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Revealing Early Iron Age Social Organization in Southern Tianshan, Xinjiang through Multi-scale Spatial Analysis of the Mohuchahan Cemetery

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Article

Keywords: Early Iron Age, Social organization, Mortuary archaeology, Spatial analysis, Mohuchahan Cemetery, Xinjiang

Posted Date: August 14th, 2026

DOI: https://doi.org/10.21203/rs.3.rs-10550824/v1

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Additional Declarations: No competing interests reported.

Abstract

The Early Iron Age was a critical period of transformation in social organization and subsistence across the eastern Eurasian Steppe, yet the relationship between cemetery spatial organization and social structure remains insufficiently explored. This study investigates the Mohuchahan Cemetery (1000–800 BC), a representative Chawuhu culture cemetery in the southern piedmont of the Tianshan Mountains, Xinjiang. A spatial database was established from the spatial coordinates and mortuary data of 225 excavated burials and analysed using nearest-neighbor statistics, hierarchical clustering, and quantitative analyses of mortuary attributes to investigate the cemetery's internal spatial organization and its social implications. The results demonstrate that the cemetery was not formed through random burial placement but exhibits a spatially structured organization comprising four distinct burial clusters. These clusters differ in burial size, grave-good investment, burial orientation patterns, the number of individuals per burial, and sex composition, suggesting differences in household organization, local communities, and associated mortuary practices within the cemetery. Overall, the evidence indicates that social differentiation at Mohuchahan Cemetery did not develop into a strongly hierarchical system but instead reflects a composite social organization centred on family units and local communities. This study demonstrates that integrating spatial clustering with quantitative analyses of mortuary attributes can effectively reveal latent patterns of prehistoric social organization and provides a transferable analytical framework for investigating the social organization of Early Iron Age cemeteries in Xinjiang and the eastern Eurasian Steppe.

1 Introduction

Understanding the emergence and development of social organization during the Early Iron Age remains a central issue in Eurasian archaeology because profound transformations in subsistence strategies, mobility, metallurgy, and interregional interaction reshaped societies across the Eurasian Steppe and Central Asia throughout the first millennium BC [1–5]. Situated at the crossroads of Inner Eurasia, Xinjiang connected the Altai Mountains, the Tianshan Mountains, the Pamirs, the Tarim Basin, and the oases of Central Asia, making it a key region for investigating population movement, technological transmission, and cultural interaction. Recent archaeological research has demonstrated substantial demographic, economic, and cultural changes across Xinjiang during the Early Iron Age, underscoring the importance of this region for understanding social organization in the eastern Eurasian Steppe [6–10]. However, despite considerable advances in chronology, cultural interaction, and subsistence studies, the organization of Early Iron Age communities in Xinjiang remains insufficiently understood.

Because social organization cannot be observed directly in the archaeological record, cemeteries provide one of the most informative sources for investigating prehistoric communities through their spatial organization and mortuary practices [11–15]. The spatial arrangement of burials, together with variation in burial construction, grave-good assemblages, burial orientation, and number of individuals per burial, preserves important evidence for reconstructing social differentiation, kinship, and community organization. Recent advances in GIS-based spatial analysis have substantially improved the quantitative

investigation of cemetery spatial organization by identifying burial clusters and spatial relationships that are difficult to recognize using conventional descriptive approaches. Integrating spatial analysis with mortuary evidence therefore provides an effective framework for exploring how social organization was expressed through burial practices.

Against this background, the Mohuchahan Cemetery, located in Hejing County, Bayingolin Mongol Autonomous Prefecture, Xinjiang, provides an important case for investigating Early Iron Age social organization. The cemetery belongs to the Chawuhu culture[16], which developed along the southern piedmont of the central Tianshan Mountains during the transition from the Late Bronze Age to the Early Iron Age. Dating primarily to the tenth–eighth centuries BC, it reflects intensive population interaction and cultural development in central Xinjiang. A total of 245 burials have been excavated from the cemetery, preserving well-documented spatial information together with diverse mortuary attributes, including burial size, grave-good investment, burial orientation, the number of individuals per burial, and biological sex [17]. Together, these well-preserved spatial and mortuary data provide a robust dataset for investigating the relationship between cemetery spatial organization and social organization.

Previous studies of the Mohuchahan Cemetery have focused primarily on chronology, ceramics, subsistence strategies, and stable isotope analyses, whereas the relationship between cemetery spatial organization and social organization has received comparatively little attention [6, 10–13]. This study investigates how cemetery spatial organization reflects social organization through an integrated analysis of burial distribution and mortuary variability. Specifically, we examine whether spatial clustering corresponds to systematic differences in burial size, grave-good investment, burial orientation patterns, the number of individuals per burial, and biological attributes, and whether these patterns reflect social differentiation or broader forms of community organization. By quantitatively integrating spatial clustering with mortuary evidence, this study provides new archaeological evidence for understanding the social organization of the Chawuhu culture and offers a transferable analytical framework for investigating Early Iron Age communities in Xinjiang and the eastern Eurasian Steppe.

2 Materials and Methods

2.1 Cemetery dataset and spatial database construction

The Mohuchahan Cemetery provides the archaeological dataset for this study and is one of the best-preserved and most extensively excavated cemeteries of the Early Iron Age Chawuhu culture in Xinjiang (Fig. 1). The cemetery is divided into two burial zones (Zone I and Zone II) by a seasonal gully running from northeast to southwest. Archaeological information, including burial layout, grave structures, grave-good investment, and human remains, was obtained from the excavation report The Mohuchahan Cemetery in Xinjiang [17], which serves as the primary source of both the spatial data and mortuary variables analysed in this study.

A GIS-based spatial database was constructed to support quantitative analysis of cemetery organization. The published cemetery plan was georeferenced using the lower-left corner as the origin (0, 0) of a Cartesian coordinate system, with the X- and Y-axes representing the horizontal and vertical directions, respectively. Spatial coordinates for each burial were digitized from the excavation plan and linked to the corresponding mortuary attributes recorded in the excavation report through burial identification numbers. The resulting database integrates spatial coordinates with mortuary information for each burial .

Because this study focuses on the Early Iron Age occupation, Han-dynasty burials located on the periphery of Zone II were excluded. The final dataset comprises 225 burials, which form the basis for all subsequent analyses (Fig. 2).

2.2 Spatial analysis

To examine the internal spatial organization of the cemetery, nearest-neighbor analysis and Ward's hierarchical clustering were employed to identify spatial relationships and burial groups. These complementary approaches quantify spatial proximity among burials and identify spatial clusters that can subsequently be compared using mortuary variables.

Nearest-neighbor analysis was first used to calculate the distance from each burial to its closest neighbour, providing a quantitative measure of local spatial relationships within the cemetery [18–20]. The resulting nearest-neighbor distance matrix served as the basis for hierarchical clustering.

Ward's hierarchical clustering was then applied to the distance matrix to identify spatially coherent burial groups. Ward's method minimizes within-cluster variance during successive agglomeration and is well suited to identifying compact spatial clusters from two-dimensional coordinate data [21, 22]. The spatial clusters identified through this procedure formed the analytical framework for subsequent comparisons of mortuary attributes.

