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A Multi-Seasonal Solar Landscape System: Cultural and Archaeological Implications of Monumental Shadow Interactions in the Bosnian Valley of the Pyramids

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Abstract

Large-scale solar alignments in archaeological contexts are typically treated as single-event phenomena, most often associated with solstices or equinoxes. The Bosnian Valley of the Pyramids presents a different pattern: a sequence of repeated solar interactions distributed across the annual cycle. This paper analyzes shadow relationships between the Bosnian Pyramids of the Sun, the Moon, and Love using LiDAR-derived elevation models, geodetic data, and solar geometry, supported by multi-season field observations. At the summer solstice, the shadow of the Bosnian Pyramid of the Sun extends toward the Bosnian Pyramid of the Moon. At mid-summer (early August), the same shadow reaches the summit of the Bosnian Pyramid of the Moon. At the equinox, two concurrent interactions are recorded: the shadow of the Sun Pyramid approaches from the northern sector, while the shadow of the Love Pyramid extends along an east-west axis across the same structure. At the winter solstice, the Bosnian Pyramid of the Moon is positioned between opposing shadow trajectories from both sides of the valley. These patterns match calculated solar azimuths and are consistent across both observed and modeled data. Rather than isolated alignments, the evidence reveals a recurring seasonal sequence embedded in the landscape's spatial organization. This configuration indicates a systematic relationship between monument placement and the annual solar cycle, supporting the interpretation of the valley as an integrated observational landscape.

Keywords

Archaeoastronomy, Landscape Archaeology, Solar Cycles, Seasonal Shadow

Interactions, Monumental Landscape Systems, LiDAR Analysis, Spatial Patterning, Bosnian Valley of the Pyramids, Solar Geometry, Shadow Modeling

1. Introduction

Large-scale relationships between monuments and solar movement are widely documented in archaeological research. Most studies treat such relationships as single-event alignments, typically associated with solstices or equinoxes, where a structure marks a specific solar position on the horizon (Aveni, 2001; Ruggles, 2015; Belmonte, 2001). Examples from Egypt, Mesoamerica, and Neolithic Europe demonstrate that architectural orientation was often linked to calendrical, symbolic, or ritual functions (Šprajc, 2018; Magli, 2013; Hoskin, 2001). Recent work in archaeoastronomy has also emphasized the need for statistical testing and reproducibility in evaluating such alignments, particularly when multiple candidate relationships are present within a landscape (Ruggles, 2015; Šprajc, 2018). In these cases, interpretation usually centers on one directional axis and one moment in the solar year.

The Bosnian Valley of the Pyramids, located near Visoko in central Bosnia-Herzegovina, presents a different spatial configuration. The landscape includes several prominent features known as the Bosnian Pyramid of the Sun, the Bosnian Pyramid of the Moon, the Bosnian Pyramid of Love, the Bosnian Pyramid of the Dragon, and the Temple of Mother Earth. Previous work has identified geometric relationships among these features, including linear alignments, triangular configurations, and proportional spacing (Osmanagich et al., 2026; Osmanagich, 2025a; Osmanagich, 2025b; Osmanagich, 2025c; Osmanagich, 2025d). These studies also point to non-random spatial patterning and the presence of large-scale geometric structures within the valley.

A high-resolution LiDAR digital elevation model (**Figure 1**) shows that these features form a coherent spatial cluster. Their relative positions, elevations, and intervisibility (**Figures 2-4**) support the interpretation of a structured landscape rather than a set of independent landforms. LiDAR-based approaches have increasingly been used in landscape archaeology to identify subtle topographic features, intervisibility relationships, and spatial organization that are not evident from ground observation alone (Chase et al., 2012; Doneus et al., 2013; Bobáľ et al., 2017). The coordinate dataset used in this study (**Figure 5**, **Table 1** and **Table 2**) provides a consistent spatial framework for evaluating azimuths, distances, and directional relationships between the principal monuments.

Within this framework, particular attention is given to the Bosnian Pyramid of the Sun, the Bosnian Pyramid of the Moon, and the Bosnian Pyramid of Love. These three features form the core of the shadow interaction patterns examined here. Observations conducted over multiple seasons, combined with solar geometry modeling, show that their relationships are not limited to a single alignment.

