Rivers and Waterways in the Roman World

Empire of Water

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Introduction

The Tiber was essential to the ability of ancient Rome to grow to be a city of one million inhabitants. Recent intensive archaeological work in the lower Tiber valley, between Rome and Ostia/Portus, has deepened understanding of the organisation of the supply of maritime cargoes upstream to the city. In contrast, supply downstream from the upper/middle valley to Rome has received less attention. Moreover, studies of these two sections of the river remain largely separate, creating the impression of two distinct river supply systems. We examine the origins and implications of this disconnect, before presenting a new model of fluvial and terrestrial mobility in Rome's hinterland. We start by suggesting that the emphasis on Rome as an all-consuming market casts the city as a singular centre rather than as one node in a network; this distracts attention from the through-movement of goods and the role of Rome for transshipment, effectively splitting the Tiber into two separate rivers. The differing natures of these two supply systems and their archaeological study have further entrenched this divide. A second issue is that the 'two Tibers' are typically studied in isolation from the regional road network, giving the impression that river transport was quite separate and invariably preferred over land transport due to the lower costs incurred. Our model of mobility in the middle/lower valley therefore reconnects the Tiber north and south of Rome and integrates the river with the road network in order to assess how transport decisions were made. By measuring costs in terms of the force required to move loads and factoring in transshipment costs, we demonstrate how the terrestrial and fluvial supply of Rome, and the movement of goods more widely around its hinterland, may have been organised. Part of a larger project, here we present results relating to the movement of cargoes by oxcart and river boat, modelling four journeys through the lower/middle valley.

The 'Two Tibers'

Scholarly assessments of the role and significance of the Tiber during the Roman period are predominantly framed in terms of the supply of food and other goods to the city. These works focus heavily on the lower river, the 30 kilometres between

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Ostia/Portus and Rome (e.g. Le Gall, 2005). Studies of the middle/upper river, stretching 110 kilometres north from Rome into Umbria, are scarcer (e.g. Quilici, 1986; Figure 4.1). Typically, publications focusing on the supply of Rome via the lower Tiber barely acknowledge the middle/upper river (e.g. Aldrete and Mattingly, 1999); conversely, studies of the middle/upper Tiber rarely connect to the range of activity downstream of Rome (e.g. Coarelli and Patterson, 2008). Even in publications that deal holistically with the river and its supply role, there is typically an emphasis on the lower Tiber (for exceptions, see Campbell, 2012; Boetto, 2016). Why do historical and archaeological studies treat the Tiber as two distinct rivers?