2.3 Analysis of mortuary variables

Following the identification of spatial clusters, four categories of mortuary variables were analysed to evaluate whether variation in cemetery organization corresponded to differences in social organization: burial investment, burial orientation, number of individuals per burial, and biological sex.

Burial investment was represented by burial volume, which was analysed both as a continuous variable and as categorized classes based on its frequency distribution. Burial orientation was examined to evaluate the degree of consistency in mortuary practice among spatial clusters. number of individuals per burial was classified as single, double, or triple burials to compare co-burial patterns across the cemetery.

Biological sex was analysed separately for single and multiple burials. Individuals in single burials were classified as male, female, or indeterminate according to the excavation report. For multiple burials, sex

combinations (e.g., male–male, male–female, female–female, and male–male–female) were recorded to preserve the internal composition of each burial. Individuals of indeterminate sex were retained as a separate category throughout the analysis to avoid potential bias resulting from forced assignment.

Differences among spatial clusters were evaluated using descriptive statistics and graphical visualization. Burial volume was summarized using box plots and violin plots, burial orientation was illustrated with rose diagrams, and number of individuals per burial and sex composition were compared using proportional charts. Together, these analyses were used to assess whether variation in mortuary practices corresponded to the spatial organization of the cemetery and to provide a basis for interpreting patterns of social organization.

3 Results

3.1 Spatial organization of the Mohuchahan Cemetery

Ward's hierarchical clustering was performed using the planar coordinates of the 225 burials to investigate the internal spatial organization of the Mohuchahan Cemetery. Although silhouette coefficient analysis identified K = 3 as the statistically optimal solution, the four-cluster solution (K = 4) was adopted because it corresponds more closely to the observed cemetery layout and provides greater discrimination among subsequent mortuary variables (Fig. 3).

The analysis identified four spatial clusters comprising 61, 39, 70, and 55 burials, respectively (Fig. 4). The clusters form discrete spatial groups rather than a random distribution of burials. Cluster 3 occupies the southwestern part of the cemetery, Cluster 2 lies northeast of Cluster 3, Cluster 1 is concentrated in the east-central area, and Cluster 4 is located primarily in the northern part of the cemetery. Together, the four clusters define a continuous southwest–northeast spatial arrangement.

Nearest-neighbor analysis indicates strong local spatial association among the burials. The mean nearest-neighbor distance for the cemetery is 2.56 m, with a median of 2.37 m. Mean nearest-neighbor distance varies among the four clusters, ranging from 2.19 m in Cluster 3 to 2.88 m in Cluster 4 .

Comparison with the excavation zoning shows that Clusters 1–3 are entirely located within Zone I, whereas Cluster 4 corresponds exclusively to Zone II. This correspondence indicates that the spatial clusters are consistent with the primary division of the cemetery into two burial zones.

3.2 Spatial variation in burial investment

Burial volume was analysed as a measure of mortuary investment. Among the 225 burials included in the analysis, burial volume ranges from 0 to 8.1 m^3, with a mean of 2.73 m^3 and a median of 2.69 m^3. The distribution is relatively compact, with no exceptionally large burials.

Burial volume differs among the four spatial clusters (Fig. 5). Cluster 1 has the largest burial volumes (mean = 3.43 m^3, median = 3.40 m^3), followed by Cluster 4 (mean = 3.13 m^3, median = 3.11 m^3). Cluster 2 shows intermediate values (mean = 2.63 m^3, median = 2.41 m^3), whereas Cluster 3 has the smallest burial volumes (mean = 1.64 m^3, median = 1.54 m^3).

To facilitate comparison, burial volume was classified into four categories using the natural-break (Jenks) method: low (0–1.5 m^3), medium (1.5–2.9 m^3), high (2.9–4.4 m^3), and very high (4.4–8.1 m^3). Clusters 1 and 4 contain relatively higher proportions of high- and very high-volume burials, whereas Cluster 3 is dominated by low-volume burials. Cluster 2 exhibits an intermediate distribution between these patterns (Fig. 5).

3.3 Spatial variation in burial orientation

Burial orientation was analysed to examine directional patterns across the cemetery. Overall, burial orientations are strongly concentrated, with most burials aligned close to due north or north-by-east. All four spatial clusters exhibit a high degree of internal consistency in burial orientation.

Mean burial orientation differs slightly among the spatial clusters (Fig. 6). Mean orientations are approximately 22° for Cluster 1, 24° for Cluster 2, 18° for Cluster 3, and 3° for Cluster 4. Clusters 1–3 are oriented predominantly north-by-east, whereas Cluster 4 is oriented more closely toward due north.

Frequency distributions also differ among the four clusters. In Clusters 1–3, most burials fall within the 0°–60° range, particularly the 0°–30° and 30°–60° intervals. By contrast, Cluster 4 contains a greater proportion of burials within the 0°–30° and 330°–360° intervals, indicating a stronger concentration around due north.

3.4 Co-burial patterns

Co-burial patterns were analysed based on both the number of interred individuals and the composition of multiple burials. Among the 225 burials, 187 (83.1%) are single burials, 24 (10.7%) are double burials, and 3 (1.3%) are triple burials, whereas the remaining 11 burials contain no identifiable human remains. Single burials therefore constitute the predominant burial form at the Mohuchahan Cemetery.

The proportions of single, double, and triple burials are broadly comparable among the four spatial clusters (Fig. 7). Single burials account for 87.1% of burials in Cluster 1, 79.5% in Cluster 2, 83.6% in Cluster 3, and 80.0% in Cluster 4. Double burials occur in all four clusters, whereas triple burials are present only in Clusters 2–4. Cluster 4 contains the highest proportion of multiple burials, whereas Cluster 1 contains the highest proportion of single burials.

The composition of multiple burials varies among the spatial clusters (Fig. 8). Male–female pairs represent the most common co-burial type in Cluster 1, accounting for 66.7% of all multiple burials within the cluster. By contrast, male–male pairs predominate in Cluster 2 (60.0%) and Cluster 3 (42.9%),

together with smaller numbers of male–female, male–indeterminate, and triple-burial combinations. Cluster 4 exhibits the greatest diversity of co-burial combinations, including male–male, male–female, female–female, male–indeterminate, and female–female–female burials, with male–male pairs accounting for 44.4% of multiple burials.

3.5 Sex composition

Sex composition was analysed using individuals recovered from single burials. Male, female, and indeterminate individuals are represented in all four spatial clusters.

The proportions of males and females vary among the spatial clusters (Fig. 9). Males account for 54.1% of single burials in Cluster 1, 48.4% in Cluster 2, 39.2% in Cluster 3, and 50.0% in Cluster 4. Corresponding proportions of females are 31.1%, 32.3%, 47.1%, and 45.5%, respectively. Individuals of indeterminate sex comprise between 4.5% and 19.4% of single burials across the four clusters.

Cluster 1 contains the highest proportion of males, whereas Cluster 3 contains the highest proportion of females. Cluster 4 exhibits the most balanced male-to-female ratio among the four spatial clusters.

