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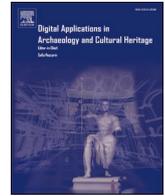
Cinzia Bettineschi, Stefan Reuter, Sebastian Gairhos, Natascha Sojc

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Coins as proxy for urban development: Rethinking *Augusta Vindelicum* via digital geonumismatics

Cinzia Bettineschi^{a,*}, Stefan Reuter^b, Sebastian Gairhos^c, Natascha Sojc^a^a University of Augsburg, Faculty of Philology and History, Department of Classical Archaeology, Universitätsstraße 10, 86159, Augsburg, Germany^b Freelance Archaeologist, Neu-Ulm, Germany^c Stadt Augsburg, Stadtarchäologie, Zur Kammgarnspinnerei 9, 86153, Augsburg, Germany

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ABSTRACT

Coins constitute an exceptional source of archaeological, chronological, and historical information. In this paper, we explore the potential of Geographic Information Systems (GIS) for analyzing a selection of over 4000 Roman coins unearthed within the city of Augsburg (Germany). By integrating the numismatic database built by the local Stadtarchäologie in the existing AugustaGIS developed in cooperation with the University of Augsburg, we were able to visualize the density and distribution of the coins, offering new hints to interpret the urban development of the city. In particular, we present two case studies to showcase the relevance of the approach, the first related to the formative phase of the settlement in early Imperial times, and the second devoted to better understanding the extension of the city during the Late Roman period (4th to early 5th century AD).

1. Introduction

Digital numismatics represent an expanding field at the intersection of archaeology, history, and digital humanities (Alegre et al., 2019; Arandjelović and Zachariou, 2020; Dahmen et al., 2018; Gruber and Meadows, 2021; Hoyer, 2018; Oksanen et al., 2023). By employing computational tools and digital frameworks, researchers can address complex questions related to monetary circulation, economic systems, and cultural interactions in ways that were previously unattainable, opening new avenues for exploring the spatial, temporal, and material dimensions of coins as archaeological artifacts. Advances in 3D scanning and photogrammetry have enabled high-resolution documentation of coins, which is critical for addressing questions of iconographic detail, wear patterns, and minting techniques (Calomino et al., 2023; De Guio and Magnini, 2019; Hödlmoser et al., 2010; Morris et al., 2022; Zambanini et al., 2010). Recently, machine learning and artificial intelligence are also emerging as valuable tools for automated classification and die-link analysis (Anwar et al., 2019; Cooper and Arandjelović, 2020; Cornet et al., 2024; Guo et al., 2023; Riede et al., 2024; Ünlü, 2019).

The potential of digital numismatics lies not only in the preservation and accessibility of numismatic data but also in its ability to synthesize

and analyze large datasets across diverse contexts. Coins, as standardized and well-dateable findings, provide unique insights into trade networks, political propaganda, and the economic landscape of past societies in absolute chronology (Kemmers and Myrberg, 2011). The use of statistics has additionally revolutionized the study of coin finds by allowing researchers to identify patterns in their circulation, as discussed in the seminal work by Lockyear on Roman coin hoards (Lockyear, 2007, 2018).

A critical milestone in digital numismatics has been the development of open-access platforms, such as the [Nomisma.org](https://nomisma.org) project (Celesti et al., 2017; Gruber et al., 2012; Heath, 2018; Rantala et al., 2022), which has established a shared ontology for numismatic studies. This initiative fosters interoperability among databases and promotes standardized vocabularies for describing coins.

Being highly mobile and standardized objects, coins serve as crucial evidence for understanding ancient economic and social processes (Newton, 2006). In this framework, an integrated approach encompassing Geographic Information Systems (GIS) is incredibly powerful because it enables researchers to map the spatial distribution of coins, revealing patterns that might otherwise go unnoticed. Despite GIS has been recognized as the benchmark for spatial analyses in archaeology for decades (Bettineschi et al., 2022; Conolly and Lake, 2006; Lock and

* Corresponding author.

E-mail address: cinzia.bettineschi@unipegaso.it (C. Bettineschi).¹ present affiliation: Department of Literary, Linguistic, and Philosophical Studies, Pegaso University, Centro Direzionale Isola F2, Via Giovanni Porzio, 4, 80143 (Naples, Italy).<https://doi.org/10.1016/j.daach.2026.e00523>

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Stancic, 2022; Magnini et al., 2019), its application in numismatics is still limited (see, however: Breier, 2011; Favretto and Callegger, 2017), especially within a wide interpretive framework.

This is probably because challenges remain in the application of geonumismatics. The completeness and accuracy of datasets are critical for reliable analyses, yet many coin finds – especially those from historical excavations, private collections, or the antiquity market – have no known spatial references and sometimes not even generic provenance, limiting their utility for GIS-based studies. Furthermore, issues of data standardization and interoperability across different databases persist despite the efforts of the researchers. However, the development and spread of numismatic geodatabases can further enrich our approaches to visualize and analyze coin finds within their broader archaeological, geographical, and socio-economic contexts, providing a powerful tool for addressing questions about ancient trade networks, settlement hierarchies, and economic systems.