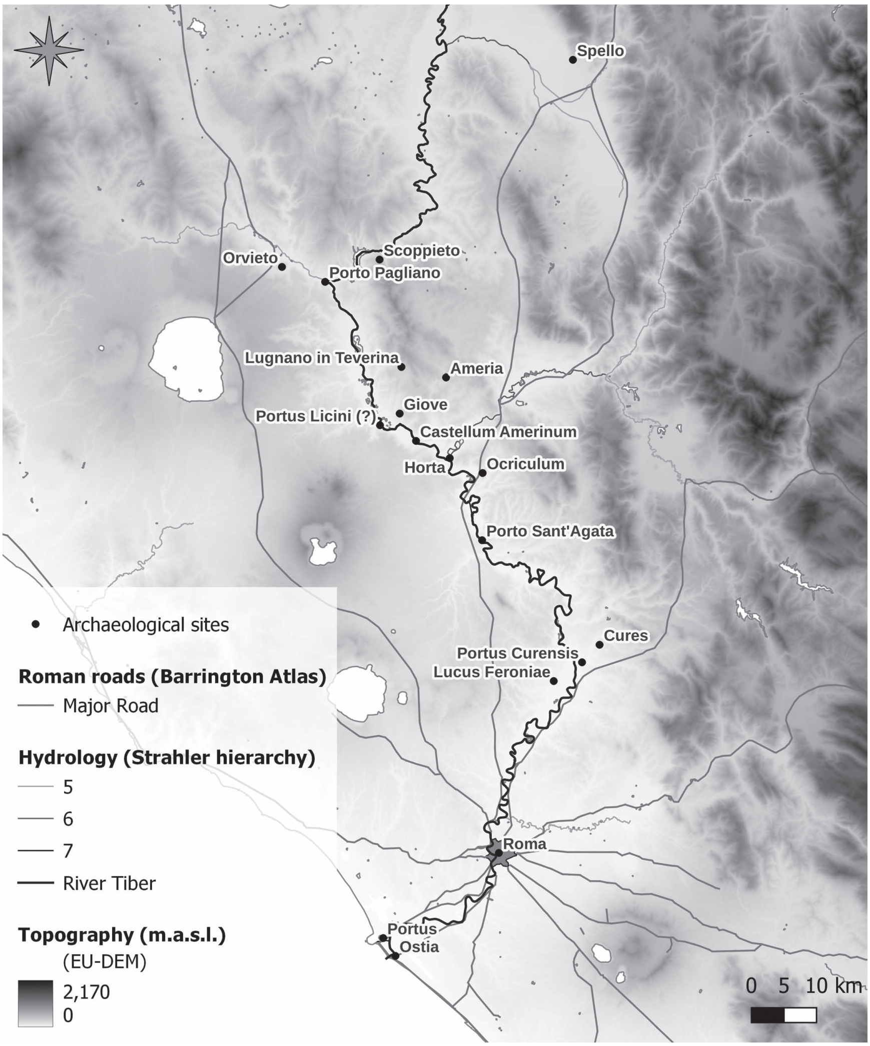

Figure 4.1 Location of places mentioned in the text and transport zones based on Boetto (2016). (*Source*: The authors.)

And what are the implications for understanding the Tiber's role in the supply of Rome and, more broadly, for mobility around its hinterland?

One explanation for the splitting in two of the Tiber relates to perceptions of the city of Rome and, specifically, its status as a metropolis of unparalleled size in the ancient Mediterranean. Whether conceived ideologically (*Caput Mundi*) or economically (the archetypal parasitic consumer-city), Rome is always central, drawing in vast quantities of goods, people and ideas. From an unexceptional Iron Age settlement, peripheral to both the Etruscan and Latin worlds, socio-economic and physical (road) networks were reoriented to converge on the city (Prignano *et al.*, 2019). The aphorism that 'all roads lead to Rome' continues to influence perceptions of the city as central to, rather than as one node in, a wider network. Hence, just as a traveller transiting the city by road would follow a single route of two distinctly named sections (north-south across the viae Flaminia and Appia), so the Tiber is also conceptualised as divided into two rivers that converge on Rome. More broadly, this splitting of the Tiber is mapped onto two different supply scales: the lower river connected to Rome's Mediterranean hinterland and the middle/upper valley as part of the city's regional supply zone. In redirecting attention to the latter, Morley's (1996) influential *Metropolis and Hinterland* sought to complement the scholarly emphasis on Rome's provincial supply via Ostia/Portus, yet by retaining Rome as the focal point, the 'two Tibers' remain analytically distinct.

If the division of the Tiber has been shaped by perceptions of Rome's centrality, it also reflects the divergent nature of the archaeological evidence for the organisation of supply north and south of the city. Recent research has transformed understanding of the supply system connecting Ostia/Portus with Rome (e.g. DeLaine, 2000; Keay *et al.*, 2005; Keay, 2012). Studies of boats (e.g. Casson, 1965), bioarchaeological evidence (e.g. O'Connell *et al.*, 2019) and landscape (e.g. Keay and Paroli, 2011) now permit reconstruction both of the general evolution of Ostia/Portus as a monumental 'maritime façade' (Purcell, 1996) and the logistical details of moving grain, wine, oil and marble through docks and warehouses, along roads and canals, and upstream to Rome (James, 2020; Keay *et al.*, 2021).

By comparison, the evidence from the middle/upper valley is modest and fragmentary. Here, goods entered the system at multiple points, with smaller ports strung along the river. As well as towns with associated port facilities (Lucus Feroniae, Ocriculum, Horta), dedicated river ports also provided services for surrounding territories. Some of these ports may have specialised in handling certain goods, including millstones at Pagliano (McCallum, 2010) and brick at Horta and other ports around the modern Lazio/Umbria border (Filippi and Stanco, 2005). With multiple entry points, the logistical organisation of the middle/upper river is more complex to model than the direct transport of goods between Ostia/Portus and Rome. A larger number of smaller, less archaeologically visible sites in the middle/upper river also means that knowledge of this system is less complete than that of the lower river. In particular, compared to the investment in conspicuous storage and infrastructure at Ostia/Portus, ports in the middle/upper valley were less monumental, as timber and brick did not require the permanent or complex storage facilities needed for grain; these smaller, less monumental sites are more vulnerable to erosion by the shifting river. Some port facilities are attested to only epigraphically, for example, 'Portus Curensis' (*AE* 1958, 0269); some such toponyms have been geolocated, such as 'Portus Licini' in the territory of Statonia; concentrations of material, close to the river, such as at Giove (loc. Torricella) near Ameria, may represent other port facilities (both 'Portus Licini' and Giove were likely linked to the shipping of brick from nearby *figlinae*, Gasperoni and Scardozzi, 2010, p. 86). In addition, there are stone quays associated with villas, including Porto S. Agata and possibly Lugnano in Teverina (Patterson, Witcher and Di Giuseppe, 2020, p. 160).