3.6 Spatial variation in grave-good investment

Grave-good investment were analysed based on the numbers of bronze objects, ceramic vessels, bone objects, and total grave goods recovered from each burial. Across the 225 burials, the mean number of grave goods is 2.03 per burial, with a median of one item and a maximum of 17 items. Bronze objects constitute the most abundant category, averaging 1.03 items per burial, followed by ceramic vessels (0.78) and bone objects (0.16).

The distribution of grave-good categories differs among the four spatial clusters (Fig. 10). Cluster 2 contains the highest average number of bronze objects (1.31 per burial), followed by Cluster 3 (1.21) and Cluster 1 (1.16), whereas Cluster 4 contains substantially fewer bronze objects (0.45 per burial). Ceramic vessels display a different spatial pattern. Cluster 4 contains the highest average number of ceramic vessels (1.11 per burial), whereas Clusters 1, 2, and 3 average 0.71, 0.64, and 0.70 vessels per burial, respectively. Bone objects are comparatively uncommon throughout the cemetery but occur most frequently in Cluster 2 (0.31 per burial), compared with 0.11, 0.03, and 0.15 in Clusters 1, 3, and 4, respectively.

The total number of grave goods also varies among the four spatial clusters. Cluster 2 has the highest average number of grave goods (2.28 items per burial), followed by Cluster 1 (2.06), Cluster 3 (1.95), and Cluster 4 (1.91).

4 Discussion

4.1 Cemetery Spatial Organization and Social Organization

The Mohuchahan Cemetery exhibits a well-defined internal spatial structure rather than a random distribution of burials. Although silhouette analysis identified a three-cluster solution as the statistically optimal result, the four-cluster model corresponds more closely to the observed cemetery layout and the spatial distribution of mortuary variables. This comparison illustrates that statistical optimization alone is insufficient for archaeological interpretation and that clustering results should be evaluated together with independent archaeological evidence.

The identified spatial clusters reveal a multi-level pattern of cemetery organization. Cluster 4 corresponds entirely to Zone II, whereas Clusters 1–3 are located within Zone I, indicating that the cemetery comprises both primary burial zones and secondary spatial clusters. Such a pattern suggests that burial placement followed a structured spatial logic rather than accumulating through successive, uncoordinated interments.

Spatial clustering alone, however, cannot be interpreted as direct evidence of kin groups or social-status groups [11]. Recent studies have emphasized that the social significance of cemetery spatial patterning should be evaluated by integrating multiple categories of mortuary evidence, including burial investment, grave-good investment, burial orientation, co-burial practices, and biological attributes [23–27]. The Mohuchahan Cemetery provides an opportunity to examine these relationships because its well-preserved spatial information can be directly linked to multiple dimensions of mortuary variability.

Comparison of the four spatial clusters reveals systematic differences in mortuary practices. Cluster 1 is characterized by relatively greater burial investment and a higher proportion of male burials, whereas Cluster 3 contains smaller burials and higher burial density. Cluster 2 occupies an intermediate position between these patterns, while Cluster 4 is spatially distinct, corresponds entirely to Zone II, exhibits burial orientations closer to due north, and contains a slightly higher proportion of multiple burials. These observations indicate that spatial organization was closely associated with variation in mortuary behaviour.

Burial investment provides further evidence for this relationship. Clusters 1 and 4 contain relatively higher proportions of large burials, whereas Cluster 3 is dominated by small- and medium-sized burials. Cluster 2 again occupies an intermediate position, indicating gradual variation in mortuary investment across the cemetery rather than sharply bounded social categories. At the same time, the cemetery contains no exceptionally large or monumentally constructed burials, with the maximum burial volume reaching only 8.08 m^3. This pattern differs from strongly hierarchical mortuary systems characterized by a small number of elaborate elite burials [12]. Instead, the burial evidence suggests moderate social differentiation expressed through unequal investment in burial construction without indicating a highly stratified social structure.

An additional feature of the cemetery is that differences in burial investment are more pronounced than differences in the quantity of grave goods. Although the relative proportions of bronze objects, ceramic vessels, and bone objects vary among the spatial clusters, the overall quantity of grave goods remains broadly comparable. This contrast suggests that social differentiation at the Mohuchahan Cemetery was

expressed primarily through the organization of burial space and investment in burial construction rather than through the accumulation of grave goods. Spatial organization therefore appears to have provided the principal framework through which social differentiation was materialized.

4.2 Family organization and co-burial practices

Although single burials dominate the Mohuchahan Cemetery, the presence of double and triple burials demonstrates that co-burial formed a regular component of mortuary practice rather than an exceptional phenomenon. Previous studies have shown that multiple burials provide important evidence for investigating household organization, kinship, and social relationships in prehistoric cemeteries [12]. Similar approaches have recently been applied to the Yanghai Cemetery, where GIS-based analyses highlighted the value of co-burial patterns for reconstructing community organization in prehistoric Xinjiang [25].

The overall frequency of multiple burials differs only slightly among the spatial clusters, whereas their internal composition varies more substantially. Cluster 1 is dominated by male–female pairs, Clusters 2 and 3 contain relatively higher proportions of male–male pairs, and Cluster 4 exhibits the greatest diversity of co-burial combinations. These differences indicate that co-burial practices were not spatially uniform across the cemetery and that different burial groups followed distinct mortuary practices.

The social significance of these patterns should nevertheless be interpreted with caution. Without ancient DNA or other direct evidence, co-burial cannot be assumed to represent biological kinship. Instead, the observed variation is more appropriately interpreted as reflecting differences in household organization, social affiliation, or mortuary practice rather than specific genealogical relationships. This interpretation is consistent with broader archaeological evidence indicating that Early Iron Age communities in Xinjiang practiced mixed agro-pastoral economies rather than exclusively pastoral lifeways [3, 6, 28, 29]. Under these conditions, households likely constituted the basic units of production and social organization, and variation in co-burial practices may reflect differences in the organization of these social units.

Recent ancient DNA studies of Iron Age populations across the eastern Eurasian Steppe have demonstrated that mortuary variability may correspond closely with biological relatedness and lineage organization [30]. Integrating molecular evidence with spatial and mortuary analyses therefore represents an important direction for future research on the social organization of the Mohuchahan Cemetery.

4.3 Ritual standardization and spatial variation

Analysis of burial orientation indicates a high degree of ritual standardization at the Mohuchahan Cemetery. Most burials are oriented close to due north or north-by-east, suggesting that funerary practices followed a broadly shared set of mortuary conventions [11–14]. Similar orientation patterns have frequently been interpreted as reflecting common ritual traditions and ideological frameworks within prehistoric communities.

Despite this overall consistency, moderate spatial variation is evident. Clusters 1–3 are oriented predominantly north-by-east, whereas Cluster 4 is oriented more closely toward due north. This distinction corresponds closely to the separation between Zones I and II and suggests that localized variation in mortuary practice existed within the cemetery. However, the magnitude of this variation remains limited, indicating that differences in burial organization developed within a shared ritual framework rather than representing fundamentally different funerary traditions.

