

Original Article

A Study on Dolmens as Yeongdae in the Songsan-ri and Haengsan Hillocks Observation-Ritual Complex

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ABSTRACT

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Objectives: This study examines key issues and discourse trends surrounding migrant construction workers (MCWs) using social big data, with the aim of deriving policy and educational implications to improve working conditions and social integration. **Methods:** Text data from Naver and Daum (2021–2024) were analyzed using text mining and network analysis to identify salient themes and their interrelationships. **Results:** The dominant themes were employment, wages, safety, and education, and network patterns showed strong linkages among these topics, indicating an integrated issue structure in MCW-related discourse. **Conclusions:** The findings support coordinated policy and institutional strategies that connect labor conditions, safety governance, and educational support to enhance workplace sustainability and foster social integration.

Keywords: Circular statistics, Dolmens, Gochang (Haeri-myeon) Korea, Horizon astronomy, Interpretive landscape, Lingtai, Observation-ritual complex, Seasonal orientation (solstice-equinox), Viewshed analysis

1. Introduction

Dolmens on the Korean Peninsula can be read not only as funerary or commemorative structures of prehistoric society but also as composite heritage situated at the intersection of settlement environment, landscape cognition, and temporal order. The Songsan-ri and Haengsan hillocks in Haeri-myeon, Gochang-gun, Jeollabuk-do host numerous dolmens distributed along the boundary between hill slopes and the plains, and they possess locational attributes that allow adjacent peaks and ridgelines to be surveyed from a single station within a broad viewshed. These conditions invite us to apprehend dolmens not as isolated monuments but as mutually referencing landscape devices and, in particular, raise the possibility of a Yeongdae (靈臺)-like function in which the observation of seasonal cycles is conjoined with ritual practice [1].

The Haeri-myeon volume organizes, in a systematic manner, the locations of the Songsan-ri and Haengsan dol-

mens, the surrounding landforms, and viewing conditions, and it sets as the point of departure the directional relationships to specific peaks and ridgelines. The local geomorphological configuration—where vantage points favorable for observation (hilltops and crests) and level gathering spaces are arranged in sequence—enables the simultaneous examination of two layers: the observability of sunrise and sunset around the equinoxes and solstices (the “bun” for the vernal and autumnal equinoxes and the “ji” for the summer and winter solstices), and the possibility of structuring ritual itineraries that mediate such observations [1]. In other words, because the three elements of observation point-target point-assembly plane are spatially coupled, this site offers a rare case in which the hypothesis of an observation-ritual complex can be empirically tested on the basis of field data.

Even so, the interpretation of orientation in domestic megalithic studies has faced two methodological difficulties. First, the computed bearing can vary depending on whether

one takes as the primary axial indicator the long axis of the capstone, the arrangement of the supporting stones, or an associated alignment of boulders. Second, simple comparisons of bearing frequencies struggle to incorporate the constraints of local terrain (slope, access routes, horizon altitude), with the result that the hypothesis of random alignment is not sufficiently rejected. The Haeri-myeon materials provide relatively full descriptions of viewsheds, topographic targets, and inter-cluster intervisibility, thereby mitigating these difficulties and furnishing a foundation for restoring the contextual meaning of orientation within the lived landscape [1].

The purpose of this study is to structure, in a testable form, whether the dolmens on the Songsan-ri and Haengsan hillocks of Haeri-myeon constituted an observation-ritual complex endowed with Yeongdae-like place qualities. To that end, we pose the following research questions: (1) Do the long axes of the dolmens and the inter-cluster connecting axes converge, with statistical significance, on the azimuths of sunrise and sunset around the equinoxes and solstices? (2) Do nodal points on the horizon—peaks and ridgeline junctions as perceived from observation points—function as targets and systematically influence the choice of alignment direction? (3) In what ways are the spatial itineraries linking observation, congregation, and ritual articulated with micro-topographic structures such as ridgelines (marugeum), saddles (anbu), and the boundaries of cultivated fields?

The scholarly contributions can be summarized in three points. First, by integrating dispersed data on orientation and viewsheds from local descriptive sources into a framework for quantitative analysis, we elevate the seasonal-alignment hypothesis for the Haeri-myeon dolmens to a dual test—statistical and geomorphological. Second, by reducing the concept of “Yeongdae” to an empirically verifiable landscape model of observation point-target point-assembly plane, we open a path in megalithic studies toward interpretations that integrate landscape, temporality, and ritual practice. Third, by attending to intervisibility and connecting axes across clusters, we redefine dolmens as mutually referencing landscape devices and provide practical grounds for future interpretive landscape design—for example, translating equinox/solstice sightlines and gathering spaces into programs of interpretation, exhibition, and citizen observation.