North of the confluence with the Paglia, knowledge of port facilities is particularly incomplete. Nonetheless, the importance of the river for the downstream distribution of goods from the upper valley is attested to by various products. For example, *terra sigillata* produced at Scoppieto, 10 kilometres upstream from the Paglia confluence, is found at Rome, Ostia and North Africa (Bergamini, 2008). Still farther upstream, wine was packaged in specialised river amphorae produced at locations in Umbria, including Montelabate and Spello, to be shipped south (Ceccarelli, 2017). In addition to the downstream distribution of goods, the river may also have been used for transporting heavy loads upstream into the middle/upper valley. The evidence, however, is circumstantial and disputed (see Bergamini, 2008). In summary, the logistical organisation of supply and mobility within the middle/upper valley is more complex and less visible than that of the lower valley.

Modelling and Quantification

A final explanation for the 'two Tibers' relates to how the evidence has been used. In particular, the abundant and monumental evidence from the lower valley has been more attractive for analyses and narratives that find scale and complexity to be suitable testimony to the organisational abilities of the Roman state. Although 'admiration' for ancient Rome is nowadays rarely articulated, contemporary society (which includes archaeologists) maintains a lingering sense of awe at the logistical capacity of pre-industrial Rome, especially when expressed in 'neutral' economic or organisational terms. More explicitly, the evidence for the lower valley is also well suited to particular methods, specifically quantification and modelling.

The metropolis of Rome required massive imports. Multiple scholars have sought to quantify the scale of the city's provincial supply system and model its complexity (e.g. Aldrete and Mattingly, 1999; Tchernia, 2000; James, 2020). Such studies typically start with variables such as Rome's population and human caloric requirements, to which values can be assigned with varying confidence (e.g. ~1 million inhabitants; ~2000–3000 calories per person per day). These variables are then combined with factors such as storage capacity, boat size and the time or energy needed to tow vessels upstream to parameterise logistical models. The results can then be systematically evaluated to assess their logic and coherence. For example, Malmberg's (2015, p. 192) modelling leads him to argue for a 'three-lane river highway', with boats towed upstream on each bank, returning downstream in the centre of the river; spatial analysis and modelling of river traffic, however, indicates such a scenario to be improbable (Moreno Escobar, 2022). In these ways, the quantification and modelling of the movement of goods between Ostia/Portus and Rome have evolved and deepened understanding of the organisation and complexity of supply.

In contrast, quantification and modelling is less well suited to the goods shipped to Rome from the middle/upper valley or to that area's more fragmentary archaeology. Attention has focused on the distribution downstream to Rome of brick manufactured in the middle valley as attested by kilns and brick stamps (Filippi and Stanco, 2002; Bukowiecki and Wulf-Rheidt, 2015). Millstones quarried near Orvieto are another archaeologically well-documented product, transported from Pagliano downstream via Rome and Ostia/Portus to western Mediterranean markets (Antonelli, Nappi and Lazzarini, 2001). Most other products from the middle/upper valley, however, are less archaeologically visible, including timber (Diosono, 2008), firewood (Graham and Van Dam, 2016), charcoal and pitch (generally, Morley, 1996). The scale of the supply of these goods cannot be parameterised in the same way as with staple foods and nutritional requirements (e.g. how much charcoal was required per person per year?). In addition, river transport methods also differed north and south of Rome; in particular, in the middle/upper valley, the use of rafts, which were probably recycled as firewood, scaffolding or shuttering (Graham, 2013), reduces archaeological visibility of 'vessels' and complicates quantification of loads. One rare example of modelling supply from the middle valley is Graham's (2013) attempt to quantify the transport of brick in relation to demand from the city. In short, the supply systems upstream and downstream of Rome were focused on different goods and organised in diverse ways, leaving distinct archaeological records that have been studied using different methods.