In this work, we aim to showcase the potential of using GIS-based spatial statistics by analyzing a selection of over 4000 coins unearthed in the ancient city of *Augusta Vindelicum*, also known as *municipium Aelium Augustum* or simply *Aelia Augusta* (Fig. 1). As capital of the *Raetia et Vindelicia* province, *Augusta Vindelicum* was one of the earliest and wealthiest Roman cities beyond the Alps (Gairhos et al., 2022). With a total collection of approximately 9300 coins, Augsburg features one of the largest assemblages of Roman coins recovered from a single archaeological site in the German-speaking world. While these numbers

look prominent, they do not even consider the recent find of approximately 5500 silver *denarii* with a chronology from Nero to Septimius Severus in a hoard discovered in 2020 in Augsburg-Oberhausen (Gairhos, 2022a; Gairhos and Brey, 2021). Hence, the *corpus* of the Roman coins from Augsburg represents an untapped primary source of paramount importance for archaeological and historical research, particularly for studies on the urban development of the city. The significance of this assemblage is further amplified by the fact that 8080 coins – especially those from excavations conducted in Augsburg since 1978 – can be precisely localized within the settlement area of the Roman city. This degree of spatial accuracy provides a robust foundation for in-depth analyses of the assemblage.

2. Materials and methods

In an attempt to encourage the digital preservation, reuse, and the advanced analysis of the numismatic evidence from the city, the *Stadtarchäologie Augsburg* promoted the revision and digitalization of the legacy, paper-based documentation pertaining to the coins in its depots. The work was initially carried out transcribing and updating the information available on the analog forms within a digital table, which was then used for preliminary queries.

When coins were selected for integration in the AugustaGIS project handled by the chair of classical archaeology of the University of Augsburg, it was soon apparent that a revision in its ontology and



Fig. 1. Location of the ancient city of *Augusta Vindelicum* in the context of central and southern Europe.

structure was necessary to maximize the potential of the approach (Table S1). A selection of 4026 occurrences, representing all Roman coins recovered from archaeological excavations conducted in the Augsburg city center between 1978 and 1997, was thus designated for this research. This subset accounts for approximately 44% of the 9300 Roman coins documented in *Augusta Vindelicum* and nearly 50% of the 8080 coins precisely located within the Roman city area. The quantity and broad spatial distribution of the artifacts grant a statistically significant and representative basis for further processing.

The Nomisma ontology, which represents the gold standard for state-of-the-art digital numismatic projects, was employed for upscaling the original dataset (Duyrat and Wigg-Wolf, 2017; Gruber et al., 2012; Heath, 2018; Tolle et al., 2020). This ontology serves as a *lingua franca*, offering a common vocabulary and structure that fosters consistency and clarity across diverse numismatic databases and research projects around the globe.

Minor adjustments were made in this project to the absolute chronologies by introducing a calculated field named “chronology (full range)”. This field automatically lists all years of minting for each coin, presented sequentially and separated by semicolons. The method used enables users to retrieve coins minted in a specific year or short timespan directly, overcoming the structural limitations commonly associated with conventional database systems. This is because traditional databases often represent chronological data as ranges defined by start and end dates. While suitable for range-based filtering, such representations present significant challenges for granular queries. For example, a coin minted between 30 AD and 50 AD is typically stored as a single range, making it difficult to directly extract it when looking for all coins minted in a specific year, such as 40 AD. This limitation necessitates additional computational operations or manual data manipulation to achieve the desired specificity. By explicitly listing each year within the production period of a coin, the “chronology (full range)” field provides a more versatile and precise tool for chronological analysis. This approach is particularly valuable for GIS-based queries requiring high temporal resolution, facilitating direct and efficient retrieval of specific years or narrower timespans within broader datasets. For consistency, dates BCE are preceded by a minus sign (es. -4 represents the year 4 BCE, while 4 corresponds to year 4 AD).

This solution addresses a challenge often encountered in numismatic research, where many works rely on very specific and narrow time spans (e.g. Kos, 2019; Ziegau, 2018). This tendency reflects the fact that coinage production and circulation are often closely linked to short-term political, economic, and administrative changes. For example, the establishment of new minting authorities, reforms in coin weight and metal content, or changes in imperial iconography can result in distinct shifts within relatively brief periods. Consequently, numismatic chronologies are frequently subdivided into fine intervals to capture these nuances. The calculated field “chronology (full range)” allows for a more flexible and precise alignment with these detailed chronological frameworks, enabling researchers to work with both broader and more narrowly defined time spans without losing analytical clarity.

The plans of the main archaeological structures and of the emergency excavations carried out in the city over the years considered were vectorialised in QGIS and associated with the standard project numbers attributed by the *Stadtarchäologie* Augsburg to all trenches and sections. This code was later used to connect the georeferenced data with the non-spatial information stored in the coin table. Kernel Density Estimation (KDE) was employed to analyze spatial patterns and identify density variations in the dataset. KDE is a non-parametric spatial analysis technique that calculates the density of occurrences within a defined bandwidth, smoothing the results using a mathematical kernel function, typically Gaussian (Scott, 1992; Silverman, 2018). This method produces a continuous raster surface (grayscale or color heatmap), highlighting regions of high and low density. The KDE method is particularly effective in archaeology for identifying spatial clusters, such as artifact scatters, site boundaries, or high-activity zones. Previous research

clearly underscores the suitability of KDE for archaeological purposes (e.g. Baxter et al., 1997; Bonnier et al., 2019).

