaborated at the regional level for the Archaic Period has been used. For the Etruscan region, instead, a comprehensive study is still lacking, although important work on Orientalizing and Archaic road cuts has been done by Tuppi (2014). In order to hypothesize the terrestrial links reconstructive proposal of various authors have therefore been considered: Bonghi Jovino (2008), Brocato (2000), Enei (2001), Potter (1979, 1985), Schiappelli (2008), Tartara (1999), and Zifferero (1995).

The different interpretations have also been tested by considering their alignment with settlements discovered more recently after the publication of those works. According to the topographical principle, the existence and/or use of older tracks has been assumed, if older settlements coherently align with later archaeologically attested roads (Roman and later) and or with natural morphological routes (e.g. River valleys, ridges, etc.) and/or significant archaeological landmark such as funerary tumuli and/or bridges, forts etc. This principle has not only been traditionally and commonly applied in topographical studies both in Italy (see e.g. volumes *Forma Italiae*) and in Germany (Müller, 1904) but also in the archaeology of the New World (Trombold, 2011[1991]).

Figure 3 shows a summary of the terrestrial network of path in Iron Age southern Etruria and *Latium vetus* with indication of the sources of the interpretations. To the work cited as used in this study, also the work by Wetter (1962) has to be added that unfortunately has been overlooked at the stage of the reconstruction of the networks and analyses. "Position S" indicates those paths hypothesized on settlement alignments. Unfortunately, it has not been possible to find enough information on paths and routes in southern Etruria during the beginning of the Final Bronze Age (FBA 1–2) and therefore this time slice for terrestrial routes in Etruria has been omitted from the analyses. Both settlements and communication routes have been considered constant within each time slice. In this sense, the analysis concerned static networks rather than an evolving system.

4 For a reconstruction of the paleo river of the Tiber especially with reference to the modern and ancient coastline see Alessandri (2007, 2013) with previous references. About the development of the Tiber delta: Bellotti et al. (2011) with previous references.

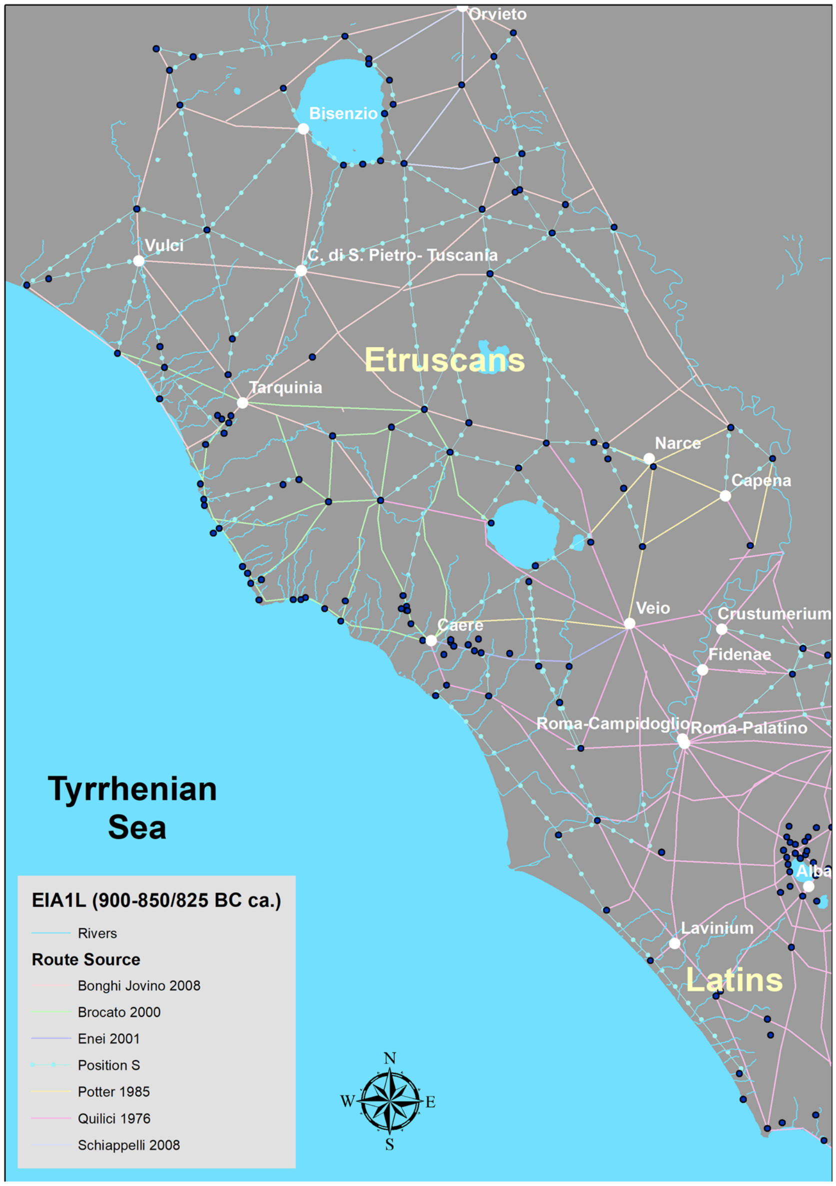


**Figure 3:** Reconstruction of Early Iron Age Terrestrial routes in Southern Etruria and Latium vetus according to various scholars (from Fulminante, 2023).

However, this does not mean that the system is constant in the six periods. Some sites are abandoned, and some others are founded; therefore, routes are not the only thing that changes but also the settlements. Finally, it ought to be mentioned here that routes and paths have not only been reconstructed topographically at a detailed small scale but also schematically at a large scale for the purpose of building the networks. In future work, we are planning to reconstruct paths and routes within a GIS platform that will make available the detailed topographical data for specialists and for the public.

# 3 Methods

The networks created according to the rules illustrated above have been analysed through centrality indexes, without taking into consideration the variable of the distance. In this section these traditional centrality indexes are illustrated mathematically.[5]

## 3.1 Betweenness Centrality

Betweenness centrality indicates the degree to which an actor controls or mediates the "relations between other pairs or dyads of actors that are not directly connected. Actor betweenness centrality measures the extent to which other actors lie on the geodesic path (or the shortest distance), between pairs of actors in the network" (Knoke & Yang, 2008, p. 68). At this point, it ought to be noted that distance in a network is not a geographical distance but the number of links which connects two nodes. In other words, the betweenness centrality measures the extent to which a node or an actor lies on the shortest route connecting each pair of other nodes/actors in the network (Knoke & Yang, 2008, pp. 68–69; but see also the seminal papers by Freeman, 1977; White & Borgatti, 1994). As originally proposed by Freeman, betweenness centrality is given by the formula:

$$C_{\mathrm{B}}(N_i) = \sum_{j<k} \frac{g_{jk}(N_i)}{g_{jk}},$$

where $g_{jk}$ is the number of geodesic paths between the two nodes $j$ and $k$ (dyad) and $g_{jk}(N_i)$ is the number of geodesics between $j$ and $k$ that contain $i$.