Reconnecting the Tibers

Although these differences of evidence and approach might explain or even justify approaching the Tiber as two rivers, there is good reason to reconnect them. Not least, Rome did not absorb every commodity produced near or passing through the city. Examples of goods that moved downstream through Rome include millstones (McCallum, 2010), brick (DeLaine, 2000) and building stone (e.g. travertine, DeLaine, 2018). It is less clear whether such goods were transshipped as they transited the city. Although bridges probably did not impede through-movement (Taylor, 2000, pp. 81–83), goods may have been reloaded from rafts or small craft onto vessels more suited to the lower river; indeed, there would have been significant capacity on empty grain vessels returning to Ostia/Portus. Conversely, transshipment was time-consuming and risky, with the potential for cargoes to be damaged or lost. More broadly, Malmberg (2015, 2021) emphasises the need to recognise Rome as a port city in its own right. Focusing on the 18-kilometre stretch of river from the Ponte Milvio to Magliana, north and south of the city, respectively, Malmberg identifies an extended set of port facilities connecting the 'two Tibers'; as a single integrated complex, this ranks as one of the largest ancient Mediterranean ports (Malmberg, 2021, p. 363).

If Malmberg's work provides the basis on which to reconnect Rome's two river supply systems and to establish the city as a place of through-movement and transshipment, it is also essential to integrate the Tiber with the terrestrial movement of goods on the region's roads. Using sources such as Diocletian's Price Edict, scholars have defined approximate cost ratios for movement by land, river and sea around the Roman world (e.g. Duncan-Jones, 1974). These ratios have been used to map the effects of demand on prices and supply zones (e.g. Morley, 1996, map 1) and to define optimal travel routes (e.g. Schiedel, 2014). Typically quoted ratios are approximately 1 (sea), 5 (downriver), 10 (upriver) and 25–40 (land). Whilst these figures would make land transport five to eight times more expensive than downriver transport, Laurence (1999) emphasises that land transport remained the default and should therefore be the baseline against which other costs are calculated.

The close integration of land and river transport is most clearly documented in the area around Ostia/Portus and upstream to Rome. Here, roads, the river and associated tow paths and canals developed in tandem to support the growing scale and logistical complexity of supplying Rome (Keay and Paroli, 2011). North of the city, in the middle valley, several ports were located where roads crossed or diverged from the river, including the Via Amerina at Castellum Amerinum and the Via Flaminia at Ocriculum (Patterson, Witcher and Di Giuseppe, 2020, pp. 148–149). This regional road network was highly developed and must have reduced the ratio difference between land and river transport costs compared with many other areas. Consequently, the absolute and relative costs of terrestrial transport around Rome's hinterland were likely lower than elsewhere, and this may have influenced users' decisions to opt for road or river transport in two specific ways. First, because the costs of loading and unloading goods for river transport were fixed regardless of distance of river travel, they formed a larger proportion of shorter journeys, which may have discouraged use of the river for local transport. For example, DeLaine (2021, p. 195) cites a pozzolan quarry near the Tiber south of Rome, arguing that its exports were more likely to have been moved the 12 kilometres to Rome by oxcart rather than loaded onto a boat and towed upriver. Second, if the well-developed roads around Rome reduced the relative difference between land and downriver transport, the difference between terrestrial and upriver transport was likely even more marginal; it is therefore crucial to consider direction of travel in any analysis. While heavy loads such as bricks came down the Tiber, roads were used to transport other goods between places around the middle/lower valley, including marble (Patterson, Witcher and Di Giuseppe, 2020, fig. 4.32), pottery (*ibid.,* table 2.4, figs 4.27 and 4.33), and even bulky basalt paving slabs (Worthing *et al*., 2017).

To formally explore these issues, especially the relationship between terrestrial and upriver movement, we model transport costs in the middle/lower valley, starting with Boetto's (2016) classification of the Tiber into two main transport zones (Figure 4.1): First, a 'floatable' section, extending from the source to the Paglia confluence, with the latter described by Pliny the Elder (*NH*) as the navigational limit (Malmberg, 2015). This section is characterised by a smaller channel and greater seasonal flow variability limiting use of the river to predominantly downstream movement of goods, largely on rafts. Boetto's second transport zone, on which we focus later, is defined as the 'navigable' section, supporting both upstream and downstream movement, extending from the Paglia confluence to the coast. Boetto subdivides this navigable stretch into a 'fluvial' section north of Rome and a 'fluvial-maritime' section south of the city, the latter accessible to larger vessels including maritime craft (Boetto, 2016). In this way, we seek to reconnect the 'two Tibers' by allowing Rome to function as a through-route and/or place of transshipment and to assess the relative costs of moving heavy loads by road and/or river.