The orientation data therefore complement evidence from burial investment and co-burial practices. Together, these observations suggest that the cemetery combined standardized ritual behaviour with moderate internal variability, reflecting localized differentiation within a broadly shared mortuary tradition rather than separate cultural communities.

5 Conclusions

This study investigated the relationship between cemetery spatial organization and social organization at the Mohuchahan Cemetery, an Early Iron Age burial ground on the southern piedmont of the Tianshan Mountains, Xinjiang, by integrating GIS-based spatial analysis with multiple categories of mortuary evidence. The results demonstrate that the cemetery exhibits a spatially structured organization comprising four distinct burial clusters rather than a random distribution of burials. Systematic differences in burial investment, grave-good investment, burial orientation, co-burial practices, and sex composition indicate that cemetery spatial organization reflects socially meaningful patterns of mortuary behaviour.

Among the mortuary variables examined, burial investment corresponds most closely to the spatial organization of the cemetery, whereas differences in grave-good investment are expressed primarily through variation in artifact composition rather than overall quantity. Burial orientation demonstrates a high degree of ritual standardization despite moderate localized variation, while co-burial practices reveal differences in household organization and social affiliation among burial groups. Together, these observations indicate that spatial organization provided the principal framework through which social differentiation was materialized at the Mohuchahan Cemetery.

Rather than representing a highly stratified society characterized by conspicuous elite burials, the Mohuchahan Cemetery was organized primarily around family units and local communities, with moderate social differentiation expressed through cemetery layout and differential investment in mortuary practices rather than through the accumulation of grave goods. These findings provide new archaeological evidence for understanding the social organization of the Chawuhu culture and demonstrate that increasing social complexity in the Early Iron Age of Xinjiang did not necessarily lead to highly hierarchical mortuary systems.

More broadly, this study demonstrates the value of integrating GIS-based spatial analysis with multiple dimensions of mortuary evidence for reconstructing prehistoric social organization. The analytical

framework developed here provides a replicable approach for investigating cemetery organization and social differentiation in other prehistoric cemeteries across Xinjiang and the eastern Eurasian Steppe.

Declarations

Author Contribution

JP.W. conceived the study, conducted the GIS-based spatial analysis, performed quantitative analysis, prepared the figures, and wrote the original manuscript draft.ZY.K. collected, organized, and curated the archaeological dataset, including cemetery information and burial attribute data.J.M. supervised the research design, contributed to the development of the analytical framework, and provided critical suggestions for manuscript preparation.X.Y. reviewed, revised, and critically edited the manuscript, improving its academic presentation and overall structure.SJ.H. provided technical guidance on GIS methodology, spatial analysis procedures, and archaeological visualization.All authors reviewed and approved the final manuscript.

Acknowledgments:

This research was funded by the National Social Science Fund of China (Grant No. 24CKG019) and the Archaeological Talent Development Program of China (Grant No. 2024 − 267). Additional support was provided by the Ministry of Education of the People's Republic of China, the China–Central Asia Belt and Road Joint Laboratory on Human and Environment Research, and the Key Laboratory of Cultural Heritage Research and Conservation.

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Figures

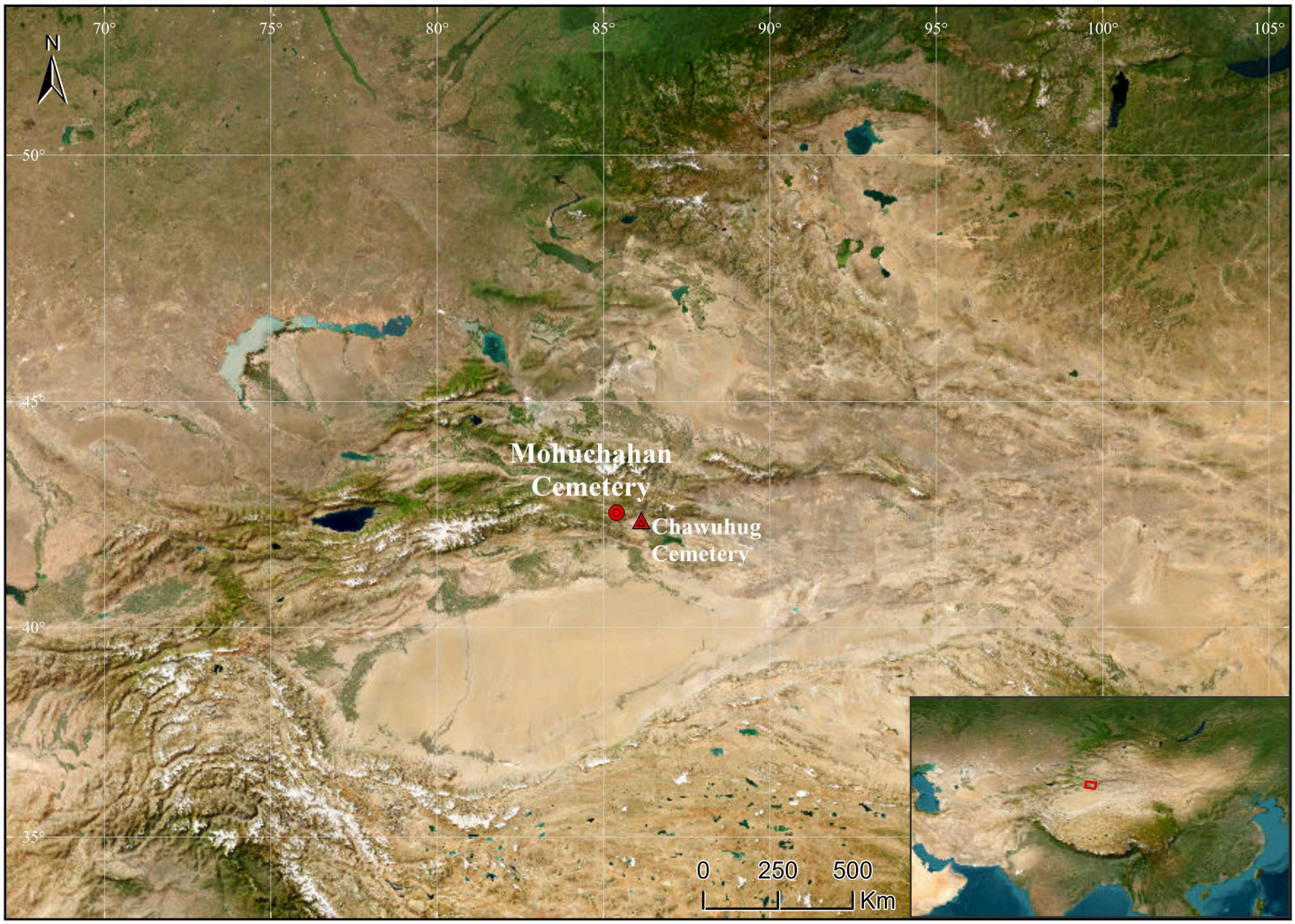


Figure 1

Location of the Mohuchahan Cemetery Basemap: Esri World Imagery. Sources: Esri, Maxar, Earthstar Geographics, and the GIS User Community (accessed May 2026).