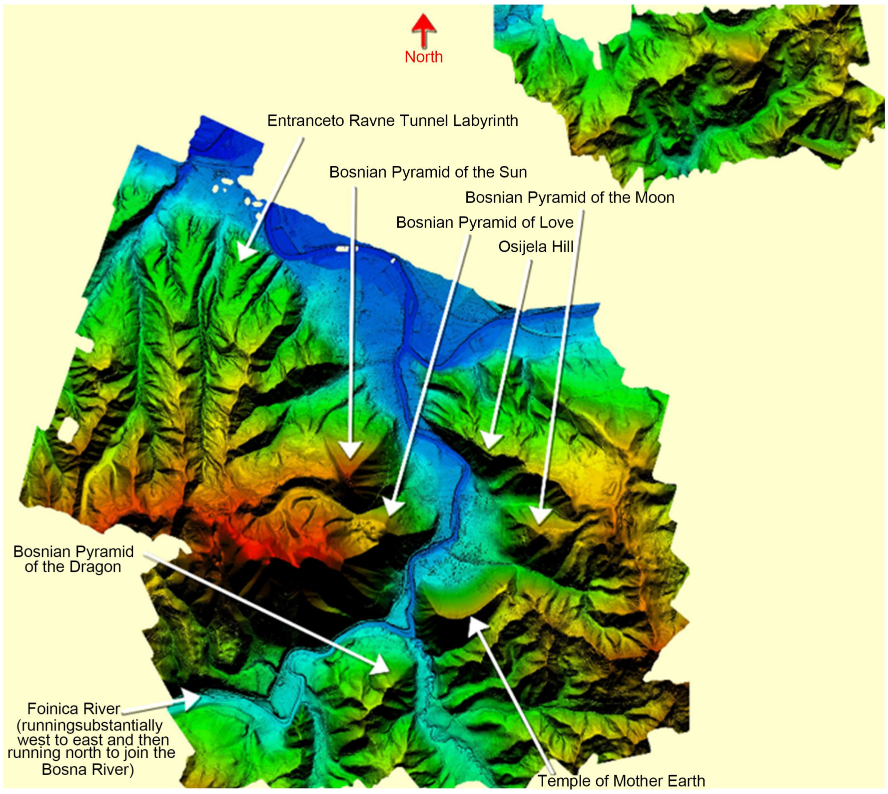

Figure 1. High-resolution LiDAR digital elevation model of the Bosnian Valley of the Pyramids. The model identifies the relative spatial distribution of the Bosnian Pyramids of the Sun, the Moon, Love, and the Dragon, and the Temple of Mother Earth. From a cultural-archaeological perspective, such a configuration may be interpreted as a structured landscape system in which prominent features participate in relational spatial organization rather than existing as isolated geomorphological forms.

Figure 2. Oblique aerial view of the Bosnian Valley of the Pyramids with principal monuments indicated. The image illustrates relative elevation, spatial distribution, and intervisibility among major features. These visibility relationships are significant in anthropological and landscape-archaeological contexts, where line-of-sight and visual prominence contribute to the perception and organization of cultural space.

The integration of field observation with solar-position modeling is consistent with established methods in archaeoastronomy and terrain-based shadow analysis, where both empirical and calculated data are used to evaluate directional correspondences.

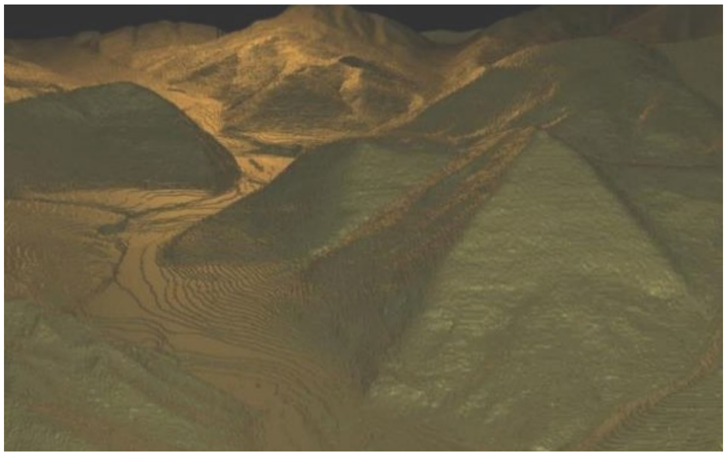

Figure 3. LiDAR-derived terrain model showing the Bosnian Pyramid of the Sun (right), the Bosnian Pyramid of Love (center), and the Temple of Mother Earth (left). The visualization highlights terrain morphology, slope geometry, and relative elevation. Within a cultural landscape framework, such spatial relationships may structure movement, orientation, and the experiential engagement of observers within the valley.

Figure 4. Composite visualization of the principal pyramid-shaped hills in the Bosnian Valley of the Pyramids. The images illustrate slope geometry, ridge orientation, and surface morphology of key features, including the Bosnian Pyramid of the Sun, the Bosnian Pyramid of the Moon, and the Bosnian Pyramid of Love. These morphological characteristics are directly relevant to the formation and direction of solar shadow projections and their potential role in structuring landscape-based observational phenomena.