Spatial Modelling

As a 'low-cost' transport corridor cutting across the regional road network, the Tiber presented users with options for moving goods or themselves through the landscape. Simultaneously, the density of the road network likely reduced the relative cost difference between land and river transport, making the former more competitive than in other areas. Such issues are well suited to spatial modelling, and the analysis of Roman-period mobility is a topic of significant current research interest. Approaches include modelling of terrestrial movement with cost surfaces and network analysis (e.g. de Soto, 2019; Lewis, 2021) and methods to assess mobility within integrated land, river and maritime networks (e.g. Scheidel, 2014; Bongers, 2020). Many of these studies are generic in that they do not specify exactly what is moving, for example, pedestrians or cargoes on wheeled vehicles, or the effects of slope and load, possibly due to the lack of suitable geographical information system (GIS) algorithms (Verhagen, Nuninger and Groenhuijzen, 2019). Multiple mobility studies have focused on Roman central Italy. Gliozzo, Fantozzi and Ionescu (2020) model pedestrian movement in the Grosseto region, factoring slope, river network and travel time; additionally, they model movement by oxcarts. However, by applying a standardised mean velocity to the network, these results omit consideration of the effects of topography and hydrology. Meanwhile, DeLaine (2018) models the relative costs of moving building materials by road or river to imperial-period Ostia, calculating a standardised equivalent of road kilometres per tonne. By focusing on relative costs, the model allows comparison of different cargoes and means of transport; without a full GIS component, however, it is impossible to evaluate the costs in the regional context in which they would have been determined. Finally, Taelman (2021) assesses the transport of marble in Roman central Adriatic Italy, modelling land routes based on cost as energy expenditure, or the force required to move loads using oxcarts by road. River transport in that region, however, was limited, and Taelman's study therefore considers only terrestrial transport. As these examples demonstrate, mobility modelling of Roman Italy is widely researched, but none of these provide a 'ready-to-use' solution to underpin a complex model of the integrated fluvial-terrestrial supply of Rome allowing, for example, the flexibility to specify what is moving and to account for the various costs incurred.

We incorporate Boetto's two fluvial transport zones and the road network into a GIS model of mobility in the middle/lower valley to evaluate movement costs under different scenarios.[1] The objective is to model the relative costs of terrestrial versus river transport as a first step towards a fuller evaluation of the organisation of the city's supply networks. To explore the range and integration of different modes of transport, we begin with two types: terrestrial, based on a *plaustrum*, a two- or four-wheeled road cart (Smith, Wayte and Marindin, 1890), and upriver transport, distinguishing between vessels used on the 'fluvial-maritime' section (*navis caudicaria*, boats with a capacity of up to 70 tonnes used both in maritime and fluvial contexts, Boetto, 2010), and the 'fluvial' section using *lintres* (flat-bottomed, elongated river boats with an estimated capacity of 1.95 tonnes, propelled by punting or rowing; Casson, 1965; Le Gall, 2005, pp. 262–267; Bukowiecki and Wulf-Rheidt, 2015).

Using a digital elevation model (DEM), the road network and the course of the Tiber,[2] and accounting for post-Roman changes to the river's course between Rome and the sea,[3] we model the costs of movement across the landscape. Specifically, we use an algorithm based on the physics of movement (Raepsaet, 2002) to determine the influence of slope and surface type on the force (in newtons) required to move specific loads overland.[4] This approach is fundamental if we are to advance to more complex simulations, for example, exploring travel time. We also estimate the force required to move loads upriver using *naves caudicariae* and *lintres*; again, this is a first step towards more sophisticated modelling of the movement of loads up and down river under different conditions, such as variable winds and currents. These factors are combined into four scenarios used to generate and compare the costs of different routes (Table 4.1).

We compare modelled routes between pairs of locations as a means to evaluate the factors that may have shaped the movement of goods around the middle/lower Tiber (Table 4.2). To allow comparison between different means of transport, the model calibrates costs to a standard unit (the equivalent of transporting 1 tonne). Comparison of the transport distances and costs under each scenario reveals the

Table 4.1 Factors Considered When Modelling Scenarios A–D

Scenario	*Terrestrial Oxcart Travel*	*Crossing Streams (Additional Cost)*	*Road Network (Reduced Cost)*	*Upriver Navigation*
A	✓	X	X	X
B	✓	✓	X	X
C	✓	✓	✓	X
D	✓	✓	✓	✓

Table 4.2 Length (Kilometres), Left, and Accumulated Cost (Force in Newtons), Right, of Journeys Between Specified Points of Departure and Destination Under Four Scenarios (A–D)

Scenario	*Length (Kilometres)*				*Cost (Newtons)*			
	Portus – C. Amerinum	*Rome – C. Amerinum*	*Portus – L. Feroniae*	*Rome – L. Feroniae*	*Portus – C. Amerinum*	*Rome – C. Amerinum*	*Portus – L. Feroniae*	*Rome – L. Feroniae*
A	81.361	75.584	51.229	29.453	130562709	116267341	76239378	43551169
B	82.852	73.410	51.827	29.711	131687563	118424829	78783984	44846528
C	86.657	71.816	61.189	31.419	105511712	90782793	49013667	27564362
D	157.919	129.731	79.776	51.546	7273822	7435844	6656623	6727062

degree of marginality that may have factored into the decision to move by land and/or river.