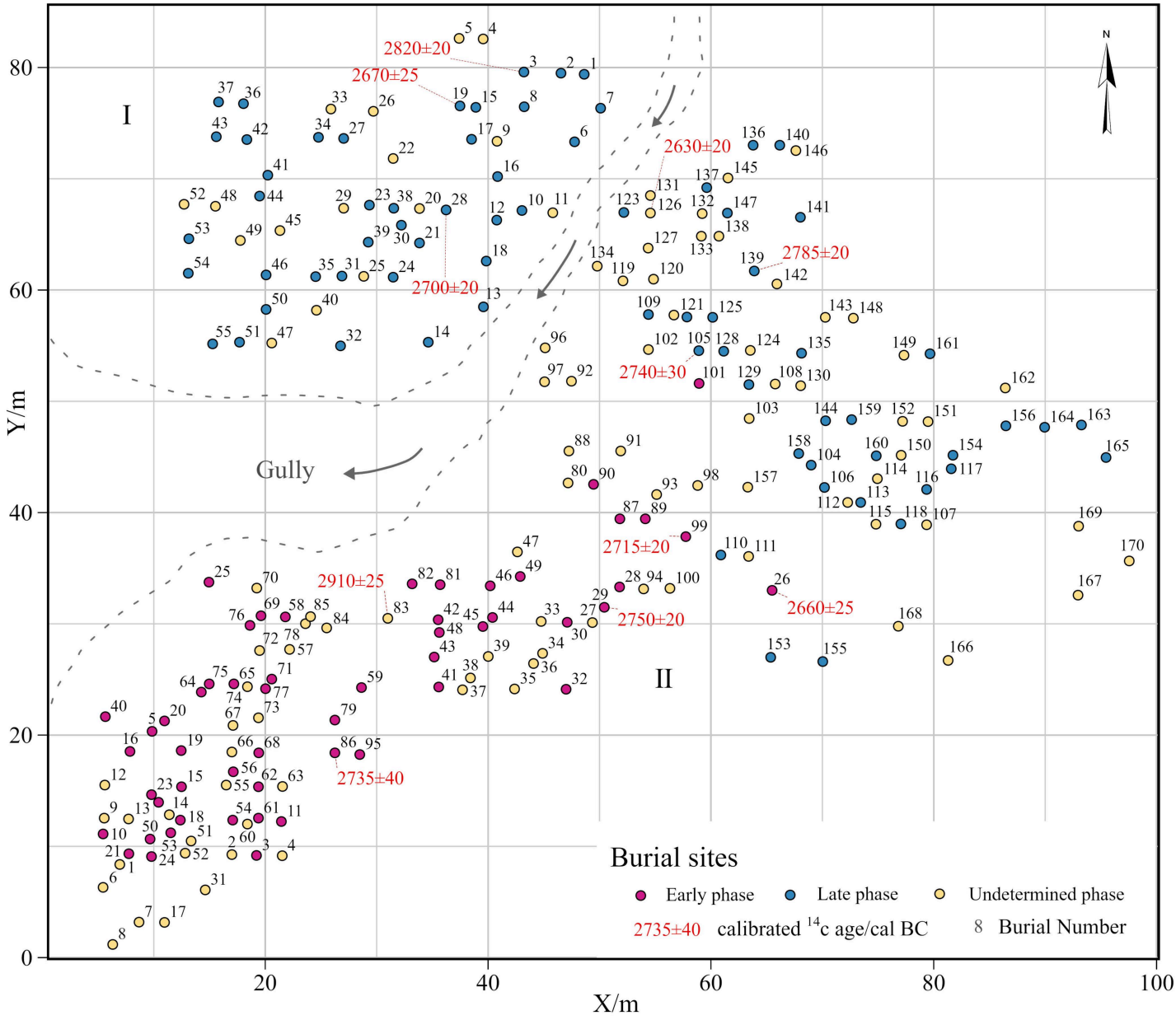


Figure 2

Spatial distribution of the 225 burials included in the analysis.

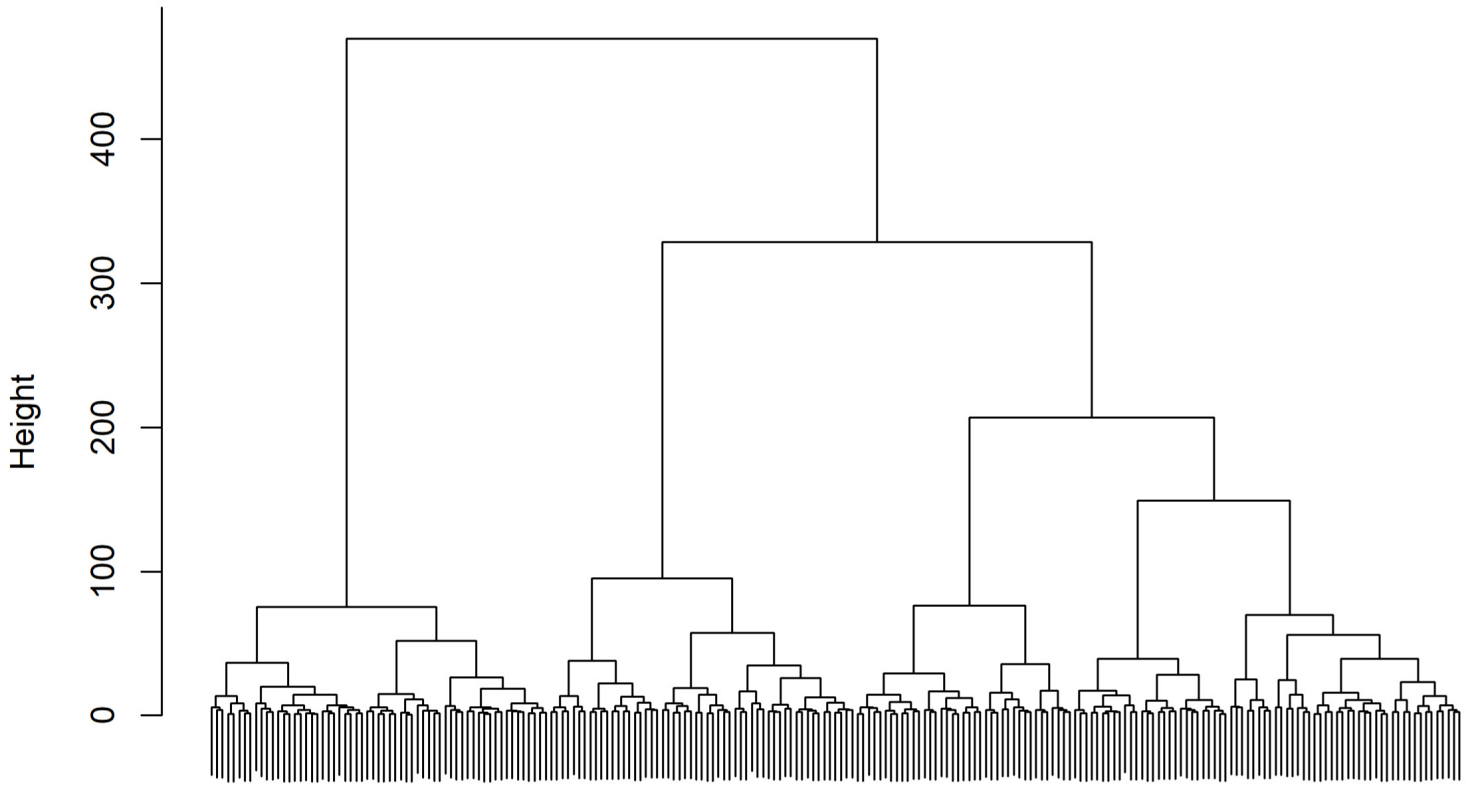


Figure 3

Ward hierarchical clustering dendrogram of the Mohuchahan Cemetery.