Location	Latitude	Longitude	Y Gauss-Kruger	X Gauss-Kruger	Absolute Elevation
Bosnian Pyramid of the Sun	43°58'36" N	18°10'35" E	6514549.010	4870258.900	764.856
Temple of Mother Earth	43°57'51" N	18°11'24" E	6515656.180	4868887.120	659.695
Tumulus in Vratnica	44°00'28" N	18°12'56" E	6517695.090	4873744.790	506.710
Bosnian Pyramid of the Moon	43°58'20" N	18°12'03" E	6516518.910	4869793.150	666.060
Tunnel Ravne Entrance	43°59'44" N	18°09'39" E	6513311.590	4872362.840	496.650
Bosnian Pyramid of Love	43°58'21" N	18°10'51" E	6514934.430	4869818.840	668.310
Bosnian Pyramid of Dragon	43°57'29" N	18°10'56" E	6515038.980	4868199.190	595.530
Krtnice	43°58'09" N	18°10'01" E	6513819.850	4869456.670	844.000
Četnice	43°58'11" N	18°10'17" E	6514157.130	4869489.700	836.340
Bedem	43°57'13" N	18°10'14" E	6514109.610	4867713.720	527.510

Figure 5. Coordinate dataset of analyzed summit locations, including geographic coordinates, projected Gauss-Krüger coordinates, and elevations for all principal features. This dataset defines the fixed spatial framework used in the analysis and provides the basis for evaluating inter-monument relationships. In an archaeological context, such spatial datasets support the examination of structured landscape organization and non-random spatial patterning.

Table 1. Principal monument elevations and selected geometric parameters used in the analysis.

Monument	Absolute elevation (m a.s.l.)	Estimated height (m)	Notes
Bosnian Pyramid of the Sun	764.856	≈368	LiDAR-based original height estimate
Bosnian Pyramid of the Moon	666.060	≈190	Estimated from LiDAR-derived elevation differences; independent of shadow modeling
Bosnian Pyramid of Love	668.310	≈269	Absolute summit elevation only
Temple of Mother Earth	659.695	≈260	Reference monument used in spatial screening
Bosnian Pyramid of Dragon	595.530	≈196	Included as a comparative monument

Table 2. Core inter-monument azimuths and distances derived from projected Gauss-Krüger coordinates.

Source → target	Azimuth (˚)	Distance (m)	Interpretive note
Bosnian Pyramid of the Sun → Bosnian Pyramid of the Moon	103.30	2024.21	Primary Sun-Moon axis; strongest mid-summer candidate
Bosnian Pyramid of Love → Bosnian Pyramid of the Moon	90.93	1584.69	Near-equinoctial alignment; strongest eastward candidate
Bosnian Pyramid of the Sun → Bosnian Pyramid of Love	138.79	584.98	Internal core-system geometry
Bosnian Pyramid of the Sun → Temple of Mother Earth	141.09	1762.84	Secondary reference axis used in screening

Instead, a sequence of recurring interactions is observed across the annual cycle. At the summer solstice, the shadow of the Bosnian Pyramid of the Sun extends toward the Bosnian Pyramid of the Moon, approaching its base and reflecting a close correspondence between shadow length and monument height (Figure 6). At mid-summer (early August), the same shadow reaches the summit of the Bosnian Pyramid of the Moon (Figure 7). At the equinox, two simultaneous directions of interaction are present: one from the northern sector associated with the Sun Pyramid, and another along an east-west axis associated with the Pyramid of Love (Figures 8-10). At the winter solstice, the Bosnian Pyramid of the Moon lies between opposing shadow trajectories extending from both sides of the valley (Figure 9). These observations are summarized in Table 3 and are consistent with calculated solar azimuths.

Figure 6. Summer solstice shadow interaction between the Bosnian Pyramid of the Sun and the Bosnian Pyramid of the Moon. Observed near sunset on 21 June, the shadow of the Bosnian Pyramid of the Sun extends toward the southern slopes of the Bosnian Pyramid of the Moon, forming a geometrically consistent projection. This recurring phenomenon represents the initial phase of a seasonal solar-landscape interaction sequence.

Figure 7. Mid-summer shadow interaction between the Bosnian Pyramid of the Sun and the Bosnian Pyramid of the Moon. On 6 August, the shadow extended across the western slope of the Bosnian Pyramid of the Moon, with the shadow tip approaching or reaching the summit. This phase indicates continuity in directional solar-landscape relationships beyond the solstitial event.

Figure 8. Equinoctial shadow interactions in the Bosnian Valley of the Pyramids. Around the equinox, the shadow of the Bosnian Pyramid of the Sun approaches the Bosnian Pyramid of the Moon from the northern sector, while the shadow of the Bosnian Pyramid of Love extends toward the Bosnian Pyramid of the Moon along an approximately east-west direction. This dual interaction represents a transitional phase within the seasonal cycle and suggests a coordinated spatial relationship involving multiple structures.