In this study, KDE was achieved using the “Heatmap (Kernel Density Estimation)” tool in QGIS and was represented with a color palette from blue (low density) to red (high density). The following parameters were applied: Gaussian Kernel Function with radius of 130 m. The value was defined after a tradeoff study according to the spatial resolution and scale of analysis to ensure that relevant spatial patterns were captured; the resulting image was also optimized for a smooth representation of densities. The numerical values associated with the KDE colour scale represent estimated point densities per unit area and not absolute numbers of coins. This approach enabled the visualization and quantitative assessment of spatial relationships within the dataset, which were subsequently integrated into the broader historic, archaeological, and numismatic framework of this study, supporting interpretations on the temporality of the expansion and contraction of the *municipium* of *Augusta Vindelicum*. To provide further data on the robustness of our interpretations, we also reported in the figure captions the absolute number of coins retrieved by each query. This choice provides transparency on the subset sizes underlying the heatmaps and allows readers to directly assess the statistical significance of the visualized distributions.

3. Results

Two case studies were identified to illustrate the potential of our GIS-based approach in analyzing urbanization dynamics across different periods (for a comparative overview of the coin distribution during the 2nd cent. AD see Fig. S1). The first focuses on the formative phase of *Augusta Vindelicum*, examining coins minted during the late Republican and early Imperial periods. The second addresses the settlement dimensions in the Late Roman period (4th to early 5th century AD), a time when many provincial cities experienced significant struggles, often reflected in reductions in size (Johannessen, 2017; Witschel, 2004; Ziolkowski, 2011).

In both cases, coin hoards were deliberately excluded from the analysis to prevent distortions in spatial distribution patterns. Tests conducted with and without the hoard from *Springergäßchen* 8 dating to the late 4th - early 5th century AD (Kos, 2006) demonstrate that their inclusion can substantially alter these patterns (Fig. 2).

In the first case study (Fig. 3), the chronological analysis of coin distributions reveals clear progression. Coins from the Augustan period predominantly cluster inside and around the Roman fort, with only sparse occurrences outside. By the Tiberian period, the distribution expands linearly to the southwest of the *castrum*. During the reigns of Caius and Claudius, a new significant concentration emerges for the first time to the north of the fort. Under Nero, the coin distribution shifts further south, aligning with the *decumanus maximus* and near the area where the city walls were later constructed in the mid-2nd century AD.

Burnt coins were also mapped in this early phase to investigate their potential correlation with documented firing episodes recorded in literary sources and the archaeological record. Notably, these coins exhibit a distinct concentration only near the southern corner of the *castrum* (Fig. 4). This pattern suggests that the area may have been a focal point of the destruction caused by the violent fire episode occurred around 69-70 AD, known from historical and archaeological records (Kopf, 2024; Ortisi, 2022). The clustering of burnt coins could, indeed, indicate that this part of the *castrum* experienced particularly intense devastation, with coins severely exposed to fire, to such an extent that surface alteration and deformation are still recognizable on the objects themselves.

The second case study examines the spatial distribution of coins during the Late Roman period (4th cent. AD, ca. 313-403/408 AD). As previously mentioned, the precision of the start and end dates in the analysis of coin distribution is supported by established numismatic frameworks used in previous research (e.g. Kos, 2019; Ziegau, 2018).