Results

To exemplify the range of possible outcomes, and to assess the centrality of Rome in particular, we focus on four journeys: 1) Rome to the *municipium* of Lucus Feroniae; 2) Rome to the road station/port of Castellum Amerinum; 3) Portus to Lucus Feroniae; and 4) Portus to Castellum Amerinum. For each journey, our model generates routes under four scenarios (A–D; Figure 4.2). First, we compare

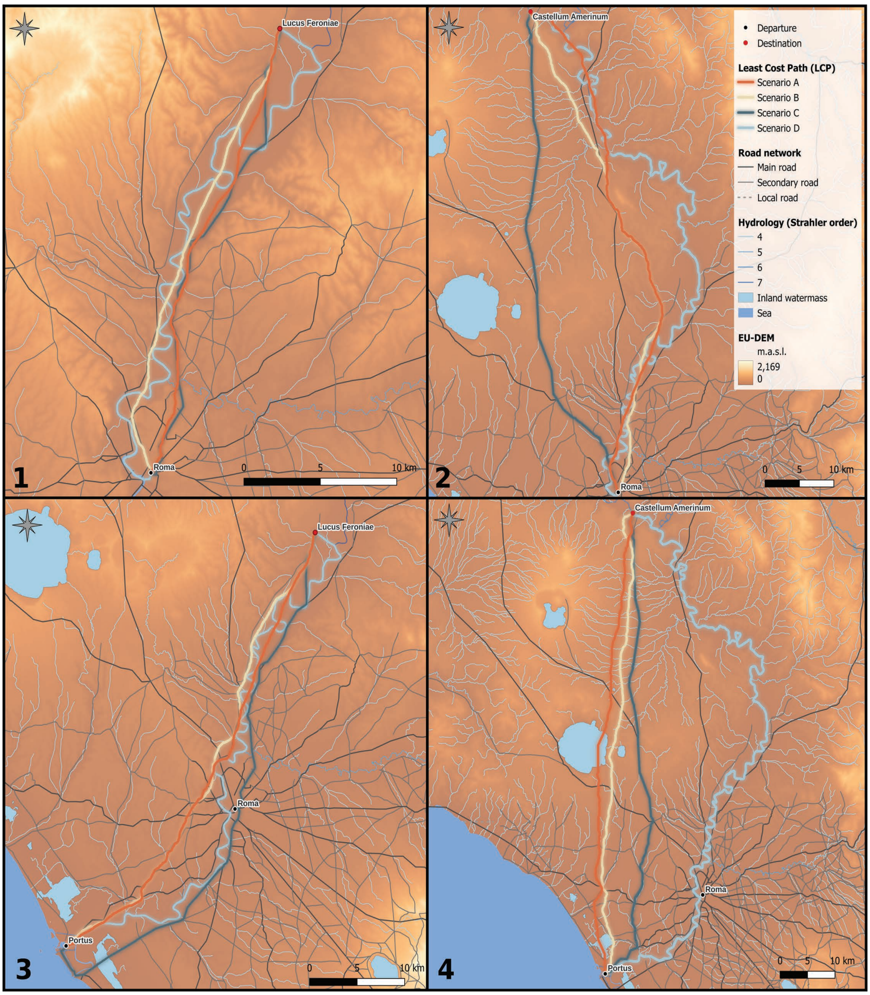

Figure 4.2 Modelling of routes between four pairs of places under the four scenarios (A–D): 1) Rome to Lucus Feroniae; 2) Rome to Castellum Amerinum; 3) Portus to Lucus Feroniae; 4) Portus to Castellum Amerinum. (*Source*: The authors.)

the differing lengths of the cost paths under each scenario, expressed as a percentage of scenario A (Figure 4.3). Typically, we might expect that the more complex the model (i.e. the greater the number of factors influencing mobility), the longer the modelled routes would be. Here, however, for three of the four journeys, the route lengths under scenarios A, B and C remain similar or become only slightly longer, and in one case (Rome to Castellum Amerinum) the lengths slightly fall.