Then, dividing $g_{jk}(N_i)$ by $g_{jk}$ measures the proportion of geodesic path connecting $j$ and $k$ in which node $i$ is involved. Summing across all the dyads not including node $i$ measure the extent to which $i$ sits on the geodesic path of the other network members. Wasserman and Faust suggest normalizing the actor betweenness centrality by dividing it by the maximum theoretical value of $\frac{(g-1)(g-2)}{2}$ assuming each pair has only one geodesic according to the formula:

$$C'_{\mathrm{B}}(N_i) = \frac{C_B(N_i)x2}{(g-1)(g-2)}.$$

The standardized actor betweenness centrality is 0.0, when the original betweenness centrality is 0, and it is 1.0 when node $i$ falls on the geodesic path of every dyad of the remaining $g-1$ nodes. Therefore, the closer the standardized betweenness centrality is to 1.0, the more the actor controls or mediates relations in the network (Knoke & Yang, 2008, p. 68).

## 3.2 Closeness Centrality

The closeness centrality of an actor/node, developed by Sabidussi (1966), measures the extent to which a node/actor is close to all other actors/nodes in the network. It is based on the total distance between the node/actor and all other nodes/actors, where larger distances imply lower closeness centrality values. Closeness and distance refer to how quickly an actor/node can interact with others, e.g. by communicating directly or via few intermediaries; again, the geodesic or the shortest path is a key concept and distance means the number of links which connect two nodes and not the geographical distance.

5 This section reproduces the methodology already illustrated in Fulminante (2012) to which we refer also for further details.

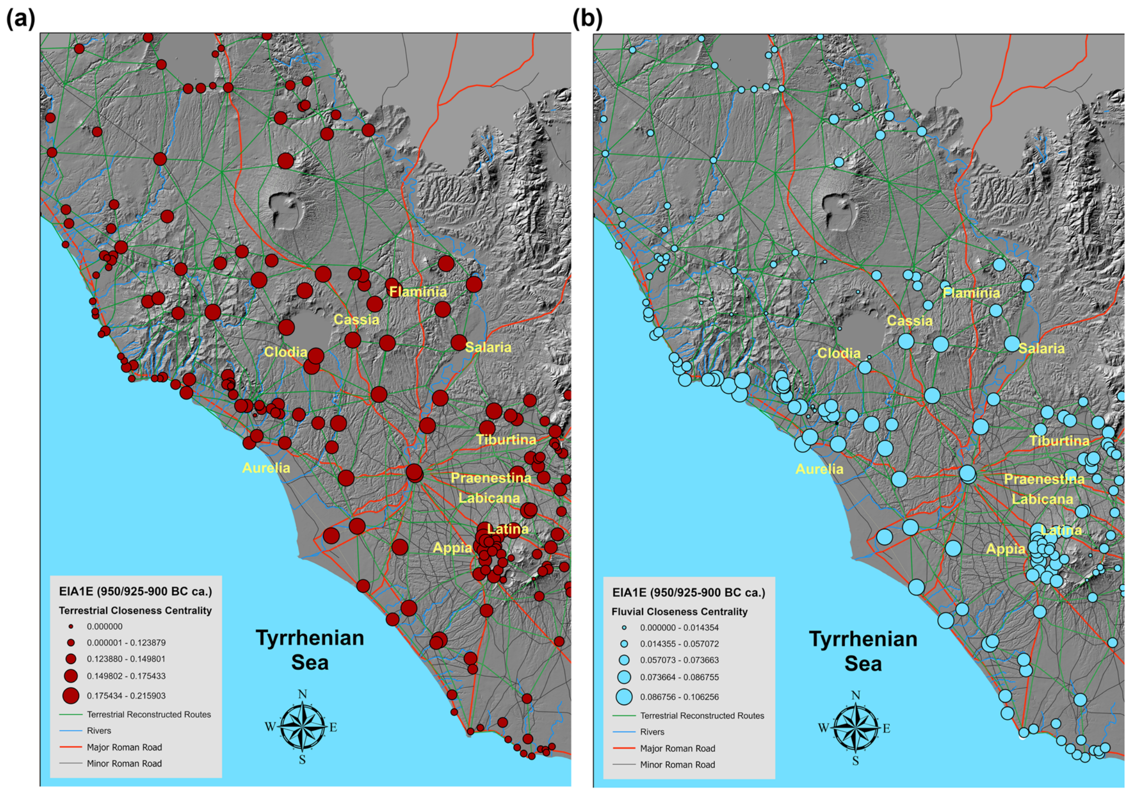


**Figure 4:** Central Italy. Early Iron Age 1 Early. Closeness Centrality. (a) Terrestrial routes and (b) Fluvial routes.

In fact, the closeness centrality ($C_C$) of an actor/node ($N_i$) is based on the geodesic to all other nodes "and is computed as the inverse of the sum of the geodesic distances between actor $i$ and the $g - 1$ other actors" (Knoke & Yang, 2008, p. 65):

$$C_c(N_i) = \frac{C_c(N_i)x2}{(g-1)(g-2)}.$$

Again, closeness centrality might vary with network size. Therefore, Beauchamp suggested that the index of actor closeness centrality should be standardized by multiplying it by the maximum of nodes in the network minus 1 (Beauchamp, 1965 quoted in Knoke & Yang, 2008, p. 66):

$$C_c(N_i) = (g-1)(C_c(N_i)).$$

## 3.3 Normalized Degree Centrality

The degree centrality measures "the extent to which a node connects to all other nodes in a social network" and indicates how easily information can reach a node. It is based on the assumption that more links and neighbours a node has, the higher the probability of that node to receive information and is given by the following equation (Knoke & Yang, 2008, p. 63):

$$C_D(N_i) = \sum_{j=1}^{g} X_{ij}(i \neq j).$$

This means that in a simple and undirected network (where g is the total number of nodes or actors), the degree centrality ($C_D$) of an actor or node $i$ ($N_i$) is given by the sum of the number of its direct links to the $g - 1$