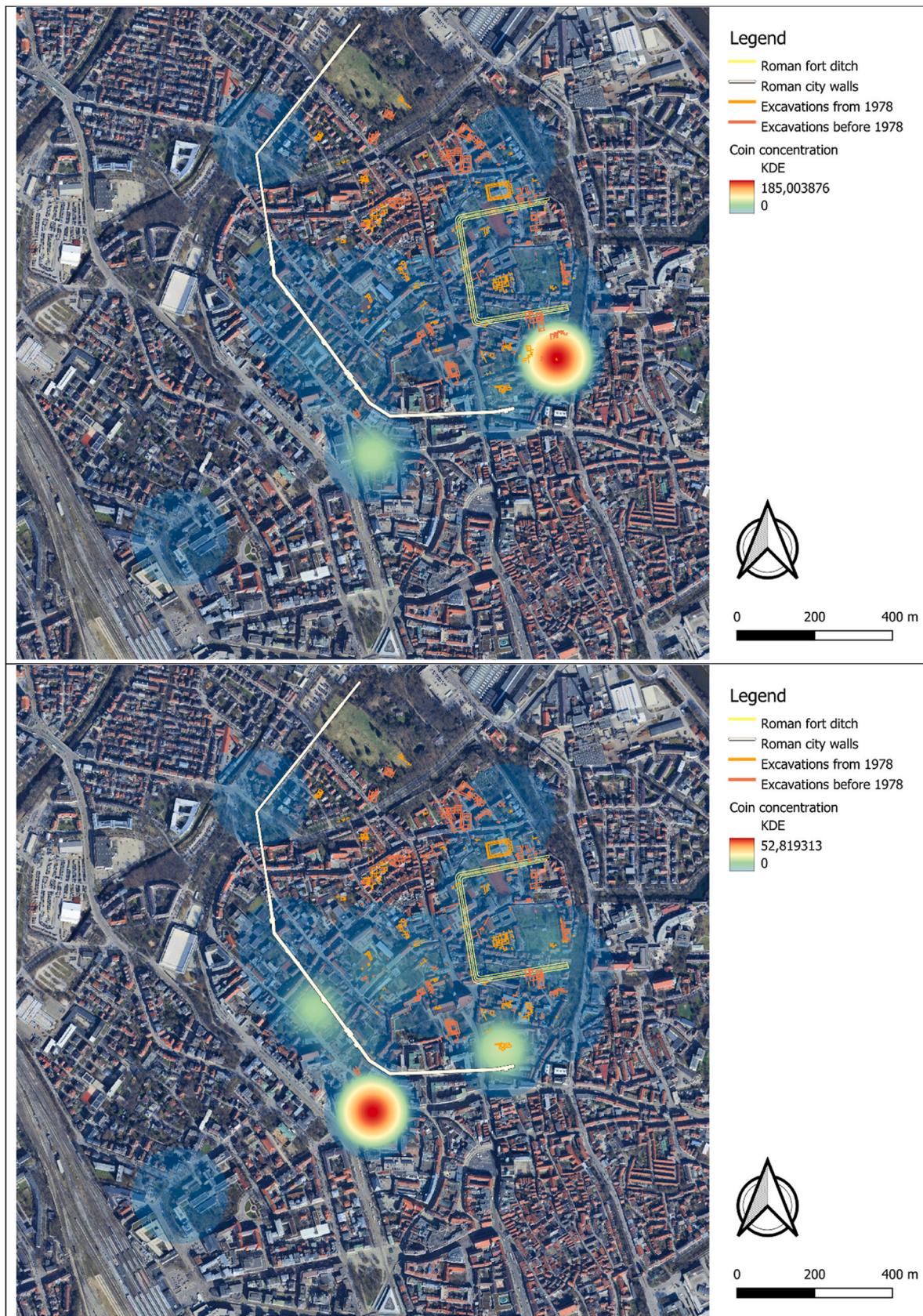


Fig. 2. Heatmaps of the late 4th - early 5th century AD coins in the city of *Augusta Vindelicum*. The image above shows the kernel density estimation including the hoard from *Springergäßchen 8* (total coins = 313), while the image below shows the distribution patterns without that same hoard (total coins = 128).