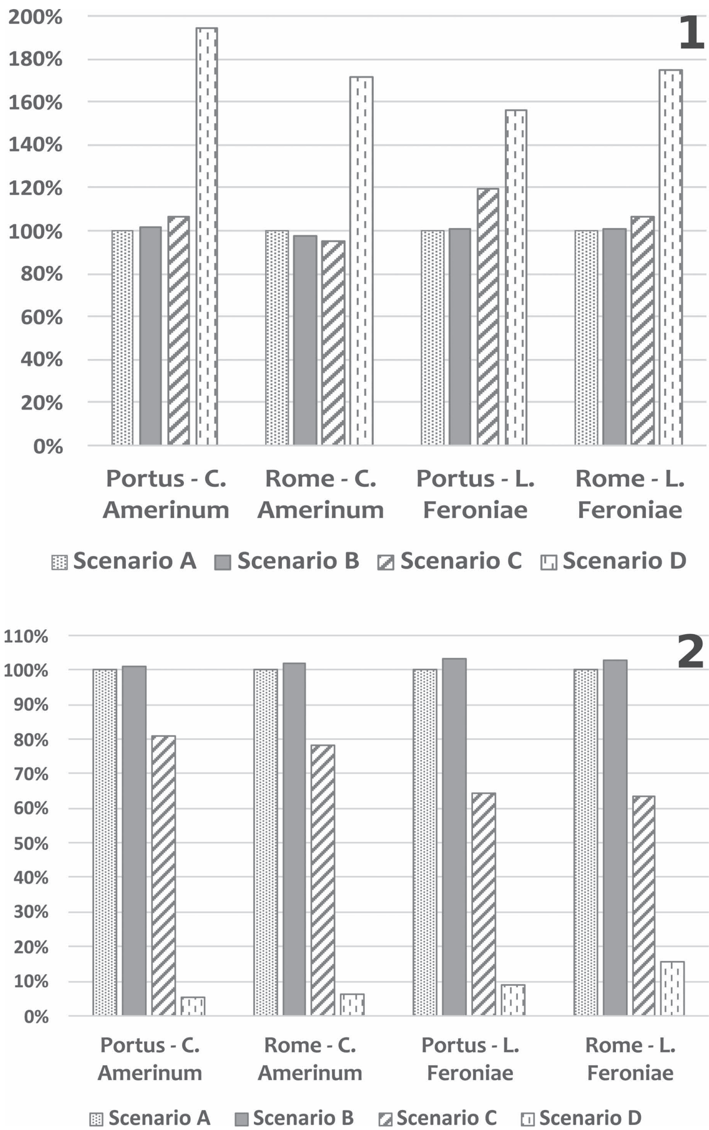

Figure 4.3 Relative difference (in percentage) between 1) estimated lengths of modelled paths and 2) between maximum accumulated costs under four scenarios. (*Source*: The authors.)

This could be because all of the selected places are well connected by relatively direct routes and therefore adding in the road network does not divert travellers on longer but lower-cost routes; this could be tested by simulating movement between pairs of places where either the point of origin and/or destination are located away from the known roads. Factoring in the option to use the Tiber, scenario D, substantially increases the length of the least-cost paths calculated between all four pairs of locations. From Portus to Lucus Feroniae, the distance is 56% greater than under scenario A, and to Castellum Amerinum it is 94% greater. In contrast, the increases in distance from Rome to both Lucus Feroniae and Castellum Amerinum are of similar magnitude to one another, 71% and 75% higher than under scenario A, respectively. These results suggest that when switching to the river, the farther apart the point of departure and destination, the greater the relative increase in path length becomes compared to land transport. This is because transshipment costs form a shrinking percentage of costs on longer journeys; although meandering and moving upstream, the river is substantially more efficient than land transport for moving heavy loads long distances. Conversely, the shorter the distance between the point of departure and destination, the smaller the relative cost advantage of upriver transport; the precise 'break-even' point will have varied depending on the load being transported.

A second way to assess the four scenarios is to compare the relative difference in accumulated costs. Figure 4.3 shows that using the Tiber for upriver transport (scenario D) incurs substantially lower cost than land transport, while scenario C, which factors only the road network, also leads to a notable reduction in costs compared to scenarios A and B. Again, as distances between point of departure and destination increase, the more cost-efficient river transport becomes, rising from six times less than land transport for Rome to Lucus Feroniae to seventeen times less for Portus to Castellum Amerinum. Examining how these long, lower-cost routes develop, it is evident that if the point of departure is close to the river, the additional costs of transshipment are quickly compensated for by the significantly lower costs of moving loads by water.