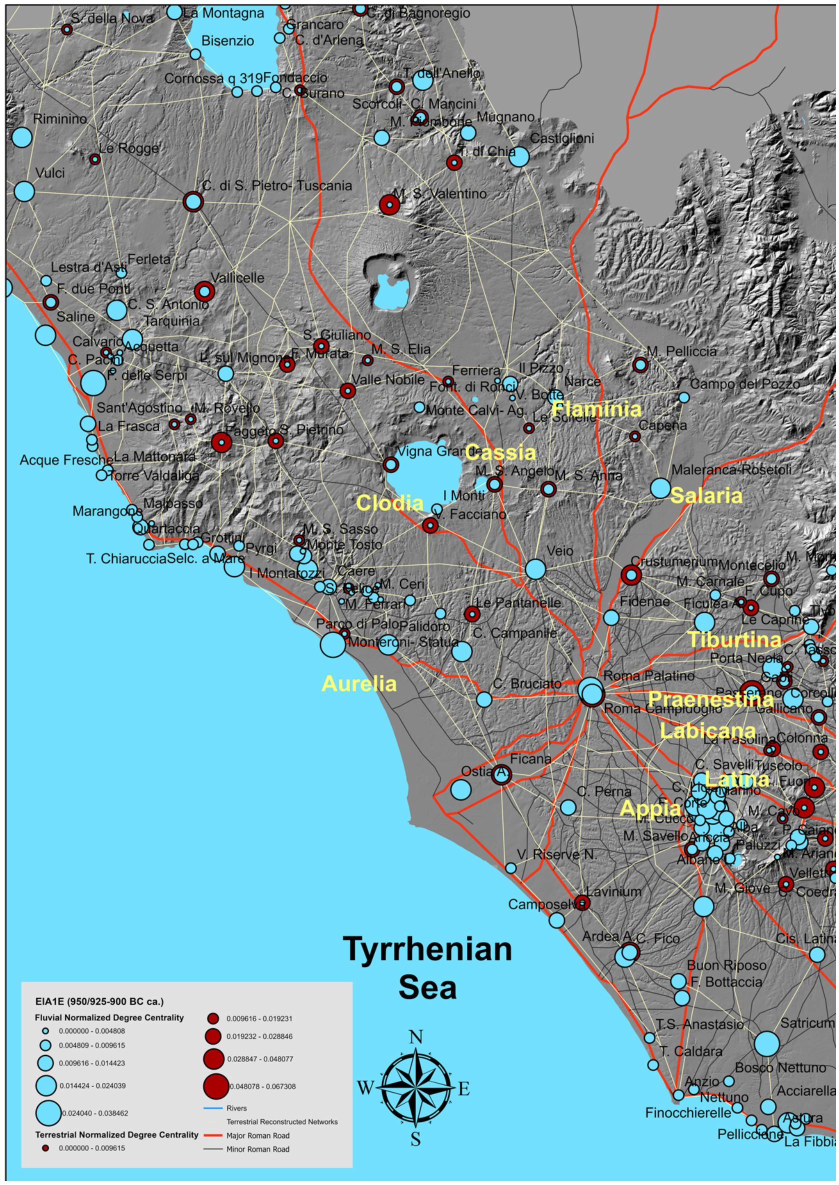


**Figure 5:** Central Italy. Early Iron Age 1 early. Normalized degree centrality. Fluvial routes and terrestrial routes.

other *j* nodes of the networks that is, in simple term, the number of its neighbours (Knoke & Yang, 2008, p. 63). Actor degree centrality, however, may vary with the size of the network (*g* or the number of nodes/actors). In fact, the larger the network, or the number of its nodes/actors, the higher the potential of each single node/actor to be directly linked to other nodes/actors. For example, an absolute degree centrality of 3 (which means direct links to three other actors) might represent a high value in a network of 5 nodes/actors but would be a very low value in a network of 50 or more nodes/actors.

Therefore, Wasserman and Faust, to eliminate the effect of variation in degree centrality caused by the size of the network (*g*), suggest it to be normalized according to the following formula (Wasserman & Faust, 2007, p. 179 quoted in Knoke & Yang, 2008, p. 63):