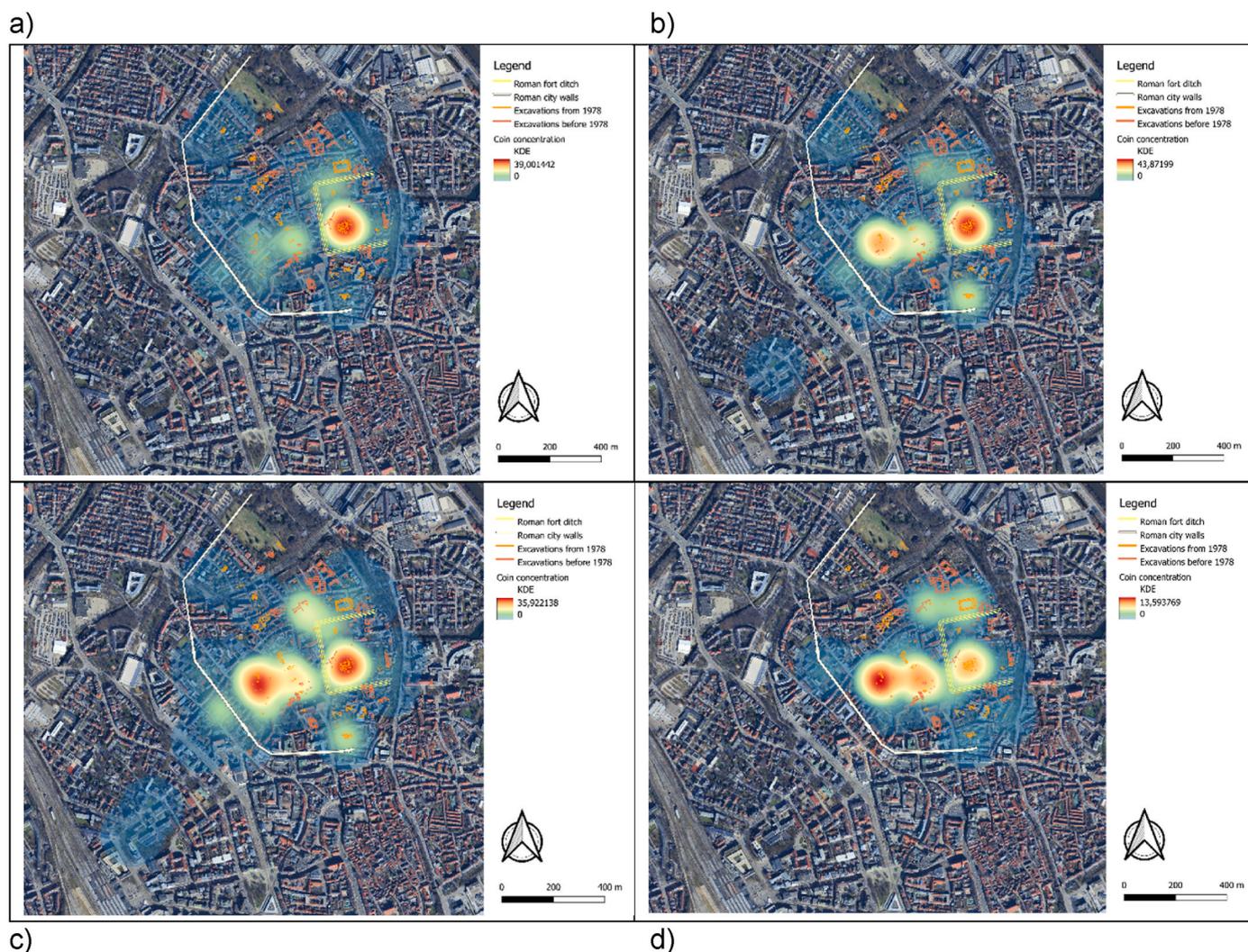


Fig. 3. Heatmaps of the formative period of the city of *Augusta Vindelicum*: a) Augustan coins (total coins = 107); b) Tiberian coins (total coins = 162); c) coins of the rule of Caius and Claudius (total coins = 181); d) Neronian coins (total coins = 54).

The choice of 313 AD as the starting point is grounded in the significant monetary reforms introduced by Constantine I, and particularly the reduction in the weight of bronze coinage in 312/313 AD, which followed an initial debasement in 307 AD (Harden, 2018; Kent, 1957). This change led to the rapid disappearance of pre-313 bronze coins from circulation, marking a major shift in imperial coinage policy and production.

Judging from Fig. 5, the results indicate a broad occupation within and immediately surrounding the city walls. However, a notable shift occurs at the end of the 4th and early 5th centuries AD, when coin occurrences diminish significantly and become restricted to the southernmost part of the city (Fig. 5d). This observed decrease can be most probably connected to a context of political fragmentation and economic decline.

4. Discussion

The geonumismatic approach employed in this study provides a multi-faceted perspective on the urbanization dynamics of *Augusta Vindelicum*, offering both validation of previous hypotheses and novel insights into the city development through time. By integrating coin-derived absolute dating and spatial patterns with archaeological and historical records, this method helps researchers to fine tune the spatial and temporal resolution of our historical reconstructions.

4.1. 1st century AD

The results of the KDE of the 1st century AD coins align closely with the chronological phases outlined by Bettina Tremmel, who systematically analysed the traces of the wooden structures and the material remains from the excavations in the early *vicus* (Tremmel, 2012). In general, the distribution of the late Republican and early Imperial coins is directly correlated to the expansion of the *vicus*, which extended towards south-west, along the road towards *Cambodunum* (modern Kempten), the first administrative center of *Raetia*. The spatial correlation between coin concentrations and key urban structures provides critical insights into the symbiotic relationship between *Augusta Vindelicum*'s urban growth and coin circulation. The integration of military and civilian spaces reflects the city's progressive strategic role as a regional hub within the province, facilitating trade, administrative functions, and cultural exchange (Kopf and Oberhofer, 2021; Schaub and Bakker, 2001).

Considering the distribution maps, the military camp, future founding nucleus of the Roman city of *Augusta Vindelicum*, appears to be initiated under Augustus (Bakker, 1999). The historical framework reflects the military and administrative reorganization initiated under Augustus following the conquest of *Raetia* in 15 BCE (Gergő Farkas, 2015). The establishment of *Augusta Vindelicum* as a military camp on an elevated platform above the Lech valley was part of Rome's strategic