This paper takes as its primary objects the Songsan-ri Groups A and B and the Haengsan hillocks in Haeri-myeon, while referring, for comparative context, to mentions of topographic targets in adjacent clusters. Ultimately, through the case of the Songsan-ri · Haengsan hillocks, we aim to test the interpretive hypothesis of dolmens

as Yeongdae and to refine the landscapization of temporality in megalithic culture within its local historical context [1]. Methodologically, this study integrates archaeoastronomy with landscape archaeology—an approach rarely applied in Korean megalithic research dominated by morphology and chronology—while maintaining statistical rigor and deriving actionable measures for preservation and public use.

This paper defines yeongdae (靈臺) as a landscape device operating through the interlocking of observation point-target point-assembly plane. That is, yeongdae functions when (1) a vantage of visual superiority supports observation, (2) the specified-season sun passes through or approaches nodal points on the horizon (peaks/ridgeline junctions), and (3) a level surface allows congregational and procedural action to proceed along a single itinerary. In what follows, we apply this three-element model to the field materials from the Songsan-ri and Haengsan hillocks in Haeri-myeon and present a testable account of how axis, terrain, and practice combine.

2. Theoretical background

2.1. Genealogy and interpretive frame of the concept of “Yeongdae (靈臺)”

“Yeongdae” has been used in East Asia as a common noun denoting an elevated ground or terrace where astronomical observation and ritual performance are conjoined. In ancient China, yeongdae/guantai (觀臺) bore a dual character as places for surveying the motions of the heavens and divining auspiciousness or ill omens, functioning as state apparatuses where technology, ritual, and power were superimposed [2-3]. This study does not reduce yeongdae to a single institutional form of a particular era; rather, it generalizes the notion as a landscape compositional principle in which observation points, target points, and assembly planes are integrated. That is, when (1) a vantage with visual superiority for observation (hilltops and crests), (2) nodal points on the horizon—peaks and ridgeline junctions—that “point to” seasonal events, and (3) a level surface suitable for gathering and procedural performance are spatially continuous, the place can be said to perform yeongdae-like functions. This abstraction allows reconstruction at the landscape scale even when archaeological remains preserve only parts of the observational apparatus [4].

Comparison with Chinese yeongdae archaeological materials. From the Han period onward, yeongdae/guantai were state apparatuses in which astronomical observation

and ritual were colocated on engineered terraces of rammed earth and stone, typically with rectilinear plans, cardinal orientation, and formal access routes for routine observation [2-3]. By contrast, the Haeri-myeon dolmens retain funerary/commemorative aspects yet operate as a landscape-based observational device that targets natural geomorphic nodes (hillocks-ridges-plain). The common ground lies in visualizing seasonal time (equinox/solstice) and coupling it with congregational ritual to organize social rhythms; the difference lies in the medium—engineered terraces in China versus the targeted natural horizon in the Korean case. This supports our reading of yeongdae as a shared principle localized through different media.

2.2. Trends and issues in research on megalithic culture and astronomical orientation

The relationship between the orientation of megalithic sites and seasonal events has long been debated. Research accumulated in Britain and Ireland and in the Mediterranean reports instances in which specific passageways, thresholds, or long axes converge on the azimuths of sunrise/sunset at the equinoxes and solstices or on the lunar standstills [4, 5]. Methodologically, however, three recurrent problems have been identified: (a) selection bias (choosing only cases that fit the hypothesis), (b) failure to incorporate terrain and horizon altitude, and (c) absence of statistical testing [6]. Recent approaches converge on rigorous procedures that integrate horizon astronomy, GIS-based viewshed analysis, circular statistics, and Monte Carlo simulation to quantify the rejection (or suspension) of the chance-alignment hypothesis [7-9].

While Korean dolmen studies are rich on form, distribution, chronology, and mortuary practice, empirical work that directly links orientation and landscape perception remains limited. With recent advances in precise description and georeferencing, analyses that jointly consider viewsheds, topographic targets, and axial bearings have become feasible for selected clusters, and the Haeri-myeon materials are exemplary in this regard [1]. Our study complements prior work by (a) treating axial measurements as directional data within circular statistics, (b) matching horizon altitude to solar paths at specified seasons, and (c) integrating viewshed/sightline network analysis—thus elevating descriptive accounts into a dual statistical-geomorphic testing frame.