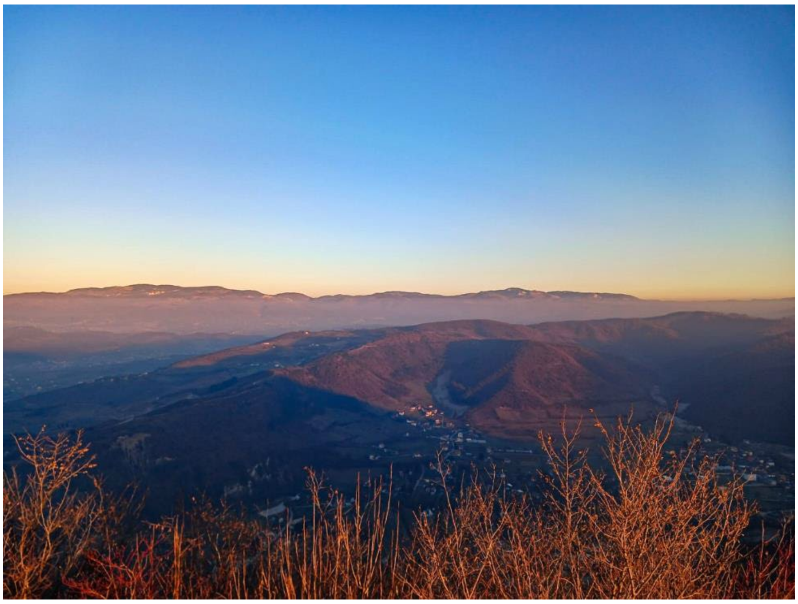

Figure 9. Winter solstice shadow geometry in the Bosnian Valley of the Pyramids. Near sunset on 21 December, the shadow of the Bosnian Pyramid of the Sun extends across one side of the valley, while the shadow of the Bosnian Pyramid of Love approaches from the opposite direction, with the Bosnian Pyramid of the Moon positioned between these trajectories. This configuration represents a complementary or inverse phase within the seasonal interaction cycle.

Figure 10. Equinoctial multi-monument shadow interaction involving the Bosnian Pyramid of the Sun, the Bosnian Pyramid of the Moon, and the Bosnian Pyramid of Love. The upper panel shows the shadow of the Bosnian Pyramid of the Sun approaching the Bosnian Pyramid of the Moon from the northern sector, while the lower panel illustrates the shadow of the Bosnian Pyramid of Love extending across the same structure along an approximately east-west direction. The simultaneous interaction of multiple shadow trajectories highlights the integrated nature of the seasonal solar-landscape system.

Table 3. Observed and modeled seasonal shadow events used in the present study.

Seasonal date	Shadow source	Target/interaction	Approx. shadow azimuth	Observed/modeled effect	Status
Summer solstice (21 June)	Bosnian Pyramid of the Sun	Bosnian Pyramid of the Moon (BPM)	≈123.5˚	Shadow approaches BPM from the southern side; shadow height corresponds to BPM and touches its foundations	Observed + modeled
Mid-summer (early August)	Bosnian Pyramid of the Sun	Bosnian Pyramid of the Moon	≈110˚	Shadow covers the western side of BPM; tip reaches or approaches the summit	Observed + modeled
Autumn equinox (23 September)	Bosnian Pyramid of the Sun	Bosnian Pyramid of the Moon	≈90˚	Shadow approaches BPM from the northern side	Observed + modeled
Autumn equinox (23 September)	Bosnian Pyramid of Love	Bosnian Pyramid of the Moon	≈90˚	Shadow covers the western side of BPM; strongest equinoctial directional fit	Observed + modeled
Winter solstice (21 December)	Bosnian Pyramid of the Sun + Bosnian Pyramid of Love	Bosnian Pyramid of the Moon	≈56.5˚ sector	BPM remains framed between the BPS and BPL shadow trajectories	Observed + modeled
Spring equinox	Bosnian Pyramid of the Sun/Bosnian Pyramid of Love	Bosnian Pyramid of the Moon	≈90˚	Mirror configuration relative to the autumn equinox	Observed + modeled

This pattern differs from the standard model of isolated solar alignment. Rather than marking a single event, the spatial configuration of the monuments registers multiple points within the annual solar cycle. The repetition and directional variation of these interactions suggest that solar movement was observed as a continuous process, not as a single moment. Such multi-event or sequential solar relationships have been discussed in limited cases in archaeoastronomy but remain less commonly documented than single-axis alignments, particularly at the landscape scale.