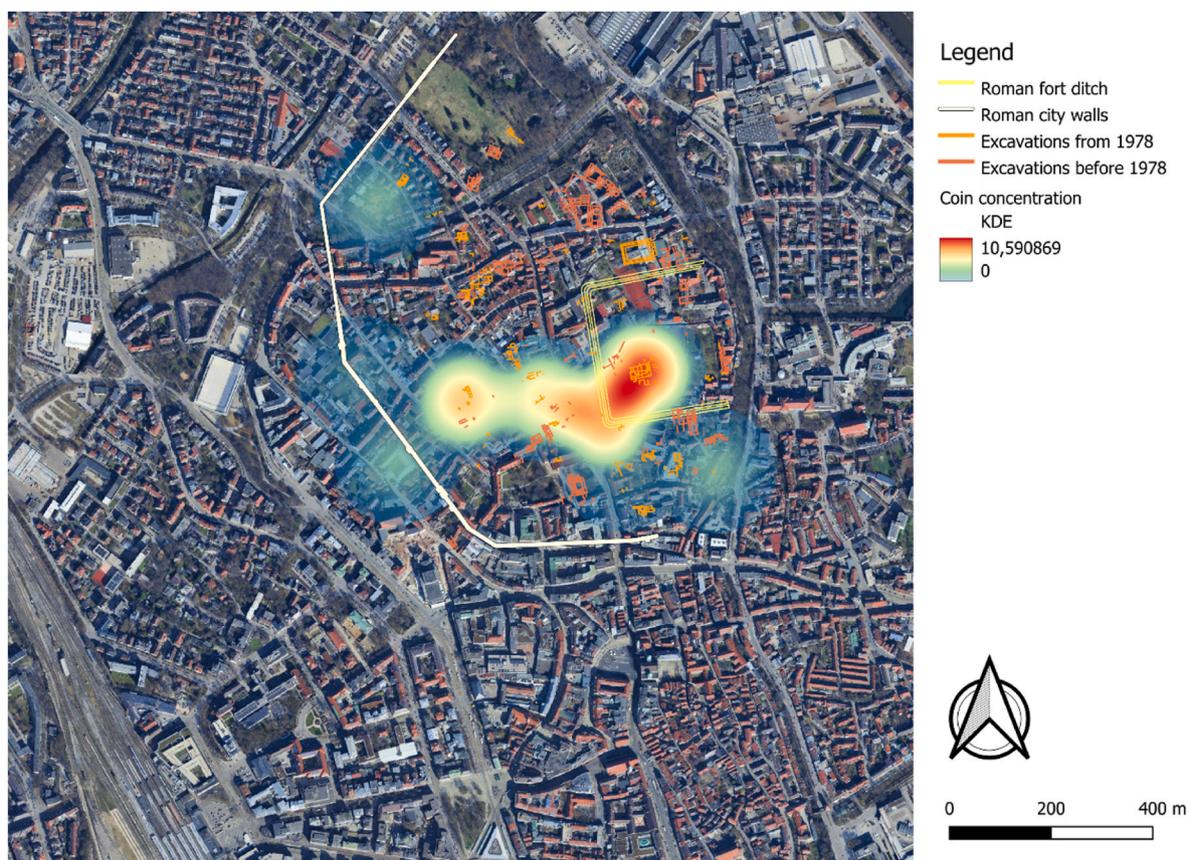


Fig. 4. Heatmap showing the distribution of coins with burning traces with a chronology from Tiberius to Vitellius (burnt coins 39 out of 543 total coins).

effort to secure the Alpine frontier and control key trade routes through the province. The construction of the camp under Augustus is well in line with the early phases of provincial restructuring and the creation of a permanent military presence to consolidate Roman authority in the region (Moosbauer, 2024).

In Tiberian times, the south-western *vicus* marked the first significant civilian expansion, pointing towards an incipient process of Romanization and urbanization in *Raetia*. The growth of civilian settlements around military installations was a common phenomenon in the western provinces, where discharged veterans and local inhabitants were drawn to the economic and social opportunities provided by proximity to military infrastructure (Woolf, 1998). The further expansion of the northern *vicus* under Claudius (41-54 AD) seems to mirror the increasing economic significance of *Augusta Vindelicum* as a trading and administrative center. This growth trajectory is consistent with the administrative reforms under Claudius, which sought to strengthen imperial control over provincial territories and integrate them more closely into the Roman economic network (Drinkwater, 1987). These spatial patterns underscore the central role of the military in shaping *Augusta Vindelicum*'s protourban landscape and cross-validate the chronological trajectory proposed in prior research.

4.2. Burnt coins

The distribution of burnt coins minted between the reigns of Tiberius and Vitellius (Fig. 4) questions the traditional interpretation of a widespread conflagration associated with the political turmoil following Nero's death (Kopf, 2024; Ortisi, 2022). This event triggered the so-called *Year of the Four Emperors* (69 AD), a civil war marked by a rapid succession of claimants to the imperial throne, Galba, Otho, Vitellius, and finally Vespasian, who all relied heavily on the support of the provincial legions (Tacitus, *Histories* books I-III). This period of instability

directly affected the western provinces, including *Raetia*, which supplied troops to competing factions, and likely resulted in retaliatory or defensive military actions in key provincial centers, including *Augusta Vindelicum* (Wellesley, 2002).

While literary sources and archaeological evidence attribute the complete destruction of the vexillation camp and surrounding *vicus* to a single, substantial firing event, the localized concentration of burnt coins near the southern corner of the *castrum* and upper portion of the *vicus* suggests that the destruction was not uniform across the settlement but instead affected specific areas with varying intensity. This may reflect targeted damage linked to military engagement, localized fires resulting from internal conflict or defensive measures, or even deliberate clearance and rebuilding efforts following the conflict. Such coin pattern thus opens new interpretative possibilities. If the distribution of burnt coins reflects selective or localized damage rather than a widespread conflagration, this would suggest that *Augusta Vindelicum*'s military and civilian infrastructure remained partly intact or was rapidly reconstructed. This contrasts with the prevailing historical narrative of complete devastation and points to a more resilient urban landscape. Furthermore, the absence of burnt coins in other parts of the site suggests that damage was confined to military installations or administrative quarters rather than fully affecting the civilian settlement. This would be consistent with other examples from the western provinces, where military structures often bore the brunt of conflict while civilian spaces showed more continuity (Drinkwater, 1987).

This observation calls for a thorough reassessment of the scale, uniformity, and impact of the catastrophe, necessitating a critical re-evaluation of both structural and stratigraphic evidence, and raising the possibility that the historical sources may have overemphasized the extent of the event.