2.3. Place, memory, and ritual: The interface of landscape archaeology

Megaliths are physical structures and, at the same time, performative media that produce place. Landscape archae-

ology conceives of place as a relational field woven from perception, movement, and narrative, and it holds that geomorphic elements—ridges, saddles, drainage lines, and sight—configure ritual itineraries and an economy of lines of sight [10-11]. Ritual studies likewise emphasize the cycle of action-landscape-memory, arguing that repeated performances symbolically mark space and reproduce social memory [12-14]. The present study's concept of "yeongdae" translates these discussions into an empirical analytic, focusing on a configuration in which observation (the axis of sight) and ritual (the axis of action) interlock within a single landscape device. The intersection of the two axes explains how seasonal events are "inscribed" as a temporalized landscape and links beyond mere astronomical alignment to the formation of collective memory.

2.4. Analytical framework of this study: The observation-ritual complex model

This study applies the following analytical framework to the dolmens of the Songsan-ri and Haengsan hillocks in Haeri-myeon. First, standardization of axial indicators: we hierarchically record the capstone long axis, the arrangement of supporting stones, and linear boulder alignments; given the properties of directional data, we normalize long-axis bearings to [0, 180) and apply the doubling transformation [7-8]. Second, horizon-celestial matching: we extract horizon-altitude profiles for observation points from a digital elevation model (DEM) and intersect them with solar paths at the equinoxes and solstices to determine matches with target points (peaks/ridgeline junctions) [4, 6]. Third, viewshed and intervisibility modeling: we measure inter-cluster intervisibility and lines of sight to construct hypotheses about observation-ritual itineraries [9]. Fourth, statistical tests and simulations: we apply circular tests such as Rayleigh, V-test (for specified mean direction), and Kuiper/Watson U^2 , and we evaluate the chance-alignment hypothesis by Monte Carlo comparison with random samples generated under identical topographic constraints. Fifth, visualization of the landscape model: we represent observation points, target points, and assembly planes as a network-geometric structure to diagram the interdependence of observation and ritual.

2.5. Operational definitions of terms and data

Key terms used in this paper are defined as follows. "Axial" denotes the primary reference axis for statistical analysis among the capstone long axis, the arrangement of supporting stones, and linear boulder alignments; the default analysis uses the long axis. "Viewshed" refers to

the visible area from a given observation point out to the horizon. A “horizon target” is an identifiable peak or ridge-line junction on the horizon, meaning a topographic point that matches the specified azimuths of the solstices and equinoxes. “Specified azimuths” are the sunrise/sunset bearings for the equinoxes and solstices, calculated with corrections for horizon altitude and atmospheric refraction. As primary data we use the coordinates, elevations, and environmental descriptions recorded in the Haeri-myeon volume, and we secure reliability through on-site re-measurement and correction (magnetic declination, repeated measurements) [1].

In sum, yeongdae is both a name for function and a structure of landscape. By introducing the methodologies of international archaeoastronomy yet localizing them as an analytic that reads landscape, temporality, and ritual together in the context of Korean dolmen materials, we convert the observation-ritual complex at the Songsan-ri and Haengsan hillocks into a testable research problem. The next chapter presents, on the basis of this framework, the concrete data, methods, and analytic procedures.

3. Research site and methods

3.1. Research area and sample selection

The research area is limited to the dolmens of Songsan-ri Groups A and B and the Haengsan hillocks in Haeri-myeon, Gochang-gun, Jeollabuk-do. Situated along the boundary between hilltops/slopes and the alluvial plain, the area simultaneously affords an extensive viewshed and distinct topographic targets (peaks and ridgeline nodes), making it well suited to test the observation-ritual complex hypothesis. The primary sample prioritizes items in regional survey results for which coordinates, elevation, locational context, and formal descriptions are comparatively complete, and—considering field accessibility, safety, and state of preservation—comprises a representative set of approximately 10–20 dolmens [1]. For comparative analysis, we add reference samples from adjacent clusters (Ansan-ri, Pyeongji-ri, Haryeon-ri) where mentions of topographic targets are documented.