$$C'_D(N_i) = \frac{C_D(N_i)}{g-1}.$$

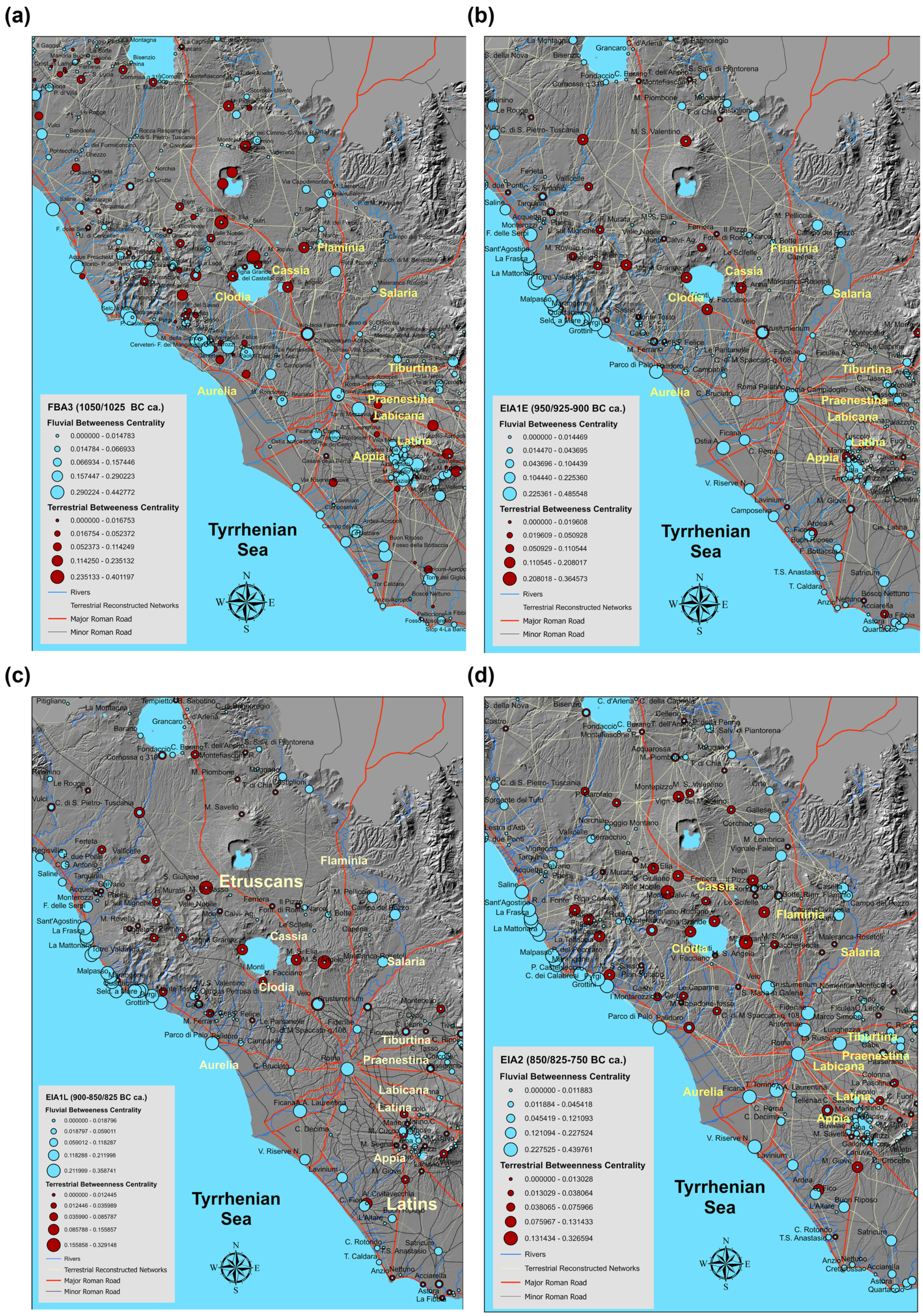


**Figure 6:** Central Italy. Betweenness centrality: fluvial and terrestrial routes. (a) FBA3; (b) EIA1E; (c) EIA1L; (d) EIA2; (e) Orientalizing age and (f) Archaic Period.

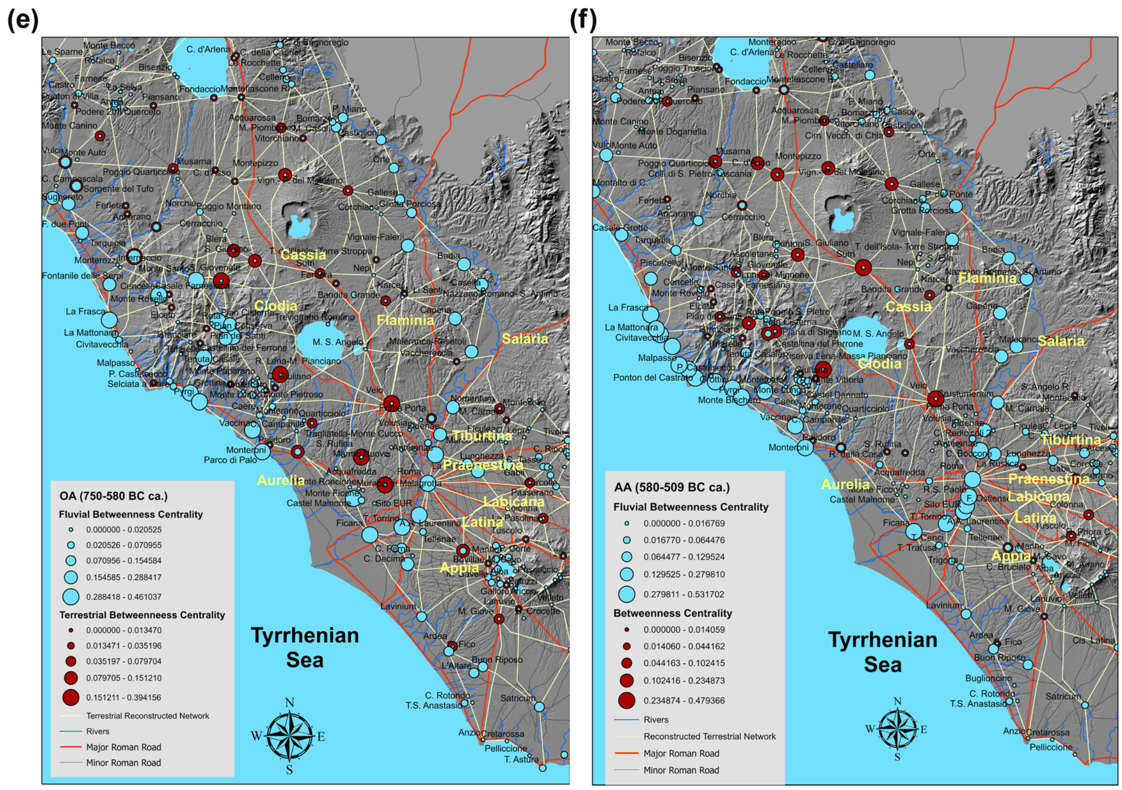


**Figure 6:** (*Continued*)

Then, the normalized degree centrality ($C'_D$) of a node $i$ ($N_i$) is given by its degree centrality ($C_D(N_i)$) divided by the maximum number of possible connections with other nodes/actors that is the total number of nodes ($g$) minus one, the node itself ($g - 1$). In this way, it is possible to yield the "proportion of the network members with direct ties to actor $i$. Proportion varies between 0.0 indicating no connections with any actor (i.e. isolate), to 1.0 reflecting direct ties to everyone. Normalised degree centrality measures the extent to which an actor is involved in numerous relationships. Actors with high scores are the most visible participants in a network" (Knoke & Yang, 2008, pp. 63–64).

## 4 Discussion of the Results

In this work, we have used an exploratory application of traditional centrality indexes: betweenness centrality, closeness centrality, and degree centrality in combination with spatial data and GIS visualization tools to obtain new insights on salt-production sites in central Italy from the Bronze Age to the Archaic Period. These methods are not new, but they have never been applied to this type of site and the results are innovative and illuminating and deserve further investigation with more sophisticated models and targeted excavations.