It also underscores the potential of geospatial data to challenge established interpretations and reopen questions previously regarded as

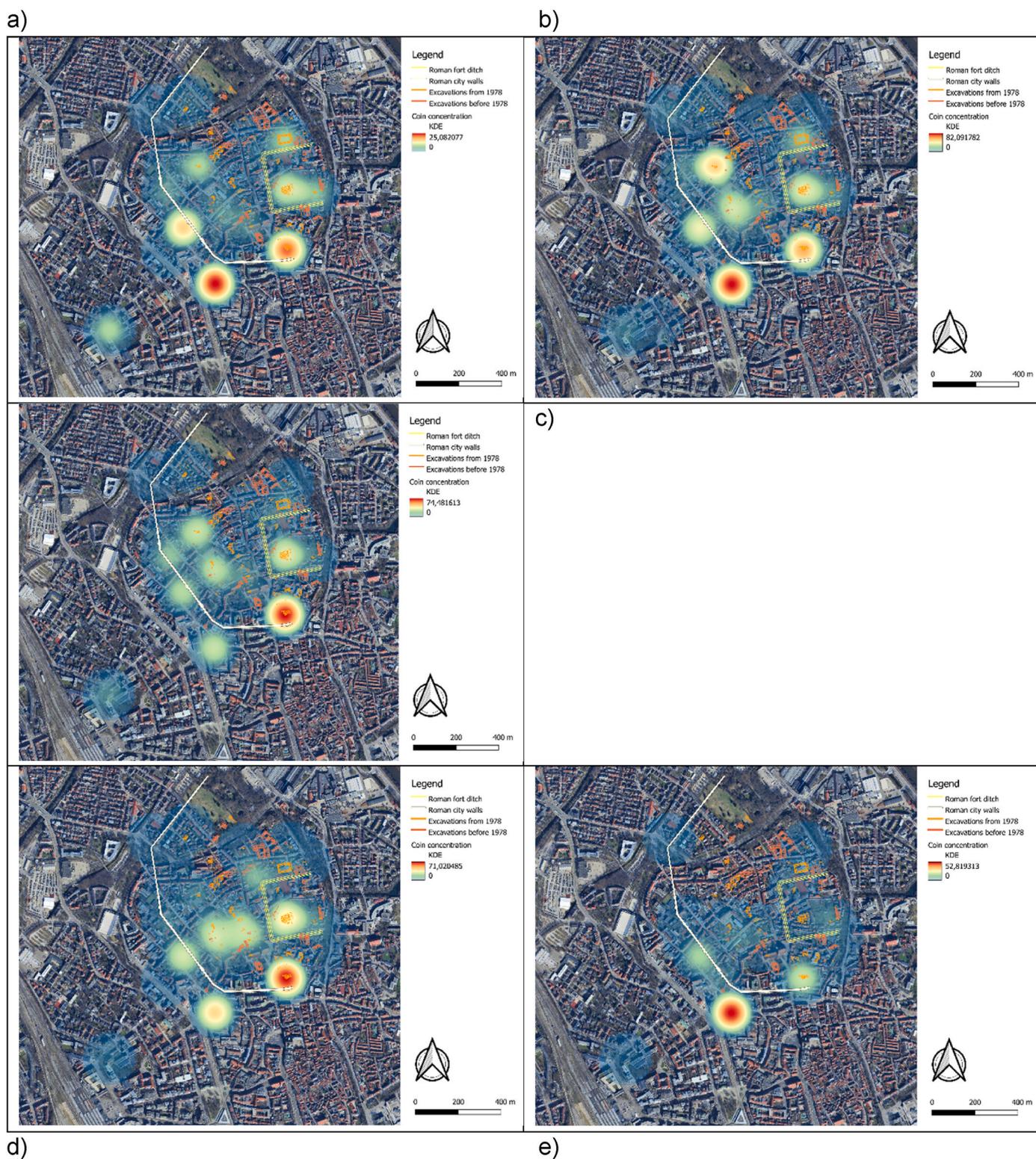


Fig. 5. Heatmaps of *Augusta Vindelicum* during the Late Antiquity (4th to early 5th century AD): a) coins 313-330 AD (total coins = 126); b) coins 330-348 AD (total coins = 419); c) coins 348-364 AD (total coins = 314); d) coins 364-383 AD (total coins = 352); e) coins 383-403/408 AD (total coins = 128).

settled in historical reconstructions.

4.3. Late Roman occupation

The GIS analysis provided critical support for hypotheses regarding the spatial and temporal extent of Late Roman occupation. Ceramic studies had previously suggested that the entire walled area of the city

remained settled during this period, a peculiarity which is probably due to the incorporation of novel inhabitants from the *vici* of the countryside that were not sufficiently fortified and military defended to protect their villagers (Heimerl, 2014). This assertion is now substantiated by the heatmaps of Late Roman coin distributions, which reveal a systematic and consistent presence of coins across the walled area during the 4th century AD.

This phase of urban continuity and coin circulation may reflect local stability and economic prosperity under the Tetrarchy (293-313 AD) and the subsequent reign of Constantine I (306-337 AD) (Witschel, 2004). The confirmation of *Augusta Vindelicum* as the capital of *Raetia Secunda* in the early 4th century after the provincial reform of the Constantinian period is consistent with the city's strategic importance in the context of imperial defense and administration. The abundant presence of coins from this period within the city walls suggests that *Augusta Vindelicum* maintained and strengthened its role as a key organizational and economic hub.