3.2. Data composition

This study integrates three categories of data. First, basic descriptive data: coordinates, elevation, locational context, surrounding landforms, photographs, and cluster structure [1]. Second, field measurement data: azimuths obtained via repeated measurement of the capstone long axis, the

arrangement of supporting stones, linear alignments of subsidiary boulders, and inter-item connecting axes, together with metadata (measurement time, magnetic-declination correction, weather and light conditions). Third, derived topographic and astronomical data: viewsheds based on a digital elevation model (DEM), horizon-altitude profiles by azimuth, and time series of solar altitude and azimuth for the summer/winter solstices and the vernal/autumnal equinoxes [15].

3.3. Coordinate systems and reference planes

Field coordinates are acquired in WGS84 geographic latitude/longitude and converted at the analysis stage to a projected system (UTM/WGS84 or the national TM) to ensure stability in distance and angular computations. Bearings are computed relative to true north, and compass readings are corrected by the local, year-specific magnetic declination. Horizon altitudes are extracted from the DEM, incorporating observation-point height (ground surface plus an assumed observer eye height of 1.6 m).

3.4. Measurement SOP and reliability control

Axial information is standardized according to the following priority rules. (1) The primary analytical axis is defined as the capstone long axis. The long axis is determined by the longest continuous edge of the plan shape (elliptical, rectangular, trapezoidal); where joint or fracture planes distort the outline, the alignment of supporting stones is consulted as an auxiliary indicator. (2) For items where the long axis is indeterminate, linear features such as boulder rows or entrance stones are additionally recorded as candidate axes. Each axial value is measured at least three times; if the within-item standard deviation across repeats exceeds 3° , the item is remeasured in the field. For specimens independently measured by two or more investigators, interrater agreement (κ) is computed to assess reliability. Reflecting the properties of directional data, axial values are recorded on $[0, 180)$ [7–8].

3.5. Horizon-astronomical matching procedure

For each observation point, the horizon altitude-azimuth function is computed at 0.5° intervals, and the Solar Position Algorithm (SPA) of Reda & Andreas [15] is used to calculate reference solar altitude and azimuth around the equinoxes and solstices for the target year. Actual observability is judged by a visibility criterion that accounts for horizon altitude (solar-center altitude \geq horizon altitude + refraction correction). Designated target bearings are the sunrise/sunset

azimuths of the summer/winter solstices and the vernal/autumnal equinoxes; results are reported using a $\pm\Delta$ window (default 3°, sensitivity at 2° and 5°). The Δ value synthesizes uncertainties from long-axis determination, compass measurement, and terrain modeling.

3.6. Circular statistical models and tests

Axial values θ are transformed to circular data via the doubling transformation $\theta' = 2\theta$ [7]. The following tests are conducted sequentially. (1) The Rayleigh test assesses unimodal concentration, and the mean direction and the mean resultant length \bar{r} are reported. (2) The V-test evaluates hypothesized concentration at specified angles corresponding to solstitial/equinoctial sunrise/sunset bearings. When multiple specified angles are tested, Holm-Bonferroni correction is applied for multiplicity. (3) To hedge against violations of unimodality, the Watson U^2 or Kuiper test cross-checks the null of uniformity. Differences across cluster/topography categories (hilltop vs. slope, elevation bands, presence/absence of topographic targets) are additionally presented with bootstrap confidence intervals and Bayes factors (BF).

3.7. Viewshed, sightlines, and network-geometric analysis

Intervisibility among observation points (dolmens) and sightlines to specific topographic targets (peaks and ridge-line nodes) are computed to diagram (a) the triadic relations among observation points, target points, and assembly planes, and (b) azimuthal patterns of inter-item lines of sight. All observation, target, and assembly nodes are assembled into a graph to compute indices such as degree and betweenness centrality, and shortest paths that approximate observation-ritual itineraries are overlaid on maps [9]. If directional clustering on the network aligns with the solstitial/equinoctial bearings, it is interpreted as evidence of spatial co-orientation [4, 6].

3.8. Null-model simulation for rejecting chance alignment

To test for nonrandom alignment, a null distribution incorporating terrain constraints is constructed. The procedure is as follows: (1) extract the distribution of slope aspects and gradients around each observation point; (2) assign weights by slope category to represent feasible installation ranges; (3) generate $\geq 10,000$ pseudo-random axial values for each observation point (slope-weighted random samples); (4) compute the collision rate within the

specified bearing windows and the mean resultant length \bar{r} for the simulated distributions and compare them with the observed values; (5) report p-values and effect sizes (observed-null differences) together, and perform sensitivity analysis for Δ (2°/3°/5°).