The aim of this paper is to document these shadow relationships and evaluate them within a cultural and archaeological framework. The analysis considers the full sequence of seasonal interactions and their consistency across observed and modeled data. In doing so, it addresses whether a monumental landscape can be organized to reflect the progression of the solar year, rather than a single alignment event. To the author's knowledge, this represents one of the first structured attempts to evaluate recurring, multi-season shadow interactions at the landscape scale using combined LiDAR, geodetic, and solar modeling approaches.

2. Materials and Methods

2.1. Study Area and Spatial Data

The study was conducted in the Bosnian Valley of the Pyramids near Visoko, Bosnia-Herzegovina. The analysis focuses on the Bosnian Pyramids of the Sun (BPS), the Moon (BPM), and Love (BPL), as well as selected reference points within the valley. The analyzed features are prominent topographic summits identified from LiDAR data, characterized by clear elevation prominence, well-defined slope, and intervisibility within the valley landscape.

Spatial data were derived from high-resolution LiDAR surveys, supplemented by satellite imagery and geodetic measurements. The LiDAR dataset provides sufficient resolution to define summit elevations, slope geometry, and terrain morphology, as well as intervisibility between major features (Figure 1). Oblique aerial views and terrain models (Figures 2-4) were used to examine relationships between relative elevation and visibility. Local topographic maxima were identified using elevation thresholds and slope continuity criteria to ensure consistency in feature selection.

Geographic and projected (Gauss-Krüger) coordinates of all analyzed points are presented in Figure 5, Table 1 and Table 2. These data form the fixed spatial framework used for all subsequent calculations.

2.2. Geometric and Spatial Analysis

Distances and azimuths between monuments were calculated using projected coordinate data. All azimuths were computed in degrees relative to true north using Gauss-Krüger projected coordinates to minimize distortion at the study scale. Core directional relationships were derived from these coordinates and used to define the spatial structure of the system.

The analysis focused on three principal relationships:

1) Bosnian Pyramid of the Sun → Bosnian Pyramid of the Moon (primary axis);
2) Bosnian Pyramid of Love → Bosnian Pyramid of the Moon (equinoctial axis);
3) Internal geometry between the Sun and Love pyramids.

These relationships were compared with calculated solar azimuths to evaluate directional correspondence (Table 2). Directional correspondence was assessed within a defined angular tolerance (see Analytical Approach).

2.3. Solar Geometry and Observation Dates

Solar azimuths and elevation angles were calculated for specific dates corresponding to key points in the annual cycle:

- 21 June (summer solstice);
- 6 August (mid-summer);
- 23 September (autumn equinox);
- 21 December (winter solstice);
- 21 March (spring equinox).

These dates correspond to field observations and photographic documentation of shadow interactions within the Bosnian Valley of the Pyramids. Observations were conducted across multiple years under comparable atmospheric conditions. Field observations were conducted approximately 60 minutes before local sunset (±10 minutes), corresponding to periods of low solar elevation when shadow elongation is maximized. Based on local solar conditions in Visoko, this corresponds to approximate observation times of 19:30 (21 June), 19:10 (6 August), 18:00 (23 September), 15:15 (21 December), and 17:05 (21 March).

Standard solar geometry equations were used to determine the sun's position relative to the local horizon. Calculated azimuths were then compared with measured inter-monument directions. Approximate solar elevation angles during observations ranged from ~5˚ (winter solstice) to ~15˚ (mid-summer), depending on date and observation time.

Terrain effects were partially incorporated using LiDAR-derived elevation models, allowing estimation of shadow interception by intermediate topography. Atmospheric refraction was not explicitly modeled but is expected to have a limited effect at the spatial scale of the observed relationships.

2.4. Shadow Modeling and Observation

Shadow projections were evaluated using a combination of geometric modeling and direct field observation. Shadow length was estimated from monument height and solar elevation angle, allowing comparison between expected and observed shadow positions. Monument heights were derived from LiDAR-based elevation differences between summit points and surrounding terrain baselines, ensuring independence from the shadow relationships under investigation.

The following recurring interactions were documented:

- 21 June: The shadow of the Bosnian Pyramid of the Sun extends toward the Bosnian Pyramid of the Moon and reaches its base.
- 6 August: The same shadow extends further and reaches the summit of the Bosnian Pyramid of the Moon.
- 23 September and 21 March: Dual shadow interactions occur, with the Bosnian Pyramid of the Sun casting a shadow from the northern sector and the Bosnian Pyramid of Love producing an east-west shadow across the Bosnian Pyramid of the Moon.
- 21 December: The Bosnian Pyramid of the Moon lies between opposing shadow trajectories extending from both sides of the valley.

These observations are summarized in Table 3 and correspond to calculated solar azimuths. Observed shadow directions were compared with modeled projections to confirm directional consistency within defined tolerances.