However, a marked contraction in coin distribution (and thus, possibly, of settlement size) seems to be documented already by the end of the 4th and early 5th centuries AD, with monetary occurrences concentrated in the southern portion of the city. This decline aligns with general patterns of urban contraction and political instability following the death of Theodosius I in 395 AD and the subsequent division of the Roman Empire. The sack of Rome by Alaric in 410 AD and the increasing pressure from Germanic groups along the northern frontiers likely contributed to the weakening of urban networks (Heather, 2005). The concentration of coin finds in the southern sector of *Augusta Vindelicum* may imply that urban activity became increasingly localized, possibly reflecting a shift towards defensive consolidation and reduced administrative capacity during the early 5th century (Gairhos, 2022b). These findings suggest a progressive urban decline, which becomes particularly evident from the mid-5th century AD reflecting, with a meaningful delay, broader provincial trends during Late Antiquity.

4.4. Coin circulation and settlement activity

The analysis of coins from *Jesuitengasse* 10 and 14, used both for residential and economic purposes, reveals significant variations in minting-period representation. Early Constantine coins are notably underrepresented, whereas coins from later periods – except those of the last two decades of the 4th century AD – are prevalent.

These findings suggest that different areas of the city experienced distinct trajectories of coin circulation and settlement activity, pointing to potential economic or administrative zoning within the urban fabric. Additionally, they indicate a possible urban economic restructuring during the later empire, where the concentration of wealth and executive functions in specific areas of the city often mirrored shifts in imperial policy and local governance (Witschel, 2004). Particularly, the uneven representation of Constantine's coinage may reflect restricted patterns of monetary supply or circulation, influenced by *Augusta Vindelicum*'s position within the provincial administrative and military network.

5. Conclusions

The research presented in this paper serves as a further demonstration that geonumismatic data, integrated with archaeological and historical evidence, can provide a high-resolution framework for understanding the development and transformation of ancient cities, offering novel insights to interpret established historical narratives. Specifically, these short notes contribute to highlight the complex interplay between imperial policies, local economic conditions, and urban infrastructure in shaping coin circulation and settlement dynamics in *Augusta Vindelicum*.

The incorporation of Roman coins into the AugustaGIS represents a significant leap in the archaeological and numismatic study of the site. The results obtained transcend the classic historiographic approach, transforming coins and their spatial attributes into pivotal markers for reconstructing the city's evolution across various historical periods. Additionally, the GIS analyses performed provide a visual narrative of coin distributions, which not only facilitates the interpretation of the results but also contributes to strengthening previous hypotheses and suggesting new perspectives. The relevance of the patterns emerged

from this study is not limited to pinpointing the wealth distribution in the various districts through time but especially promotes a better understanding of the societal, cultural, and political dynamics that shaped the city. The AugustaGIS prototype's ability to seamlessly integrate archaeological and numismatic data emphasizes its potential for broader applications. For example, the observed variations in minting-period representation at specific findspots can inform studies of economic activity, coin supply, and local administrative practices. Moreover, the heatmaps of Late Roman coin distributions offer a powerful tool for fine-tuning issues such as settlement continuity and decline, addressing questions central to the study of urban resilience in Late Antiquity.

The adoption of [Nomisma.org](https://nomisma.org) ontology offered a standardized framework for optimizing, describing, and organizing the numismatic data from *Augusta Vindelicum*. This common vocabulary ensured on one hand coherence within this project and on the other will facilitate seamless collaboration and data exchange with other digital numismatic databases and research initiatives. It will promote interoperability, enabling scholars to fully exploit the potential of this exceptional dataset. The integration of the “chronology (full range)” field further enhances the analytical efficacy of our approach by allowing for precise year-specific queries and more refined chronological analyses, thereby overcoming the structural limitations of traditional range-based catalogue systems. What is more, the project's reliance on free and open-source GIS technologies guarantees the sustainability and accessibility of the data collected (Ducke, 2012; Wilson and Edwards, 2015), assuring that the findings and insights gleaned from this project remain available and usable for future research, enriching the collective understanding of *Augusta Vindelicum*'s history.

Finally, while only two representative case studies were selected for presentation in this contribution, current research focuses on answering additional historical and numismatic questions related to the archaeology of *Augusta Vindelicum*, which will be presented in dedicated future works.

In summary, the AugustaGIS geonumismatic project has provided an effective lens for examining *Augusta Vindelicum*'s urbanization dynamics. As seen above, this approach has not only reaffirmed established narratives, but also introduced new perspectives on the city's development. Future studies are further expected to expand on these findings, exploring the integration of additional datasets such as ornamental objects, specific pottery classes, or inscriptions to enhance our understanding of urban dynamics in one of the most relevant Roman provincial cities beyond the Alps.

CRediT authorship contribution statement

Cinzia Bettineschi: Writing – original draft, Visualization, Software, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Stefan Reuter:** Writing – review & editing, Validation, Data curation. **Sebastian Gairhos:** Writing – review & editing, Validation, Supervision, Conceptualization. **Natascha Sojc:** Writing – review & editing, Validation, Supervision, Project administration, Funding acquisition, Conceptualization.

Data availability statement

The geodatabase utilized in this study is copyrighted by the *Stadtarchäologie* Augsburg and the chair of Classical Archaeology at the University of Augsburg. Due to the inclusion of unpublished numismatic data currently under study and pending publication by one of the authors, the full dataset cannot be shared openly at this time. For further inquiries, please contact the aforementioned institutions.

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.daach.2026.e00523>.

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