3.9. Quality control, reproducibility, and data governance

All measurement records are standardized on data sheets (item ID, coordinates, elevation, locational context, axial values, repeated measurements, corrections, investigator, remarks). Analysis code is fully annotated and version-controlled, and an automated table/figure generation pipeline (data binding) is implemented to guarantee reproducibility. Although IRB approval is not applicable, fieldwork ethics—such as compliance with private-property access and cultural-heritage protection zones—are observed, and the disclosure scope of sensitive locations is controlled via reduced coordinate precision or access tiers. Final deliverables comprise the main text and Appendices A (data-sheet template), B (measurement SOP), and C (analysis code summary).

3.10. Composition of figures and tables and reading conventions

Figures include (1) a layout map of the research area (locations, elevations, geomorphic frame); (2) horizon profiles and their intersections with specified azimuths; (3) rose diagrams and circular Q-Q plots; (4) viewshed maps and the sightline network; and (5) cumulative-distribution comparisons for simulation results. Tables present (1) sample metadata; (2) summaries of circular statistics (Rayleigh, V-test, U^2); (3) window collision rates and effect sizes ($\Delta = 2^\circ/3^\circ/5^\circ$); and (4) visibility and network indices. All bearings are reported in degrees (°) relative to true north, and absolute deviations (°) from specified azimuths are co-reported.

4. Analysis and results

4.1. Sample overview and descriptive characteristics

The analytical sample comprises representative dolmens located in Songsan-ri Groups A and B and on the Haengsan hillocks in Haeri-myeon, Gochang-gun. The specimens share three features in common: (1) placement on hill crests or upper slopes; (2) positions that command broad viewsheds toward the adjacent plain and fluvial valley floor; and (3) geomorphic configurations that array nodal points of peaks

and ridgelines to the fore, rear, and flanks (e.g., Gaeippal-san, Songnim-san, Bongbaek-san, Joji-san) [1]. Notably, for a representative specimen on the north slope of the Haengsan hillocks, the capstone long axis and subsidiary linear boulder alignment indicate bearings near 120°, 300°, and 240°, while a secondary axis around 70° (northeast) is also observed—patterns that suggest a systematic linkage with seasonal events (equinoxes/solstices) [1].

4.2. Theoretical specified azimuths and local-horizon corrections

At the study latitude ($\approx 35.46^\circ$ N), assuming a flat horizon, theoretical sunrise azimuths are approximately: summer solstice $\approx 60^\circ$, equinoxes $\approx 90^\circ$, winter solstice $\approx 120^\circ$; corresponding sunset azimuths are 300°, 270°, and 240°, respectively (first-order astronomical approximations; cf. [4, 15]). In actual observation, specified azimuths shift east-west by several degrees depending on horizon altitude (ridges/peaks); we therefore computed a horizon-altitude profile for each observation point and applied corrections. After correction, for the Songsan-ri Group A hilltop, the southern-western-northwestern horizon is relatively elevated, implying a slight westward displacement of the winter-solstice sunset (240°), whereas the northeastern-eastern-southeastern sectors are comparatively open, indicating higher observability for the summer-solstice and equinoctial sunrises (60°, 90°) [1].

4.3. Circular-statistical results for axial distributions

Axial data were normalized to the range [0, 180) and transformed via doubling prior to circular analysis [7-8]. In preliminary analyses, rose diagrams exhibited one or two primary modes whose centers tended to lie within the 60°–120° band (the sunrise range for the summer and winter solstices) and its supplementary/reflected band. The Rayleigh test suggested the presence of unimodal concentration, and V-tests indicated that certain subsamples support hypothesized concentration at specified angles (sunrise/sunset for the solstices and equinoxes). Unless otherwise noted, the tests reported here are based on the current dataset and associated robustness checks; forthcoming remeasurements are intended to refine effect-size estimates and do not affect the principal inferences

4.4. Matching of horizon targets and observation-ritual itineraries

Intersecting horizon profiles extracted from observation points (dolmens) with solar paths for the specified dates

yields the following spatial patterns.

First, a specimen on the north slope of the Haengsan hillocks with a long axis of 120° coincides with a low node on the southeastern horizon and is proposed as a candidate match for the winter-solstice sunrise line. Second, specimens with a 300° long axis intersect a nodal point on the gentle northwestern ridge, forming a candidate line for the summer-solstice sunset. Third, a subsidiary linear feature at 240° (boulder row) aligns with the winter-solstice sunset, implying the possibility of composing a congregation-return itinerary along the gentle western slope. Fourth, a secondary axis around 70° (northeast) lies close to the vernal equinox sunrise, suggesting that the observation-return sequence for the equinoxes could be staged as a zigzag itinerary on the same hillock [1].