In particular, the closeness centrality is probably the index that provides the less interesting results. As shown in Figure 4, the closeness centrality, which indicates the accessibility of sites from every part in the region, of both terrestrial and fluvial routes, illustrated for an early phase of the Early Iron Age as an example, shows that almost all sites have more, or less, equal values, as it is probably foreseeable in a relatively small and compact region such as Latium and Etruria. Differently, the normalized degree centrality, presented in Figure 5, and illustrating again the first part of the Early Iron Age as an example, indicates some centres with a higher number of neighbours, which often seems to coincide with important centres also according to archaeological or historical evidence.

However, the more interesting results come from the betweenness centrality. As explained in Section 3, the betweenness centrality indicated the most travelled sites by an ideal traveller, moving through all the systems.[6] Therefore, as already suggested by Tom Brughmans (Personal communication mentioned in de Haas, 2017), the routes indicated by the highest betweenness centrality should be the most commonly used or potentially the most commonly used routes. This analysis (Figure 6) shows that during the Bronze and the Iron Age, the most commonly used routes are the coastal and sea route parallel to the Thyrrhenian coast of Italy, while with the Orientalizing and Archaic Period, the fluvial route of the Tiber and the terrestrial route of the Tiber valley became more prominent.

This could be put in connection with the fact that during the Bronze and Iron Age, the coastal sites are most commonly used for salt production with the briquetage technique described above. Later, possibly during the VII century BCE, the marine salt fields at the mouth of the Tiber were started to be used with the technique of sun evaporation (Bellotti et al., 2011; Grossi et al., 2015; Ruggeri et al., 2010). This is also the time when the use of the route, later known as Salaria, from the mouth of the Tiber to the mountains inland, became intensified. The shift from briquetage technique to marine salterns had already been hypothesized and the analysis presented in this study suggests a plausible context and scenario, which had previously been never advanced and that deserve further analyses and also more targeted excavations.

## 5 Conclusion

In this study, we focused on salt-production settlements in central Italy from the Bronze Age to the Archaic Period. We adopted an exploratory approach consisting of the combination of traditional centrality indexes, common in social network analysis: betweenness centrality, closeness centrality, and degree centrality, with spatial data and GIS visualization tools. These methods are not new, but they have never been applied to this type of site and the results are innovative and illuminating.

Probably, as should be expected, the closeness and the degree centrality do not yield particularly interesting results. However, the betweenness centrality, which indicates the most commonly used routes in a given region, provide powerful insights. In fact, this analysis indicated a shift in the most common routes through time, from the terrestrial and sea route along the coast in the Bronze and Iron Age to the use of the Tiber river and Tiber valley as route, in the Orientalizing and Archaic Period.

This provides a potential and plausible scenario which could be connected with the potential shift of intensification in the different salt-production techniques. It is possible that the briquetage salt production technique was used more intensively in the Bronze and Iron Age on the coastal sites, which was also the most common route used in the region. While the coastal sites attest a long duration and long use as salt-production places, it is possible that the proper marine production at the mouth of the Tiber, both on the Etruscan and Latin side, might develop and intensify their use during the Orientalizing and Archaic Age, together with a renovated and intensified use of the Tiber river as way of communication and use of the Via Salaria, running from the coast to the mountains of Latium, along the Tiber river.

To conclude, the use of traditional centrality indexes combined with spatial data and tools has allowed us to elaborate hypotheses about the use and change in intensification of different salt-production techniques and it would be interesting to confirm these hypotheses with further analyses and also targeted excavations.

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**6** For betweenness centrality calculated for networks of Etruscan and Latin regions, see the supplementary table accompanying the online version of the article at https://doi.org/10.1515/opar-2024-0003.

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## References

Alessandri, L. (2007). *L'occupazione costiera protostorica del Lazio centromeridionale*. Oxford: Archaeopress.
Alessandri, L. (2013). *Latium Vetus in the Bronze Age and Early Iron Age/Il Latium vetus nell'età del Bronzo e nella prima età del Ferro*. Oxford: BAR Publishing.
Alessandri, L., Achino, K. F., Attema, P. A. J., de Novaes Nascimento, M., Gatta, M., Rolfo, M. F., … van Gorp, W. (2019). Salt or fish (or salted fish)? The Bronze Age specialised sites along the Tyrrhenian coast of Central Italy: New insights from Caprolace settlement. *PLoS One*, *14*(11), e0224435. doi: 10.1371/journal.pone.0224435.
Alessandri, L., & Attema, P. (2022). From briquetage to salterns in protohistoric central Italy. Research of a fundamental subsistence commodity. *IpoTESI di Preistoria*, *14*, 161–168. doi: 10.6092/issn.1974-7985/14338.
Alessandri, L., Attema, P. A. J., Bulian, F., Sevink, J., De Neef, W., Baiocchi, V., … Vagliviello, S. (2024). Salt in Late Iron Age Italy. A multidisciplinary approach to the exploration of Italy's coastal exploitation sites: Piscina Torta (Ostia, Rome) case study. *Journal of Archaeological Science: Reports*, *53*, 104361. doi: 10.1016/j.jasrep.2023.104361.
Arnoldus Huyzendveld, A., Gioia, P., Mineo, M., & Pascucci, P. (1995). Preliminary results of the Malafede survey 1990–1992. In N. Christie (Ed.), *Settlement and economy in Italy 1500 B.C. to A.D. 1500 (Papers of the Fifth Conference of Italian Archaeology, Oxford 1992)* (pp. 47–56). Oxford: Oxbow.
Attema, P. (1990). Tracce, siti ed insediamenti protostorici nel paesaggio pontino-lepino. *Archeologia Laziale 10.2 (Quaderni del centro di studio per l'Archeologia Etrusco-Italica*, *19*, 228–240.
Attema, P. (1993). *An archaeological survey in the Pontine Region. A contribution to the early settlement history of south Lazio 900–100 BC*. Groningen: Rijkuniversiteit Groningen.
Attema, P., Burgers, G. J., van Joolen, E., van Leusen, M., & Mater, B. (Eds.). (2002). New developments in Italian landscape archaeology: Theory and methodology of field survey land evaluation and landscape perception, pottery production and distribution. *Proceedings of a three-day conference held at the University of Groningen, April 13–15, 2000*. Oxford: BAR Publishing.
Attema, P., de Haas, T., & Tol, G. (Eds.). (2010). *Between satricum and antium. Settlement dynamics in a coastal landscape in Latium Vetus* (BaBesch supplement series). Leuven-Paris-Walpole, MA: Peeters.
Attema, P., van Leusen, M., Alessandri, L., & Anastasia, C. (2007). Land system, insediamenti e strategie di sussistenza nella protostoria della regione pontina. In *Strategie di insediamento fra Lazio meridionale e Campania centro-settentrionale in età preistorica e protostorica. Atti della XL riunione scientifica IIPP. Roma, sala dello Stenditoio del MBAC, 30 Novembre-3 Dicembre 2005. Atti delle Riunioni Scientifiche* (Vol. 40, pp. 657–669). Firenze: Istituto Italiano di Preistoria e Protostoria.
Barbaro, B. (2010). *Insediamenti, aree funerarie ed entita' territoriali in Etruria meridionale nel Bronzo finale*. Firenze: All'insegna del Giglio.
Beauchamp, M. (1965). An improved index of centrality. *Behavioral Science*, *10*, 161–163.