2.5. Analytical Approach

The analysis does not focus on a single alignment but on the repetition of shadow interactions across multiple dates. Observed and modeled results were compared to identify consistent patterns in both direction and timing. Initial exploratory screening considered multiple candidate feature relationships; however, the reported Sun-Moon-Love configuration was evaluated using predefined criteria to reduce selection bias.

Only relationships that:

- Correspond to calculated solar azimuths, and;
- Repeat under comparable seasonal conditions.

were considered significant. Directional correspondence was defined using an angular tolerance of ±2˚.

To evaluate the likelihood of such configurations arising by chance, a constrained Monte Carlo simulation was implemented. Randomized configurations were generated using candidate summit locations identified as local topographic maxima within the LiDAR dataset. A configuration was classified as "equal or more structured" if it reproduced at least three seasonal directional correspondences within the defined tolerance. The reported probability represents the proportion of random configurations meeting this criterion, with uncertainty estimated using bootstrap resampling.

The approach emphasizes pattern recognition across the annual cycle rather than isolated events, allowing evaluation of whether the spatial configuration reflects a recurring solar sequence within the landscape.

3. Results

3.1. Spatial Configuration and Terrain Geometry

The LiDAR-derived elevation model (**Figure 1**) shows that the principal features of the Bosnian Valley of the Pyramids form a coherent spatial cluster. The Bosnian Pyramid of the Sun (BPS), Bosnian Pyramid of the Moon (BPM), Bosnian Pyramid of Love (BPL), Bosnian Pyramid of the Dragon, and the Temple of Mother Earth are positioned within a relatively confined area, with clear differences in elevation and prominence.

Oblique aerial views and terrain models (**Figures 2-4**) indicate strong intervisibility between the main features. Line-of-sight analysis based on the LiDAR elevation model confirms unobstructed visibility between the principal summits under standard atmospheric conditions. The BPS dominates the landscape in both elevation and visual prominence, while the BPM and BPL occupy positions that are clearly visible from the central part of the valley.

The morphology of the analyzed features is also consistent across datasets. In particular, the western slope of the Bosnian Pyramid of the Moon exhibits a well-defined triangular geometry (**Figure 4**). This geometric regularity is relevant for the interpretation of shadow projection patterns observed during different parts of the year.

The coordinate dataset (**Figure 5**, **Table 1** and **Table 2**) defines the spatial relationships between the main monuments. The primary axis between the BPS and BPM has an azimuth of approximately 103˚, while the axis between the BPL and BPM is close to 91˚, corresponding to an east-west direction. These values are consistent with the directional patterns observed in the shadow interactions. Measured azimuth differences between monument axes and corresponding solar azimuths are within a small angular deviation (see **Table 2**), supporting directional correspondence.

3.2. Summer Solstice and Mid-Summer Shadow Interactions

Field observations conducted on 21 June show that, near sunset, the shadow of the Bosnian Pyramid of the Sun extends toward the Bosnian Pyramid of the Moon (**Figure 6**). The shadow reaches the base of the BPM, forming a triangular projection consistent with the geometry of the source structure. The observed shadow direction corresponds closely to the calculated solar azimuth for the same time window.

The triangular shape of the shadow corresponds visually to the triangular slope of the BPM. The shadow boundary aligns with the lower portion of the western slope, indicating a close geometric relationship between shadow form and terrain morphology. Observed shadow boundaries fall within the expected projection range based on solar elevation and monument height.

Observations conducted on 6 August (mid-summer) show a further extension of the same shadow (**Figure 7**). At this date, the shadow of the BPS reaches the summit of the Bosnian Pyramid of the Moon. The transition from base contact (21 June) to summit contact (6 August) represents a measurable change in shadow length over time. This change is consistent with the decrease in solar elevation angle between the two observation dates.

3.3. Equinoctial Shadow Interactions

Observations conducted on 23 September (autumn equinox) and 21 March (spring equinox) reveal different configurations (**Figure 8** and **Figure 10**). Two distinct shadow directions are present during these dates.

The shadow of the Bosnian Pyramid of the Sun approaches the Bosnian Pyramid of the Moon from the northern sector. At the same time, the shadow of the Bosnian Pyramid of Love extends along an approximately east-west axis toward the BPM. Both directions correspond to calculated solar azimuths for the respective observation times.

During these conditions, the shadow of the Bosnian Pyramid of Love fully covers the western slope of the Bosnian Pyramid of the Moon. This coverage closely matches the triangular geometry of the slope and results in clear visual overlap between the shadow and the terrain. The extent of coverage is consistent with modeled shadow projections under equinoctial solar elevation conditions.

The simultaneous presence of two shadow directions distinguishes the equinoctial configuration from the summer pattern, where only a single dominant shadow direction is observed. This dual-direction configuration represents a distinct geometric condition within the annual sequence.