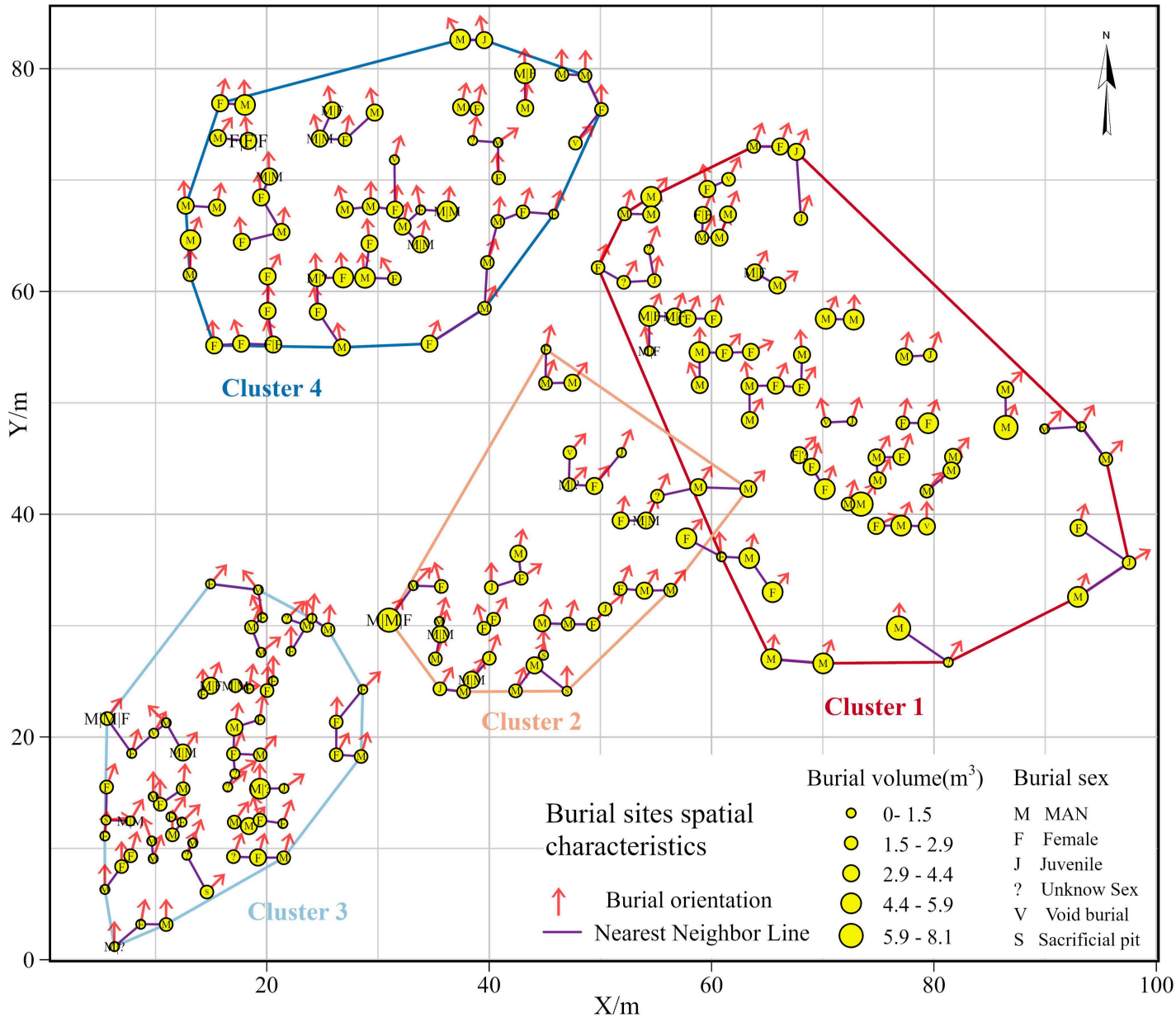


Figure 4

Spatial organization of the Mohuchahan Cemetery showing hierarchical clusters, nearest-neighbor relationships, burial volume, burial orientation, and sex composition.