Belardelli, C. (2011). Siti costieri villanoviani a nord di Roma (Italia): Un paesaggio 'industriale' protostorico. In J. Studer, M. David-Elbiali, & M. Besse (Eds.), *Paysage...Landschaft...Paesaggio..., L'impact Des Activités Humaines Sur l'environnement Du Paléolithique à La Période Romaine* (pp. 223–235). Lausanne: Cahiers d'archéologie romande.

Belardelli, C. (2013). Coastal and underwater Late Urnfield sites in South Etruria. *Skyllis*, *1*, 5–17.

Bellotti, P., Calderoni, G., Di Rita, F., D'Orefice, M., D'Amico, C., & Esu, D. (2011). The Tiber river delta plain (central Italy): Coastal evolution and implications for the ancient Ostia Roman settlement. *The Holocene*, *21*(7), 1105–1116. doi: 10.1177/0959683611400464.

Bietti Sestieri, A. M. (1989). Siti e territori nell'età dei metalli. Elementi per l'inferenza archeologica sulle componenti politiche dell'organizzazione territoriale. In *Dottrina e metodologia della ricerca preistorica. Atti della XXVII riunione scientifica, Ferrara, 17–20 Novembre 1987* (pp. 227–249). Ferrara: Universita' degli studi di Ferrara.

Bietti Sestieri, A. M., & Sebastiani, R. (1986). Preistoria e Protostoria nel territorio di Roma. Modelli di insediamento e vie di comunicazione. *Archeologia Laziale 7.2 Quaderni del Centro di Studio per L'archeologia Etrusco-italica*, *12*, 30–69.

Bonghi Jovino, M. (2008). *Tarquinia etrusca. Tarconte e il primato della citta'*. Rome: 'L'Erma' di Bretschneider.

Brocato, P. (2000). *La necropoli etrusca della Riserva del Ferrone*. Roma: Edizioni Quasar.

Brughmans, T., Collar, A., & Coward, F. (Eds.). (2016). *The connected past: Challenges to network studies in archaeology and history*. Oxford: Oxbow.

Carandini, A. (Ed.). (2012). *Atlante di Roma*. Milano: Electa.

Cascino, R., Di Giuseppe, H., & Patterson, H. L. (Eds.). (2012). *Veii. The historical topography of the ancient city. A restudy of John Ward Perkins's survey, archaeological monographs of the British school at Rome 19*. London: The British School at Rome.

Collar, A., Coward, F., Brughmans, T., & Mills, B. (Eds.). (2015). The connected past: Critical and innovative approaches to networks in archaeology. *Journal of Archaeological Method and Theory*, 22(1). Springer. https://link.springer.com/journal/10816/volumes-and-issues/22-1.

Colonna, G. (Ed.). (1976). *Civiltà del Lazio Primitivo (exhibition catalogue)*. Roma: Multigrafica Editrice.

Dawson, H., & Iacono, F. (2020). Bridging social and physical space through networks. *Proceedings of the Topoi Conference, Berlin 2016*. Leiden: Sidestone Press Academics.

De Haas, T. (2011). *Fields, farms and colonists* (pp. 1–2) Groningen: Groningen Archaeological Studies.

de Haas, T. (2017). The geography of Roman Italy and its implications for the development of rural economies. In T. De Haas & G. Tol (Eds.), *The economic integration of Roman Italy: Rural communities in a globalising world* (pp. 51–82). Leiden: Brill.

Della Fina, G. M., & Pellegrini, E. (2013). *Da Orvieto a Bolsena. Un percorso tra Etruschi e Romani*. Roma: Pacini editore.

Dennis, G. (1848). *Cities and cemeteries of Etruria* (pp. 1–2). London: J.M. Dent.

Di Fraia, T. (2023). 'Reddish olle' and production and use of salt: An open question. In M. Alexianu, R.-G. Curcă, O. Weller, & A. A. Dumas (Eds.), *Mirrors of salt: Proceedings of the First International Congress on the Anthropology of Salt*. Iași, Romania: 'Al. I. Cuza' University. doi: 10.2307/jj.5329287.

di Gennaro, F. (1986). *Forme di insediamento fra Tevere e Fiora dal Bronzo Finale al principio dell'età del Ferro, Firenze*. Firenze: All'Insegna del Giglio.

di Gennaro, F. (1988). Il popolamento dell'Etruria meridionale e le caratteristiche degli insediamenti tra l'età del Bronzo e l'età del Ferro. In G. Colonna, C. Bettini, & R. A. Staccioli (Eds.), *Etruria meridionale. Conoscenza, conservazione e fruizione (Atti del Convegno, Viterbo, 1985)* (pp. 59–82). Roma: Ed. Quasar.

di Gennaro, F., & Peroni, R. (1986). Aspetti regionali dello sviluppo dell'insediamento protostorico nell'Italia centro- meridionale alla luce dei dati archeologici e ambientali. *Dialoghi di Archeologia*, *3*, 193–200.

Donnellan, L. (Ed.). (2020). *Archaeological networks and social interaction*. London-New York: Routledge.

Enei, F. (2001). *Progetto Ager Caeretanus. Il litorale di Alsium: Ricognizioni archeologiche nel territorio di Ladispoli, Cerveteri e Fiumicino (Alsium-Caere-Ad Turres-Ceri)*. Regione Lazio e Comune di Ladispoli.

Felder, K., & Evans, S. C. (Eds.). (2014). Social network perspectives in archaeology. *Archaeological Review from Cambridge*, *29*(1). Cambridge.

Flad, R. K., Zhu, J., Wang, C., Chen, P., von Falkenhausen, L., Sun, Z., & Li, S. (2005). Archaeological and chemical evidence for early salt production in China. *Proceedings of the National Academy of Sciences of the United States of America*, *102*, 12618–12622. doi: 10.1073/pnas.0502985102.