3.4. Winter Solstice Shadow Geometry

Observations conducted on 21 December (winter solstice) show a further change in the spatial configuration (**Figure 9**). At this time of year, the Bosnian Pyramid of the Moon is positioned between two opposing shadow trajectories.

The shadow of the Bosnian Pyramid of the Sun extends across one side of the valley, while the shadow of the Bosnian Pyramid of Love approaches from the opposite direction. The BPM lies between these shadow paths, serving as a central reference point within the configuration. The opposing directions are consistent with low solar elevation and seasonal changes in solar azimuth.

This arrangement differs from both the summer and equinoctial conditions, as neither a single-direction interaction nor full slope coverage is observed. Instead, the configuration reflects a spatially distributed shadow pattern under winter solar conditions.

3.5. Seasonal Sequence and Pattern Consistency

The observed shadow interactions form a consistent sequence across the annual cycle. This sequence can be summarized as follows (**Table 3**):

- 21 June: Shadow of BPS reaches the base of BPM;
- 6 August: Shadow of BPS reaches the summit of BPM;
- 23 September/21 March: Dual shadow interaction (BPS from north; BPL along east-west axis), including full coverage of BPM western slope;
- 21 December: BPM positioned between opposing shadow trajectories.

These observations correspond to calculated solar azimuths and are consistent across both field observations and modeled results. Directional correspondence is maintained within defined angular tolerances across all observation dates.

Rather than a single alignment, the data show a progression of shadow relationships that change with solar position over time. The direction, length, and interaction of shadows vary systematically across the year while maintaining consistent spatial relationships between the main monuments. This consistency across multiple dates and conditions indicates a stable and repeatable pattern within the observed dataset.

4. Discussion

The results presented here differ from the standard model of solar alignment in archaeological contexts. Most documented sites are defined by a single directional relationship, typically marking the position of the Sun at a solstice or equinox (Aveni, 2001; Ruggles, 2015). In such cases, the alignment is fixed and associated with one moment in the annual cycle. The configuration observed in the Bosnian Valley of the Pyramids shows a different structure. Instead of a single alignment, the data indicate a sequence of repeated interactions distributed across multiple dates. This distinction shifts the analytical focus from isolated alignments to temporally extended spatial relationships.

The progression from the summer solstice to mid-summer, followed by equinoctial and winter configurations, forms a continuous pattern. At the summer solstice, the shadow of the Bosnian Pyramid of the Sun approaches the Bosnian Pyramid of the Moon from the southern sector. This direction corresponds to the period of highest solar elevation and longest days. At the equinox, the same interaction shifts to the northern sector, marking a transition toward lower solar paths and shorter days. This directional change introduces a clear seasonal contrast within the spatial system. The landscape does not register a single solar event but reflects the movement of the Sun across the year. Such directional transitions are consistent with expected seasonal variation in solar azimuth and elevation.

The geometric relationship between shadow form and terrain morphology is also significant. The triangular shadow cast by the Bosnian Pyramid of the Sun corresponds closely to the triangular western slope of the Bosnian Pyramid of the Moon. During equinoctial conditions, the shadow of the Bosnian Pyramid of Love fully covers this slope, producing a complete overlap between shadow and surface geometry. This level of correspondence suggests that shadow projection is not random but interacts with specific morphological features of the terrain. However, this correspondence should be interpreted as a geometric relationship observed under specific solar conditions, rather than as evidence of intentional design.

A further structural element of the system is the orientation of the principal monuments. The Bosnian Pyramids of the Sun and the Moon are aligned close to the cardinal directions, while the Bosnian Pyramid of Love is oriented at approximately 60˚ relative to this axis (Osmanagich, 2025c). This angular offset introduces a secondary directional framework within the landscape. The combination of cardinal alignment and a 60˚ deviation is consistent with the triangular relationships observed between the monuments and with the directional pattern of shadow interactions. Within the observed sequence, the cardinal aligned structures define the primary north-south and east-west reference system, while the Pyramid of Love introduces an oblique axis that becomes particularly evident during equinoctial shadow interactions. Similar multi-axis configurations have been discussed in archaeoastronomical studies where more than one directional system is present within a single site (Ruggles, 2015; Šprajc, 2018).

A further point is the relationship between monument height and shadow length. At the summer solstice, the shadow of the Bosnian Pyramid of the Sun reaches the base of the Bosnian Pyramid of the Moon. By early August, the same shadow extends to the summit. Visually, the length of the shadow corresponds to the vertical dimension of the target structure. This relationship introduces a measurable link between elevation and solar geometry within the system. This correspondence is consistent with expected geometric relationships between object height, solar elevation angle, and shadow length.