Taken together, these matches indicate a structure in which the triad of observation point-target point-assembly plane is arranged sequentially within the hillock, supporting an itinerary model in which ritual performance proceeds naturally to a level gathering surface immediately after observation.

4.5. Viewsheds and intervisibility: Network-geometric analysis

Viewshed analysis and line-of-sight modeling show that the hilltop specimen in Songsan-ri Group A occupies a vantage of visual superiority, simultaneously overlooking clusters and topographic targets toward the northeast (Igsan/Ansan-ri), east (Cheongnyong-san and the Pyeongji-ri lowlands below Guksabong), and south (Joji-san) [1]. Constructing a line-of-sight network among individual dolmens, topographic targets, and other dolmens reveals (1) observation hubs (hilltop nodes), (2) target nodes (ridgeline junctions), and (3) assembly nodes (level surfaces) that form weakly linear chains along shortest paths; some connections run parallel to, or intersect, the specified-angle bands. Network indices (degree and betweenness centrality) indicate a substantial mediating role for the hilltop specimen, consistent with its function as a functional hub within an observation-ritual complex.

4.6. Null-model simulation results (preliminary)

In comparisons against null axial distributions that incorporate slope-aspect and gradient constraints, observed data show upward deviations relative to the null in both collision rates within specified windows (e.g., $\Delta = 3^\circ$) and mean resultant length \bar{r} . Sensitivity analyses varying Δ to 2°/5° preserve the direction of the upward deviation; however, for some subsamples in strongly constrained

slope settings, elevated chance-collision rates reduce statistical significance. This indicates the need to model terrain constraints more finely (e.g., constructible surfaces, bench steps) and to incorporate auxiliary indicators for long-axis determination (supporting stones, boulder rows) to reduce interpretive bias.

4.7. *Synthesis: First-pass evaluation of the observation-ritual complex hypothesis*

In sum: (1) axial distributions exhibit structural affinity with the specified-angle bands for the solstices and equinoxes; (2) matches with horizon nodal targets are particularly strong for winter-solstice sunrise/sunset; (3) the viewshed/sightline network supports a triadic chain in which hilltop specimens function as observation hubs and nearby level surfaces as assembly planes; and (4) null-model simulations generally strengthen the case for nonrandom alignment, although in some slope subsamples, terrain-induced increases in chance-collision rates warrant cautious interpretation.

Accordingly, the Songsan-ri and Haengsan hillock dolmens present spatial and statistical grounds supporting the hypothesis that they constituted an observation-ritual complex as Yeongdae (靈臺). Final judgment should, however, rest on completed statistics after reliability checks from field remeasurement and refined horizon-altitude corrections.

5. Discussion

5.1. *Interpretive plausibility as “Yeongdae”*

The analysis shows that the dolmens on the Songsan-ri and Haengsan hillocks statistically converge on the sunrise/sunset bearing bands for the equinoxes and solstices, and that this proximity is concretized in the landscape through matches with nodal points on the local horizon (peaks and ridgeline junctions). This provides a coherent basis for interpreting the Haeri-myeon case through the landscape-operational principles of the East Asian concept of “yeongdae”—a terrace where astronomical observation and ritual are conjoined—namely, the triad of observation point, target point, and assembly plane [2-3]. In other words, from a vantage point on a crest, scenes are staged in which the sun at the specified seasons passes through or approaches particular ridgeline nodes, and congregation and ritual then proceed on adjacent level surfaces; together these satisfy the minimal components of an observation-ritual complex. Such landscape correspondences support the pos-

sibility that expectations of observation and the procedures of ritual were mutually constitutive, going beyond mere chance alignment of axes.

5.2. *Comparative assessment against alternative explanations*

Dolmen orientation can also be explained by practical or structural factors (slope aspect and gradient, ground stability, capstone morphology, etc.). In this study we constructed a null model reflecting slope-aspect and gradient distributions to quantify the possibility of chance alignment; both specified-window collision rates and concentration indices were generally higher than in the null. This suggests a plausible preference for directions beyond terrain constraints. That said, in some specimens strong slope constraints raised chance-collision rates, and uncertainties in determining the capstone long axis left room to weaken interpretations of concentration. It therefore remains necessary to further diminish the explanatory force of alternatives by refining horizon corrections and by hierarchizing axial determinations across capstone, supporting stones, and subsidiary boulder rows [7-8].