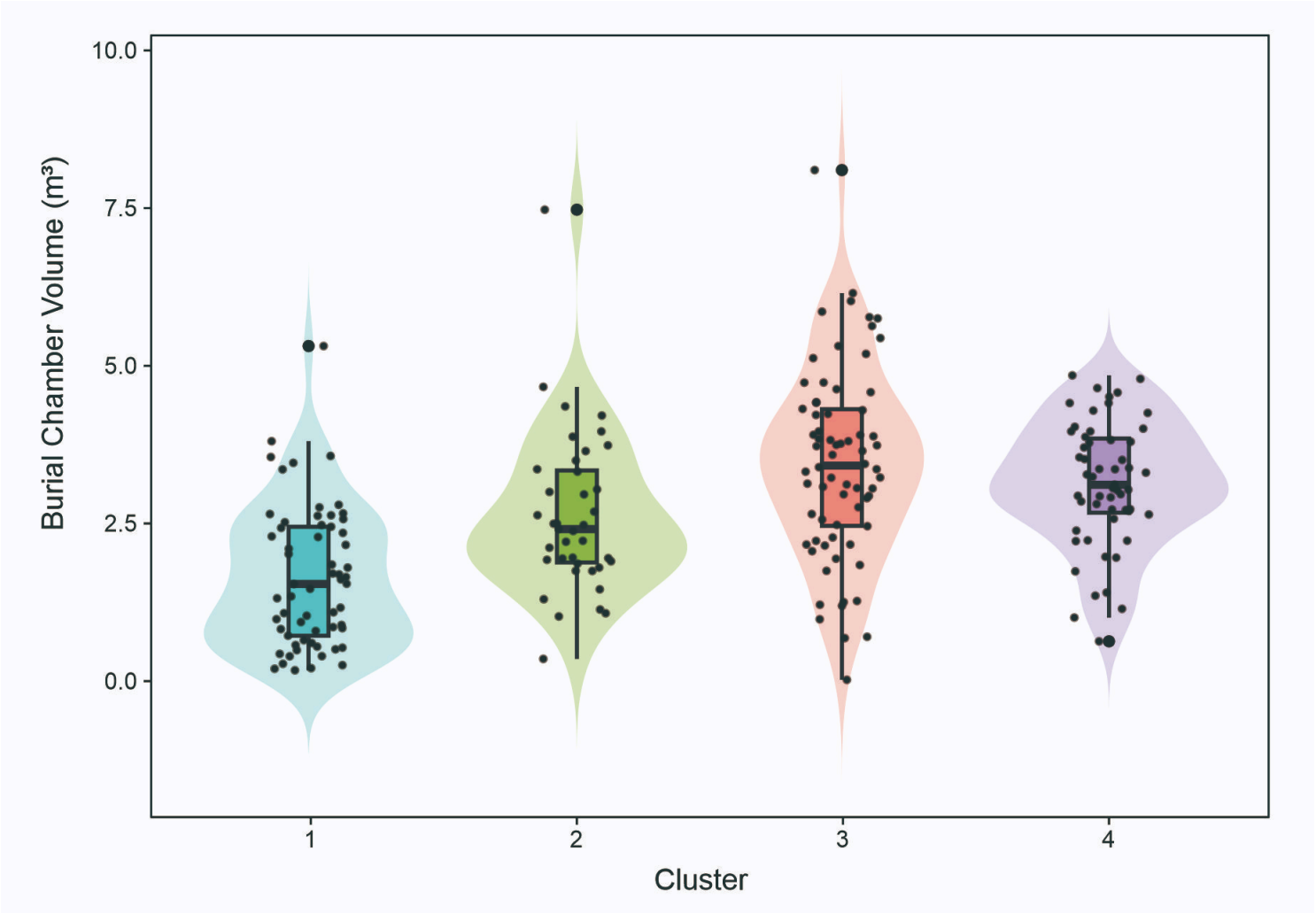


Figure 5

Distribution of burial volume among the four spatial clusters.



Figure 6

Distribution of burial orientation among the four spatial clusters.



Figure 7

Distribution of number of individuals per burial among the four spatial clusters.

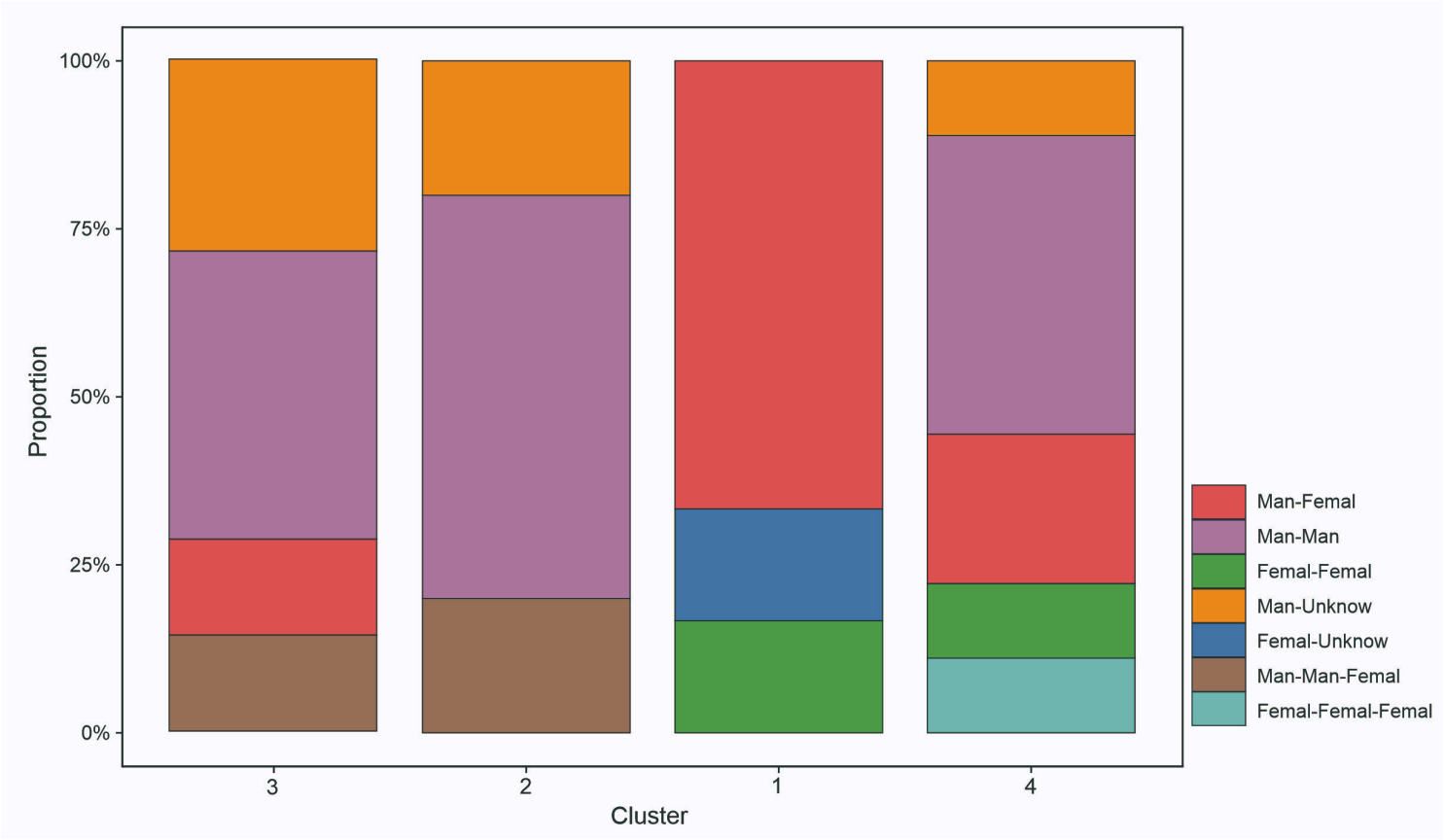


Figure 8

Composition of multiple burials in the four spatial clusters.