Taken together, these observations indicate that the spatial configuration of the monuments functions as more than a set of isolated alignments. The repeated interactions, consistent directions, and geometric correspondences point to a structured relationship between terrain and solar movement. One possible interpretation is that the system enabled observation of changes in the solar position throughout the year from a fixed vantage point. In this context, the summit of the Bosnian Pyramid of the Sun may have served as a primary observation point, offering clear views of the Bosnian Pyramid of the Moon and other features within the valley. This interpretation is presented as a functional hypothesis consistent with the observed spatial relationships. Alternative explanations, including natural geomorphological patterning or observer-dependent selection effects, cannot be fully excluded.

The pattern identified in the Bosnian Valley of the Pyramids differs from well-documented examples of solar alignment in other archaeological contexts. At Giza, the primary emphasis is on cardinal orientation and horizon-based solar relationships (Magli, 2013). Stonehenge is structured around a solstitial axis marking sunrise and sunset positions (Ruggles, 2015). In Mesoamerican sites, alignments are often associated with specific calendar dates and horizon markers (Šprajc, 2018). In each case, the focus remains on discrete events. By contrast, the configuration described here is not limited to a single alignment but reflects a sequence of repeated interactions across the solar year. This distinction places the present study within a less commonly explored category of landscape-scale, multi-event solar relationships.

This interpretation does not rely on a single axis or a single date. Instead, it considers the full sequence of seasonal changes and their repetition over time. Compared with sites characterized by individual alignments, the Bosnian Valley of the Pyramids presents a more dynamic model in which landscape, geometry, and solar movement operate as a continuous system.

5. Limitations

This study is based on a combination of field observations, LiDAR-derived terrain data, and solar geometry modeling. Although the observed shadow interactions are consistent across multiple dates and correspond to calculated solar azimuths, the analysis is limited by the number of observation points within the annual cycle. In particular, observations are concentrated around key seasonal dates and do not represent continuous monitoring throughout the year. Additional observations under varying atmospheric and seasonal conditions would further strengthen the dataset.

The interpretation presented here focuses on spatial and geometric relationships and does not rely on independent archaeological dating or cultural attribution of the structures. As a result, the conclusions are based on observed patterning rather than direct evidence of construction intent. Accordingly, the results should be interpreted as descriptive of spatial relationships rather than as confirmation of anthropogenic design.

Finally, while the identified relationships differ from typical single-event alignments, broader comparative analysis with other archaeological sites would be required to fully assess the uniqueness and cultural significance of the observed system. Further validation using independent datasets and alternative analytical approaches would be necessary to confirm the robustness of the identified patterns.

6. Conclusion

The results presented in this study show that the Bosnian Valley of the Pyramids is not characterized by a single solar alignment, but by a sequence of repeated shadow interactions distributed across the annual cycle. Observations conducted at the summer solstice, mid-summer (6 August), equinoxes (21 March and 23 September), and winter solstice (21 December) demonstrate consistent directional relationships among the Bosnian Pyramids of the Sun, the Moon, and Love. These interactions follow a clear progression. The shadow of the Bosnian Pyramid of the Sun extends from the south toward the Bosnian Pyramid of the Moon at the summer solstice and reaches its summit by mid-summer. During the equinoxes, dual shadow interactions occur, including complete coverage of the western slope of the Bosnian Pyramid of the Moon by the Bosnian Pyramid of Love. At the winter solstice, the Bosnian Pyramid of the Moon lies between opposing shadow trajectories. These patterns correspond to calculated solar azimuths and remain consistent across observed and modeled data. Directional correspondence is maintained within defined angular tolerances across all observation dates.

In contrast to sites defined by isolated alignments, the observed configuration forms a recurring seasonal system embedded in the spatial organization of the landscape. The combination of cardinal orientation, a 60˚ secondary axis, and consistent geometric relationships between terrain and shadow supports the interpretation of a structured interaction between monuments and solar movement. This interpretation is based on observed spatial regularities and is presented as a functional model consistent with the available data.

The findings indicate that the landscape reflects not a single solar event, but the progression of the solar year. This shifts the focus from alignment to system and opens the possibility that large-scale landscapes can function as continuous frameworks for observing solar change over time. These results should be understood as hypothesis-generating and provide a basis for further investigation using expanded datasets and independent verification.

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Data Availability Statement

The data supporting the findings of this study, including geodetic measurements, LiDAR-derived elevation models, and derived spatial datasets, are available from the corresponding author upon reasonable request.

Ethical Statement

This study did not involve human participants, animal subjects, or sensitive cultural materials requiring ethical approval. All analyses were conducted using publicly accessible landscape features and non-invasive geospatial data.

Author Contributions

Sam Osmanagich, Ph.D. conceived the study, conducted the analysis, performed the modeling, and wrote the manuscript.

Conflicts of Interest

The author declares no conflict of interest.

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