Freeman, L. C. (1977). A set of measures of centrality based upon betweenness. *Sociometry*, *40*, 35–41.

Fulminante, F. (2012). Social network analysis and the emergence of central places. A case study from Bronze and Early Iron Age Central Italy. *BaBesch (Bulletin Antieke Beschaving)*, *87*, 1–27.

Fulminante, F. (2014). *The urbanization of Rome and Latium vetus from the Bronze Age to the Archaic Era*. Cambridge: Cambridge University Press.

Fulminante, F. (2023). *The rise of early Rome. Transportation networks and domination in Central Italy, 1050–500 BC*. Cambridge: CUP 2023.

Gell, W. (1934). *The topography of Rome and its Vicinity, I–II* (2nd ed., 1846). London: Saunders and Otley.

Giovannini, A. (1985). Le sel et la fortune de Rome. *Athenaeum*, *63*, 373–386.

Giuliani, C. F. (1966). *Tibur. II*. Florenze: Leo. S. Olschki.

Giuliani, C. F. (1970). *Tibur. I*. Roma: De Luca.

Giuliani, C. F., & Quilici, L. (1964). *La via Caere-Pyrgi*. Roma: Quaderni dell'Istituto di Topografia Antica.

Graham, S. (2006). *EX FIGLINIS: The network dynamics of the Tiber valley brick industry in the Hinterland of Rome, BAR International Series 1468*. Oxford: John Hedges Ltd.

Grossi, M. C., Sivilli, S., Arnoldus-Huyzendveld, A., Facciolo, A., Rinaldi, M. L., & Ruggeri, D. (2015). A complex relationship between human and natural landscape: A multidisciplinary approach to the study of the roman saltworks in “Le Vignole – Interporto” Maccarese, Fiumicino – Roma. In R. Brigand & O. Weller (Eds.), *Archaeology of salt. Approaching an invisible past* (pp. 83–101). London: Sidestone.
Guidi, A. (1984). Marcellina. Un insediamento della Media età del Bronzo. *Archeologia Laziale 6 Quaderni del centro di studi per l’Archeologia Etrusco-Italica*, *8*, 25–29.
Guidi, A. (1986a). Gli insediamenti perilacustri di riva d’età protostorica nel Lazio centro-meridionale. *Quaderni di Protostoria*, *1*, 239–247.
Guidi, A. (1986b). Strategie insediamentali nelle valli del Tevere e dell’Aniene dall’Eneolitico alla prima età del Ferro. *Archeologia Laziale 7.2 Quaderni del centro di studio per l’Archeologia Etrusco-Italica*, *12*, 23–29.
Guidi, A., Gabrielli, R., & Santoro, P. (2003). Il Progetto Galantina. In J. Rasmus Brandt, X. Dupré Raventos, & G. Ghini (Eds.), *Lazio & Sabina. Lavori e studi della Soprintendenza per i Beni Archeologici del Lazio, 1* (pp. 109–114). Roma: De Luca Editore.
Guidi, A., Rioda, V., & Santoro, P. (2008). Fattori culturali e condizionamento ambientale nel popolamento di epoca protostorica nell’area del Progetto Galantina nella Sabina Tiberina. In N. Negroni Catacchio (Ed.), *Paesaggi reali e paesaggi mentali. Ricerche e scavi. Preistoria e Protostoria in Etruria VIII* (pp. 399–408). Milano: Centro Studi di Preistoria e Archeologia.
Harding, A. (2013). *Salt in Prehistoric Europe*. Leiden: Sidestone.
Harding, A. (2021). *Salt: White Gold in Early Europe*. Elements in the Archaeology of Europe. Cambridge: Cambridge University Press. doi: 10.1017/9781009038973.
Hocquet, J.-C. (1973). Monopole et concurrence à la fin du moyen âge: Venise et les salines de Cervia (XII–XVI siècles). *Studi Veneziani*, *15*, 21–133.
Hocquet, J.-C. (1979). *Le sel et la fortune de Venise, Vol. 2: Voiliers et commerce en Mediterranée, 1200–1650*. Lille: Presses de l’Université de Lille III.
Iaia, C., & Mandolesi, A. (2010). Comunita’ e Territori nel Villanoviano evoluto dell’Etruria meridionale. In N. Negroni Catacchio (Ed.), *L’Alba dell’Etruria Fenomeni di continuita’ e trasformazione tra XII e VIII secolo. Ricerche e Scavi. Atti del nono incontro di studi Valentano (Vt)- Pitigliano (Gr) 12–14 Settembre 2008* (pp. 61–78). Milano: Centro Studi di Preistoria e Archeologia.
Knappett, C. (Ed.). (2013). *Network analysis in archaeology. New approaches to regional interaction*. Oxford: Oxford University Press.
Knoke, D., & Yang, S. (2008). *Social network analysis* (1st ed. 1982). Los Angeles, London, New Delhi, Singapore: Sage Publications.
Lanciani, R. A. (1909). *Wanderings in the Roman Campagna*. Boston, New York: Houghton Mifflin company.
Lugli, G. (1962). *Carta archeologica del territorio di Roma (scala 1:50.000)*. Roma: Litografia Artistica Cartografica.
Mackie, Q. (2001). *Settlement archaeology in a Fjiordland Archipelago. Network analysis, social practice and the built environment of Western Vancouver Island, British Columbia, Canada, sice 2,000 BP*. Oxford: BAR Publishing.
Müller, S. (1904). *Vej og Bygd i Sten- og Bronzealderen*. Aarbøger.
Nibby, A. (1837). *Analisi storico-topografico-antiquaria della Carta de’ Dintorni di Roma, I–III* (2nd ed., 1846). Roma: Tipografia delle Belle Arti.
Nissen, H. (1883–1902). *Italische landeskunde* (pp. 1–2). Berlin: Weidmansche Bookhandlung.
Pacciarelli, M. (1991). Territorio, insediamento, comunità in Etruria meridionale agli esordi del processo di urbanizzazione. *Scienze Dell’antichità*, *5*, 162–232.
Pacciarelli, M. (2001). *Dal villaggio alla citta’. La svolta proto-urbana del 1000 a.C. nell’Italia tirrenica*. Firenze: All’Insegna del Giglio.
Patterson, H., di Gennaro, F., di Giuseppe, H., Fontana, S., Rendeli, M., Sansoni, M., … Witcher, R. (2004). The re-evaluation of the South Etruria Survey: The first Results from Veii. In H. Patterson (Ed.), *Bridging the Tiber. Approaches to regional archaeology in the Middle Tiber Valley. Archaeological monograph of the British School at Rome* (Vol. 13, pp. 11–35). London: British School at Rome.
Patterson, H., Di Giuseppe, H., & Witcher, R. (Eds.). (2020). *The changing landscapes of Rome’s Northern Hinterland The British School at Rome’s Tiber Valley Project*. Oxford: Archeopress.
Patterson, H., & Millett, M. (1998). The Tiber Valley project. *Papers of the British School at Rome*, *66*, 1–20.
Potter, T. W. (1979). *The changing landscape of south Etruria, London*. London: Elek.
Potter, T. W. (1985). *Storia del paesaggio dell’Etruria meridionale*. Roma: La Nuova Italia Scientifica.
Quilici, L. (1974). *Collatia*. Roma: De Luca editore.
Rees, J. (2014). *Refrigeration nation: A history of ice, appliances, and enterprise in America*. Baltimore: The Johns Hopkins University Press.
Rendeli, M. (1993). *Città aperte. Ambiente e paesaggio rurale organizzato nell’Etruria meridionale costiera durante l’età orientalizzante e arcaica*. Roma: Gruppo Editoriale Internazionale.
Roberts, J. M., Dorshorst, E., Yin, Y., Peeples, M. A., Breiger, R. L., & Mills, B. J. (2023). Sampling variability and centrality score comparisons in archaeological network analysis: A case study of the San Pedro Valley, Arizona. *Journal of Archaeological Science: Reports*, *51*, 104100. doi: 10.1016/j.jasrep.2023.104100.
Ruggeri, D., Gala, M., Facciolo, A., Grossi, M. C., Morelli, C., & Rinaldi, M. L. (2010). Località Le Vignole, Maccarese (Fiumicino, Roma): risultati preliminari dello scavo protostorico. In N. Negroni Catacchio (Ed.), *L’alba dell’Etruria Fenomeni di continuità e trasformazione nei secoli XII–VIII aC Atti del IX incontro di studi Preistoria e Protostoria in Etruria* (pp. 327–338). Milano: Centro Studi di Preistoria e Archeologia.
Sabidussi, G. (1966). The centrality index of a graph. *Psycometrika*, *31*, 581–603.
Sandu, I., Weller, O., Stumbea, D., & Alexianu, M. (2012). Analyses archéométrique sur les moules à sel chalcolithiques de l’est de la Roumanie. In V. Nikolov & K. Bacvarov (Eds.), *Salz Und Gold: Die Rolle Des Salzes Im Prähistorischen Europa/Salt and Gold: The Role of Salt in Prehistoric Europe* (pp. 143–154). Provadia, Veliko Tarnovo: Verlag Faber.
Santos, J. (2022). Why did Cities Evolve in Gharb Al-Andalus? Network analysis as a potential method for charting city growth. *Internet Archaeology*, *59*. doi: 10.11141/ia.59.9.