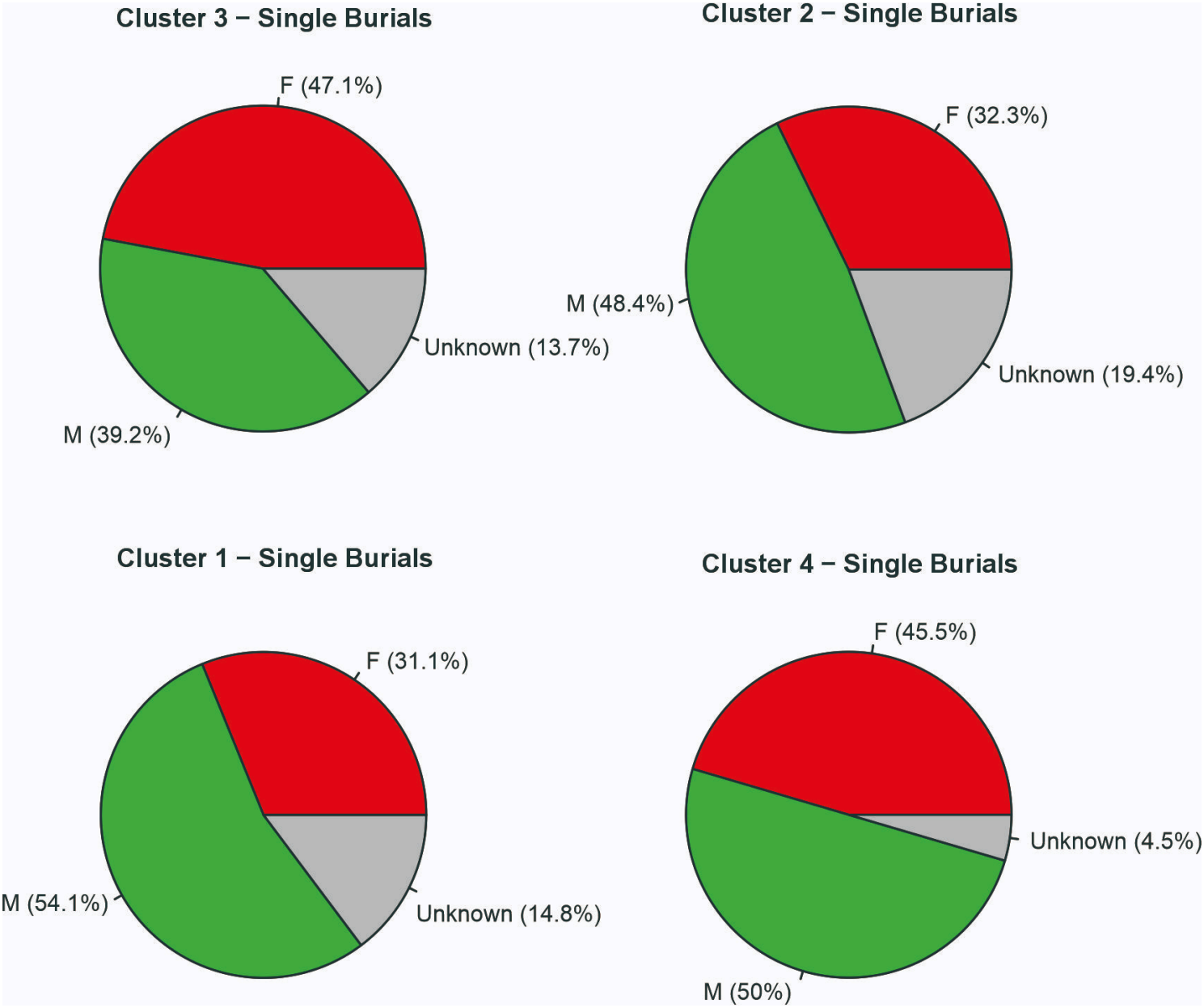


Figure 9

Sex composition of individuals in single burials across the four spatial clusters.

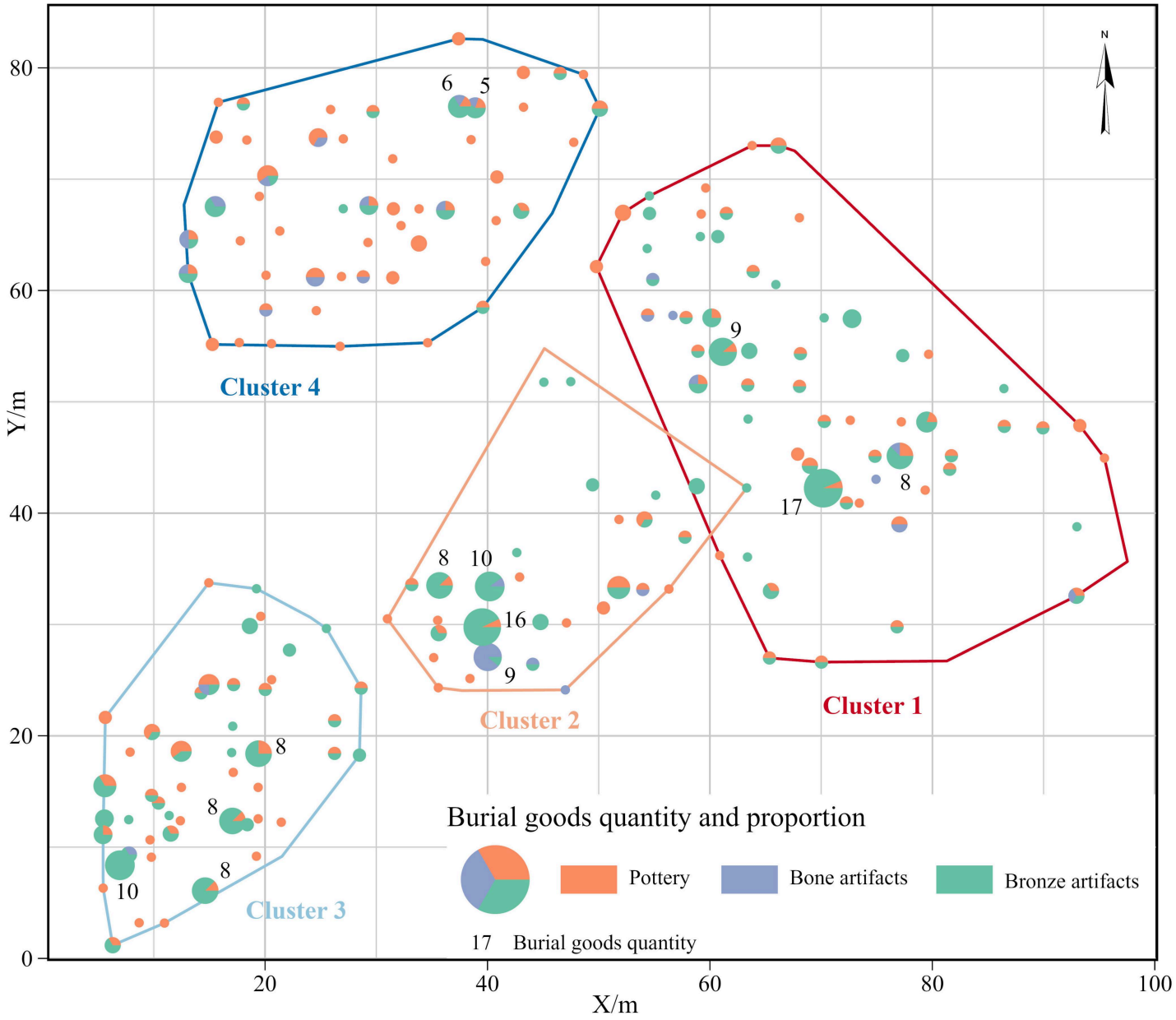


Figure 10

Distribution of grave-good investment among the four spatial clusters.

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- 01MohuchahanCemeterySpatialAnalysisAttributeData.csv
- 02MohuchahanCemeteryNearestNeighbor.csv