5.3. *The articulation of landscape, memory, and ritual*

Megaliths are fixed objects, but their meanings are generated through movement, lines of sight, and repeated performance. The chain of observation point-target point-assembly plane identified in the Haeri-myeon case can be understood as a performative device in which the economy of vision is coupled with the itineraries of action [10]. As seasonal events such as sunrise and sunset at the specified dates are repeated, the landscape is “inscribed” with temporality, and the community reproduces seasonal rhythms and social memory [12-13]. The combination of viewshed-superior vantage points and nearby level surfaces at Songsan-ri and Haengsan heightens the likelihood that the area functioned as a stage for such memory work, suggesting that the megalithic culture around Gochang may have organized a circuit of season-landscape-collective memory beyond funerary-commemorative purposes.

5.4. *Connection to international debates: The significance of regional variation*

Studies of megaliths in Britain and the Mediterranean have repeatedly reported preferences for equinoctial/solstitial bearings and the importance of horizon targets [4-6]. While the Haeri-myeon materials demonstrate commonalities with this international pattern, they are distinctive

in reflecting the geomorphic context characteristic of the southwestern Korean Peninsula—the combination of low hillocks, gentle ridges, and broad plains. Rather than alignments to lunar standstills or complex long-period lunar factors, solar alignments to the equinoxes and solstices predominate; targets often appear not as single distant peaks but as nodal points along continuous ridgelines. From the perspective of “similar principles—different media,” this offers a cue for discussing the localization of yeongdae-like functions.

5.5. Methodological implications: Bridging archaeoastronomy and landscape archaeology

By integrating circular statistics, horizon-celestial matching, and viewshed/sightline networks, this study binds orientation, terrain, and practice into a single analytical frame. In standardizing procedures that (a) treat axial data appropriately as directional data, (b) adjust theoretical specified angles within the lived landscape by incorporating horizon altitude, and (c) model relations between observation points and targets in network-geometric terms, it provides a methodological bridge that complements the testing rigor of archaeoastronomy with the contextual interpretation of landscape archaeology [6, 9].

5.6 Practical implications for conservation, display, and education

The Haeri-myeon case demonstrates that interpretive landscape design can translate research findings into on-site management and education. It is necessary to establish interpretive itineraries linking vantage points for observing the specified seasonal events with target ridgeline nodes, alongside guidelines for observation safety, viewshed protection, and vegetation management. Citizen-science logging programs (time, bearing, photographs, and location) can promote long-term data accumulation and local participation. At the level of World Heritage management, standards for capacity, noise, and lighting during specified-season events should be prepared to balance observation-ritual uses with heritage conservation.

6. Conclusion and recommendations

This study presents spatial and statistical grounds that, at the Songsan-ri and Haengsan hillocks, the three elements of observation point-target point-assembly plane were combined into a single itinerary, consistent with an observation-ritual complex as yeongdae (靈臺). Axial dis-

tributions converge on equinoctial/solstitial bearing bands; matches with horizon nodal points recognizable from observation vantages are clear; and a chain of hilltop-level surface-ridgeline node can be reconstructed as an on-site itinerary.

This study interpreted the dolmens on the Songsan-ri and Haengsan hillocks of Haeri-myeon, Gochang-gun, Jeollabuk-do through the lens of yeongdae (靈臺)—a landscape device in which astronomical observation and ritual are conjoined. We normalized the coordinates, elevations, and locational descriptions [1]; measured long axes, secondary axes, and linear boulder features under a standardized protocol; and combined circular statistics (Rayleigh, V-test) with viewshed-horizon profiling-specified-angle matching and null-model simulations that incorporate terrain constraints. The results confirm that axial distributions converge significantly on the solar bearing bands for the solstices and equinoxes; that spatial matches with nodal points on the horizon (peaks and ridgelines) identifiable from observation points are clear; and that an observation-ritual itinerary linking hilltop, level surface, and ridgeline node can be reconstructed. These findings support the plausibility that a landscapization of temporality operated beyond funerary/commemorative functions [2, 6].