Schiappelli, A. (2008). *Sviluppo storico della Teverina*. Firenze: All'Insegna del Giglio.
Sevink, J., De Neef, W., Alessandri, L., van Hall, R., Ullrich, B., & Attema, P. A. J. (2021). Protohistoric briquetage at Puntone (Tuscany, Italy): principles and processes of an industry, based on the leaching of saline lagoonal sediments. *Geoarchaeology*, *36*, 54–71. doi: 10.1002/gea.21820.
Smith, C. (2017). J.B. Ward-Perkins, the BSR and the landscape tradition in post-war Italian archaeology. *Papers of the British School at Rome* (pp. 1–22). doi: 10.1017/S006824621700037X.
Solari, A. (1915–20). *Topografia Storica dell'Etruria*. Pisa: E. Spoerri.
Sordoillet, D., Weller, O., Rouge, N., Buatier, M., & Sizun, J.-P. (2018). Earliest salt working in the world: From excavation to microscopy at the prehistoric sites of Ţolici and Lunca (Romania). *Journal of Archaeological Science*, *89*, 46–55. doi: 10.1016/j.jas.2017.11.003.
Stoddart, S. (Ed.). (2000). *Landscapes from Antiquity.* Cambridge: Cambridge UNiversity Press.
Tartara, P. (1999). *Torrimpietra*. Firenze: Leo. S. Olschki.
Trombold, C. D. (Ed.). (2011[1991]). *Ancient road networks and settlement hierarchies in the New World*. Cambridge, New York: CUP.
Tuppi, J. (2014). Approaching road-cutting as instruments of early urbanization in central Tyrrhenian Italy. *Papers of the British School at Rome*, *82*, 41–74.
Vasilache, V., Kavruk, V., & Tencariu, F.-A. (2020). OM, SEM–EDX, and micro-FTIR analysis of the Bronze Age pottery from the Băile Figa salt production site (Transylvania, Romania). *Microscopy Research and Technique*, *83*, 604–617. doi: 10.1002/jemt.23451.
Ward-Perkins, J. B. (1961). Veii. The historical topography of the ancient city. *Papers of the British School at Rome*, *29*, 1–123.
Ward-Perkins, J. B. (1962). Etruscan towns, Roman roads and medieval villages: The historcal geography of southern Etruria. *Geographical Journal*, *128*, 389–405.
Wasserman, S., & Faust, K. (2007). *Social network analysis. Methods and application* (1st ed. 1994). Cambridge: Cambridge University Press.
Weller, O., & Brigand, R. (Eds.). (2015). *Archaeology of Salt: Approaching an invisible past*. Leiden: Sidestone Press.
Weller, O., & Dumitroaia, G. (2005). The earliest salt production in the world: an early Neolithic exploitation in Poiana Slatinei-Lunca, Romania. *Antiquity*, 79.
Wetter, E. (1962). Studies and strolls in Southern Etruria. In A. Boethius (Ed.), *Etruscan culture, land and people* (pp. 165–232). Malmo: AB Allhem.
White, D. R., & Borgatti, S. P. (1994). Betweenness centrality measures for directed graphs. *Social Networks*, *16*, 335–346.
Zifferero, A. (1995). Economia divinita' e frontiere: sul ruolo di alcuni santuari di confine in Etruria meridionale. *Ostraka*, *4*, 333–350.