Discussion

Our model demonstrates that, compared to road transport, the Tiber – even travelling upstream – was significantly less costly (in newtons) for moving heavy loads. Land transport, however, undoubtedly offered greater flexibility to move via alternative routes and through intermediate places. Notably, when the option of using the Tiber (scenario D) is omitted, the terrestrial routes generated for journeys from Portus make Rome less central in the system than the radial nature of its road network leads us to expect. The modelled land routes from Portus to Castellum Amerinum (and even to Lucus Feroniae under scenarios A and B) bypass Rome by following secondary cross-country routes that connect to the main consular roads north of the city. Despite the network centrality of Rome, cargoes destined for the middle valley that did not travel by river may have bypassed the city altogether. The identification of the role of cross-country routes redirects attention towards the investigation of transport infrastructure in Rome's hinterland (e.g. *mansiones*).

In evaluating the cost of transporting loads in terms of force (newtons), the model omits consideration of time, both the relative velocities of oxcarts versus river vessels and of the types of cargoes involved (e.g. perishable goods). The model also makes no differentiation concerning the socio-economic status of the actors involved, effectively assuming merchants, aristocratic landowners and peasants had equal agency in choosing between types of transport. Nor does the model factor in considerations such as road and river capacity or the possibility of seasonal limitations, such as reduced navigability due to summer drought or autumn floods. All of these factors highlight that the transport of goods around the region was characterised by complexity: there was no single set of costs; rather, these varied according to actor, cargo, time requirements and season. Evaluating the Tiber's supply role therefore requires the integration of numerous additional considerations. The flexibility of the model presented here is that these other variables and parameters can be added to and continually refined in order to systematically assess their significance.

In formally modelling the use of the Tiber alongside the road network, our analysis also highlights the sensitivity of the results to issues with the quality of cartographic sources. For example, while here the course of the lower Tiber has been adjusted based on environmental and geomorphological studies (Moreno Escobar, 2022), we have had to use the modern river in the middle valley, where we have limited evidence for its ancient course (though here the river's lateral movement is more restricted by topography). Similarly, although Rome is renowned for its roads, the digital cartographic sources available for the network are generally small scale (here, 1:1,000,000), especially when compared to high-resolution DEMs, leading to insensitivity to local topography; additionally, knowledge of secondary routes is particularly incomplete, which may underestimate the relative importance of land transport in the model. More accurate and detailed mapping of both ancient rivers and roads will increase the robustness of such modelling.

Conclusions

Through its critical role in the supply of the goods to ancient Rome, the Tiber has come to be studied as two separate rivers. Moreover, because river transport is widely recognised as less costly than land transport, research on the Tiber has been divorced from the study of terrestrial networks. Here, we have sought to reconnect the 'two Tibers' into a single fluvial supply route and reintegrate the river with the road network to assess the relative costs of transporting heavy loads by land and/or river and user decision-making under different scenarios. Finally, we have also built on research that emphasises the function of Rome as a river port to highlight the role of the city for transhipment within the regional supply network. Strikingly, the results pull in different directions: emphasising the importance of Rome for fluvial transshipment, but decentring the city as a terrestrial hub connecting the coast and the middle/upper valley. As a long-distance, downstream transport corridor, the Tiber was hard to beat; but as the relative cost difference between land and upstream transport was smaller, shorter journeys by road more likely bypassed the city. These results reinforce Laurence's (1999) argument that, despite the lower costs of moving goods by river, land transport remained the baseline in the Roman world. As with any model, our results should be considered provisional and subject to revision as further variables are added and parameters refined. The intention therefore is not to answer definitively questions about the scale and complexity of the supply of ancient Rome and mobility more generally around the city's hinterland, but rather to develop an exploratory and iterative approach to the logic and limits of the evidence. We hope that the first results convincingly illustrate that the role of the river can only be understood when the 'two Tibers' are reconnected and reintegrated with the regional road network.

Acknowledgements

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Notes

1 Using r.cost (knight's move) and r.drain in QGIS 3.22.
2 25 m resolution DEM (EU-DEM; European Environment Agency, 2017); hydrology (EU-hydro dataset; European Environment Agency, 2020); Roman road network (Ancient World Mapping Center, 2016, after Barrington Atlas).
3 Reconstructed for Trajanic-Hadrianic times. Moreno Escobar (2022) for a list of transformations.
4 T = kP + Pi, where k is a coefficient for the type of surface where movement develops, P is the total weight of the loaded vehicle, estimated at 1300 kg, and i is the slope (as percentage).

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