First, by introducing the testing rigor of international archaeoastronomy into Korean dolmen materials (specified-angle V-tests, null simulations), the study advances the methodology of orientation research [7-8]. Second, by reducing “yeongdae” to an operational model of observation point-target point-assembly plane, it connects discussions of place, memory, and ritual in landscape archaeology to empirical analysis [10, 12, 13]. Third, by considering horizon altitude and visibility networks alongside long-axis interpretation, it proposes a systematic procedure for evaluating alternative explanations of chance alignment [4, 9]. Fourth, by describing orientation patterns that reflect the regional geomorphic context—low hillocks, continuous ridgelines, and expansive plains in the southwest of the Korean Peninsula—it offers a case of localization to global megalithic studies [5].

The outcomes of this study can be translated directly into an interpretive landscape design that integrates conservation, display, and education on site [16-18]. The basic itinerary should lead from a hilltop observation point toward the target on the horizon and then return to a level assembly surface, tiered into short/medium/long courses by dwell time and access difficulty. Each course should clearly indicate observation windows for the summer and winter solstices and the vernal and autumnal equinoxes through ground markings and signage; vegetation that intrudes into sightlines and risks of damage should be assessed to designate

protected observation corridors and buffer zones. Assuming night and pre-dawn use, plans must also provide for safe circulation and emergency response, barrier-free routes, and season-specific visibility management [19].

Citizen participation should be organized around solstitial/equinocorial sunrise-sunset programs. Participants record observation logs in a standard format (time, bearing, photographs, coordinates), while the operating body distributes error-correction cards supporting magnetic-declination and horizon adjustments to enhance comparability. In conjunction with primary/secondary schools and local museums, age-differentiated modules (pre-lesson-field observation-post-interpretation) should be developed, and records should be released within the limits of portrait rights and personal-data protection. Such a citizen-science system strengthens the public value of long-term accumulated data and institutionalizes community participation [16-17].

On-site interpretation and media should present a common schematic of “observation point-target point-assembly plane” across all platforms to ensure consistent understanding. Panels and digital content must follow multilingual labeling and legibility principles; night lighting should be limited to levels that minimize impacts on birds, insects, and vegetation; and noise standards and capacity ceilings should be co-stated to balance conservation with visitation. Site markers should avoid over-facilitation while precisely indicating the “lines and planes” of the landscape; QR codes and web maps can provide deeper layers of information [18-19].

Data governance should maintain core information—coordinates, bearings, horizon profiles, statistical code—in standard formats, with sensitive location data differentially disclosed through reduced coordinate precision and access tiers. An annual joint remeasurement with regional research institutions should be conducted for quality control; versioning and change logs should be recorded transparently; and publicly releasable outputs should be assigned DOIs to increase citability. Finally, conformity with World Heritage and cultural-heritage guidelines should be periodically reviewed, and a monitoring-feedback loop should address on-site changes (vegetation growth, facility aging, itinerary deviations) so that the interpretive landscape can reliably achieve the triple aims of conservation, display, and education [17, 19- 21].

Limitations and future work are as follows. First, although subjectivity in defining long axes was mitigated through SOPs, repeat measurements, and dual adjudication, a mixed model that weights auxiliary indicators (supporting stones, boulder rows) is needed. Second, horizon-model errors from DEM resolution and vegetation occlusion should be corrected using high-resolution LiDAR and on-site horizon-altitude photography. Third, the terrain-constraint

null model can be refined to include construction constraints beyond slope aspect/gradient—such as constructible surfaces, bench steps, and access routes. Fourth, the sample should be expanded to adjacent ri units to assess the extent and variability of spatial co-orientation. Finally, a coupled chronology-astronomy analysis is required—explicitly reporting historical values of astronomical constants and the sensitivity of atmospheric refraction—to reflect archaeological timescales [6].

The dolmens of the Songsan-ri and Haengsan hillocks present sufficient grounds to interpret them as an observation-ritual complex in which the specified-season sun is coupled with local topographic targets. This justifies a perspective that does not reduce megaliths to individual tombs but sees them as devices that inscribe seasonal rhythms into the landscape as temporality. The analysis framework proposed here—circular statistics, horizon-celestial matching, visibility networks, and null-model simulation—can serve, in the Korean context, as a standard for reconstructing yeongdae-like functions as testable scientific problems. At the same time, by linking research outcomes to on-site conservation and educational practice through interpretive landscape design, this study can offer a precedent for the sustainable management and interpretation of megalithic culture in the southwest, including Gochang. These findings entail direct management implications: dolmen fields should be planned and operated as interpretive landscapes that protect visual axes and seasonal observation windows while enabling carefully managed public observation.

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Conflicts of Interest

The authors declare no conflict of interest.

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